U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NUREG-1437, Volume 1
Revision 1

Generic Environmental Impact Statement for License Renewal of Nuclear Plants

Main Report

Final Report

Office of Nuclear Reactor Regulation

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Abstract

U.S. Nuclear Regulatory Commission (NRC) regulations allow for the renewal of commercial nuclear power plant operating licenses. To support the license renewal environmental review process, the NRC published the *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (GEIS) in 1996. The proposed action considered in the GEIS is the renewal of nuclear power plant operating licenses.

Since publication of the GEIS, approximately 40 plant sites (70 reactor units) have applied for license renewal and undergone environmental reviews, the results of which were published as supplements to the 1996 GEIS. This GEIS revision reviews and reevaluates the issues and findings of the 1996 GEIS. Lessons learned and knowledge gained during previous license renewal reviews provide a significant source of new information for this assessment. In addition, new research, findings, public comments, and other information were considered in evaluating the significance of impacts associated with license renewal.

The intent of the GEIS is to determine which issues would result in the same impact at all nuclear power plants and which issues could result in different levels of impact at different plants and thus require a plant-specific analysis for impact determinations. The GEIS revision identifies 78 environmental impact issues for consideration in license renewal environmental reviews, 59 of which have been determined to be generic to all plant sites. The GEIS also evaluates a full range of alternatives to the proposed action. For most impact areas, the proposed action would have impacts that would be similar to or less than impacts of the alternatives, in large part because most alternatives would require new power plant construction, whereas the proposed action would not.

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Acronyms, Abbreviations, and Chemical Nomenclature

ABWR	advanced boiling water reactor
AC	alternating current
ACRS	Advisory Committee on Reactor Safeguards
ACS	American Cancer Society
ADAMS	Agencywide Documents Access and Management System
AEA	Atomic Energy Act
AEC	U.S. Atomic Energy Commission
AGNIR	Advisory Group on Non-ionizing Radiation
AIRFA	American Indian Religious Freedom Act of 1978
ALARA	as low as is reasonably achievable
ALI	annual limit on intake
APE	Area of Potential Effect
ALWR	advanced light water reactor
ASLB	Atomic Safety and Licensing Board
ASME	American Society of Mechanical Engineers
AWEA	American Wind Energy Association
BEIR	Biological Effects of Ionizing Radiation (National Research Council Committee)
BLM	U.S. Bureau of Land Management
BLS	U.S. Bureau of Labor Statistics
BMPs	best management practices
BPA	Bonneville Power Administration
BWR	boiling water reactor
BOEMRE	Bureau of Ocean Energy Management, Regulation, and Enforcement
CAA	Clean Air Act
CADHS	California Department of Health Services
CCS	carbon capture and storage
CCW	coal combustion waste
CDC	Centers for Disease Control and Prevention
CDF	core damage frequency
CdTe	cadmium telluride
CEC	California Energy Commission
CEDE	committed effective dose equivalent

CEG	Constellation Energy Group
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	capacity factor
CFR	*Code of Federal Regulations*
CGEC	California Geothermal Energy Collaborative
CH_4	methane
CHP	combined heat and power
CIGS	copper-indium-gallium-selenide
CLB	current licensing basis
CO	carbon monoxide
CO_2	carbon dioxide
COL	combined operating license
CSP	concentrating solar power
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DC	direct current
DDREF	dose and dose rate effectiveness factor
DNC	Dominion Nuclear Connecticut
DNI	direct normal insolation
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
DSM	demand-side management
EA	environmental assessment
EAB	exclusion area boundary
ECRR	European Committee on Radiation Risk
EEI	Edison Electric Institute
EERE	Energy Efficiency and Renewable Energy
EEZ	Exclusive Economic Zone
EF	enhanced Fujita (scale)
EFH	essential fish habitat
EGS	engineered geothermal systems
EI	exposure index
EIA	Energy Information Administration
EIML	Environmental Incorporated Midwest Laboratory
EIS	environmental impact statement
EJ	environmental justice
ELF-EMF	extremely low frequency-electromagnetic field

EMF	electromagnetic field
EMF-RAPID	Electric and Magnetic Fields Research and Public Information Dissemination (Program)
EP	emergency planning
EPA	U.S. Environmental Protection Agency
EPAct	Energy Policy Act of 2005
EPCRA	Emergency Planning and Community Right-to-Know Act
EPRI	Electric Power Research Institute
ER	environmental report
ERCOT	Electric Reliability Council of Texas
ERO	Electric Reliability Organization
ESA	Endangered Species Act
ESP	early site permit
Exelon	Exelon Generating Company LLC
F	Fujita (scale)
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FDOH	Florida Department of Health
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FES	final environmental statement
FGD	flue gas desulfurization
FICN	Federal Interagency Committee on Noise
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FPL	Florida Power & Light Company
FR	*Federal Register*
FRCC	Florida Reliability Coordinating Council
FSAR	Final Safety Analysis Report
FS	U.S. Forest Service
GALL	Generic Aging Lessons Learned
GAO	U.S. General Accounting Office (now U.S. Government Accountability Office)
GCRP	U.S. Global Change Research Program
GDC	General Design Criterion
GEA	Geothermal Energy Association
GEIS	generic environmental impact statement
GHG	greenhouse gas
GIS	geographic information system
GNEP	Global Nuclear Energy Partnership

GSMFC	Gulf States Marine Fisheries Commission
GTCC	greater than Class C
HAP	hazardous air pollutant
HAPC	habitat area of particular concern
HAWT	horizontal axis wind turbine
HCCP	Harvard Center for Cancer Prevention
HDR	hot dry rock
HFC	hydrofluorocarbon
HCFC	hydrochlorofluorocarbon
HHV	higher heating value
HLW	high-level (radioactive) waste
HVAC	heating, ventilation, and air conditioning
IAEA	International Atomic Energy Agency
IARC	International Agency for Research on Cancer
ICM	Interim Compensatory Measure
ICRP	International Commission on Radiological Protection
IDPH	Illinois Department of Public Health
IDNR	Idaho Department of Natural Resources
IEEE	Institute of Electrical and Electronic Engineers
IGCC	integrated gasification combined cycle
IMP	Indiana Michigan Power
INIRC	International Non-Ionizing Radiation Commission
IPE	Individual Plant Examination
IPEEE	Individual Plant Examination of External Events
IRPA	International Radiation Protection Association
ISFSI	independent spent fuel storage installation
ISI	in-service inspection
IWSA	Integrated Waste Services Association
LERF	large early release frequency
LET	linear energy transfer
LFG	landfill gas
LLAP	*Legionella*-like amoebal pathogen
LLD	lower limit of detection
LLNL	Lawrence Livermore National Laboratory
LLW	low-level (radioactive) waste
LLRWPA	Low-Level Radioactive Waste Policy Act
LLTF	Lessons Learned Task Force
LLWPAA	Low-Level Radioactive Waste Policy Act Amendments

LOA	letter of authorization
LOEL	lowest observed effects level
LWR	light water reactor
MACCS	MELCOR Accident Consequence Code System
MACT	maximum achievable control technology
MCAQD	Maricopa County Air Quality Department
MCL	maximum contaminant level
MEI	maximally exposed individual
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MSW	municipal solid waste
MTBE	methyl tertiary butyl ether
NAAQS	National Ambient Air Quality Standards
NaCl	sodium chloride (salt)
NAICS	North American Industry Classification System
NAGPRA	Native American Graves Protection and Repatriation Act
$NaNO_3$	sodium nitrate
NAS	National Academy of Sciences
National Register	*National Register of Historic Places*
NCDC	National Climatic Data Center
NCRP	National Council on Radiation Protection and Measurements
NEI	Nuclear Energy Institute
NEPA	National Environmental Policy Act of 1969
NERC	North American Electric Reliability Corporation
NESC	National Electrical Safety Code
NETL	National Energy Technology Laboratory
NGCC	natural gas combined cycle
NGL	natural gas liquids
NHPA	National Historic Preservation Act of 1966
$(NH_4)SO_4$	ammonium sulfate
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NJDEP	New Jersey Department of Environmental Protection
NMC	Nuclear Management Company
NMFS	National Marine Fisheries Service
NO	nitrogen oxide
N_2O	nitrous oxide
NO_2	nitrogen dioxide

NOAA	National Oceanic and Atmospheric Administration
NORM	naturally occurring radioactive material
NOS	National Oceanic Service
NO_x	nitrogen oxides
NPCC	Northeast Power Coordinating Council
NPDES	National Pollutant Discharge Elimination System
NPP	nuclear power plant
NRC	U.S. Nuclear Regulatory Commission
NREL	National Renewable Energy Laboratory
NRPB	National Radiological Protection Board
NSPS	New Source Performance Standards
NWI	National Waste Initiative; National Wetland Inventory
NWPA	National Waste Policy Act
NYSDEC	New York State Department of Environmental Conservation
NYSDOL	New York State Department of Labor
O_3	ozone
OCS	Outer Continental Shelf
ODCM	Offsite Dose Calculation Manual
OPPD	Omaha Public Power District
OTA	Office of Technology Assessment
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbon
PARS	Publicly Available Record System
Pb	lead
PC	pulverized coal
PCB	polychlorinated biphenyl
PDR	Public Document Room
PEIS	programmatic environmental impact statement
PFC	perfluorocarbon
PI	performance indicator
PILOT	payments in lieu of tax
PM	particulate matter
$PM_{2.5}$	particulate matter with a mean aerodynamic diameter of 2.5 μm or less
PM_{10}	particulate matter with a mean aerodynamic diameter of 10 μm or less
POTW	publicly owned treatment works
PPE	personal protective equipment
PRA	probabilistic risk assessment
PSD	prevention of significant deterioration
PTC	production tax credit

PURPA	Public Utility Regulatory Act of 1978
PV	photovoltaic
PVC	photovoltaic cell
PWR	pressurized water reactor
RCRA	Resource Conservation and Recovery Act of 1976
RD&D	research, development, and demonstration
RDF	refuse-derived fuel
REMP	Radiological Environmental Monitoring Program
RER	radiological effluent release
RERR	radiological effluent release report
RES	Renewable Energy Standard
RFC	Reliability First Corporation
ROP	Reactor Oversight Program
ROW	right-of-way
RPS	Renewable Portfolio Standards
RNA	ribonucleic acid
RRC	Regional Reliability Council
RRY	reference reactor year
SAAQS	State Ambient Air Quality Standards
SAMA	severe accident mitigation alternative
SAMDA	severe accident mitigation design alternative
SCE	Southern California Edison
SCR	selective catalytic reduction
SDWA	Safe Drinking Water Act
SEIS	supplemental environmental impact statement
SER	safety evaluation report
SFP	spent fuel pool
SHPO	State Historic Preservation Office or Officer
SIP	State implementation plan
SMITTR	surveillance, monitoring, inspection, testing, trending, and recordkeeping
SNYPSC	State of New York Public Service Commission
SO_2	sulfur dioxide
SOARCA	state-of-the-art reactor consequence analysis
SPAR	standardized plant analysis risk
SPDES	State Pollutant Discharge Elimination System
SPP	Southwest Power Pool
SRM	Staff Requirements Memorandum
SSCs	systems, structures, and components

Stat.	*Statutes at Large*
STG	steam turbine generator
TCEQ	Texas Commission on Environmental Quality
TDS	total dissolved solids
TEDE	total effective dose equivalent
TESS	threatened and endangered species system
THPO	Tribal Historic Preservation Officer
TLD	thermoluminescence dosimeter
TSCA	Toxic Substances Control Act
TSS	total suspended solids
TTU	Texas Tech University
TVA	Tennessee Valley Authority
TXU	TXU Generation Company
UCB	upper confidence bound
UCS	Union of Concerned Scientists
UF_6	uranium hexafluoride
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UO_2	uranium dioxide
U_3O_8	triuranium octaoxide
USACE	U.S. Army Corps of Engineers
USC	*United States Code*
USCB	U.S. Census Bureau
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VOC	volatile organic compound
WCNOC	Wolf Creek Nuclear Operating Corporation
WCS	Waste Control Specialists LLC
WEC	wave energy capture
WGA	Western Governors' Association
WHO	World Health Organization

Shortened Nuclear Power Plant Names Used in This Report

Arkansas	Arkansas Nuclear One
Beaver Valley	Beaver Valley Power Station
Braidwood	Braidwood Station
Browns Ferry	Browns Ferry Nuclear Plant
Brunswick	Brunswick Steam Electric Plant
Byron	Byron Station
Callaway	Callaway Plant
Calvert Cliffs	Calvert Cliffs Nuclear Power Plant
Catawba	Catawba Nuclear Station
Clinton	Clinton Power Station
Columbia	Columbia Generating Station
Comanche Peak	Comanche Peak Steam Electric Station
Cooper	Cooper Nuclear Station
Crystal River	Crystal River Nuclear Power Plant
Cook	Donald C. Cook Nuclear Plant
Davis-Besse	Davis-Besse Nuclear Power Station
Diablo Canyon	Diablo Canyon Power Plant
Dresden	Dresden Nuclear Power Station
Arnold	Duane Arnold Energy Center
Farley	Joseph M. Farley Nuclear Plant
Fermi	Enrico Fermi Atomic Power Plant
FitzPatrick	James A. FitzPatrick Nuclear Power Plant
Fort Calhoun	Fort Calhoun Station
Ginna	R.E. Ginna Nuclear Power Plant
Grand Gulf	Grand Gulf Nuclear Station
Harris	Shearon Harris Nuclear Power Plant
Hatch	Edwin I. Hatch Nuclear Plant
Hope Creek	Hope Creek Generating Station
Indian Point	Indian Point Energy Center
Kewaunee	Kewaunee Power Station
LaSalle	LaSalle County Station
Limerick	Limerick Generating Station
McGuire	McGuire Nuclear Station
Millstone	Millstone Power Station
Monticello	Monticello Nuclear Generating Plant
Nine Mile Point	Nine Mile Point Nuclear Station
North Anna	North Anna Power Station
Oconee	Oconee Nuclear Station
Oyster Creek	Oyster Creek Nuclear Generating Station

Palisades	Palisades Nuclear Plant
Palo Verde	Palo Verde Nuclear Generating Station
Peach Bottom	Peach Bottom Atomic Power Station
Perry	Perry Nuclear Power Plant
Pilgrim	Pilgrim Nuclear Power Station
Point Beach	Point Beach Nuclear Plant
Prairie Island	Prairie Island Nuclear Generating Plant
Quad Cities	Quad Cities Nuclear Power Station
River Bend	River Bend Station
Robinson	H.B. Robinson Steam Electric Plant
St. Lucie	St. Lucie Nuclear Plant
Salem	Salem Nuclear Generating Station
San Onofre	San Onofre Nuclear Generating Station
Seabrook	Seabrook Station
Sequoyah	Sequoyah Nuclear Plant
South Texas	South Texas Project Electric Generating Station
Summer	Virgil C. Summer Nuclear Station
Surry	Surry Power Station
Susquehanna	Susquehanna Steam Electric Station
Three Mile Island	Three Mile Island, Unit 1
Turkey Point	Turkey Point Nuclear Plant
Vermont Yankee	Vermont Yankee Nuclear Power Station
Vogtle	Vogtle Electric Generating Plant
Waterford	Waterford Steam Electric Station
Watts Bar	Watts Bar Nuclear Plant
Wolf Creek	Wolf Creek Generating Station

Units of Measure

ac	acre(s)
bbl	barrel(s)
Btu	British thermal unit(s)
°C	degree(s) Celsius
cm	centimeter(s)
d	day(s)
dB	decibel(s)

°F	degree(s) Fahrenheit
ft	foot (feet)
ft^2	square foot (feet)
ft^3	cubic foot (feet)
gal	gallon(s)
gpd	gallon(s) per day
gpm	gallon(s) per minute
Gy	gray(s)
ha	hectare(s)
hr	hour(s)
Hz	hertz
in.	inch(es)
kg	kilogram(s)
km	kilometer(s)
kV	kilovolt(s)
kW	kilowatt(s)
kWh	kilowatt-hour(s)
L	liter(s)
lb	pound(s)
m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
mA	milliampere(s)
mg	milligram(s)
mG	milligauss
mGy	milligray(s)
MHz	megahertz
mi	mile(s)
min	minute(s)
mL	milliliter(s)
MMBtu	million Btu
MPa	megapascal(s)
mph	mile(s) per hour
mrad	milliard(s)
mrem	millirem(s)

Notation

mSv	millisievert(s)
mT	milliTesla(s)
MT	metric tonne(s)
MTHM	metric tonne(s) of heavy metal
MTU	metric tonne(s) of uranium
MW	megawatt(s)
MWe or MW(e)	megawatt(s) electric
MW(t)	megawatt(s) thermal
MWh	megawatt-hour(s)
pCi	picocurie(s)
ppm	part(s) per million
ppmv	parts per million by volume
ppt	part(s) per thousand
psi	pound(s) per square inch
rad	radian
rem	roentgen-equivalent-man
s	second(s)
scf	standard cubic foot (feet)
Sv	sievert(s)
T	tesla(s)
TPY	ton(s) per year
V	volt(s)
yr	year(s)
μCi	microcurie(s)
μGy	microgray(s)
μm	micrometer(s)
μT	microtesla(s)

Conversion Table

Multiply	By	To Obtain
To Convert English to Metric Equivalents		
acres	0.4047	hectares (ha)
cubic feet (ft^3)	0.02832	cubic meters (m^3)
cubic yards (yd^3)	0.7646	cubic meters (m^3)
curies (Ci)	3.7×10^{10}	becquerels (Bq)
degrees Fahrenheit (°F) -32	0.5555	degrees Celsius (°C)
feet (ft)	0.3048	meters (m)
gallons (gal)	3.785	liters (L)
gallons (gal)	0.003785	cubic meters (m^3)
inches (in.)	2.540	centimeters (cm)
miles (mi)	1.609	kilometers (km)
pounds (lb)	0.4536	kilograms (kg)
rads	0.01	grays (Gy)
rems	0.01	sieverts (Sv)
short tons (tons)	907.2	kilograms (kg)
short tons (tons)	0.9072	metric tons (t)
square feet (ft^2)	0.09290	square meters (m^2)
square yards (yd^2)	0.8361	square meters (m^2)
square miles (mi^2)	2.590	square kilometers (km^2)
yards (yd)	0.9144	meters (m)
To Convert Metric to English Equivalents		
becquerels (Bq)	2.7×10^{-11}	curies (Ci)
centimeters (cm)	0.3937	inches (in.)
cubic meters (m^3)	35.31	cubic feet (ft^3)
cubic meters (m^3)	1.308	cubic yards (yd^3)
cubic meters (m^3)	264.2	gallons (gal)
degrees Celsius (°C) +17.78	1.8	degrees Fahrenheit (°F)
grays (Gy)	100	rads
hectares (ha)	2.471	acres
kilograms (kg)	2.205	pounds (lb)
kilograms (kg)	0.001102	short tons (tons)
kilometers (km)	0.6214	miles (mi)
liters (L)	0.2642	gallons (gal)
meters (m)	3.281	feet (ft)
meters (m)	1.094	yards (yd)
metric tons (t)	1.102	short tons (tons)
sieverts (Sv)	100	rems
square kilometers (km^2)	0.3861	square miles (mi^2)
square meters (m^2)	10.76	square feet (ft^2)
square meters (m^2)	1.196	square yards (yd^2)

Summary

The Atomic Energy Act of 1954 authorizes the U.S. Nuclear Regulatory Commission (NRC) to issue commercial nuclear power plant operating licenses for up to 40 years and permits the renewal of the licenses as well. NRC regulations allow for the renewal of these operating licenses for up to an additional 20 years, depending on the outcome of safety and environmental reviews. There are no specific limitations in the Atomic Energy Act or the NRC's regulations restricting the number of times a license may be renewed.

The license renewal process is designed to assure safe operation of the nuclear power plant and protection of the environment during the license renewal term. Under the NRC's environmental protection regulations in Title 10, Part 51, of the *Code of Federal Regulations* (10 CFR Part 51), which implement Section 102(2) of the National Environmental Policy Act (NEPA), renewal of a nuclear power plant operating license requires the preparation of an environmental impact statement (EIS).

To support the preparation of these EISs, the NRC issued the *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (GEIS), NUREG-1437, in 1996. The original 1996 GEIS[a] for license renewal was prepared to assess the environmental impacts associated with the continued operation of nuclear power plants during the license renewal term. The NRC also promulgated a rule that codified the findings of the 1996 GEIS into its regulations at 10 CFR Part 51, Subpart A, Appendix B, Table B-1 (61 FR 28467, June 5, 1996). The intent was to determine which environmental impacts would result in essentially the same (generic) impact at all nuclear power plants and which ones could result in different levels of impacts at different plants and would require a plant-specific analysis to determine the impacts. For those issues that could not be generically addressed, the NRC would prepare plant-specific supplemental EISs (SEISs) to the GEIS.

The GEIS is intended to improve the efficiency of the license renewal process by (1) providing an evaluation of the types of environmental impacts that may occur from renewing commercial nuclear power plant operating licenses, (2) identifying and assessing impacts that are expected to be generic (the same or similar) at all nuclear plants (or plants with specific plant or site characteristics), and (3) defining the number and scope of environmental impact issues that need to be addressed in plant-specific EISs.

(a) Any reference in this document to the 1996 GEIS includes the two-volume set published in 1996 and Addendum 1 to the GEIS published in 1999.

As stated in the 1996 final rule that incorporated the findings of the GEIS in 10 CFR Part 51, the NRC recognized that environmental impact issues might change over time, and that additional issues may need to be considered. As further stated in the preamble to Table B-1, the NRC indicated that it intended to review the material in Table B-1 on a 10-year basis. The NRC began this review on June 3, 2003, by publishing a notice of intent to revise the 1996 GEIS (68 FR 33209). As part of this process and pursuant to 10 CFR 51.29, the NRC conducted scoping and held a series of public meetings (*see* 74 FR 38119 for more details). The original public comment period began in June 2003 and closed in September 2003. The project was inactive for the next two years due to limited NRC staff resources and competing demands. On October 3, 2005 (70 FR 57628), the NRC reopened the public comment period and extended it until December 30, 2005.

On July 31, 2009 (74 FR 38117), the NRC published the proposed rule, "Revisions to Environmental Review for Renewal of Nuclear Power Plant Operating Licenses," for public comment in the *Federal Register*. The proposed rule would amend Table B-1, by updating the Commission's 1996 findings on the environmental impacts related to the renewal of nuclear power plant operating licenses, and other NRC environmental protection regulations (e.g., 10 CFR 51.53, which sets forth the contents of the applicant's environmental report). Together with the proposed rule, the NRC also published a notice of availability of the draft revised GEIS (ADAMS Accession No. ML090220654); a proposed Revision 1 of Regulatory Guide (RG) 4.2, Supplement 1, "Preparation of Environmental Reports for Nuclear Power Plant License Renewal Applications" (ADAMS Accession No. ML091620409); and a proposed Revision 1 to NUREG–1555, Supplement 1, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants" (ADAMS Accession No. ML090230497), in the *Federal Register* (74 FR 38238). All of the documents requested public comments.

The proposed revision to the above documents were based on consideration of 1) comments received from the public during the public scoping period, 2) a review of comments received on plant-specific SEISs completed since the 1996 GEIS was issued, and 3) lessons learned and knowledge gained from previous and ongoing license renewal environmental reviews. The history of this rulemaking is discussed in more detail in the July 31, 2009 (74 FR 38117), proposed rule.

Since publication of the GEIS in 1996, approximately 40 nuclear plant sites (70 reactor units) have been the subject of plant-specific environmental reviews. This revision to the GEIS is intended to incorporate lessons learned and knowledge gained from these plant-specific environmental reviews, as well as changes to Federal laws and new information and research published since the 1996 GEIS.

S.1 Purpose and Need for the Proposed Action

The proposed action is the renewal of commercial nuclear power plant operating licenses. The NRC reviews each application submitted by licensees of operating nuclear power plants. A renewed license is just one of a number of conditions that licensees must meet if the licensee is to continue plant operations during the renewal term.

The purpose and need for NRC's proposed action is to provide an option to continue plant operations beyond the current licensing term to meet future system generating needs, as such needs may be determined by State, utility, system, and, where authorized, Federal (other than NRC) decision-makers. Unless there are findings in the safety review required by the Atomic Energy Act or in the NEPA environmental review that would lead the NRC to reject a license renewal application, the NRC has no role in the energy-planning decisions of power plant owners, State regulators, system operators, and, in some cases other Federal agencies, as to whether the plant should continue to operate.

In addition, the NRC has no authority or regulatory control over the ultimate selection of future replacement power alternatives. The NRC also cannot ensure that environmentally preferable replacement power alternatives are used in the future. While a wide range of replacement power alternatives are discussed in the GEIS, the only alternative to license renewal within NRC's decision-making authority is to not issue a renewed operating license. The impacts of not issuing a renewed operating license are addressed under the no-action alternative.

At some point, all nuclear power plants will terminate operations and undergo decommissioning. Under the no-action alternative, plant operations would be terminated at or before the end of the current license term. The no-action alternative, unlike the other alternatives, does not expressly meet the purpose and need of the proposed action, as it does not provide a means of meeting future electric system needs. No action, on its own, would likely create a need for replacement power, conservation and energy efficiency (demand-side management), purchased power, or some combination of these options.

A full range of replacement power alternatives are evaluated in the GEIS, including fossil fuel, new nuclear, and renewable energy sources. Conservation and power purchasing are also considered as replacement power alternatives to license renewal, because they represent other options for electric system planners.

S.2 Development of the Revised Generic Environmental Impact Statement

The GEIS documents the results of the systematic approach NRC used to evaluate the environmental consequences of renewing the licenses of commercial nuclear power plants and operating the plants for an additional 20 years beyond the current license term. The environmental consequences of license renewal include (1) impacts associated with continued operations and refurbishment activities similar to those that have occurred during the current license term; (2) impacts of various alternatives to the proposed action; (3) impacts from the termination of nuclear power plant operations and decommissioning after the license renewal term (with emphasis on the incremental effect caused by an additional 20 years of operation); (4) impacts associated with the uranium fuel cycle; (5) impacts of postulated accidents (design-basis accidents and severe accidents); (6) cumulative impacts of the proposed action; and (7) resource commitments associated with the proposed action, including unavoidable adverse impacts, the relationship between short-term use and long-term productivity, and irreversible and irretrievable commitment of resources. The environmental consequences of these activities are discussed in the GEIS.

In the 1996 GEIS, the NRC identified and assessed 92 environmental issues. This GEIS revision reviews and reevaluates the environmental impact issues and findings in the original GEIS. Experience gained from license renewal reviews conducted since the 1996 GEIS was published provides a source of new information for the evaluation presented in this revision. In addition, new research, findings, and other information were considered in evaluating the significance of impacts associated with license renewal. The purpose of the evaluation was to determine if the findings presented in the 1996 GEIS remain valid. In doing so, the NRC considered the need to modify, add to, group, or delete any of the 92 issues evaluated in the 1996 GEIS.

In a Notice of Intent published in the *Federal Register* on June 3, 2003, the NRC notified the public of its plan to revise the GEIS and to give people an opportunity to participate in the environmental scoping process. This step was the initial opportunity for public participation in the GEIS revision. In July 2003, the NRC held public scoping meetings in four locations (one in each of the four NRC regions)—Atlanta, Georgia; Oak Lawn, Illinois; Anaheim, California; and Boston, Massachusetts.

Participation in the scoping process by members of the public and local, State, Tribal, and Federal government agencies was encouraged and used to (1) determine the scope of the GEIS revision and identify whether there are any significant new issues that should be analyzed in depth; (2) identify and eliminate from detailed study those issues that are peripheral, are not significant, or have been covered by prior environmental reviews; (3) identify any environmental assessments and other EISs that are being or will be prepared that are related to, but are not part of, the scope of the proposed action; and (4) identify other environmental review and consultation requirements related to the proposed action.

The initial scoping period for this GEIS revision was from June 3, 2003, to September 17, 2003, but scoping was reopened between September 27, 2005, and December 30, 2005. The NRC staff reviewed the transcripts and all written material received during the scoping periods and identified individual comments. All comments and suggestions received orally during the scoping meetings or in writing were considered.

In evaluating the impacts of the proposed action and considering comments received from the public, agencies and other entities during the scoping period, the NRC identified 78 impact issues: 70 impact issues were associated with continued operations, refurbishment, and other supporting activities; 2 with postulated accidents; 1 with termination of plant operations and decommissioning; 4 with the uranium fuel cycle; and 1 with cumulative impacts. For all of these issues, the incremental effect of license renewal was the focus of the evaluation.

For each potential environmental impact issue, the revised GEIS (1) describes the nuclear power plant activity that could affect the resource, (2) identifies the resource that is affected, (3) evaluates past license renewal reviews and other available information, (4) assesses the nature and magnitude of the environmental impact on the affected resource, (5) characterizes the significance of the effect, (6) determines whether the results of the analysis apply to all nuclear power plants (whether the impact issue is Category 1, Category 2, or uncategorized), and (7) considers additional mitigation measures for adverse impacts.

The scope of the revised GEIS also evaluates the impacts of alternatives to license renewal, including replacement power generation (using fossil fuels, nuclear, and/or renewable energy), conservation and energy efficiency (demand-side management), and purchased power. It also evaluates the impacts from the no-action alternative (not renewing the operating license). This GEIS includes the NRC's evaluation of construction, operation, postulated accidents, decommissioning, and fuel cycles for these alternatives.

The NRC issued the revised GEIS as a draft on July 31, 2009; the NRC published a notice of the issuance in the *Federal Register* (34 FR 38238, July 31, 2009). The NRC also issued a proposed rule, which would codify the findings of the revised GEIS in Table B-1 of 10 CFR Part 51 as well as amend related 10 CFR Part 51 regulations (34 FR 38117, July 31, 2009). Both the notice issuing the draft revised GEIS and the proposed rule asked for public comments. The public comment period ran from July 31, 2009 to January 12, 2010. The NRC received several comment submissions (e.g., letters, e-mails), which contained, in aggregate, several hundred written comments. During the public comment period, the NRC also held six public meetings, which were transcribed (see ML093070141 for a summary of the public meetings).

All in-scope comments, both written and those received during the public meetings, were considered in preparing this revised GEIS.

S.3 Impact Definitions and Categories

The NRC's standard of significance for impacts uses the Council on Environmental Quality (CEQ) terminology for "significantly" (40 CFR 1508.27), which requires consideration of both "context" and "intensity." Based on this, the NRC established three levels of significance for potential impacts: SMALL, MODERATE, and LARGE. The definitions of the three significance levels, which are presented in the footnotes to Table B-1 of 10 CFR Part 51, Subpart A, Appendix B, follow:

- SMALL impact: Environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the Commission has concluded that those impacts that do not exceed permissible levels in the Commission's regulations are considered SMALL.

- MODERATE impact: Environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.

- LARGE impact: Environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

In addition to a determination of significance of environmental impacts associated with an issue, a determination was made whether the analysis in the GEIS could be applied to all nuclear plants (as well as to all plants with certain plant or site characteristics). Issues were assigned a Category 1 or Category 2 designation as follows:

Category 1 issues are those that meet all of the following criteria:

(1) The environmental impacts associated with the issue have been determined to apply either to all plants or, for some issues, to plants having a specific type of cooling system or other specified plant or site characteristics;

(2) A single significance level (i.e., SMALL, MODERATE, or LARGE) has been assigned to the impacts (except for offsite radiological impacts—collective impacts from other than the disposal of spent fuel and high-level waste);

(3) Mitigation of adverse impacts associated with the issue has been considered in the analysis, and it has been determined that additional plant-specific mitigation measures are not likely to be sufficiently beneficial to warrant implementation.

For issues that meet the three Category 1 criteria, no additional plant-specific analysis is required in future SEISs unless new and significant information is identified.

Category 2 issues are those that do not meet one or more of the criteria of Category 1, and therefore, require additional plant-specific review.

S.4 Affected Environment

For purposes of the evaluation in this GEIS revision, the “affected environment” is the environment currently existing around operating commercial nuclear power plants. Current conditions in the affected environment are the result of past construction and operations at the plants. The NRC has considered the effects of these past and ongoing impacts and how they have shaped the environment. The NRC evaluated impacts of license renewal that are incremental to existing conditions. These existing conditions serve as the baseline for the evaluation and include the effects of past and present actions at the plants. It is this existing affected environment that comprises the environmental baseline against which potential environmental impacts of license renewal are evaluated.

The NRC described the affected environment in terms of the following resource areas and activities: (1) land use and visual resources; (2) meteorology, air quality, and noise; (3) geologic environment; (4) water resources (surface water and groundwater resources); (5) ecological resources (terrestrial resources, aquatic resources, special status species and habitats); (6) historic and cultural resources; (7) socioeconomics; (8) human health (radiological and nonradiological hazards); (9) environmental justice; and (10) waste management and pollution prevention. The affected environments of the operating plant sites represent diverse environmental conditions.

S.5 Impacts from Continued Operations and Refurbishment Activities Associated with License Renewal

NRC identified 78 impact issues from continued operations and refurbishment associated with license renewal. Seventeen of these issues were identified as Category 2 issues and would require plant-specific evaluations in future SEISs. The conclusions in each resource topical area are summarized here.

Land Use

- The impacts of continued operations and refurbishment on onsite land use would be SMALL. Changes in onsite land use from continued operations and refurbishment would be a small fraction of the nuclear power plant site and would only involve land that is controlled by the licensee. This is a Category 1 issue.

- The impacts of continued operations and refurbishment on offsite land use would be SMALL. Offsite land use would not be affected from continued operations and refurbishment associated with license renewal. This is a Category 1 issue.

- Use of transmission line right-of-ways (ROWs) would continue with no change in offsite land use restrictions. This is a Category 1 issue.

Visual Resources

- No important changes to the visual appearance (aesthetics) of plant structures or transmission lines are expected from continued operations and refurbishment. This is a Category 1 issue.

Air Quality

- Air quality impacts from continued operations and refurbishment activities would be SMALL. Emissions from refurbishment activities at locations in or near air quality nonattainment or maintenance areas would be short-lived and would cease once the activities are completed. Operating experience has shown that the scale of refurbishment activities has not resulted in exceedances in the *de minimis* thresholds for criteria pollutants. Best management practices, including fugitive dust controls and the imposition of permit conditions in State and local air emissions permits, would ensure conformance with applicable State or Tribal Implementation Plans. Emissions from emergency diesel generators and fire pumps and routine operations of boilers used for space heating would not be a concern, even for plants located in or adjacent to nonattainment areas. Impacts from cooling tower particulate emissions even under the worst-case situations have been SMALL. This is a Category 1 issue.

- Production of ozone and oxides of nitrogen from transmission lines is insignificant and does not contribute measurably to ambient levels of these gases. This is a Category 1 issue.

Noise Impacts

- The impacts of continued operations and refurbishment on offsite noise levels would be SMALL. Noise levels would remain below regulatory guidelines for offsite receptors. This is a Category 1 issue.

Geology and Soils

- The effect of geologic and soil conditions on plant operations and the impact of continued operations and refurbishment activities on geology and soils would be SMALL and would not change appreciably during the license renewal term. This is a Category 1 issue.

Surface Water Resources

- The non-cooling system impacts of continued operations and refurbishment on surface water use and quality would be SMALL if best management practices are employed to control soil erosion and spills. Surface water use would not increase significantly or would be reduced if refurbishment occurs during a plant outage. This is a Category 1 issue.

- Altered current patterns would be limited to the area in the vicinity of the intake and discharge structures. These impacts have been SMALL at operating nuclear power plants. This is a Category 1 issue.

- Effects on salinity gradients would be limited to the area in the vicinity of the intake and discharge structures. These impacts have been SMALL at operating nuclear power plants. This is a Category 1 issue.

- Effects on thermal stratification in lakes would be limited to the area in the vicinity of the intake and discharge structures. These impacts have been SMALL at operating nuclear power plants. This is a Category 1 issue.

- Scouring effects would be limited to the area in the vicinity of the intake and discharge structures. These impacts have been SMALL at operating nuclear power plants. This is a Category 1 issue.

- Discharges of metals in cooling system effluent have not been found to be a problem at operating nuclear power plants with cooling-tower-based heat dissipation systems and have been mitigated at other plants. Discharges are monitored as part of the National Pollutant Discharge Elimination System (NPDES) permit process. This is a Category 1 issue.

- The discharge and effects of biocides, sanitary wastes, and minor chemical spills are regulated by State and Federal environmental agencies. Discharges are monitored and controlled as part of the NPDES permit process. These impacts have been SMALL at operating nuclear power plants. This is a Category 1 issue.

- Surface water use conflicts have not been found to be a problem at operating nuclear power plants with once-through heat dissipation systems. This is a Category 1 issue.

- Surface water use conflicts could occur with nuclear power plants that rely on cooling ponds or cooling towers using makeup water from a river. Impacts could be SMALL or MODERATE, depending on makeup water requirements, water availability, and competing water demands. This is a Category 2 issue.

- Dredging to remove accumulated sediments in the vicinity of intake and discharge structures and to maintain barge shipping has not been found to be a problem for surface water quality. Dredging is performed under permit from the U.S. Army Corps of Engineers, and possibly, from State or local agencies. This is a Category 1 issue.

- Temperature effects on sediment capacity have not been found to be a problem at operating nuclear power plants and are not expected to be a problem during the license renewal term. This is a Category 1 issue.

Groundwater Resources

- The non-cooling system impacts of continued operations and refurbishment on groundwater would be SMALL. Extensive dewatering is not anticipated during continued operations. Industrial practices involving the use of solvents, hydrocarbons, heavy metals, or other chemicals and/or the use of wastewater ponds or lagoons have the potential to contaminate site groundwater, soil, and subsoil. Contamination is subject to State or U.S. Environmental Protection Agency (EPA)-regulated cleanup and monitoring programs. The application of best management practices for handling any materials produced or used during these activities would reduce impacts. This is a Category 1 issue.

- Groundwater use conflicts are not anticipated for nuclear power plants that withdraw less than 100 gallons per minute. This is a Category 1 issue.

- Groundwater use conflicts with nearby groundwater users could occur with nuclear power plants that withdraw more than 100 gallons per minute. Impacts could be SMALL, MODERATE, or LARGE. This is a Category 2 issue.

- For plants with closed-cycle cooling systems that withdraw makeup water from a river, groundwater use conflicts could result from water withdrawals from rivers during low-flow conditions, which may affect aquifer recharge. The significance of impacts would depend on makeup water requirements, water availability, and competing water demands. The impacts on groundwater quality could be SMALL, MODERATE, or LARGE. This is a Category 2 issue.

- Groundwater withdrawals at operating nuclear power plants would not significantly degrade groundwater quality. This is a Category 1 issue.

- For plants with closed-cycle cooling ponds in salt marshes, groundwater quality could be degraded; the impact would be SMALL. However, groundwater in salt marshes is naturally brackish and thus, not potable. Consequently, the human use of such groundwater is limited to industrial purposes. This is a Category 1 issue.

- For plants with closed-cycle cooling ponds at inland sites, the impacts on groundwater quality could be SMALL, MODERATE, or LARGE. The significance of the impact would depend on cooling pond water quality; site hydrogeologic conditions (including the interaction of surface water and groundwater); and the location, depth, and pump rate of water wells. This is a Category 2 issue.

- Radionuclides released to groundwater, particularly tritium, due to inadvertent leaks of radioactive liquids from plant components and pipes could result in SMALL or MODERATE groundwater quality impacts. Such leaks have occurred at numerous plants. Groundwater protection programs have been established at all operating nuclear power plants to minimize the potential impact from any inadvertent releases. This is a Category 2 issue.

Terrestrial Resources

- Non-cooling system impacts of continued operations and refurbishment may affect terrestrial communities. Application of best management practices would reduce the potential for impacts. The magnitude of impacts (SMALL, MODERATE, or LARGE) would depend on the nature of the activity, the status of the resources that could be affected, and the effectiveness of mitigation. This is a Category 2 issue.

- The impacts of the exposure of terrestrial organisms to radionuclides would be SMALL. Doses to terrestrial organisms are expected to be well below exposure guidelines developed to protect these organisms. This is a Category 1 issue.

- Cooling system impacts on terrestrial resources would be SMALL for all nuclear plants with once-through cooling systems or cooling ponds. No adverse effects to terrestrial plants or animals have been reported as a result of increased water temperatures, fogging, humidity, or reduced habitat quality. Due to the low concentrations of contaminants in cooling system effluents, uptake and accumulation of contaminants are not expected to be significant. This is a Category 1 issue.

- Cooling tower operations and the impacts from salt drift, icing, fogging, or increased humidity associated with cooling tower operation have the potential to affect adjacent vegetation. However, these impacts have been SMALL at operating nuclear power plants and are not expected to change over the license renewal term. This is a Category 1 issue.

- Bird collisions with cooling towers and other plant structures and transmission lines occur at rates that are unlikely to affect local or migratory populations, and the rates are not expected to change during the license renewal term. This is a Category 1 issue.

- Water use conflicts with terrestrial resources for plants with cooling ponds or cooling towers using makeup water from a river could be SMALL or MODERATE. Impacts on terrestrial resources in riparian communities affected by water use conflicts could be of moderate significance in some situations. This is a Category 2 issue.

- Transmission line ROW management impacts on terrestrial resources would be SMALL. Continued ROW management is expected to keep terrestrial communities in their current condition. Application of best management practices would reduce the potential for impacts. This is a Category 1 issue.

- Impacts of electromagnetic fields on flora and fauna would be SMALL. No significant impacts of electromagnetic fields on terrestrial flora and fauna have been identified. Such effects are not expected to be a problem during the license renewal term. This is a Category 1 issue.

Aquatic Resources

- The impacts of impingement and entrainment of aquatic organisms could be SMALL, MODERATE, or LARGE at nuclear plants with once-through cooling systems or cooling ponds. The impacts are SMALL at many plants but may be MODERATE or even LARGE at a few plants, depending on cooling system withdrawal rates and volumes and the aquatic resources at the site. This is a Category 2 issue.

- The impacts of impingement and entrainment of aquatic organisms would be SMALL at plants with cooling towers. Impingement and entrainment rates are lower at plants that use closed-cycle cooling with cooling towers because the rates and volumes of water withdrawal needed for makeup are minimized. This is a Category 1 issue.

- Entrainment of phytoplankton and zooplankton has not been found to be a problem at operating nuclear power plants and is not expected to be a problem during the license renewal term. This is a Category 1 issue.

- Thermal impacts on aquatic organisms could be SMALL, MODERATE, or LARGE at nuclear plants with once-through cooling systems or cooling ponds. Most of the effects associated with thermal discharges are localized and are not expected to affect overall stability of populations or resources. The magnitude of impacts would depend on site-specific thermal plume characteristics and the nature of aquatic resources in the area. This is a Category 2 issue.

- Thermal impacts on aquatic organisms associated with plants that use cooling towers would be SMALL because of the reduced amount of heated discharge. This is a Category 1 issue.

- Infrequently reported thermal impacts would be SMALL for all nuclear plants during the license renewal term. Cold shock has been satisfactorily mitigated at operating nuclear plants with once-through cooling systems, has not endangered fish populations or been found to be a problem at operating nuclear power plants with cooling towers or cooling ponds, and is not expected to be a problem. Thermal plumes have not been found to be a problem at operating nuclear power plants and are not expected to be a problem. Thermal discharge may have localized effects but is not expected to affect the larger geographical distribution of aquatic organisms. Premature emergence has been found to be a localized effect at some operating nuclear power plants but has not been a problem and is not expected to be a problem. Stimulation of nuisance organisms has been mitigated at the single nuclear power plant with a once-through cooling system where previously it was a problem. It has not been found to be a problem at operating nuclear power plants with cooling towers or cooling ponds and is not expected to be a problem. This is a Category 1 issue.

- The effects of cooling water discharge on dissolved oxygen, gas supersaturation, and eutrophication are expected to result in SMALL impacts at all nuclear plants. Gas supersaturation was a concern at a small number of operating nuclear power plants with once-through cooling systems but has been satisfactorily mitigated. Low dissolved oxygen was a concern at one nuclear power plant with a once-through cooling system, but the problem has been effectively mitigated. Eutrophication (nutrient loading) and resulting effects on chemical and biological oxygen demands have not been found to be a problem at operating nuclear power plants. This is a Category 1 issue.

- The impacts of nonradiological contaminants on aquatic organisms would be SMALL. Best management practices and discharge limitations of NPDES permits are expected to minimize the potential for impacts to aquatic resources. Accumulation of metal contaminants has been a concern at a few nuclear power plants, but has been satisfactorily mitigated by replacing copper alloy condenser tubes with those of another metal. This is a Category 1 issue.

- The impacts of radionuclides on aquatic organisms would be SMALL. Doses to aquatic organisms are expected to be well below exposure guidelines developed to protect these organisms. This is a Category 1 issue.

- The effects of dredging on aquatic resources would be SMALL. Dredging at nuclear power plants is expected to occur infrequently, would be of relatively short duration, and would affect relatively small areas. Dredging is performed under permit from the U.S. Army Corps of Engineers, and possibly, from other State or local agencies. This is a Category 1 issue.

- Water use conflicts with aquatic resources for plants with cooling ponds or cooling towers using makeup water from a river could be SMALL or MODERATE. Impacts on aquatic resources in stream communities affected by water use conflicts could be of moderate significance in some situations. This is a Category 2 issue.

- The non-cooling system impacts of continued operations and refurbishment activities on aquatic resources would be SMALL. Licensee application of appropriate mitigation measures is expected to result in no more than small changes to aquatic communities from their current condition. This is a Category 1 issue.

- The impacts of transmission line ROW management on aquatic resources would be SMALL. Licensee application of best management practices to ROW maintenance is expected to result in no more than small impacts to aquatic resources. This is a Category 1 issue.

- Losses from predation, parasitism, and disease among organisms exposed to sublethal stresses would be SMALL. These types of losses have not been found to be a problem at operating nuclear power plants and are not expected to be a problem during the license renewal term. This is a Category 1 issue.

Special Status Species and Habitats

- The magnitude of impacts on threatened, endangered, and protected species, critical habitat, and essential fish habitat would depend on the occurrence of listed species and habitats and the effects of power plant systems on them. Consultation with appropriate agencies would be needed to determine whether special status species or habitats are present and whether they would be adversely affected by continued operations and refurbishment associated with license renewal. This is a Category 2 issue.

Historic and Cultural Resources

- Continued operations and refurbishment associated with license renewal are expected to have no more than small impacts on historic and cultural resources located onsite and in the transmission line ROWs because most impacts could be mitigated by avoiding those resources. The National Historic Preservation Act (NHPA) requires the Federal agency to consult with the State Historic Preservation Officer (SHPO) and Native American Tribes to determine the potential effects on historic properties and mitigation, if necessary. This is a Category 2 issue.

Socioeconomics

- Although most nuclear plants have large numbers of employees with higher than average wages and salaries, employment, income, recreation, and tourism, impacts from continued operations and refurbishment associated with license renewal are expected to be SMALL. This is a Category 1 issue.

- Impacts on tax revenues would be SMALL. Nuclear plants provide tax revenue to local jurisdictions in the form of property tax payments, payments in lieu of tax (PILOT) payments, or tax payments on energy production. The amount of tax revenue paid during the license renewal term as a result of continued operations and refurbishment associated with license renewal is not expected to change. This is a Category 1 issue.

- Changes to community services and education resulting from continued operations and refurbishment associated with license renewal would be SMALL. With little or no change in (1) employment at the licensee's plant, (2) value of the power plant, (3) payments on energy production, and (4) PILOT payments expected during the renewal term, community and educational services would not be affected by continued power plant operations. This is a Category 1 issue.

- Population and housing impacts would be SMALL as changes resulting from continued operations and refurbishment associated with license renewal to regional population and housing availability and value would be SMALL. With little or no change in employment at the licensee's plant expected during the license renewal term, population and housing availability and values would not be affected by continued power plant operations. This is a Category 1 issue.

- Transportation impacts would be SMALL as changes resulting from continued operations and refurbishment associated with license renewal to traffic volumes would be SMALL. This is a Category 1 issue.

Human Health

- Radiation doses to the public from continued operations and refurbishment associated with the license renewal term are expected to continue at current levels and would be well below regulatory limits. The impacts from radiation doses to the public would be SMALL. This is a Category 1 issue.

- Radiation doses to plant workers from continued operations and refurbishment associated with license renewal are expected to be within the range of doses experienced during the current license term and would continue to be well below regulatory limits. The impacts from radiation doses to plant workers would be SMALL. This is a Category 1 issue.

- Chemical hazards to plant workers resulting from continued operations and refurbishment associated with license renewal are expected to be minimized by the licensee implementing good industrial hygiene practices as required by permits and Federal and State regulations. Chemical releases to the environment and the potential for impacts to the public are expected to be minimized by adherence to discharge limitations of NPDES and other permits. The impacts from chemical hazards to plant workers would be SMALL. This is a Category 1 issue.

- Microbiological hazards to the public are not expected to be a problem at most operating plants but could result in SMALL, MODERATE, or LARGE impacts at plants with cooling ponds, lakes, canals, or that discharge to a river. Impacts would depend on site-specific characteristics. This is a Category 2 issue.

- Microbiological hazards to plant workers would be SMALL. Occupational health impacts are expected to be controlled by continued application of accepted industrial hygiene practices to minimize worker exposures as required by permits and Federal and State regulations. This is a Category 1 issue.

- The chronic effects of electromagnetic fields (EMFs) associated with nuclear plants and associated transmission lines are uncertain. Studies of 60-Hz EMFs have not uncovered consistent evidence linking harmful effects with field exposures. EMFs are unlike other agents that have a toxic effect (e.g., toxic chemicals and ionizing radiation) in that dramatic acute effects cannot be forced and longer-term effects, if real, are subtle. Because the state of the science is currently inadequate, no generic conclusion on human health impacts is possible. This issue has not been categorized.

- Physical occupational safety and health hazards are generic to all types of electrical generating stations, including nuclear power plants, and are of small significance if the workers adhere to safety standards and use personal protective equipment as required by Federal and State regulations. This is a Category 1 issue.

- Electric shock hazards could result in SMALL, MODERATE, or LARGE impacts. Electrical shock potential is of small significance for transmission lines that are operated in adherence with the National Electrical Safety Code (NESC). Without a review of conformance with NESC criteria of each nuclear power plant's in-scope transmission lines, it is not possible to determine the generic significance of the electrical shock potential. This is a Category 2 issue.

Postulated Accidents

- The environmental impacts of design-basis accidents are SMALL for all nuclear plants. Due to the requirements for nuclear plants to maintain their licensing basis and implement aging management programs during the license renewal term, the environmental impacts during a license renewal term should not differ significantly from those calculated for the design-basis accident assessments conducted as part of the initial plant licensing process. This is a Category 1 issue.

- For severe accidents, the probability-weighted consequences of atmospheric releases, fallout onto open bodies of water, releases to groundwater, and societal and economic impacts from severe accidents are SMALL for all plants. However, alternatives to mitigate severe accidents must be considered for all plants that have not considered such alternatives. This is a Category 2 issue.

Environmental Justice

- Impacts to minority and low-income populations and subsistence consumption resulting from continued operations and refurbishment associated with license renewal will be addressed in plant-specific reviews. See NRC Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions (69 FR 52040, August 24, 2004). This is a Category 2 issue.

Waste Management and Pollution Prevention

- The impacts from low-level waste (LLW) storage and disposal would be SMALL. The comprehensive regulatory controls that are in place and the low public doses being achieved at reactors ensure that the radiological impacts on the environment would remain SMALL during the license renewal term. This is a Category 1 issue.

- The impacts from onsite storage of spent nuclear fuel would be SMALL. The expected increase in the volume of spent fuel from an additional 20 years of operation can be safely accommodated onsite during the license renewal term with small environmental effects through dry or pool storage at all plants. This is a Category 1 issue.

- The impacts from offsite radiological impacts of spent nuclear fuel and high-level waste (HLW) disposal are uncertain. The issue is not categorized.

- The impacts from mixed-waste storage and disposal would be SMALL. The comprehensive regulatory controls and the facilities and procedures that are in place ensure proper handling and storage, as well as negligible doses and exposure to toxic materials for the public and the environment at all plants. License renewal would not increase the small continuing risk to human health and the environment posed by mixed waste at all plants. The radiological and nonradiological environmental impacts of long-term disposal of mixed waste from any individual plant at licensed sites are SMALL. This is a Category 1 issue.

- The impacts from nonradioactive waste storage and disposal would be SMALL. No changes to systems that generate nonradioactive waste are anticipated during the license renewal term. Facilities and procedures are in place to ensure continued proper handling, storage, and disposal, as well as negligible exposure to toxic materials for the public and the environment at all plants. This is a Category 1 issue.

Cumulative Impacts

- Cumulative impacts are those impacts on the environment that result from the incremental impact of the proposed action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency (Federal or non-Federal) or person undertakes such other actions. The cumulative impacts of continued operations and refurbishment associated with license renewal must be considered on a plant-specific basis. Impacts would depend on regional resource characteristics, the resource-specific impacts of license renewal, and the cumulative significance of other factors affecting the resource. This is a Category 2 issue.

Uranium Fuel Cycle

- The individual offsite radiological impacts resulting from portions of the uranium fuel cycle, other than the disposal of spent fuel and HLW, would be SMALL. The impacts on individuals from radioactive gaseous and liquid releases during the license renewal term would remain at or below the NRC's regulatory limits. This is a Category 1 issue.

- With respect to the collective offsite radiological impacts from the uranium fuel cycle other than the disposal of spent fuel and HLW, there are no regulatory limits applicable to collective doses to the general public from fuel-cycle facilities. The practice of estimating health effects based on collective doses may not be meaningful. All fuel-cycle facilities are designed and operated to meet the applicable regulatory dose limits and standards. Accordingly, the Commission concludes that the collective impacts are acceptable. This is a Category 1 issue.

- The nonradiological impacts of the uranium fuel cycle resulting from the renewal of an operating license for any plant would be SMALL. This is a Category 1 issue.

- The impacts of transporting materials to and from uranium-fuel-cycle facilities on workers, the public, and the environment are expected to be SMALL. This is a Category 1 issue.

Termination of Nuclear Power Plant Operations and Decommissioning

- Termination of plant operations and decommissioning would occur eventually regardless of license renewal. The additional 20-year period of operation under the license renewal term would not affect the impacts of shutdown and decommissioning on any resource or at any plant. This is a Category 1 issue.

S.6 Comparison of Alternatives

The GEIS also evaluates the impacts of the proposed action (license renewal) and alternatives to license renewal, including the no-action alternative (not renewing the operating license). It also evaluates the impacts of replacement power alternatives (fossil fuels, nuclear, and renewable energy), conservation and energy efficiency (demand-side management), and purchased power. The impacts of renewing the operating license of a nuclear power plant are comparable to the impacts of energy alternatives. Replacement power alternatives would require the construction of a new power plant or modification of the electric transmission grid. The new power plants would also have operational impacts. Conversely, license renewal does not require major construction and operational impacts, which would not change beyond what is currently being experienced. Other alternatives that would not have construction or operational impacts include conservation and energy efficiency (demand-side management), delayed retirement, repowering, and purchased power.

Operational impacts of license renewal are comparable to replacement power alternatives and some renewable alternatives in some resource areas (socioeconomics) but quite different in other resource areas (air emissions, fuel cycle, land use, and water consumption). Renewable energy alternatives (wind, ocean wave, and ocean current alternatives) have very few operational impacts, while others (biomass combustion and conventional hydropower) can have considerable impacts. Some renewable energy alternatives (wind and solar) have relatively low but regionally variable capacity factors.

License renewal and alternatives differ in other respects, including the consequences of accidents. License renewal and new nuclear energy alternatives may have low-probability but potentially high-consequence accidents. In addition, fuel cycle impacts vary across alternatives. Some, like fossil fuel, require large amounts of land for fuel extraction.

Impacts from terminating power plant operations and decommissioning would vary between license renewal and the alternatives. License renewal delays the date of reactor shutdown and decommissioning but does not alter the impact levels. Impacts would be SMALL in all resource areas. In comparison, impacts from terminating operations and decommissioning of most alternatives would be larger than impacts from license renewal.

Under NEPA, the NRC has the obligation to consider reasonable alternatives to the proposed action of renewing the license for a nuclear reactor. The GEIS facilitates that alternative analysis by providing NRC review teams with empirical evidence of the performance, environmental impacts, and resource demands and impacts of those potential replacement power alternatives current as of the time this GEIS was prepared. A site-specific analysis of alternatives will be performed for each SEIS, taking into account changes in technology and science since the preparation of this GEIS.

1 Introduction

Contents of Chapter 1

The Atomic Energy Act of 1954 authorizes the U.S. Nuclear Regulatory Commission (NRC) to issue commercial nuclear power plant operating licenses for up to 40 years. The 40-year length of the original license period was imposed for economic and antitrust reasons rather than the technical limitations of the nuclear power plant. NRC regulations allow for the renewal of these operating licenses for up to an additional 20 years, depending on the outcome of an assessment determining whether the nuclear power plant can continue to operate safely and protect the environment during the 20-year period of extended operation. There are no specific limitations in the Atomic Energy Act or the NRC's regulations restricting the number of times a license may be renewed.

The license renewal process is designed to assure the safe operation of the nuclear power plant and protection of the environment for up to an additional 20 years. Under the NRC's environmental protection regulations in Title 10, Part 51 of the *Code of Federal Regulations* (10 CFR Part 51), which implement the National Environmental Policy Act (NEPA), renewal of a nuclear power plant operating license requires the preparation of an environmental impact statement (EIS).

To support the preparation of these EISs, the NRC prepared the *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (GEIS), NUREG-1437 (NRC 1996, 1999). The original 1996 GEIS[a] for license renewal was prepared to assess the environmental impacts associated with the continued operation of nuclear power plants during the license

(a) Any reference in this document to the 1996 GEIS includes the two-volume set published in 1996 and Addendum 1 to the GEIS published in 1999.

renewal term. The intent of the GEIS is to determine which impacts would essentially be the same at all nuclear power plants and which ones could be different at different plants and would require a plant-specific analysis to determine the impacts.

1.1 Purpose of the GEIS

> ***Generic Environmental Impact Statement (GEIS)***
>
> A GEIS is an environmental impact statement that assesses the scope and impact of the environmental effects that would be associated with an action (such as license renewal) at numerous sites.
>
> ***Supplemental Environmental Impact Statement (SEIS)***
>
> A SEIS updates or supplements an existing EIS (such as the GEIS). The Commission directed the NRC staff to issue plant-specific supplements to the GEIS for each license renewal application.

The GEIS for license renewal of nuclear power plants assesses the environmental impacts that could be associated with license renewal and an additional 20 years of power plant operation. This assessment is summarized in this GEIS. This GEIS also provides the technical basis for license renewal amendments to the Commission's regulations, 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions." In the 1996 GEIS and related rulemaking, the Commission determined that certain impacts associated with the renewal of a nuclear power plant operating license were the same or similar for all plants and could be treated on a generic basis. In this way, repetitive reviews of these impacts could be avoided. The Commission based its generic assessment of certain environmental impacts on the following factors:

(1) License renewal will involve nuclear power plants for which the environmental impacts of operation are well understood as a result of lessons learned and knowledge gained from operating experience and completed license renewals.

(2) Activities associated with license renewal are expected to be within this range of operating experience; thus, environmental impacts can be reasonably predicted.

(3) Changes in the environment around nuclear power plants are gradual and predictable.

The GEIS is intended to improve the efficiency of the license renewal process by (1) providing an evaluation of the types of environmental impacts that may occur from renewing commercial nuclear power plant operating licenses, (2) identifying and assessing impacts that are expected to be generic (the same or similar) at all nuclear plants (or plants with specified plant or site characteristics), and (3) defining the number and scope of environmental impact issues that need to be addressed in plant-specific EISs. The GEIS provides information that will aid the preparation of plant-specific EISs.

1.2 Description of the Proposed Action

> ***The Proposed Action***
>
> To renew commercial nuclear power plant operating licenses.
>
> ***Purpose and Need for the Proposed Action***
>
> To provide an option to continue plant operations beyond the current licensing term to meet future system generating needs.

Under NRC's environmental protection regulations in 10 CFR 51.20, renewal of a nuclear power plant operating license is identified as a major Federal action that requires the preparation of an EIS to address the impacts of renewing a plant's operating license. The EIS requirements for a plant-specific license renewal review are specified in 10 CFR 51.71 and 51.95. NRC's public health and safety and other technical requirements for the renewal of operating licenses are found in 10 CFR Part 54. Part 54 requires applicants to perform safety evaluations and assessments of nuclear power plants and provide the NRC with sufficient information to analyze the impacts of continued operation for the requested renewal term. Applicants are required to assess the effects of aging on passive and long-lived systems, structures, and components.

Most utilities are expected to begin preparation for license renewal about 10 to 20 years before expiration of their current operating licenses. Inspection, surveillance, test, and maintenance programs to support continued plant operations during the license renewal term would be integrated gradually over a period of years. Any refurbishment-type activities undertaken for the purposes of license renewal have generally been completed during normal plant refueling or maintenance outages before the original license expires. Activities associated with license renewal and operation of a plant for an additional 20 years are discussed in Chapter 2.

1.3 Purpose and Need for the Proposed Action

The Commission acts on each application submitted by a licensee for the renewal of commercial nuclear power plant operating licenses per Section 103 of the Atomic Energy Act. A renewed license is just one of a number of conditions that licensees must meet to operate its nuclear plant during the license renewal term. State regulators, system operators, and in some cases, other Federal agencies, ultimately decide whether the plant will continue to operate based on factors such as need for power or other factors within the State's jurisdiction or owner's control. Economic considerations play a primary role in this decision.

The purpose and need for the proposed action (issuance of a renewed license) is to provide an option that allows for baseload power generation capability beyond the term of the current nuclear power plant operating license to meet future system generating needs. Such needs may be determined by other energy-planning decision-makers, such as State, utility, and, where authorized, Federal agencies (other than the NRC). Unless there are findings in the safety review required by the Atomic Energy Act or the NEPA environmental review that would lead the NRC to reject a license renewal application, the NRC does not have a role in the energy-planning decisions of whether a particular nuclear power plant should continue to operate.

From the perspective of the licensee and the State regulatory authority, the purpose of renewing an operating license is to maintain the availability of the nuclear power plant to meet system energy requirements beyond the term of the plant's current license. In cases of interstate generation or other special circumstances, Federal agencies such as the Federal Energy Regulatory Commission (FERC) or the Tennessee Valley Authority (TVA) may be involved in making these decisions.

1.4 Alternatives to the Proposed Action

In license renewal environmental reviews, the NRC considers the environmental consequences of the proposed action, the no-action alternative (i.e., not renewing the operating license), and the environmental consequences of various alternatives for replacing the nuclear power plant's generating capacity. No conclusions are made in the GEIS about the relative environmental consequences of license renewal, the no-action alternative, and the construction and operation of alternative facilities for generating electric energy. However, information presented in the GEIS can be used by the NRC and applicants in performing the plant-specific analysis of alternatives.

In plant-specific environmental reviews, the NRC compares the environmental impacts of license renewal with those of the no-action alternative and replacement power alternatives to determine whether the adverse environmental impacts of license renewal are great enough to deny the option of license renewal for energy-planning decision-makers.

1.5 Analytical Approach Used in the GEIS

1.5.1 Objectives

The GEIS serves to facilitate NRC's environmental review process by identifying and evaluating environmental impacts that are considered generic and common to all nuclear power plants. Plant-specific impact issues will be addressed in separate supplemental EISs (SEISs) to the GEIS. Generic impacts will be reconsidered in SEISs only if there is new and significant information that would change the conclusions in the GEIS.

1.5.2 Methodology

Environmental impacts of license renewal and the resources that could be affected by continued operation and refurbishment were identified. The general analytical approach for identifying environmental impacts was to (1) describe the nuclear power plant activity that could affect the resource, (2) identify the resource that is affected, (3) evaluate past license renewal reviews and other available information, (4) assess the nature and magnitude of the environmental impact on the affected resource, (5) characterize the significance of the effects, and (6) determine whether the results of the analysis apply to all nuclear power plants (whether the environmental impact issue is Category 1 or Category 2, as described below). Identifying environmental impacts (or issues) was conducted in an iterative rather than a stepwise manner. For example, after information was collected and levels of significance were reviewed, impacts were reexamined to determine if any should be removed, added, consolidated, or divided.

1.5.2.1 Defining Environmental Issues

The 1996 GEIS presents the findings of a systematic inquiry into the environmental impacts of license renewal resulting in the identification of 92 environmental issues (or impacts), which were evaluated in the GEIS. Public and stakeholder comments on previous plant-specific license renewal reviews were analyzed in an effort to reevaluate the existing environmental issues and identify new issues. Environmental issues in this GEIS are arranged by resource area. This perspective is a change from the 1996 GEIS in which environmental issues were arranged by power plant systems.

1.5.2.2 Collecting Information

Information from completed license renewal environmental reviews was collected and reviewed. Searches of the open scientific literature, databases, and Web sites were conducted for each resource area. This information was collected and evaluated to determine if the environmental issues and findings in the 1996 GEIS needed to be revised.

1.5.2.3 Determining Significance Levels for Issues

A standard of significance was established for each license renewal environmental impact issue evaluated in the 1996 GEIS based on the Council on Environmental Quality (CEQ) terminology for “significantly” (see 40 CFR 1508.27). Since the significance and severity of an impact can vary with the setting of the proposed action, both “context” and “intensity,” as defined in CEQ regulations 40 CFR 1508.27, were considered. Context is the geographic, biophysical, and social context in which the effects will occur. In the case of license renewal, the context is the environment surrounding the nuclear power plant. Intensity refers to the severity of the impact in whatever context it occurs. Based on this, the NRC established three levels of significance for potential impacts: SMALL, MODERATE, and LARGE. The definitions of these three significance levels, which are presented in the footnotes to Table B–1 in Appendix B to Subpart A of 10 CFR Part 51, follow:

- SMALL—environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the Commission has concluded that those impacts that do not exceed permissible levels in the Commission's regulations are considered SMALL.

- MODERATE—environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.

- LARGE—environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

The discussion of each environmental impact issue in the GEIS includes an explanation of how the significance category was determined. For issues in which the probability of occurrence is a key consideration (i.e., postulated accidents), the probability of occurrence has been factored into the determination of significance. Possible mitigation measures that could be used to avoid, minimize, rectify, reduce, eliminate, or compensate for adverse impacts are discussed where appropriate.

In addition to determining the significance of environmental impacts associated with an issue, a determination was made whether the analysis in the GEIS could be applied to all nuclear power plants. The categories to which an issue may be assigned are presented below.

- **Category 1**—the analysis reported in the GEIS has shown the following:

  (1) The environmental impacts associated with the issue have been determined to apply either to all plants or, for some issues, to plants having a specific type of cooling system or other specified plant or site characteristics;

  (2) A single significance level (i.e., SMALL, MODERATE, or LARGE) has been assigned to the impacts (except for collective offsite radiological impacts from the fuel cycle and from high-level waste and spent fuel); and

  (3) Mitigation of adverse impacts associated with the issue has been considered in the analysis, and it has been determined that additional plant-specific mitigation measures are not likely to be sufficiently beneficial to warrant implementation.

- **Category 2**—the analysis reported in the GEIS has shown that one or more of the criteria of Category 1 cannot be met, and therefore, additional plant-specific review is required.

If all three Category 1 criteria apply to a particular issue, then the generic impact analysis presented in this GEIS is relied upon by the NRC in evaluating license renewal applications and plant-specific SEISs provided there is no new and significant information requiring further analysis. For issues that do not meet all three Category 1 criteria, the issue is considered a Category 2 issue, and a plant-specific impact analysis is required for that issue.

1.6 Scope of the GEIS Revision

The NRC assessed the impact of license renewal on 92 environmental issues for the 1996 GEIS. Impacts associated with 69 of these issues were determined to be generic (i.e., the same or similar at all plants), or Category 1. These issues are addressed in the 1996 GEIS and do not require a plant-specific assessment unless new and significant information is found that would change the conclusions in the GEIS. Guidance on plant-specific analyses required for the other 23 issues is provided in 10 CFR Part 51. Findings on the scope and magnitude of environmental impacts of renewing a nuclear power plant operating license in the GEIS as required by section 102(2) of NEPA are summarized in Table B–1 in Appendix B to Subpart A of 10 CFR Part 51 (Table B–1).

This GEIS reviews and reevaluates the issues and findings of the 1996 GEIS in compliance with the requirement to review the material in Appendix B to Subpart A of 10 CFR Part 51 and update it on a 10-year cycle, if necessary. Lessons learned and knowledge gained during previous license renewal reviews provided a significant source of new information for this review. Public comments received during previous license renewal environmental reviews were re-examined to validate existing environmental issues and identify new ones. Since 1996, over 40 commercial nuclear power plants have undergone a license renewal environmental review. The purpose of the review for this GEIS was to determine if the findings presented in the 1996 GEIS remain valid. In doing so, the NRC considered the need to modify, add, group, or delete any of the 92 environmental impact issues evaluated in the 1996 GEIS. In addition, new research, findings, and other information were considered when the significance of impacts associated with license renewal was being evaluated. After this review, the NRC carried forward 78 environmental impact issues for detailed consideration in this GEIS.

1.7 Decisions to Be Supported by the GEIS

The decisions to be to be supported by the GEIS are whether or not to renew the operating licenses of individual commercial nuclear power plants for an additional 20 years. The GEIS was developed to support these decisions and to serve as a basis from which future NEPA analyses for the license renewal of individual nuclear power plants would tier. According to CEQ guidelines (40 CFR 1508.28), tiering refers to “the coverage of general matters in broader environmental impact statements (such as national program or policy statements) with subsequent narrower statements or environmental analyses (such as regional or basinwide program statements or ultimately site-specific statements) incorporating by reference the general discussions and concentrating solely on the issues specific to the statement subsequently prepared…. Tiering in such cases is appropriate when it helps the lead agency to focus on the issues which are ripe for decision and exclude from consideration issues already decided or not yet ripe.” The GEIS provides the NRC decision-maker with important environmental information considered common to all nuclear power plants and allows greater focus to be placed on plant-specific (i.e., Category 2) issues.

The scope of the environmental review for license renewal consists of the range of actions, alternatives, and impacts to be considered in an EIS. The purpose of scoping is to identify significant issues related to the proposed action. Scoping also identifies and eliminates from detailed study issues that are not significant or have been covered by a prior environmental review. Having a defined scope for the environmental review allows the NRC to concentrate on the essential issues resulting from the actions being considered rather than on issues that may have been or are being evaluated in different regulatory review processes, such as the license renewal safety review (NRC 2006).

The NEPA process focuses on environmental impacts rather than on issues related to safety. Safety issues become important to the environmental review when they could result in environmental impacts, which is why the environmental effects of postulated accidents are considered in the GEIS and in plant-specific supplements to the GEIS. Since NEPA regulations do not provide for a safety review, the license renewal process includes an environmental review that is distinct and separate from the safety review. Since the two reviews are separate, operational safety issues and safety issues related to nuclear power plant aging are considered outside the scope for the environmental review, just as the environmental issues are not considered as part of the safety review. However, safety issues that are raised during the environmental review are forwarded to the appropriate NRC organization for consideration and appropriate action (NRC 2006).

> ***Environmental Impact Statements***
>
> 10 CFR 51.70(b): The draft environmental impact statement … will state how alternatives considered in it and decisions based on it will or will not achieve the requirements of Sections 101 and 102(1) of NEPA. (See also the Council on Environmental Quality (CEQ) Regulations for Implementing NEPA, 40 CFR 1502.2(d).)

Actions subject to NRC approval for license renewal are limited to continued nuclear power plant operation consistent with the plant design and operating conditions for the current operating license and to the performance of specific activities and programs necessary to manage the effects of aging on the passive, long-lived structures and components identified in accordance with 10 CFR Part 54. Accordingly, the GEIS does not serve as the NEPA review for other activities or programs outside the scope of NRC's 10 CFR Part 54 license renewal review.

Separate NEPA reviews must be prepared regardless of whether the action is necessary as a consequence of receiving a renewed license, even if the activity were specifically addressed in the GEIS. For example, the environmental impacts of spent fuel pool expansion are addressed in the GEIS in the context of the environmental consequences of approving a renewed operating license. However, any specific application submitted to the NRC to expand spent fuel pool capacity at a given facility would still require its own separate NEPA review. These separate NEPA reviews may reference and otherwise use applicable environmental information contained in the GEIS. For example, an environmental assessment prepared for a separate spent fuel pool expansion request may use the information in the GEIS to support a finding of no significant impact (see June 5, 1996 Final Rule [61 FR 28467]).

There are many factors that NRC takes into consideration when deciding whether to renew the operating license of a nuclear power plant. The analyses of environmental impacts evaluated in this GEIS will provide NRC's decision-maker (in this case, the Commission) with important environmental information for use in the overall decision-making process. There are also decisions outside the regulatory scope of license renewal that cannot be made on the basis of the final GEIS analysis. These decisions include the following issues.

1.7.1 Changes to Plant Cooling Systems

The NRC will not make a decision or any recommendations on the basis of information presented in this GEIS regarding changes to nuclear power plant cooling systems, other than those involving safety-related issues, to mitigate adverse impacts under the jurisdiction of State or other Federal agencies. Implementation of the provisions of the Clean Water Act, including those regarding cooling system operations and design specifications, is the responsibility of the U.S. Environmental Protection Agency (EPA). In many cases, the EPA delegates such authority to the individual States. To operate a nuclear power plant, licensees must comply with the Clean Water Act, including associated requirements imposed by the EPA or the State, as part of the National Pollutant Discharge Elimination System (NPDES) permitting system under Section 402 of the Clean Water Act and State water quality certification requirements under Section 401 of the Clean Water Act. The EPA or the State, not the NRC, sets the limits of effluents and operational parameters in plant-specific NPDES permits. Nuclear power plants cannot operate without a valid[b] NPDES permit and a Section 401 Water Quality Certification.

1.7.2 Disposition of Spent Nuclear Fuel

The NRC will not make a decision or any recommendations on the basis of the information presented in this GEIS regarding the disposition of spent nuclear fuel at nuclear power plants. Within the context of a license renewal environmental review, the NRC concluded that the storage of spent nuclear fuel can be accomplished safely and without significant environmental impacts. The radiological impacts from the onsite storage of spent nuclear fuel to human health during the term of license renewal continue to be well within regulatory limits, and therefore, meet the standard for a conclusion of SMALL impact. Nonradiological environmental impacts also continue to be SMALL. The overall conclusion for onsite storage of spent nuclear fuel during the license renewal term is that the environmental impacts will be SMALL for each plant. Within the context of renewal, the NRC concludes that its regulatory requirements for spent nuclear fuel provide adequate protection of plant workers, the public, and the environment.

In 1982, the Congress enacted the Nuclear Waste Policy Act (NWPA), and on January 7, 1983, the President signed it into law. The NWPA defined the Federal Government’s responsibility to provide permanent disposal in a deep geologic repository for spent fuel and high-level radioactive waste from commercial and defense activities. Under amended provisions (1987) of this Act, the U.S. Department of Energy (DOE) has the responsibility to locate, build, and operate a repository for such wastes. The NRC has the responsibility to establish regulations governing the construction, operation, and closure of the repository, consistent with environmental standards established by the EPA.

The 1987 amendments required DOE to evaluate only the suitability of the site at Yucca Mountain, Nevada, for a geologic disposal facility. In addition, the amendments outlined a detailed approach for the disposal of high-level radioactive waste involving review by the President, Congress, State and Tribal governments, NRC, and other Federal agencies. In February 2002, after many years of studying the suitability of the site, DOE recommended to the President that the Yucca Mountain site be developed as a long-term geologic repository for high-level waste. In April 2002, the Governor of Nevada notified Congress of his State’s

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(b) A valid NPDES permit is considered to be one that is either current (i.e., within its current effective date) or one that has expired but has been “administratively continued” by the permitting authority upon the timely submission of an applicant for renewal pursuant to the provisions of 40 CFR 122.6.

objection to the proposed repository. Subsequently, Congress voted to override the objection of the State.

DOE submitted a license application to the NRC for construction authorization for a repository at Yucca Mountain in June 2008. Upon acceptance of the application, the NRC started its technical evaluation. However, on March 3, 2010, the U.S. Department of Energy (DOE) filed a motion with the Atomic Safety and Licensing Board (Board) seeking permission to withdraw its application for authorization to construct a high-level waste geological repository at Yucca Mountain, Nevada. The Board denied that request on June 29, 2010, in LBP-10-11, and the parties filed petitions asking the Commission to uphold or reverse this decision. On October 1, 2010, the Commission directed the staff to perform an orderly closure of its Yucca Mountain activities. As part of the orderly closure, the NRC staff prepared three technical evaluation reports documenting its work.

On September 9, 2011, the Commission issued Memorandum and Order CLI-11-07, stating that it found itself evenly divided on whether to take the affirmative action of overturning or upholding the Board's June 29, 2010, decision. Exercising its inherent supervisory authority, the Commission directed the Board to complete all necessary and appropriate case management activities by September 30, 2011. On September 30, 2011, the Board issued a Memorandum and Order suspending the proceeding.

The NRC's non-sensitive Yucca Mountain-related documents are being preserved and made available to the public as part of the NRC staff's activities to retain the accumulated knowledge and experience gained as a result of its Yucca Mountain-related activities. These documents can be viewed on the NRC's public website (http://www.NRC.gov).

DOE decisions and recommendations concerning the ultimate disposition of spent nuclear fuel are ongoing and outside the regulatory scope of this GEIS.

Further, for the offsite disposal of spent nuclear fuel, the NRC's Waste Confidence Decision and Rule represented the Commission's generic determination that spent nuclear fuel can continue to be stored safely and without significant environmental impacts for a period of time after the end of the licensed life for operation of a nuclear power plant. This generic determination meant that the NRC did not need to consider the storage of spent nuclear fuel after the end of a reactor's licensed life for operation in the NEPA documents that support its reactor and spent-fuel storage license application reviews.

The NRC first adopted the Waste Confidence Decision and Rule in 1984. The NRC amended the decision and rule in 1990, reviewed them in 1999, and amended them again in 2010 (49 FR 34694 (August 31, 1984); 55 FR 38474 (September 18, 1990); 64 FR 68005 (December 6, 1999); and 75 FR 81032 and 81037 (December 23, 2010)). The NRC made a minor amendment to the rule in 2007 to clarify that it applies to combined licenses (72 FR 49509 (August 28, 2007)). The Waste Confidence Decision and Rule are codified in the NRC regulation 10 CFR 51.23.

On December 23, 2010, the Commission published in the *Federal Register* a revision of the Waste Confidence Decision and Rule to reflect information gained from experience in the storage of spent nuclear fuel and the increased uncertainty in the siting and construction of a permanent geologic repository for the disposal of spent nuclear fuel and high-level waste (75 FR 81032 and 81037). In response to the 2010 Waste Confidence Decision and Rule, the states of New York, New Jersey, Connecticut, and Vermont, along with several other parties challenged the Commission's NEPA analysis in the decision, which provided the regulatory basis for the rule. On June 8, 2012, the United States Court of Appeals, District of Columbia Circuit, in *New York v. NRC*, 681 F.3d 471 (D.C. Cir. 2012), vacated the NRC's Waste Confidence Decision and Rule, after finding that it did not comply with NEPA.

In response to the court's ruling, the Commission issued CLI-12-16 on August 7, 2012, in which the Commission determined that it would not issue licenses that rely upon the Waste Confidence Decision and Rule until the issues identified in the court's decision are appropriately addressed by the Commission. CLI-12-16 provided, however, that the decision not to issue licenses only applied to final license issuance; all licensing reviews and proceedings should continue to move forward. In SRM-COMSECY-12-0016, dated September 6, 2012, the Commission directed the NRC staff to proceed with a rulemaking that includes the development of a generic EIS to support a revised Waste Confidence Decision and Rule and to publish both the EIS and the revised decision and rule in the *Federal Register* within 24 months (by September 6, 2014). The Commission indicated that both the EIS and the revised Waste Confidence Decision and Rule should build on the information already documented in various NRC studies and reports, including the existing environmental assessment that the NRC developed as part of the 2010 Waste Confidence Decision and Rule. The Commission directed that any additional analyses should focus on the issues identified in the court's decision. The Commission also directed that the NRC staff provide ample opportunity for public comment on both the draft EIS and the proposed Waste Confidence Decision and Rule.

In accordance with CLI-12-16, the NRC will not approve any site-specific license renewal applications until the deficiencies identified in the court's decision have been resolved. Two license renewal GEIS issues that rely, wholly or in part, upon the Waste Confidence Decision and Rule are the "onsite storage of spent nuclear fuel" and "offsite radiological impacts of spent nuclear fuel and high-level waste disposal." Both of these issues were classified as Category 1 in the 10 CFR Part 51 rule that was promulgated in 1996; the 2009 proposed rule continued the Category 1 classification for both of these issues. As part of its response to the *New York v. NRC* decision, the NRC revised these two issues accordingly. Specifically, the NRC revised the Category 1 "Onsite storage of spent nuclear fuel" issue to narrow the period of onsite storage to the license renewal term. In both the 1996 rule (in which this issue was named “onsite spent fuel”) and the 2009 proposed rule, the NRC relied upon the 1990 Waste Confidence Decision and Rule to make a generic finding that spent nuclear fuel could be stored safely onsite with no more than a small environmental impact for the term of the extended license (from approval of the license renewal application to the expiration of the operating license) plus a 30 year period following the permanent shutdown of the power reactor and expiration of the operating license.

The 1990 Waste Confidence Decision and Rule provided the basis for the 30 year period following the permanent shutdown of the reactor and expiration of the operating license. The 2010 Waste Confidence Decision and Rule extended this post-reactor shutdown onsite storage period from 30 years to 60 years. Given the *New York v. NRC* decision, and pending the issuance of a generic EIS and revised Waste Confidence Decision and Rule (as directed by SRM-COMSECY-12-0016), the period of onsite storage of spent nuclear fuel following the permanent shutdown of the power reactor and expiration of the operating license is now excluded from this GEIS issue. As revised, this issue now covers the onsite storage of spent fuel for the term of the extended license only.

Similarly, the NRC revised the Category 1 issue, “Offsite radiological impacts of spent nuclear fuel and high-level waste disposal” (this issue was named “offsite radiological impacts (spent fuel and high level waste disposal)” in the 1996 rule and GEIS). This issue pertains to the long-term disposal of spent nuclear fuel and high-level waste, including possible disposal in a deep geologic repository. Although the Waste Confidence Decision and Rule did not assess the impacts associated with disposal of spent nuclear fuel and high-level waste in a repository, it did reflect the Commission’s confidence, at the time, in the technical feasibility of a repository and when that repository could have been expected to become available. Without the analysis in the Waste Confidence Decision, the NRC cannot assess how long the spent fuel will need to be stored onsite. Therefore, the NRC reclassifies this GEIS issue from a Category 1 issue with no assigned impact level to an uncategorized issue with an impact level of uncertain.

1.7.3 Emergency Preparedness

The NRC will not make a decision or any recommendations on the basis of information presented in this GEIS regarding emergency preparedness at nuclear power plants. Nuclear power plant owners, government agencies, and State and local officials work together to create a system for emergency preparedness and response that will serve the public in the unlikely event of an emergency. The emergency plans for nuclear power plants cover preparations for evacuation, sheltering, and other actions to protect residents near plants in the event of a serious incident.

In the United States, 104 commercial nuclear power reactors are licensed to operate at 65 sites in 31 States. For each site, there are onsite and offsite emergency plans to assure that adequate protective measures can be taken to protect the public in the event of a radiological emergency. Federal oversight of emergency preparedness for licensed nuclear power plants is shared by the NRC and Federal Emergency Management Agency (FEMA). The NRC and FEMA have a Memorandum of Understanding (44 CFR Appendix A to Part 353), under which FEMA has the lead in overseeing offsite planning and response, and the NRC assists FEMA in carrying out this role. The NRC has statutory responsibility for the radiological health and safety of the public and retains the lead for oversight of onsite preparedness.

Before a plant is licensed to operate, the NRC must have reasonable assurance that adequate protective measures can and will be taken in the event of a radiological emergency. The NRC's decision of reasonable assurance is based on licensees complying with NRC regulations and guidance. In addition, licensees and area response organizations must demonstrate they can effectively implement emergency plans and procedures during periodic evaluated exercises. As part of the reactor oversight process, the NRC reviews licensees' emergency planning procedures and training. These reviews include regular drills and exercises that assist licensees in identifying areas for improvement, such as in the interface of security operations and emergency preparedness. Each plant owner is required to exercise its emergency plan with the NRC, FEMA, and offsite authorities at least once every two years to ensure that State and local officials remain proficient in implementing their emergency plans. Licensees also self-test their emergency plans regularly by conducting drills.

FEMA findings and determinations as to the adequacy and capability of implementing offsite plans are communicated to the NRC. The NRC reviews the FEMA findings and determinations as well as the onsite findings. The NRC then makes a determination on the overall state of emergency preparedness. These overall findings and determinations are used by the NRC to make radiological health and safety decisions before issuing licenses and in the continuing oversight of operating reactors. The NRC has the authority to take action, including shutting down any reactor deemed not to provide reasonable assurance of the protection of public health and safety.

The Commission considered the need for a review of emergency planning issues in the context of license renewal during its rulemaking proceedings on 10 CFR Part 54, which included public notice and comment. As discussed in the statement of consideration for rulemaking (56 FR 64966), the programs for emergency preparedness at nuclear power facilities apply to all nuclear power facility licensees and require the specified levels of protection from each licensee regardless of plant design, construction, or license date. Requirements related to emergency planning are in the regulations at 10 CFR 50.47 and Appendix E to 10 CFR Part 50. These requirements apply to all operating licenses and will continue to apply to facilities with renewed licenses. Through its standards and required exercises, the Commission reviews existing emergency preparedness plans throughout the life of any facility, keeping up with changing demographics and other site-related factors.

Therefore, the Commission has determined that there is no need for a special review of emergency planning issues in the context of an environmental review for license renewal (NRC 2006). Thus, decisions and recommendations concerning emergency preparedness at nuclear plants are ongoing and outside the regulatory scope of license renewal.

1.7.4 Safeguards and Security

The NRC requires that nuclear power plants be both safe and secure. Safety refers to operating the plant in a manner that protects the public and the environment. Security refers to protecting the plant (using people, equipment, and fortifications) from intruders who wish to damage or destroy it in order to harm people and the environment.

Security issues such as safeguards planning are not tied to a license renewal action but are considered to be issues that need to be dealt with continuously as a part of a nuclear power plant's current (and renewed) operating license. Security issues are periodically reviewed and updated at every operating plant. These reviews continue throughout the period of an operating license, whether it is the original or renewed license. If issues related to security are discovered at a nuclear plant, they are addressed immediately, and any necessary changes are reviewed and incorporated under the operating license (NRC 2006). As such, decisions and recommendations concerning safeguards and security at nuclear power plants are ongoing and outside the regulatory scope of this GEIS.

1.7.5 Need for Power

The NRC will not make a decision or any recommendations on the basis of information presented in this GEIS regarding the need for power at nuclear power plants. The regulatory authority over licensee economics (including the need for power) falls within the jurisdiction of the States and, to some extent, within the jurisdiction of FERC. The proposed rule for license renewal published on September 17, 1991 (56 FR 47016), had originally included a cost-benefit analysis and consideration of licensee economics as part of the NEPA review. However, during the comment period, State, Federal, and licensee representatives expressed concern about the use of economic costs and cost-benefit balancing in the proposed rule and the 1996 GEIS. They noted that CEQ regulations interpret NEPA to require only an assessment of the cumulative effects of a proposed Federal action on the natural and man-made environment and that the determination of the need for generating capacity has always been a State responsibility. For this reason, the purpose and need for license renewal was defined by the Commission in the June 5, 1996, final rule as follows (61 FR 28467):

> The purpose and need for the proposed action (renewal of an operating license) is to provide an option that allows for power generation capability beyond the term of a current nuclear power plant operating license to meet future system generating needs, as such needs may be determined by State, utility, and, where authorized, Federal (other than NRC) decision-makers.

10 CFR 51.95(c)(2) states:

> The supplemental environmental impact statement (SEIS) for license renewal is not required to include discussion of need for power or the economic costs and economic benefits of the proposed action or of alternatives to the proposed action except insofar as such benefits and costs are either essential for a determination regarding the inclusion of an alternative in the range of alternatives considered or relevant to mitigation.

1.7.6 Seismicity and Flooding

The NRC will not make a decision or any recommendations on the basis of information presented in this GEIS regarding seismic risk and flooding at nuclear power plants. The NRC's assessment of seismic and flood hazards for existing nuclear power plants is a separate and distinct process from license renewal reviews. Seismic and flood hazard issues are addressed by the NRC on an ongoing basis at all licensed nuclear facilities. As such, decisions and recommendations concerning seismic risk and flooding at nuclear power plants are outside the regulatory scope of this GEIS. Nevertheless, following the accident at the Fukushima Dai-ichi nuclear power plant resulting from the March 11, 2011, Great Tohoku Earthquake and subsequent tsunami, the NRC established the Near-Term Task Force as directed by the Commission on March 23, 2011, in COMGBJ-11-0002. The Japan Near-Term Task Force assessment resulted in the issuance of 10 CFR 50.54 (f) letters on March 12, 2012, directing that seismic and flooding reevaluations be conducted at existing nuclear power plants (NRC 2012).

1.8 Implementation of the Rule (10 CFR Part 51)

1.8.1 General Requirements

The regulatory requirements for conducting a NEPA review for license renewal are similar to the NEPA review requirements for other major plant licensing actions. Consistent with the current NEPA practice for major plant licensing actions, an applicant is required to submit an environmental report that assesses the environmental impacts associated with the proposed action, considers alternatives to the proposed action, and evaluates any alternatives for reducing adverse environmental effects. For license renewal, the NRC prepares a draft SEIS to the GEIS for public comment and issues a final SEIS after considering public comments on the draft.

1.8.2 Applicant's Environmental Report

The applicant's environmental report must contain an assessment of the environmental impacts of renewing a license, the environmental impacts of alternatives, and mitigation alternatives. In preparing the analysis of environmental impacts contained in the environmental report, the applicant should refer to the information provided in Table B-1 of 10 CFR Part 51. The applicant is not required to assess the environmental impacts of Category 1 issues listed in Table B-1 unless the applicant is aware of new and significant information that would change the conclusions in the GEIS. For Category 2 issues listed in Table B-1, the applicant must provide a plant-specific assessment of the impacts. 10 CFR 51.53(c)(3)(ii) specifies the areas that must be addressed for the Category 2 issues in the environmental report.

10 CFR 51.45(c) and 10 CFR 51.53(c)(2) require the applicant to consider alternatives available for reducing or avoiding adverse environmental effects associated with the proposed action. This consideration is limited to designated Category 2 issues. Pursuant to 10 CFR 51.45(d), the environmental report must include a discussion of the status of compliance with applicable Federal, State, and local environmental standards. Also, 10 CFR 51.53(c)(2) specifically excludes from consideration in the environmental report the issues of need for power, the economic costs and benefits of the proposed action, economic costs and benefits of alternatives to the proposed action, or other issues not related to environmental effects of the proposed action and associated alternatives. NRC regulations do not require a discussion of the economic costs and benefits of these alternatives in the environmental report for license renewal, except as necessary to determine whether an alternative should be included in the range of alternatives considered or whether certain mitigative actions are appropriate. The analysis should also demonstrate consideration of a range (set) of reasonable alternatives to license renewal. In preparing the alternatives analysis, the applicant is not limited to the technologies presented in this GEIS. Information provided in the applicant's environmental report will be used in preparing the NRC's SEIS.

1.8.3 NRC's SEIS

As required by 10 CFR 51.20(b)(2), the NRC is required to prepare a SEIS to the GEIS for each license renewal application. The SEIS will serve as the NRC's analysis of the environmental impacts of license renewal as well as a comparison of these impacts to the environmental impacts of alternatives. This document will also present the NRC's recommendation as to the environmental impact of license renewal. SEISs for license renewal do not need to include a discussion of the need for power or the economic costs and economic benefits of the proposed action or of alternatives to the proposed action (10 CFR 51.95(c)(2)).

1.8.4 Public Scoping and Public Comments

NRC conducts public scoping meetings in order to inform the public about the license renewal process and receive comments on the scope of the NRC's plant-specific environmental review. At the conclusion of the scoping period, NRC reviews and addresses public comments in a scoping summary report. In addition, the draft SEIS is issued for public comment (see 10 CFR 51.73). In both the scoping and the public comment process, the NRC will consider comments and will determine whether these comments provide any information that is new and significant compared with that previously considered in the GEIS (for Category 1 issues). If the comments are determined to provide new and significant information that could change the conclusions in the GEIS, these comments will be considered and addressed in the SEIS.

1.8.5 NRC's Draft SEIS

The NRC's draft SEIS will include its analysis of the environmental impacts of the proposed license renewal action and the environmental impacts of the alternatives to the proposed action. The NRC will utilize and integrate (1) the environmental impacts of license renewal as provided in Table B-1 of 10 CFR Part 51 for Category 1 issues, (2) the appropriate plant-specific analyses of Category 2 issues, and (3) any new and significant information identified in the applicant's environmental report or during the scoping and public comment process to arrive at a conclusion regarding the environmental impacts of license renewal. These impacts are compared to the environmental impacts of the alternatives presented in the SEIS.

1.8.6 NRC's Final SEIS

The NRC will issue a final SEIS in accordance with 10 CFR 51.91 and 51.93 after considering (1) the public comments, (2) the analysis of Category 2 issues, and (3) any new and significant information involving Category 1 issues. The NRC will provide a record of its decision regarding the environmental impacts of the proposed license renewal action (see 10 CFR 51.102 and 51.103). All comments on the draft SEIS will be addressed by the NRC in the final SEIS in accordance with 10 CFR 51.91(a)(1). Comments will be addressed in the following manner:

(a) NRC's response to a comment regarding the applicability of the analysis of an impact codified in the rule (i.e., 10 CFR Part 51) to the plant in question may be a statement and explanation of its view that the analysis is adequate including, if applicable, consideration of the significance of new information. A commenter dissatisfied with such a response may file a petition for rulemaking under 10 CFR 2.802. Procedures for the submission of petitions for rulemaking are explained in 10 CFR Part 2. If a commenter is successful in persuading the Commission that the new information does indicate that the analysis of an impact codified in the rule is incorrect in significant respects (either in general or with respect to the particular plant), then a rulemaking proceeding will be initiated.

(b) If a commenter provides new information that is relevant to the plant and is also relevant to other plants (i.e., generic information) and that information demonstrates that the analysis of an impact codified in the rule is incorrect, the NRC will seek Commission approval either to suspend the application of the rule on a generic basis with respect to the analysis or to delay granting the renewal application (and possibly other renewal applications) until the rule can be amended. This GEIS would reflect the corrected analysis and any additional consideration of alternatives as appropriate.

(c) If a commenter provides new, site-specific information that demonstrates that the analysis of an impact codified in the rule is incorrect with respect to the particular plant, then the NRC staff will seek Commission approval to waive the application of the rule with respect to that analysis in that specific renewal proceeding. The SEIS would reflect the corrected analysis as appropriate.

1.9 Public Comments on the Draft GEIS

The public comment process for the GEIS was similar to that used for SEISs and other NRC NEPA documents. In July 2009, NRC distributed the draft GEIS to Federal, State, and local government agencies; American Indian Tribes; environmental interest groups; and members of the public who requested copies. As part of the process to solicit public comments on the draft GEIS, the NRC:

- Placed a copy of the draft GEIS into the NRC's Public Electronic Reading Room and on its license renewal Web site;

- Sent copies of the draft GEIS to members of the public and environmental interest groups, representatives of American Indian Tribes, and Federal, State, and local agencies;

- Published a notice of availability of the draft GEIS in the *Federal Register* (74 FR 38239);

- Published a notice of an extension to the comment period from 75 to 165 days (74 FR 51522);

- Issued public announcements, such as advertisements in local newspapers and postings in public places, of the availability of the draft GEIS;

- Announced and held public meetings in (1) Atlanta, Georgia, on September 15, 2009; (2) Newton, Massachusetts, on September 17, 2009; (3) Oak Brook, Illinois, on September 24, 2009; (4) Rockville, Maryland, on October 1, 2009; (5) Pismo Beach, California, on October 20, 2009; and (6) Dana Point, California, on October 22, 2009, to receive public comments on the draft GEIS;

- Issued public service announcements and press releases announcing the issuance of the draft GEIS, the public meetings, and instructions on how to comment on the draft GEIS; and

- Established several methods for the submittal of comments on the draft GEIS, including an e-mail address to receive comments through the Internet.

During the public comment period, the NRC received a total of 32 comment letters, e-mails, and Web submissions in addition to comments received during the public meetings. The NRC reviewed public meeting transcripts and comment letters, which have been incorporated by reference in this GEIS. The public meeting transcripts and comment letters have also been made available online in the Agencywide Documents Access and Management System (ADAMS) (see GEIS Appendix A).

The NRC used public comments gathered during the meetings and comment period when developing the final GEIS. NRC responses to comments are included in GEIS Volume 2, Appendix A, Section A.2. Comments were received on a variety of topics, including (1) land use and visual impacts; (2) air quality, meteorology, and climatology; (3) soils, geology, and seismology; (4) water quality, hydrology, and use; (5) aquatic ecology, terrestrial ecology, and threatened and endangered species; (6) historic and cultural resources; (7) socioeconomics; (8) human health; (9) uranium fuel cycle and waste management; (10) cumulative impacts; (11) alternatives to license renewal; (12) postulated accidents; and (13) decommissioning. In addition, comments were received on the overall license renewal process and in opposition to nuclear power. Some comments received were editorial in nature or were considered outside of the scope of the license renewal environmental review process.

Some of the more frequently mentioned issues and their disposition in the final GEIS are described in the following paragraphs. Note that these issues are not presented in any particular order.

Seismic issues. Many commenters wanted seismic issues to be included in the rule and pointed out the importance of reassessing seismic conditions in determining the safety of operating nuclear power plants. Industry commenters disagreed and argued that seismology should not be considered part of the issue of "Impacts of nuclear plants on geology and soils" in the proposed rule because it is an ongoing safety issue that is being addressed at all plants.

The NRC agrees with the commenters that consideration of seismic conditions is an ongoing safety issue. Although seismic conditions at nuclear power plants are generically discussed in the GEIS as part of the geologic environment, seismology is not identified as a separate issue in the GEIS because the NRC considered historical earthquake data for each nuclear power plant when that plant was first licensed. The NRC requires all licensees to take seismic activity into account in order to maintain safe operating conditions at all nuclear power plants. When new seismic hazard information becomes available, the NRC evaluates the new data and models to determine if any changes are needed at existing plants regardless of whether or not a plant has renewed its license. This reactor oversight process, which includes seismic safety, remains separate from license renewal.

Unrelated to license renewal, the NRC completed the Generic Issues Program Safety/Risk Assessment Stage for Generic Issue 199 in August 2010, "Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants," which evaluated recent updates to estimates of the seismic hazard in the central and eastern United States (NRC 2010a,b). The results of the Generic Issue 199 Safety/Risk Assessment indicated that the currently operating nuclear power plants have adequate safety margin for seismic issues. The NRC's assessment indicated that overall seismic risk estimates remain SMALL, and adequate protection is maintained. The NRC's path forward for Generic Issue 199 is described in NRC Information Notice 2010–18 (NRC 2010b). It provided notice of NRC's intent to follow the appropriate regulatory process to request that operating nuclear power plants and independent spent fuel storage installations provide specific information relating to their facilities to enable the NRC staff to complete the appropriate backfit analyses (see 10 CFR 50.109) where candidate backfits would be identified and evaluated. NRC then developed a draft generic letter to request needed data from power reactor licensees. However, following the accident at the Fukushima Dai-ichi nuclear power plant resulting from the March 11, 2011 Great Tohoku Earthquake and subsequent tsunami, the NRC established the Near-Term Task Force as directed by the Commission. The Japan Near-Term Task Force assessment resulted in the issuance of 10 CFR 50.54(f) letters on March 12, 2012, that addressed GI-199 in its entirety in recommendations 2.1 and 2.3 regarding seismic and flooding reevaluations, respectively (NRC 2012). The NRC's Japan Lessons Learned Project Directorate has now assumed the work of GI-199, including the evaluation of information received and actions taken by power reactor licensees in response to the March 12, 2012 10 CFR 50.54(f) letters.

The NRC's assessment of seismic hazards for existing nuclear power plants is a separate and distinct process from license renewal reviews. Seismic hazard issues are being addressed by the NRC on an ongoing basis at all licensed nuclear facilities. Sections 3.4 and 4.4.1 of the

GEIS explain that geologic and seismic conditions were considered in the original design of nuclear power plants and are part of the license bases for operating plants. Seismic conditions are attributes of the geologic environment that are not affected by continued plant operations and refurbishment and are not expected to change appreciably during the license renewal term for all nuclear power plants.

Air quality impacts. Several commenters objected to the issue “Air quality (non-attainment and maintenance areas)” being listed as a Category 2 issue in the proposed rule. The commenters argued that air quality impacts would be SMALL even in worst-case situations because licensees are required to operate within State air permit requirements.

The NRC agrees with the commenters. Operating experience has shown that the potential impact from emergency generators and boilers on air quality would be SMALL for all plants and, given the infrequency and short duration of maintenance testing, would not be an air quality concern even at plants located in or adjacent to nonattainment areas. Based on these comments, NRC technical staff re-evaluated this issue and determined that air quality impacts would be SMALL for all plants, and the issue should be Category 1. The GEIS was revised to explain this determination.

In addition, recent analysis has shown that the worst-case emissions from cooling tower drift and particulate emissions at operating plants were also SMALL. Air quality impacts from vehicle, equipment, and fugitive dust emissions associated with refurbishment would be SMALL for most plants, but could be a cause for concern for plants located in or near air quality nonattainment or maintenance areas. However, the impacts would be temporary and would cease once projects were completed. In addition, operating experience has shown that refurbishment activities have not required the large numbers of workers and extended durations conservatively predicted and analyzed in the 1996 GEIS, nor have such activities resulted in exceedances in the *de minimis* thresholds for criteria pollutants in nonattainment and maintenance areas. Consequently, the NRC agrees with the commenters’ arguments that air quality impacts would be SMALL for all plants and should be a Category 1 issue.

Groundwater and soil contamination. Several commenters objected to the new Category 2 issue, “Groundwater and soil contamination,” in the proposed rule and draft GEIS and asserted that contamination from industrial practices is addressed by U.S. Environmental Protection Agency (EPA) and State regulations that monitor and address these impacts. Specifically, the use, storage, disposal, release, and/or cleanup of spilled or leaked solvents, hydrocarbons, and other potentially hazardous materials are governed by the Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Toxic Substances Control Act (TSCA), Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), and the Clean Water Act (CWA).

While classified as a Category 2 issue in the draft GEIS and proposed rule, further consideration of the “Groundwater and soil contamination” issue and public comments revealed that the potential impacts on groundwater and soil quality from common industrial practices (e.g., the use, handling, storage, and disposal of chemicals, petroleum products, waste, and hazardous material) can be addressed generically, as industrial practices employed by nuclear power plants are not unique but common to all industrial facilities. The NRC concludes that the overall impact of industrial practices on groundwater use and quality from past and current operations is SMALL for all nuclear power plants and not expected to change appreciably during the license renewal term. NRC agrees with the commenters to the extent that clarification was needed and that common industrial practices which can cause groundwater or soil contamination can be addressed generically as a Category 1 issue.

Further, the final rule and GEIS combine the re-classified “Groundwater and soil contamination” issue with the Category 1 “Groundwater use and quality” issue and renames the consolidated Category 1 issue as “Groundwater contamination and use (non-cooling system impacts).” These issues were consolidated because they both consider the impact of industrial activities associated with the continued operations of a nuclear power plant (not directly related to cooling system effects) on groundwater use and quality. Consolidating these issues also conforms to the resource-based approach used in this revised GEIS and serves to facilitate the license renewal environmental review process.

The previous findings for “Groundwater use and quality,” as analyzed in the 1996 GEIS, indicated that impacts of continued operations and refurbishment on groundwater use and quality would be SMALL, as extensive dewatering is not anticipated, and the application of best management practices for handling any materials produced or used during activities would reduce impacts. These findings were re-evaluated in the draft GEIS and are retained in this final GEIS.

This new consolidated issue also considers the impacts on groundwater, soil, and subsoil from the industrial use of solvents, hydrocarbons, heavy metals, or other chemicals at nuclear power plant sites during the license renewal term, including the impacts resulting from the use of wastewater disposal ponds or lagoons (both lined or unlined). Industrial practices at all nuclear plants have the potential to contaminate groundwater and soil, especially on sites with unlined wastewater and storm water lagoons. Contaminants have been found in groundwater and soil samples at some nuclear power plants during previous license renewal environmental reviews.

Any groundwater and soil contamination at operating nuclear power plants is subject to characterization and cleanup under EPA and State-regulated remediation and monitoring programs. In addition, wastewater disposal ponds and lagoons are subject to discharge authorizations under NPDES and related State wastewater discharge permit programs. Each operating nuclear power plant must comply with these EPA and State regulatory requirements.

As such, each site has an established program for handling chemicals, waste, and other hazardous materials. Moreover, nuclear power plant licensees are expected to employ best management practices, both in minimizing effluents and in remediation. Thus, this new consolidated issue, as explained in the final GEIS and rule, is a Category 1 issue.

Radionuclides in groundwater. Several commenters expressed opposition to the inclusion of a new Category 2 issue "Radionuclides released to groundwater," with an impact estimate of SMALL to MODERATE in the proposed rule and draft GEIS. Some commenters indicated that the issue category should be changed to Category 1; others suggested that the levels of significance should range from SMALL to LARGE. The argument for changing the issue to Category 1 was based on the voluntary industry-wide initiative (NEI 07-07, *Industry Ground Water Protection Initiative—Final Guidance Document*; NEI 2007) designed to protect groundwater.

This new Category 2 issue evaluates the potential contamination and degradation of groundwater resources resulting from inadvertent discharges of radionuclides into groundwater from nuclear power plants. Within the past several years, there have been numerous events at power reactor sites which involved unknown, uncontrolled, and unmonitored releases of radionuclides into the groundwater. The number of these events and the high level of public controversy have made this issue one that the NRC believes needs a "hard look" as required by NEPA.

As a voluntary action, NEI 07–07 cannot be enforced by the NRC. As such, no violations can be issued against a licensee who fails to comply with the guidance in NEI 07-07. Furthermore, the NRC cannot rely on a voluntary initiative as a basis to ensure that the nuclear power industry will have adequate information available for the NRC to determine whether a documented leak or spill does or does not have an adverse impact on groundwater resources. Regarding the magnitude of impact, the NRC bases its determination of SMALL to MODERATE impact on a review of existing plants have had inadvertent releases of radioactive liquids. Even though the NRC expects impacts for all plants to be within this range, a conclusion of LARGE impact would not be precluded for a future license renewal review based on new and significant information if the data support such a conclusion. As reflected in the final GEIS and rule, "Radionuclides released to groundwater" remains a Category 2 issue.

Radiation exposure to the public. Many commenters identified recent studies that claim an association between cancer risk and proximity to nuclear power facilities.

The NRC's primary mission is to protect the public health and safety and the environment from the effects of radiation from nuclear reactors, materials, and waste facilities. The NRC's regulatory limits for radiological protection are set to protect workers and the public from the harmful health effects (i.e., cancer and other biological impacts) of radiation to humans. The limits are based on the recommendations of scientific standards-setting organizations. These radiation standards reflect extensive scientific study by national and international organizations. The NRC actively participates in and monitors the work of these organizations to remain current on the latest trends in radiation protection. If the NRC determines that there is a need to revise its radiation protection regulations, it will initiate a separate rulemaking. The models recognized by the NRC for use by licensees to calculate dose incorporate conservative assumptions to ensure that workers and members of the public are adequately protected from radiation.

On April 7, 2010, the NRC announced that it asked the National Academy of Sciences (NAS) to perform a state-of-the-art study on cancer risk for populations surrounding nuclear power facilities (ADAMS Accession No. ML100970142). The NAS has a broad range of medical and scientific experts who can provide the best available analysis of the complex issues involved in discussing cancer risk and commercial nuclear power plants. The NAS is a nongovernmental organization chartered by the U.S. Congress to advise the nation on issues of science, technology, and medicine. Through the National Research Council and Institute of Medicine, it carries out studies independently of the government, using processes designed to promote transparency, objectivity, and technical rigor. More information on its methods for performing studies is available at http://www.nationalacademies.org/studycommitteprocess.pdf.

The NAS study will update the 1990 U.S. National Institutes of Health National Cancer Institute (NCI) report, “Cancer in Populations Living Near Nuclear Facilities” (Jablon et al. 1991), which concluded there was no evidence that nuclear facilities may be linked casually with excess death from leukemia or from other cancers in populations living nearby. The study’s objectives are to (1) evaluate whether cancer risk is different for populations living near nuclear power facilities; (2) include cancer occurrence; (3) develop an approach to assess cancer risk in geographic areas that are smaller than the county level; and (4) evaluate the study results in the context of offsite doses from normal reactor operations. The study began in the summer of 2010 and is expected to be completed within three years. A discussion about NRC’s sponsorship of this follow-up study is in Section 3.9.1.3 of the GEIS.

Onsite storage of spent nuclear fuel, waste disposal, and Yucca Mountain. Please see section 1.7.2, “Disposition of Spent Nuclear Fuel,” above.

Postulated accidents. Numerous comments were received on the NRC’s evaluation and classification of postulated accidents. One commenter disagreed with the GEIS’s conclusion that environmental impact from design basis accidents (DBAs) is SMALL. Also, several commenters disagreed with the GEIS conclusion that the environmental impact from severe accidents is SMALL, and further, that the evaluation is not adequate because of its use of probability-weighted risk assessments. Their position is that for severe accidents, the revised GEIS should also evaluate the consequences of reactor accidents and expand the evaluation to include spent fuel pool accidents and accidents due to age-related plant component degradation. In addition, some of the commenters stated that the NRC has gained enough information from the many plant licenses it has renewed to make a determination, on a generic basis, that the “Severe accidents” issue should be reclassified as Category 1.

Design Basis Accidents. The NRC does not agree that the GEIS’s evaluation of DBAs is incorrect. The NRC evaluates and presents the potential consequences of DBAs in nuclear power plant licensing documents and considers them in the GEIS for license renewal.
In order to receive NRC approval for an initial operating license, an applicant must submit a final safety analysis report (FSAR) as part of its application. The FSAR presents the applicable design criteria and design information for the proposed reactor, as well as comprehensive data on the proposed site. The FSAR also discusses hypothetical reactor accident situations and addresses the safety features that prevent and mitigate those accidents. During the initial licensing process for a power reactor, the NRC reviews the FSAR to determine whether or not the plant design meets the NRC’s regulations.

At initial licensing, the NRC also considered the environmental impact of DBAs at each operating nuclear power plant. DBAs are those events that both the applicant and the NRC evaluate to ensure that the plant can withstand normal and abnormal transients (e.g., rapid changes in reactor power) without undue risk to the health and safety of the public. Although the NRC does not expect that all of these postulated events will occur during the life of the plant, the NRC evaluates them to establish the basis for the preventive and mitigative safety systems of the facility. The acceptance criteria for DBAs are described in 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” and 10 CFR Part 100, “Reactor Site Criteria.” Compliance with these regulations provides reasonable assurance of adequate protection of public health and safety.

During operations, the NRC requires that each power plant licensee maintains acceptable design and performance criteria in accordance with the NRC regulations, including during any license renewal period. Therefore, the calculated releases from DBAs will remain within the NRC regulatory limits.

The 1996 GEIS, in Section 5.2, discusses the impacts of potential accidents. It contains a discussion of plant accidents and consequences. This discussion addresses general characteristics of design basis (and severe) accidents, characteristics of fission products, meteorological considerations, possible exposure pathways, potential adverse health effects, avoiding adverse health effects, accident experience and observed impacts, and emergency preparedness. This GEIS reexamined the information from the 1996 GEIS and concluded that it is still valid. Because the information on DBAs is valid and has not changed, this GEIS does not repeat the information from the 1996 GEIS.

Severe Accidents. The NRC does not agree with the comments that the GEIS evaluation is inadequate regarding the impacts from severe accidents because it uses probability-weighted risk assessments. Severe accidents (i.e., beyond design-basis accidents) are those that could result in substantial damage to the reactor core, whether or not there are serious off-site consequences. The 1996 GEIS estimated and considered the potential impacts on human health and economic factors from full-power severe reactor accidents initiated by internal events at different types of nuclear facilities located in different types of settings. That evaluation included modeling the release of radioactive materials into the environment and modeling the pathways (i.e., exposure to the radioactive plume, inhalation of radioactivity, consumption of contaminated food) through which members of the public could potentially be exposed to doses of radiation. Based on the calculated doses, the 1996 GEIS reported the consequences (i.e., potential early and latent fatalities) from such accidents. In developing a potential impact level, however, the NRC took into account the very low probability of such events, as well as their potential consequences, and concluded that the likely impact from individual nuclear power plants is small.

In this GEIS, the NRC expanded the scope of the severe accident evaluations and used more recent technical information that included both internal and external event core-damage frequency, as well as improved severe accident source terms, spent fuel pool accidents, low power and reactor shutdown events, new radiation risk-coefficients from the National Academy of Sciences, "Health Risks from Exposure to Low Levels of Ionizing Radiation: Biological Effects of Ionizing Radiation (BEIR) VII report," and risk impacts of reactor power uprates and higher fuel burn-up levels. As a result, this GEIS considers updated information in determining the potential consequences of a reactor accident. Considering this updated information and that severe reactor accidents remain unlikely, this GEIS concludes that the environmental impacts of a severe accident remain small.

The NRC notes, however, that the GEIS is not the primary vehicle the NRC uses to address and regulate risks from severe accidents. The NRC's regulations and regulatory practices employ safety standards in the design, construction, and operation of nuclear power plants as well as risk models to ensure the public is adequately protected on an on-going basis. The NRC 's ongoing oversight addresses the public's risk from nuclear power plant accidents, accounts for the effects of proposed changes that may be made as part of power plant operations, and considers new information about the facility or its environment when necessary.

Although the NRC has determined that impacts from severe accidents are small for all facilities, the NRC continues to maintain that severe accidents cannot be a Category 1 issue because plant-specific mitigation measures vary greatly based on plant designs, safety systems, fuel type, operating procedures, local environment, population, and siting characteristics. Thus, severe accidents remain a Category 2 issue. Accordingly, the NRC has not changed the requirements in 10 CFR 51.53(c)(3)(ii)(L) that an applicant's environmental report must contain a discussion that considers alternatives to mitigate severe accidents if the NRC has not previously considered this issue in an environmental impact statement or environmental assessment for the facility.

Spent Fuel Pool Accidents. The 1996 GEIS included a quantitative analysis of a severe accident involving a reactor operating at full power. A qualitative evaluation of SFP accidents is presented in Appendix E of this GEIS. Based on this evaluation, this GEIS concludes that the environmental impacts from accidents involving SFPs are comparable to those from the reactor accidents at full power that were evaluated in the 1996 GEIS, and as such, SFP accidents do not warrant separate evaluation. Based on the continued validity of conclusions from the 1996 GEIS, as affirmed by the Commission (see following paragraph), this GEIS does not contain a quantitative evaluation of SFP accidents.

The issue of an accident involving the spent fuel was specifically addressed by the NRC in response to two Petitions for Rulemaking (PRM), PRM-51-10 and PRM-51-12, submitted by the Attorney General of the Commonwealth of Massachusetts in 2006 and the Attorney General of California in 2007, respectively (collectively, the Petitioners). The Petitioners challenged the 1996 GEIS Category 1 classification for this issue.[c] The Petitioners requested that the NRC initiate a rulemaking concerning the environmental impacts of the high-density storage of spent nuclear fuel in spent fuel pools (SFPs). The Petitioners asserted that ''new and significant information'' showed that the NRC incorrectly characterized the environmental impacts of high-density spent fuel storage as ''insignificant'' in the 1996 GEIS for the renewal of nuclear power plant licenses. Specifically, the Petitioners asserted that spent fuel stored in high-density SFPs is more vulnerable to a zirconium fire than the NRC concluded in its NEPA analysis.

On August 8, 2008 (73 FR 46204), the Commission denied the petitions, stating:

> Based upon its review of the petitions, the NRC has determined that the studies upon which the Petitioners rely do not constitute new and significant information. The NRC has further determined that its findings related to the storage of spent nuclear fuel in pools, as set forth in NUREG-1437 and in Table B-1, of Appendix B to Subpart A of 10 CFR Part 51, remain valid. Thus, the NRC has met and continues to meet its obligations under NEPA. For the reasons discussed previously, the Commission denies PRM-51-10 and PRM-51-12.[d]

(c) The details of the petitions and the NRC's evaluations of those petitions are available to the public through the ADAMS electronic reading room (at www.nrc.gov using ADAMS accession number ML073310115) and in the Federal e-Rulemaking Portal (http://www.regulations.gov, Docket ID [NRC-2006-0022] (PRM-51-10), and [NRC-2007-0019] (PRM-51-12)).

(d) 73 FR 46204, 46212 (August 8, 2008). The NRC decision to deny the two rulemaking petitions was upheld by the United States Court of Appeals for the Second Circuit. *New York v. the Nuclear Regulatory Commission*, 589 F.3d 551 (2nd Cir. 2009).

Based on the continued validity of conclusions from the 1996 GEIS, and as affirmed by the Commission in its denial of PRM-51-10 and PRM-51-12, the NRC concludes that the onsite storage of spent fuel is properly classified as Category 1.

Aging-Related Degradation. Issues related to age-related plant component degradation are addressed in the NRC's safety evaluation of the plant's license renewal application. The regulations covering the safety review for license renewal are in 10 CFR Part 54.

The 1996 GEIS discusses the potential effects of age on the physical plant and notes that such deterioration could result in an increased likelihood of component or structure failure that could increase the rate of plant accidents. The GEIS notes that the NRC requires an applicant for license renewal address the issue of age-related degradation by identifying, in an integrated plant assessment process, those passive, long-lived structures and components that are susceptible to age-related degradation and whose functions are necessary to ensure that the facility's current licensing basis will be maintained in the license renewal period. The GEIS found that the safety evaluation performed by the NRC as part of the license renewal process provides reasonable assurance that age-related degradation will be managed and adequate protection of the health and safety of the public will be maintained during the license renewal period. Therefore, the 1996 GEIS concluded "the probability of any radioactive releases from accidents will not increase over the license renewal period." Based on nuclear power plants' continued compliance with 10 CFR Part 54 to manage age-related degradation, this GEIS did not alter or revise this conclusion.

Climate change. Several commenters discussed the need to include a discussion of the effects of climate change on plant operations and the effect of continued operations during the license renewal period on environmental resources affected by climate change.

Like other Federal agencies, the NRC has begun to evaluate the effects of greenhouse gas (GHG) emissions and its implications for global climate change in its environmental reviews for both new reactor and license renewal applications. Changes in climate have the potential to affect air and water resources, ecological resources, and human health, and should be taken into account when evaluating cumulative impacts over the license renewal term.

Subsequent to the publication of the proposed rule and during the public comment period, the Commission issued a memorandum and order concerning two combined license applications for new reactor units at the Tennessee Valley Authority Bellefonte site in Alabama and the Duke Energy Carolinas Lee site in South Carolina (CLI–09–21, November 3, 2009). The memorandum and order stated:

> [B]ecause the Staff is currently addressing the emerging issues surrounding greenhouse gas emissions in environmental reviews required for the licensing of nuclear facilities, we believe it is prudent to provide the following guidance to the Staff. We expect the Staff to include consideration of carbon dioxide and other greenhouse gas emissions in its environmental reviews for major licensing actions under the National Environmental Policy Act. The Staff's analysis for reactor applications should encompass emissions from the uranium fuel cycle as well as from construction and operation of the facility to be licensed. The Staff should ensure that these issues are addressed consistently in agency NEPA evaluations and, as appropriate, update Staff guidance documents to address greenhouse gas emissions.[e]

Presently, insufficient data exists to support an impact level on a generic basis. The NRC only has direct emission data for a handful of facilities. Although some States have varying reporting requirements, GHG emissions reporting nationwide is in its infancy. The EPA promulgated its GHG emissions reporting rule on October 30, 2009 (74 FR 56260). In accordance with this rule, the first industry reporting date was March 31, 2011.[f] Moreover, the 25,000 annual metric ton reporting threshold EPA established in the above final rule are not an indication of what EPA considers to be a significant (or insignificant) level of GHG emissions on a scientific basis, but a threshold chosen by EPA for policy evaluation purposes.[g]

In order to comply with the Commission's direction in CLI–09–21 and in response to the comments received, a new section, "GHG Emissions and Climate Change" (Chapter 4, Section 4.12.3.2), summarizing the potential cumulative impacts of GHG emissions and global climate change, has been added to the final GEIS. The NRC will also include within each SEIS a plant-specific analysis of any impacts caused by GHG emissions over the course of the license renewal term as well as any cumulative impacts caused by potential climate change upon the affected resources during the license renewal term. The final rule was not revised to include any reference to GHG emissions or climate change.

Recent advances in (replacement power alternatives. Several commenters asserted that much of the information describing replacement power alternatives did not reflect the state-of-

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(e) In the matter of Duke Energy Carolinas, LLC (Combined License Application for William States Lee III Nuclear Station, Units 1 and 2); in the matter of Tennessee Valley Authority (Bellefonte Nuclear Power Plant, Units 3 and 4), CLI–09–21 (NRC November 3, 2009).

(f) 74 FR 56260, 56267 (October 30, 2009), codified at 40 CFR 98.3(b) ("The annual GHG report must be submitted no later than March 31 of each calendar year for GHG emissions in the previous calendar year").

(g) EPA concluded for policy evaluation purposes, the 25,000 metric ton threshold more effectively targets large industrial emitters and suppliers, covers approximately 85 percent of U.S. emissions, and minimizes the burden on smaller facilities.

the-science. In some cases, commenters noted facts and events that occurred after the publication date of the draft GEIS.

The NRC has updated the final GEIS to incorporate the latest information on replacement power alternatives, but it is inevitable that rapidly evolving technologies will outpace information presented in the GEIS. Incorporation of this information is more appropriately made in the context of plant-specific license renewal reviews, rather than in the GEIS. As with renewable energy technologies, energy policies are evolving rapidly. While the NRC acknowledges that legislation, technological advancements, and public policy can underlie a fundamental paradigm shift in energy portfolios, the NRC cannot make decisions based on anticipated or speculative changes. Instead, the NRC considers the status of alternatives and energy policies when conducting plant-specific environmental reviews. The introduction to GEIS Section 2.3.4 has been revised to clarify NRC's approach to evaluating replacement power alternatives.

Emergency preparedness and security. Many commenters expressed concern with emergency preparedness, evacuation, and safety and security planning at nuclear power plants. Commenters stated that these concerns were not adequately covered in the draft GEIS and should be included in the scope of plant-specific license renewal supplements to the GEIS.

As explained in GEIS Section 1.7.3, emergency preparedness and planning are part of a nuclear power plant's current operating license. Before a nuclear power plant is licensed to operate, the NRC must have "reasonable assurance that adequate protective measures can and will be taken in the event of a radiological emergency" (10 CFR 50.47). Therefore, the Commission determined that decisions and recommendations concerning emergency preparedness at nuclear plants are ongoing and outside the regulatory scope of license renewal.

The Commission considered the need for a review of emergency planning issues in the context of license renewal during its rulemaking proceedings on 10 CFR Part 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants," which included public notice and comment. As discussed in the Statement of Consideration for rulemaking (56 FR 64966; December 13, 1991), the programs for emergency preparedness at nuclear power facilities apply to all nuclear power facility licensees and require the specified levels of protection from each licensee regardless of plant design, construction, or license date. NRC requirements related to emergency planning are in the regulations at 10 CFR 50.47 and Appendix E to 10 CFR Part 50, "Emergency Planning and Preparedness for Production and Utilization Facilities." These requirements apply to all operating licenses and will continue to apply to facilities with renewed licenses. Through its standards and required exercises, the Commission reviews existing emergency preparedness plans throughout the life of any facility, keeping up with changing demographics and other site-related factors.

Further, the NRC actively reviews its regulatory framework to ensure that the emergency preparedness regulations are current and effective. The agency began a major review of its emergency preparedness framework in 2005, including a comprehensive review of the emergency preparedness regulations and guidance, the issuance of generic communications regarding the integration of emergency preparedness and security, and outreach efforts to interested persons to discuss emergency preparedness issues. In 2011, these activities culminated in the issuance of a final rule that enhances a nuclear power plant's response to possible hostile action events by making drill and exercise programs more challenging, changing the criteria for declaring emergencies, and taking additional steps to protect workers. The rule also includes other new requirements such as when updates to evacuation time estimates are required.

As explained in GEIS Section 1.7.4, security issues are not tied to a license renewal action but are considered to be issues that need to be dealt with continuously as a part of the current (and renewed) operating license. If issues related to security are discovered at a nuclear plant, they are addressed immediately, and any necessary changes are reviewed and incorporated under the current operating license (NRC 2006). For example, after the terrorist attacks of September 2001, the NRC issued security-related orders and guidance to nuclear power plants. These orders and guidance included interim measures for emergency planning. Nuclear industry groups and Federal, State, and local government agencies assisted in the prompt implementation of these measures and participated in drills and exercises to test these new planning elements. The NRC reviewed licensees' commitments to address these requirements and verified their implementation through inspections to ensure public health and safety.

In summary, the issue of security (and risk from terrorist acts against nuclear power plants) is not unique to facilities requesting license renewal. The NRC routinely assesses threats and other information provided by other Federal agencies and sources. The NRC also ensures that licensees meet their security requirements through its ongoing regulatory process (routine inspections) as a current and generic regulatory issue that affects all nuclear power plants. Therefore, as discussed in the Statements of Consideration for the 10 CFR Part 54 rulemaking, the Commission has determined that there is no need for a special review of security issues in the context of an environmental review for license renewal.

Fukushima earthquake and tsunami. On March 11, 2011, a massive earthquake off the east coast of Honshu, Japan, produced a devastating tsunami that struck the coastal town of Fukushima. The six-unit Fukushima Dai-ichi nuclear power plant was directly impacted by these events. The resulting damage caused the failure of several of the units' safety systems needed to maintain cooling water flow to the reactors. As a result of the loss of cooling, the fuel overheated, and there was a partial meltdown of the fuel contained in several of the reactors. Damage to the systems and structures containing reactor fuel resulted in the release of radioactive material to the surrounding environment.

In response to the earthquake, tsunami, and resulting reactor accidents at Fukushima Dai-ichi (hereafter referred to as the “Fukushima events”), the Commission directed the staff to convene an agency taskforce (Japan Near-Term Task Force) of senior leaders and experts to conduct a methodical and systematic review of the relevant NRC regulatory requirements, programs, and processes, including their implementation, and to recommend whether the agency should make near-term improvements to its regulatory system. As part of the short-term review, the taskforce concluded that, while improvements are expected to be made as a result of the lessons learned from the Fukushima events, the continued operation of nuclear power plants and licensing activities for new plants do not pose an imminent risk to public health and safety (NRC 2011).

During the time that the taskforce was conducting its review, groups of individuals and non-governmental organizations petitioned the Commission to suspend all licensing decisions in order to conduct a separate, generic NEPA analysis to determine whether the Fukushima events constituted “new and significant information” under NEPA that must be analyzed as part of environmental reviews. The Commission found the request premature and noted, “In short, we do not know today the full implications of the [Fukushima] events for U.S. facilities.”[h] However, the Commission found that if “new and significant information comes to light that requires consideration as part of the ongoing preparation of application-specific NEPA documents, the agency will assess the significance of that information, as appropriate.”[i] The Federal courts of appeal and the Commission have interpreted NEPA such that an EIS must be updated to include new information only when that new information provides “a seriously different picture of the environmental impact of the proposed project from what was previously envisioned.”[j]

In the context of the GEIS, the Fukushima events are considered a severe accident (i.e., a type of accident that may challenge a plant’s safety systems at a level much higher than expected) and more specifically, a severe accident initiated by an event external to the plant. The 1996 GEIS concluded that risks from severe accidents initiated by external events (such as an earthquake) could have potentially high consequences but found that external events are adequately addressed through a consideration of a severe accident initiated by an internal event (such as a loss of cooling water). Therefore, an applicant for license renewal need only analyze

(h) *Union Electric Co. d/b/a Ameren Missouri* (Callaway Plant, Unit 2), CLI-11-05, 74 NRC __, __ (slip op. at 30) (Sept. 9, 2011).
(i) *Id.* at 30-31.
(j) *Id*. at 31 (quoting *Hydro Resources, Inc.* (2929 Coors Road, Suite 101, Albuquerque, NM 87120), CLI-99-22, 50 NRC 3, 14 (1999) (citing *Marsh v. Oregon Natural Resources Council*, 490 U.S. 360, 373 (1989))). The Commission also noted that it can modify a facility’s operating license outside of a renewal proceeding and made clear that “it will use the information from these activities to impose any requirement it deems necessary, irrespective of whether a plant is applying for or has been granted a renewed operating license.” *Id.* at 26-27.

the environmental impacts from an internal event in order to adequately characterize the environmental impacts from either type of event. Prior to the Fukushima events, this GEIS examined more recent and up-to-date information regarding external events and concluded that the analysis in the 1996 GEIS remains valid.

Meanwhile, the Japan Near-Term Task Force assessment resulted in the issuance of 10 CFR 50.54(f) letters on March 12, 2012, to address seismic and flooding reevaluations (NRC 2012). As of the publication date of this GEIS, the NRC's evaluation of the consequences of the Fukushima events is ongoing under the direction of the NRC's Japan Lessons Learned Project Directorate. As such, the NRC will continue to evaluate the need to make improvements to existing regulatory requirements based on the task force report and additional studies and analyses of the Fukushima events as more information is learned. To the extent that any revisions are made to NRC regulatory requirements, they would be made applicable to nuclear power reactors regardless of whether or not they have a renewed license. Therefore, no additional analyses have been performed in this GEIS as a result of the Fukushima events. In the event that the NRC identifies information from the Fukushima events that constitutes new and significant information with respect to the environmental impacts of license renewal, the NRC will discuss that information in its site-specific SEISs to the GEIS, as it does with all such new and significant information.

1.10 Changes from the Draft GEIS

In response to public comments on the proposed rule (74 FR 38117, July 21, 2009) and draft GEIS and as a result of information that was unavailable at the time of the issuance of the draft GEIS, the final GEIS contains revisions and new information. Volume 2, Appendix A, Section A.2 presents the comments received during the public comment period on the proposed rule and draft GEIS and NRC's responses to those comments. A brief discussion of the most important changes is provided in this section.

1.10.1 General Overview of Rule-Related Changes

Based on public comments and direction from the Commission, a number of the environmental impact issues identified in Table B-1 of the proposed rule and the associated technical basis for the findings in the draft GEIS were re-evaluated for the final GEIS and rule. Some of these environmental impact issues are discussed in the Section 1.9, "Public Comments on the Draft GEIS." These changes are discussed in detail in Chapter 4 in this final GEIS and are briefly summarized as follows:

- "Air quality (non-attainment and maintenance areas)" issue was changed from a Category 2 to a Category 1 issue and renamed, "Air quality impacts (all plants)."

- "Groundwater and soil contamination," was changed from a Category 2 to a Category 1 issue and consolidated with "Groundwater use and quality" into a single renamed Category 1 issue, "Groundwater contamination and use."

- "Thermal impacts on aquatic organisms" issues were reorganized to separate out several Category 1 thermal impact issues (grouped together with a Category 2 thermal impact issue in the proposed rule) to create a new separate combined Category 1 issue, "Infrequently reported thermal impacts (all plants)," which also includes the previously separate "Stimulation of aquatic nuisance species (e.g., shipworms)" Category 1 thermal impact issue. Like Category 1 issues had been grouped together within the larger context of the Category 2 issue in the proposed rule to facilitate the environmental review process consistent with the resource-based approach in this GEIS.

- "Impingement and entrainment of aquatic organisms" issues were reorganized to separate out a single impingement and entrainment Category 1 issue (grouped with other impingement and entrainment issues in the proposed rule) to create a new separate Category 1 issue, "Entrainment of phytoplankton and zooplankton (all plants)." Like impingement and entrainment issues had been grouped together within the larger context of the Category 2 issue, "Impingement and entrainment of aquatic organisms (plants with once-through cooling systems or cooling ponds)" in the proposed rule to facilitate the environmental review process consistent with the resource-based approach in this GEIS.

- The NRC revised the Category 1 "Onsite storage of spent nuclear fuel"[(k)] issue to narrow the period of onsite storage to the license renewal term as a result of the 2012 D.C. Circuit decision in *New York v. NRC*, and the Commission's subsequent direction. As described in section 1.7.2, "Disposition of spent nuclear fuel," above, pending the issuance of a generic EIS and revised Waste Confidence Decision and Rule, the period of onsite storage of spent nuclear fuel following the permanent shutdown of the power reactor and expiration of the operating license is now excluded from this GEIS issue. As revised, this issue now covers the onsite storage of spent fuel for the term of the extended license only; it remains classified as a Category 1 issue.

- The "Offsite radiological impacts of spent nuclear fuel and high-level waste disposal" issue[(l)] was determined to be a Category 1 issue in the 1996 GEIS, but given the 2012

(k) The issue was named "On-site spent fuel" in the 1996 rule and GEIS.
(l) The issue was named "Offsite radiological impacts (spent fuel and high level waste disposal)" in the 1996 rule and GEIS.

> D.C. Circuit decision in *New York v. NRC*, and the Commission's subsequent direction, the NRC reclassified the issue to uncategorized in the final GEIS. As the NRC has now determined that this issue is uncategorized, pending further action by the Commission to address the issues raised in *New York v. NRC*, an applicant is not required to conduct a plant-specific assessment of the environmental impacts associated with this issue in its environmental report.

As a result, 59 environmental impact issues were determined to be Category 1 and would not require additional plant-specific analysis unless new and significant information is identified during a plant-specific license renewal environmental review that would change the conclusions in the GEIS. Of the remaining 19 issues, 17 were determined to be Category 2, and two are uncategorized. These 78 issues are evaluated in the final GEIS. No environmental issues evaluated in the 1996 GEIS were eliminated, but certain issues have been consolidated or grouped due to the related nature of the impacts.

1.10.2 Greenhouse Gas Emissions and Climate Change

A discussion of greenhouse gas emissions and climate change has been added to the final GEIS.

1.10.3 Miscellaneous Revisions and Editorial Changes

Several sections in the final GEIS were revised to reflect the availability of more recent information or to include corrections, fix erroneous information, improve the presentation, and to make other editorial changes. Sections of the GEIS were also revised in response to the Plain Writing Act of 2010, which directs Federal agencies to write all new publications, forms, and publicly distributed documents in a clear, concise, organized manner and to follow other best practices appropriate to writing for the public. None of these revisions and editorial changes affect the assessment of environmental impacts to the 78 environmental issues addressed in the final GEIS.

1.11 Lessons Learned

As previously discussed, the NRC reviewed and reevaluated the impacts of license renewal on the 92 environmental issues addressed in the 1996 GEIS. Over 40 nuclear plants (70 reactor units) have since undergone license renewal environmental reviews. Lessons learned and knowledge gained from these license renewal environmental reviews have provided a significant source of new information for this GEIS revision.

The purpose of this review and reevaluation was to determine if the findings presented in the 1996 GEIS remain valid. In doing so, the NRC considered the need to modify, add, group, or delete any of the 92 issues in the 1996 GEIS. After this review and reevaluation, the NRC carried forward 78 impact issues for detailed consideration in this GEIS revision. The issues identified in the 1996 GEIS have served to accurately categorize most environmental impacts associated with license renewal, and there have been no cases where new and significant information called into question the original findings of the GEIS. There have been a number of instances where new (but not significant) information was discovered during a license renewal review. In most cases, the new information identified did not fit into one of the 92 environmental issues addressed in the 1996 GEIS but still warranted review in the plant-specific SEIS. For example, the environmental review for license renewal at the D.C. Cook plant in Michigan considered the effects of sanitary sewage lagoons on groundwater quality as a new issue. The review for the Oyster Creek plant considered the effects of a small dam built to impound water for fire-fighting purposes. The license renewal environmental review process established in 10 CFR Part 51 has proven to be robust because it allows new information and lessons learned to be addressed in subsequent plant-specific license renewal environmental reviews.

1.12 New Organization of the GEIS

This GEIS revision adopts the NRC’s standard format for EISs as established in 10 CFR Part 51, Subpart A, Appendix A. Consequently, the organizational structure of this GEIS is quite different from that of the 1996 GEIS. The 1996 GEIS presented impacts organized around plant systems (e.g., cooling systems, transmission lines) and activities (e.g., refurbishment). This GEIS takes a more typical NEPA resource-based approach to presenting impacts where all components of the proposed action and alternatives are presented for each resource area. The following list describes the contents of each chapter of GEIS:

- **Chapter 2** presents brief descriptions of the proposed action (including nuclear plant operations, refurbishment, and termination of operations and decommissioning) during the license renewal term and summary of impacts; the no-action alternative; and replacement power alternatives.

- **Chapter 3** presents a general description of the affected environment in the vicinity of operating commercial nuclear power plants in the United States. Included are descriptions of nuclear power plant facilities and operations followed by general descriptions of existing conditions in the following topical areas: (1) land use and visual resources; (2) meteorology, air quality, and noise; (3) geologic environment; (4) water resources (surface water and groundwater resources); (5) ecological resources (terrestrial resources, aquatic resources, special status species and habitats); (6) historic and cultural resources; (7) socioeconomics; (8) human health (radiological and nonradiological hazards); (9) environmental justice; and (10) waste management.

- **Chapter 4** presents the environmental consequences associated with the proposed action (license renewal) and replacement power alternatives (including the effects of construction and operations) on each of the topical areas presented in Chapter 3. Impacts common to all alternatives (including the environmental consequences of fuel cycles and terminating power plant operations), cumulative impacts, and resource commitments associated with the proposed action are also discussed.

- **Chapter 5** presents a list of the preparers of this GEIS, their affiliations, authorship responsibilities, and qualifications.

- **Chapter 6** provides a list of the agencies, organizations, and persons receiving copies of the GEIS.

- **Chapter 7** provides for a glossary of terms used in the GEIS.

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2 Alternatives Including the Proposed Action

The proposed action considered in this generic environmental impact statement (GEIS) is the renewal of commercial nuclear power plant operating licenses. Although the U.S. Nuclear Regulatory Commission's (NRC's) decision-making authority is limited to deciding whether to renew a nuclear power plant's operating license, the NRC's implementation of the National Environmental Policy Act (NEPA) requires the NRC to consider the environmental impacts of potential alternatives to renewing a plant's operating license. In plant-specific environmental reviews, the NRC compares the impacts of renewing the operating license and the impacts from continued plant operations to the environmental impacts of alternatives. This process allows the NRC to determine whether the environmental impacts of license renewal are so great that preserving the option of license renewal for energy-planning decision makers would be unreasonable. If the NRC decides not to renew the operating license of a nuclear power plant, energy-planning decision makers will then have to find alternative means to address energy needs. Alternatives to license renewal include other means of generating electricity, as well as offsetting demand using conservation and energy efficiency measures (demand-side management) or purchasing sufficient power to replace the capacity supplied by the existing nuclear power plant.

Contents of Chapter 2

If the NRC renews the operating license, the decision on whether or not to continue nuclear plant operations will be made by the licensee and State or other Federal (non-NRC) decision makers. This decision may be based on economic, reliability, operational, policy, and environmental objectives.

Alternatives to the Proposed Action Considered in the GEIS

- Not renewing the operating licenses of commercial nuclear power plants (no-action alternative).
- Replacing existing nuclear generating capacity using other energy sources (including fossil fuel, new nuclear, and renewable energy).
- Offsetting generation capacity using conservation and energy efficiency (demand-side management) or purchased power.

A full range of replacement power generation alternatives are evaluated in the GEIS, including fossil-fueled generation, new nuclear power, and renewable energy sources. Conservation and energy efficiency, as well as power purchasing, are also considered as alternatives to license renewal. Section 2.1 describes the proposed action, including power plant operations during the license renewal term, refurbishment, and other activities associated with license renewal. Most of these activities would be the same as or similar to those occurring during the current license term. Termination of nuclear power plant operations would occur at or before the end of the license renewal term, and decommissioning activities would commence after operations have ceased.

Impacts of the proposed action are presented in Section 2.1.4, including each of the 78 impact issues, their significance (SMALL, MODERATE, or LARGE, as defined in Section 1.5), and whether the impact designation would apply to all plants. Section 2.2 describes the no-action alternative (not renewing the operating license), and Section 2.3 presents replacement power alternatives capable of replacing the existing nuclear power capacity, including fossil fuel, new nuclear, renewable energy, conservation and energy efficiency, and purchased power. The NRC has not reached any generic conclusions regarding the impacts for alternatives to license renewal and will consider such impacts (as well as the future state of technology and, possibly, other reasonable alternatives) in future site-specific supplemental environmental impact statements (SEISs). Finally, Section 2.4 presents a summary comparison of the impacts of the proposed action and the alternatives.

2.1 Proposed Action

As stated in Section 1.2, the proposed action is the renewal of commercial nuclear power plant operating licenses. For NRC to determine whether the license should be renewed, an applicant is required to perform certain analyses to demonstrate that the nuclear power plant could effectively manage the effects of aging and continue safe operations beyond its current licensing period. These analyses include an assessment of the effects of potential age-related degradation on certain long-lived, passive systems, structures, and components. This requires applicants to describe the conditions under which the plant would operate during the license renewal term. A description of normal power plant operations during the license renewal term is provided in Section 2.1.1.

Applicants for license renewal may perform certain refurbishment activities (replacement of major components and systems) to continue operating beyond the current license term. These activities are described in Section 2.1.2, and impacts are generically discussed in Chapter 4. Section 2.1.3 provides an overview of the termination of nuclear power plant operations and decommissioning process. Impacts associated with termination of operations and the decommissioning of nuclear and other power plants are discussed in Section 4.11.2.

2.1.1 Plant Operations during the License Renewal Term

This section describes plant operations, routine maintenance, and refueling operations during the license renewal term. It also provides an overview of the aging management reviews required for license renewal applications. During the license renewal term, commercial nuclear power plants would continue to operate in the same manner as they had during the original license term. All nuclear reactors currently operating in the United States are light water reactors, of which there are two basic types—pressurized water reactors and boiling water reactors. A brief description of these reactors and the baseline conditions during their operation are presented in Chapter 3.

The types of activities that are conducted at nuclear power plants can be classified as:

- Reactor operations;
- Waste management (processing, storage, packaging, and offsite shipment of wastes);
- Security (includes site security personnel);
- Office and clerical work (management, public relations, and support staff);
- Laboratory analysis;
- Surveillance, monitoring, and maintenance (personnel involved in equipment testing, inspections, and monitoring activities); and
- Refueling and other outages (usually involves additional workers brought on site during the outage).

These activities are expected to continue during the license renewal term. Certain systems, structures, and components such as the reactor pressure vessel, reactor containment building, and piping are expected to operate into the license renewal term. Title 10, Part 54, of the *Code of Federal Regulations* (10 CFR Part 54) places certain requirements on licensees to make sure that such systems, structures, and components continue to operate safely. In the 1996 GEIS, the incremental aging management activities implemented to allow operation of a nuclear power plant beyond the original 40-year license term were assumed to fall under one of two broad categories: (1) surveillance, monitoring, inspection, testing, trending, and recordkeeping actions, most of which are repeated at regular intervals, and (2) major refurbishment actions, which usually occur infrequently and possibly only once in the life of the plant for any given item. Refurbishment activities are discussed in the following section.

The NRC finds that the approaches to environmental impacts from refurbishment activities contained in the 1996 GEIS (NRC 1996) are valid and conservative. The approaches yield environmental impacts that are likely greater than—or at least equal to—the actual impacts during the license renewal term.

2.1.2 Refurbishment and Other Activities Associated with License Renewal

In the 1996 GEIS, the NRC assumed that licensees would need to conduct major refurbishment activities to ensure the safe and economic operation of nuclear plants beyond the current license term. Activities included replacement and repair of major systems, structures, and components. Replacement activities included steam generators and pressurizers for pressurized water reactors (PWRs) and recirculation piping systems for boiling water reactors (BWRs). It was assumed that many nuclear plants would also undertake construction projects to replace or improve power plant infrastructure. Such projects could include construction of new parking lots, roads, storage buildings, structures, and other facilities.

The number of systems, structures, and components involved in refurbishment and the frequency and duration of each activity would vary. In many circumstances, refurbishment activities (e.g., steam generator and vessel head replacement) have already taken place during the current operating license term at a number of nuclear plants. These activities have been conducted for economic, reliability, or efficiency reasons during refueling or maintenance outages. In addition, very few applications have identified any refurbishment activities associated with license renewal. The NRC acknowledged in the 1996 GEIS that licensees may undertake refurbishment activities for reasons of safety, economics, reliability, or efficiency (i.e., not just to support license renewal).

Impacts from refurbishment activities outside of license renewal are assumed to have been accounted for in annual site evaluation reports, environmental operating reports, and radiological environmental monitoring program reports. Detailed analyses of environmental impacts have not been performed for refurbishment actions in this GEIS revision because these actions would vary at each nuclear plant. Instead, the impacts of typical activities during the license renewal term, including refurbishment activities, are generically addressed in each resource area in Chapter 4. Refurbishment activities at nuclear power plants proposed by license renewal applicants in their environmental report will continue to be addressed in plant-specific environmental reviews.

2.1.3 Termination of Nuclear Power Plant Operations and Decommissioning after the License Renewal Term

The impacts of decommissioning are described in the *Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities: Regarding the Decommissioning of Nuclear Power Reactors*, NUREG-0586 (NRC 2002a). The majority of the activities associated with plant operations would cease with reactor shutdown. Some activities (e.g., security and oversight of spent nuclear fuel) would remain unchanged, while others (waste management, office and clerical work, laboratory analysis, and surveillance, monitoring, and maintenance) would continue at reduced or altered levels. Systems dedicated to reactor operations would cease;

however, impacts from their physical presence may continue if not removed after reactor shutdown. For sites with more than one unit, shared systems may operate at reduced capacities. Impacts associated with dedicated systems that remain in place or shared systems that continue to operate at normal capacities would remain unchanged.

Termination of nuclear power plant operations would result in the cessation of activities necessary to maintain the reactor, as well as a significant reduction in plant workforce. It is assumed that the termination of operations would not immediately lead to the dismantlement of the reactor or other infrastructure. For sites with just one unit, some facilities could remain in operation to ensure the site is maintained in safe shutdown condition.

The NRC has developed regulations and guidance for the decommissioning of nuclear facilities, including nuclear power plants. These regulations are found in 10 CFR 50.82 (Termination of License), Subpart E to 10 CFR Part 20 (Radiological Criteria for License Termination), and the guidance document *Consolidated NMSS Decommissioning Guidance*, NUREG-1757 (NRC 2002b).

The decommissioning process for a nuclear power plant begins with the licensee informing the NRC that it intends to decommission the plant. The licensee then prepares a decommissioning plan and submits it to the NRC. If the plan is acceptable, the NRC then conducts a detailed technical review and evaluates the plan from safety and environmental perspectives. As part of the safety evaluation, the NRC prepares a safety evaluation report (SER) to document the methods used in the evaluation and the conclusions reached. For the environmental evaluation, the NRC prepares an environment impact statement or an environmental assessment, depending on the scope of the proposed work. At the end of the detailed technical review, the NRC determines whether to approve the decommissioning plan. Upon approval, the NRC amends the existing license of the plant to allow decommissioning to proceed. Once the decommissioning plan is approved and the license amendment is issued, the licensee implements the plan. The NRC then conducts inspections to verify compliance with the plan.

At the completion of decommissioning, which may take up to 60 years to complete (10 CFR 50.82(a)(3)), the licensee conducts a final status survey to demonstrate compliance with criteria established in the decommissioning plan. The NRC verifies the survey by one or more of the following: a quality assurance/quality control review, side-by-side or split sampling, and independent confirmatory surveys. When the NRC confirms that the criteria in the decommissioning plan for releasing the site have been met, the NRC either terminates or amends the license, depending on the intended use of the site.

At the end of the decommissioning process, the site of a nuclear power plant and any remaining structures on the site can be released for unrestricted or restricted use. The radiological criteria for releasing sites for unrestricted use are given in 10 CFR 20.1402. The criteria for restricted conditions and alternate criteria that the NRC may approve under certain conditions are listed in 10 CFR 20.1403 and 10 CFR 20.1404, respectively.

2.1.4 Impacts of the Proposed Action

In evaluating the impacts of the proposed action, 78 impact issues were identified: 70 impact issues were associated with continued operations and refurbishment; 2 with postulated accidents; 1 with the termination of nuclear power plant operations and decommissioning; 4 with the uranium fuel cycle; and 1 with cumulative impacts. For all issues, the focus of the evaluation was on the incremental effects of license renewal relative to the no-action alternative. Impact significance levels and categories are defined in Section 1.5.

A summary of the environmental impacts of the proposed action are presented in Table 2.1-1. The technical basis for the impact determinations presented in this table are found in Chapter 4 of this GEIS in Sections 4.2 through 4.13.

Table 2.1-1. Summary of Impacts Associated with License Renewal under the Proposed Action

Issue	Impact (Table B-1 Finding)
Land Use	
Onsite land use	**Small (Category 1).** Changes in onsite land use from continued operations and refurbishment associated with license renewal term would be a small fraction of the nuclear power plant site and would involve only land that is controlled by the licensee.
Offsite land use	**Small (Category 1).** Offsite land use would not be affected by continued operations and refurbishment associated with license renewal.
Offsite land use in transmission line right-of-ways (ROWs)	**Small (Category 1).** Use of transmission line ROWs from continued operations and refurbishment associated with license renewal would continue with no change in land use restrictions.
Visual Resources	
Aesthetic impacts	**Small (Category 1).** No important changes to the visual appearance of plant structures or transmission lines are expected from continued operations and refurbishment associated with license renewal.

Table 2.1-1. (cont.)

Issue	Impact (Table B-1 Finding)
Air Quality	
Air quality impacts (all plants)	**Small (Category 1).** Air quality impacts from continued operations and refurbishment associated with license renewal are expected to be small at all plants. Emissions resulting from refurbishment activities at locations in or near air quality nonattainment or maintenance areas would be short-lived and would cease after these refurbishment activities are completed. Operating experience has shown that the scale of refurbishment activities has not resulted in exceedance of the *de minimis* thresholds for criteria pollutants, and best management practices including fugitive dust controls and the imposition of permit conditions in State and local air emissions permits would ensure conformance with applicable State or Tribal implementation plans. Emissions from emergency diesel generators and fire pumps and routine operations of boilers used for space heating would not be a concern, even for plants located in or adjacent to nonattainment areas. Impacts from cooling tower particulate emissions even under the worst-case situations have been small.
Air quality effects of transmission lines	**Small (Category 1).** Production of ozone and oxides of nitrogen is insignificant and does not contribute measurably to ambient levels of these gases.
Noise	
Noise impacts	**Small (Category 1).** Noise levels would remain below regulatory guidelines for offsite receptors during continued operations and refurbishment associated with license renewal.
Geologic Environment	
Geology and soils	**Small (Category 1).** The effect of geologic and soil conditions on plant operations and the impact of continued operations and refurbishment activities on geology and soils would be small for all nuclear power plants and would not change appreciably during the license renewal term.
Surface Water Resources	
Surface water use and quality (non-cooling system impacts)	**Small (Category 1).** Impacts are expected to be small if best management practices are employed to control soil erosion and spills. Surface water use associated with continued operations and refurbishment associated with license renewal would not increase significantly or would be reduced if refurbishment occurs during a plant outage.
Altered current patterns at intake and discharge structures	**Small (Category 1).** Altered current patterns would be limited to the area in the vicinity of the intake and discharge structures. These impacts have been small at operating nuclear power plants.

Table 2.1-1. (cont.)

Issue	Impact (Table B-1 Finding)
Surface Water Resources (cont.)	
Altered salinity gradients	**Small (Category 1).** Effects on salinity gradients would be limited to the area in the vicinity of the intake and discharge structures. These impacts have been small at operating nuclear power plants.
Altered thermal stratification of lakes	**Small (Category 1).** Effects on thermal stratification would be limited to the area in the vicinity of the intake and discharge structures. These impacts have been small at operating nuclear power plants.
Scouring caused by discharged cooling water	**Small (Category 1).** Scouring effects would be limited to the area in the vicinity of the intake and discharge structures. These impacts have been small at operating nuclear power plants.
Discharge of metals in cooling system effluent	**Small (Category 1).** Discharges of metals have not been found to be a problem at operating nuclear power plants with cooling-tower-based heat dissipation systems and have been satisfactorily mitigated at other plants. Discharges are monitored and controlled as part of the National Pollutant Discharge Elimination System (NPDES) permit process.
Discharge of biocides, sanitary wastes, and minor chemical spills	**Small (Category 1).** The effects of these discharges are regulated by Federal and State environmental agencies. Discharges are monitored and controlled as part of the NPDES permit process. These impacts have been small at operating nuclear power plants.
Surface water use conflicts (plants with once-through cooling systems)	**Small (Category 1).** These conflicts have not been found to be a problem at operating nuclear power plants with once-through heat dissipation systems.
Surface water use conflicts (plants with cooling ponds or cooling towers using makeup water from a river)	**Small or moderate (Category 2).** Impacts could be of small or moderate significance, depending on makeup water requirements, water availability, and competing water demands.
Effects of dredging on surface water quality	**Small (Category 1).** Dredging to remove accumulated sediments in the vicinity of intake and discharge structures and to maintain barge shipping has not been found to be a problem for surface water quality. Dredging is performed under permit from the U.S. Army Corps of Engineers, and possibly, from other State or local agencies.
Temperature effects on sediment transport capacity	**Small (Category 1).** These effects have not been found to be a problem at operating nuclear power plants and are not expected to be a problem.

Table 2.1-1. (cont.)

Issue	Impact (Table B-1 Finding)
Groundwater Resources	
Groundwater contamination and use (non-cooling system impacts)	**Small (Category 1).** Extensive dewatering is not anticipated from continued operations and refurbishment associated with license renewal. Industrial practices involving the use of solvents, hydrocarbons, heavy metals, or other chemicals, and/or the use of wastewater ponds or lagoons have the potential to contaminate site groundwater, soil, and subsoil. Contamination is subject to State or Environmental Protection Agency regulated cleanup and monitoring programs. The application of best management practices for handling any materials produced or used during these activities would reduce impacts.
Groundwater use conflicts (plants that withdraw less than 100 gallons per minute [gpm])	**Small (Category 1).** Plants that withdraw less than 100 gpm are not expected to cause any groundwater use conflicts.
Groundwater use conflicts (plants that withdraw more than 100 gallons per minute [gpm])	**Small, moderate, or large (Category 2).** Plants that withdraw more than 100 gpm could cause groundwater use conflicts with nearby groundwater users.
Groundwater use conflicts (plants with closed-cycle cooling systems that withdraw makeup water from a river)	**Small, moderate, or large (Category 2).** Water use conflicts could result from water withdrawals from rivers during low-flow conditions, which may affect aquifer recharge. The significance of impacts would depend on makeup water requirements, water availability, and competing water demands.
Groundwater quality degradation resulting from water withdrawals	**Small (Category 1).** Groundwater withdrawals at operating nuclear power plants would not contribute significantly to groundwater quality degradation.
Groundwater quality degradation (plants with cooling ponds in salt marshes)	**Small (Category 1).** Sites with closed-cycle cooling ponds could degrade groundwater quality. However, groundwater in salt marshes is naturally brackish and thus, not potable. Consequently, the human use of such groundwater is limited to industrial purposes..
Groundwater quality degradation (plants with cooling ponds at inland sites)	**Small, moderate, or large (Category 2).** Inland sites with closed-cycle cooling ponds could degrade groundwater quality. The significance of the impact would depend on cooling pond water quality, site hydrogeologic conditions (including the interaction of surface water and groundwater), and the location, depth, and pump rate of water wells.
Radionuclides released to groundwater	**Small or moderate (Category 2).** Leaks of radioactive liquids from plant components and pipes have occurred at numerous plants. Groundwater protection programs have been established at all operating nuclear power plants to minimize the potential impact from any inadvertent releases. The magnitude of impacts would depend on site-specific characteristics.

Table 2.1-1. (cont.)

Issue	Impact (Table B-1 Finding)
Terrestrial Resources	
Effects on terrestrial resources (non-cooling system impacts)	**Small, moderate, or large (Category 2).** Impacts resulting from continued operations and refurbishment associated with license renewal may affect terrestrial communities. Application of best management practices would reduce the potential for impacts. The magnitude of impacts would depend on the nature of the activity, the status of the resources that could be affected, and the effectiveness of mitigation.
Exposure of terrestrial organisms to radionuclides	**Small (Category 1).** Doses to terrestrial organisms from continued operations and refurbishment associated with license renewal are expected to be well below exposure guidelines developed to protect these organisms.
Cooling system impacts on terrestrial resources (plants with once-through cooling systems or cooling ponds)	**Small (Category 1).** No adverse effects to terrestrial plants or animals have been reported as a result of increased water temperatures, fogging, humidity, or reduced habitat quality. Due to the low concentrations of contaminants in cooling system effluents, uptake and accumulation of contaminants in the tissues of wildlife exposed to the contaminated water or aquatic food sources are not expected to be significant issues.
Cooling tower impacts on vegetation (plants with cooling towers)	**Small (Category 1).** Impacts from salt drift, icing, fogging, or increased humidity associated with cooling tower operation have the potential to affect adjacent vegetation, but these impacts have been small at operating nuclear power plants and are not expected to change over the license renewal term.
Bird collisions with plant structures and transmission lines	**Small (Category 1).** Bird collisions with cooling towers and other plant structures and transmission lines occur at rates that are unlikely to affect local or migratory populations and the rates are not expected to change.
Water use conflicts with terrestrial resources (plants with cooling ponds or cooling towers using makeup water from a river)	**Small or moderate (Category 2).** Impacts on terrestrial resources in riparian communities affected by water use conflicts could be of moderate significance.
Transmission line ROW management impacts on terrestrial resources	**Small (Category 1).** Continued ROW management during the license renewal term is expected to keep terrestrial communities in their current condition. Application of best management practices would reduce the potential for impacts.
Electromagnetic fields on flora and fauna (plants, agricultural crops, honeybees, wildlife, livestock)	**Small (Category 1).** No significant impacts of electromagnetic fields on terrestrial flora and fauna have been identified. Such effects are not expected to be a problem during the license renewal term.

Table 2.1-1. (cont.)

Issue	Impact (Table B-1 Finding)
Aquatic Resources	
Impingement and entrainment of aquatic organisms (plants with once-through cooling systems or cooling ponds)	**Small, moderate, or large (Category 2).** The impacts of impingement and entrainment are small at many plants, but may be moderate or even large at a few plants with once-through and cooling-pond cooling systems, depending on cooling system withdrawal rates and volumes and the aquatic resources at the site.
Impingement and entrainment of aquatic organisms (plants with cooling towers)	**Small (Category 1).** Impingement and entrainment rates are lower at plants that use closed-cycle cooling with cooling towers because the rates and volumes of water withdrawal needed for makeup are minimized.
Entrainment of phytoplankton and zooplankton (all plants)	**Small (Category 1).** Entrainment of phytoplankton and zooplankton has not been found to be a problem at operating nuclear power plants and is not expected to be a problem during the license renewal term.
Thermal impacts on aquatic organisms (plants with once-through cooling systems or cooling ponds)	**Small, moderate, or large (Category 2).** Most of the effects associated with thermal discharges are localized and are not expected to affect overall stability of populations or resources. The magnitude of impacts, however, would depend on site-specific thermal plume characteristics and the nature of aquatic resources in the area.
Thermal impacts on aquatic organisms (plants with cooling towers)	**Small (Category 1).** Thermal effects associated with plants that use cooling towers are expected to be small because of the reduced amount of heated discharge.
Infrequently reported thermal impacts (all plants)	**Small (Category 1).** Continued operations during the license renewal term are expected to have small thermal impacts with respect to the following: Cold shock has been satisfactorily mitigated at operating nuclear plants with once-through cooling systems, has not endangered fish populations or been found to be a problem at operating nuclear power plants with cooling towers or cooling ponds, and is not expected to be a problem. Thermal plumes have not been found to be a problem at operating nuclear power plants and are not expected to be a problem. Thermal discharge may have localized effects but is not expected to affect the larger geographical distribution of aquatic organisms. Premature emergence has been found to be a localized effect at some operating nuclear power plants but has not been a problem and is not expected to be a problem.

Table 2.1-1. (cont.)

Issue	Impact (Table B-1 Finding)
Aquatic Resources (cont.)	
	Stimulation of nuisance organisms has been satisfactorily mitigated at the single nuclear power plant with a once-through cooling system where previously it was a problem. It has not been found to be a problem at operating nuclear power plants with cooling towers or cooling ponds and is not expected to be a problem.
Effects of cooling water discharge on dissolved oxygen, gas supersaturation, and eutrophication	**Small (Category 1).** Gas supersaturation was a concern at a small number of operating nuclear power plants with once-through cooling systems but has been mitigated. Low dissolved oxygen was a concern at one nuclear power plant with a once-through cooling system but has been mitigated. Eutrophication (nutrient loading) and resulting effects on chemical and biological oxygen demands have not been found to be a problem at operating nuclear power plants.
Effects of nonradiological contaminants on aquatic organisms	**Small (Category 1).** Best management practices and discharge limitations of NPDES permits are expected to minimize the potential for impacts to aquatic resources during continued operations and refurbishment associated with license renewal. Accumulation of metal contaminants has been a concern at a few nuclear power plants, but has been satisfactorily mitigated by replacing copper alloy condenser tubes with those of another metal.
Exposure of aquatic organisms to radionuclides	**Small (Category 1).** Doses to aquatic organisms are expected to be well below exposure guidelines developed to protect these aquatic organisms.
Effects of dredging on aquatic resources	**Small (Category 1).** Dredging at nuclear power plants is expected to occur infrequently, would be of relatively short duration, and would affect relatively small areas. Dredging is performed under permit from the U.S. Army Corps of Engineers, and possibly, from other State or local agencies.
Water use conflicts with aquatic resources (plants with cooling ponds or cooling towers using makeup water from a river)	**Small or moderate (Category 2).** Impacts on aquatic resources in stream communities affected by water use conflicts could be of moderate significance in some situations.
Effects on aquatic resources (non-cooling system impacts)	**Small (Category 1).** Licensee application of appropriate mitigation measures is expected to result in no more than small changes to aquatic communities from their current condition.
Impacts of transmission line ROW management on aquatic resources	**Small (Category 1).** Licensee application of best management practices to ROW maintenance is expected to result in no more than small impacts to aquatic systems.
Losses from predation, parasitism, and disease among organisms exposed to sublethal stresses	**Small (Category 1).** These types of losses have not been found to be a problem at operating nuclear power plants and are not expected to be a problem during the license renewal term.

Table 2.1-1. (cont.)

Issue	Impact (Table B-1 Finding)
Special Status Species and Habitats	
Threatened, endangered, and protected species and essential fish habitat	**(Category 2).** The magnitude of impacts on threatened, endangered, and protected species, critical habitat, and essential fish habitat would depend on the occurrence of listed species and habitats and the effects of power plant systems on them. Consultation with appropriate agencies would be needed to determine whether special status species or habitats are present and whether they would be adversely affected by continued operations and refurbishment associated with license renewal.
Historic and Cultural Resources	
Historic and cultural resources	**(Category 2).** Continued operations and refurbishment associated with license renewal are expected to have no more than small impacts on historic and cultural resources located onsite and in the transmission line ROW because most impacts could be mitigated by avoiding those resources. The National Historic Preservation Act (NHPA) requires the Federal agency to consult with the State Historic Preservation Officer (SHPO) and appropriate Native American Tribes to determine the potential effects on historic properties and mitigation, if necessary.
Socioeconomics	
Employment and income, recreation and tourism	**Small (Category 1).** Although most nuclear plants have large numbers of employees with higher than average wages and salaries, employment, income, recreation, and tourism, impacts from continued operations and refurbishment associated with license renewal are expected to be small.
Tax revenues	**Small (Category 1).** Nuclear plants provide tax revenue to local jurisdictions in the form of property tax payments, payments in lieu of tax (PILOT), or tax payments on energy production. The amount of tax revenue paid during the license renewal term as a result of continued operations and refurbishment associated with license renewal is not expected to change.
Community services and education	**Small (Category 1).** Changes resulting from continued operations and refurbishment associated with license renewal to local community and educational services would be small. With little or no change in employment at the licensee's plant, value of the power plant, payments on energy production, and PILOT payments expected during the license renewal term, community and educational services would not be affected by continued power plant operations.

Table 2.1-1. (cont.)

Issue	Impact (Table B-1 Finding)
Socioeconomics (cont.)	
Population and housing	**Small (Category 1).** Changes resulting from continued operations and refurbishment associated with license renewal to regional population and housing availability and value would be small. With little or no change in employment at the licensee's plant expected during the license renewal term, population and housing availability and values would not be affected by continued power plant operations.
Transportation	**Small (Category 1).** Changes resulting from continued operations and refurbishment associated with license renewal to traffic volumes would be small.
Human Health	
Radiation exposures to the public	**Small (Category 1).** Radiation doses to the public from continued operations and refurbishment associated with license renewal are expected to continue at current levels, and would be well below regulatory limits.
Radiation exposures to plant workers	**Small (Category 1).** Occupational doses from continued operations and refurbishment associated with license renewal are expected to be within the range of doses experienced during the current license term, and would continue to be well below regulatory limits.
Human health impact from chemicals	**Small (Category 1).** Chemical hazards to plant workers resulting from continued operations and refurbishment associated with license renewal are expected to be minimized by the licensee implementing good industrial hygiene practices as required by permits and Federal and State regulations. Chemical releases to the environment and the potential for impacts to the public are expected to be minimized by adherence to discharge limitations of NPDES and other permits.
Microbiological hazards to the public (plants with cooling ponds or canals or cooling towers that discharge to a river)	**Small, moderate, or large (Category 2).** These organisms are not expected to be a problem at most operating plants except possibly at plants using cooling ponds, lakes, or canals that discharge into rivers. Impacts would depend on site-specific characteristics.
Microbiological hazards to plant workers	**Small (Category 1).** Occupational health impacts are expected to be controlled by continued application of accepted industrial hygiene practices to minimize worker exposures as required by permits and Federal and State regulations.

Table 2.1-1. (cont.)

Issue	Impact (Table B-1 Finding)
Human Health (cont.)	
Chronic effects of electromagnetic fields (EMFs)	**Uncertain.** Studies of 60-Hz EMFs have not uncovered consistent evidence linking harmful effects with field exposures. EMFs are unlike other agents that have a toxic effect (e.g., toxic chemicals and ionizing radiation) in that dramatic acute effects cannot be forced and longer-term effects, if real, are subtle. Because the state of the science is currently inadequate, no generic conclusion on human health impacts is possible.
Physical occupational hazards	**Small (Category 1).** Occupational safety and health hazards are generic to all types of electrical generating stations, including nuclear power plants, and are of small significance if the workers adhere to safety standards and use protective equipment as required by Federal and State regulations.
Electric shock hazards	**Small, moderate, or large (Category 2).** Electrical shock potential is of small significance for transmission lines that are operated in adherence with the National Electrical Safety Code (NESC). Without a review of conformance with NESC criteria of each nuclear power plant's in-scope transmission lines, it is not possible to determine the significance of the electrical shock potential.
Postulated Accidents	
Design-basis accidents	**Small (Category 1).** The NRC staff has concluded that the environmental impacts of design-basis accidents are of small significance for all plants.
Severe accidents	**Small (Category 2).** The probability-weighted consequences of atmospheric releases, fallout onto open bodies of water, releases to groundwater, and societal and economic impacts from severe accidents are small for all plants. However, alternatives to mitigate severe accidents must be considered for all plants that have not considered such alternatives.
Environmental Justice	
Minority and low-income populations	**(Category 2).** Impacts to minority and low-income populations and subsistence consumption resulting from continued operations and refurbishment associated with license renewal will be addressed in plant-specific reviews. See NRC Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions (69 FR 52040, August 24, 2004).
Waste Management	
Low-level waste storage and disposal	**Small (Category 1).** The comprehensive regulatory controls that are in place and the low public doses being achieved at reactors ensure that the radiological impacts to the environment would remain small during the license renewal term.

Table 2.1-1. (cont.)

Issue	Impact (Table B-1 Finding)
Waste Management (cont.)	
Onsite storage of spent nuclear fuel	**Small (Category 1).** The expected increase in the volume of spent fuel from an additional 20 years of operation can be safely accommodated onsite during the license renewal term with small environmental effects through dry or pool storage at all plants.
Offsite radiological impacts of spent nuclear fuel and high-level waste disposal	**Uncertain impact (Uncategorized).** The generic conclusion on offsite radiological impacts of spent nuclear fuel and high-level waste is not being finalized pending the completion of a generic environmental impact statement on waste confidence.
Mixed-waste storage and disposal	**Small (Category 1).** The comprehensive regulatory controls and the facilities and procedures that are in place ensure proper handling and storage, as well as negligible doses and exposure to toxic materials for the public and the environment at all plants. License renewal would not increase the small, continuing risk to human health and the environment posed by mixed waste at all plants. The radiological and nonradiological environmental impacts of long-term disposal of mixed waste from any individual plant at licensed sites are small.
Nonradioactive waste storage and disposal	**Small (Category 1).** No changes to systems that generate nonradioactive waste are anticipated during the license renewal term. Facilities and procedures are in place to ensure continued proper handling, storage, and disposal, as well as negligible exposure to toxic materials for the public and the environment at all plants.
Cumulative Impacts	
Cumulative impacts	**(Category 2).** Cumulative impacts of continued operations and refurbishment associated with license renewal must be considered on a plant-specific basis. Impacts would depend on regional resource characteristics, the resource-specific impacts of license renewal, and the cumulative significance of other factors affecting the resource.

Table 2.1-1. (cont.)

Issue	Impact (Table B-1 Finding)
Uranium Fuel Cycle	
Offsite radiological impacts—individual impacts from other than the disposal of spent fuel and high-level waste	**Small (Category 1).** The impacts to the public from radiological exposures have been considered by the Commission in Table S-3 of this part. Based on information in the GEIS, impacts to individuals from radioactive gaseous and liquid releases including radon-222 and technetium-99 would remain at or below the NRC's regulatory limits.
Offsite radiological impacts—collective impacts from other than the disposal of spent fuel and high-level waste	**(Category 1).** There are no regulatory limits applicable to collective doses to the general public from fuel-cycle facilities. The practice of estimating health effects on the basis of collective doses may not be meaningful. All fuel-cycle facilities are designed and operated to meet the applicable regulatory limits and standards. The Commission concludes that the collective impacts are acceptable. The Commission concludes that the impacts would not be sufficiently large to require the NEPA conclusion, for any plant, that the option of extended operation under 10 CFR Part 54 should be eliminated. Accordingly, while the Commission has not assigned a single level of significance for the collective impacts of the uranium fuel cycle, this issue is considered Category 1.
Nonradiological impacts of the uranium fuel cycle	**Small (Category 1).** The nonradiological impacts of the uranium fuel cycle resulting from the renewal of an operating license for any plant would be small.
Transportation	**Small (Category 1).** The impacts of transporting materials to and from uranium-fuel-cycle facilities on workers, the public, and the environment are expected to be small.
Termination of Nuclear Power Plant Operations and Decommissioning	
Termination of plant operations and decommissioning	**Small (Category 1).** License renewal is expected to have a negligible effect on the impacts of terminating operations and decommissioning on all resources.

2.2 No-Action Alternative

The no-action alternative represents a decision by the NRC not to renew the operating license of a nuclear power plant beyond the current operating license term. At some point, all nuclear plants will terminate operations and undergo decommissioning. Under the no-action alternative, plant operations would terminate at or before the end of the current license term.

Not renewing the license and ceasing operation under the no-action alternative may lead to a variety of potential outcomes, but these would be essentially the same regardless of whether operations cease at the expiration of the original operating license or at the expiration of a renewed license. Expiration of a license will require the reactor to ultimately undergo decommissioning, which will occur under a separate NRC license. Termination of nuclear power plant operations would result in the total cessation of electrical power production. The no-action alternative, unlike the other alternatives, does not expressly meet the purpose and need of the proposed action, as it does not provide a means of delivering baseload power to meet future electric system needs. No action on its own would likely create a need for replacement power; that need could be met by installation of additional generating capacity, adoption or expansion of energy conservation and energy efficiency programs (including demand-side management), purchased power, or some combination of these options.

2.3 Replacement Power Alternatives

The following sections describe alternatives identified by the NRC as capable of meeting the purpose and need of the proposed action (license renewal) or replacing the power generated by a nuclear power plant. A reasonable alternative must be commercially viable on a utility scale and operational prior to the expiration of the reactor's operating license, or expected to become commercially viable on a utility scale and operational prior to the expiration of the reactor's operating license. As technologies improve, the NRC expects that some alternatives not currently viable may become viable at some time in the future. The NRC will make that determination during plant-specific license renewal reviews. The amount of replacement power generated must equal the baseload capacity previously supplied by the nuclear plant and reliably operate at or near the nuclear plant's demonstrated capacity factor.[a]

Should the need arise to replace the generating capacity of a nuclear reactor, power could be provided by a suite of alternatives and combinations of alternatives, including expanding the capacities of one or more existing power generating plants within a region, delaying the scheduled retirement of one more existing plants, or purchasing an equivalent amount of power. The number of possible combinations of alternatives that could replace the generating capacity of a nuclear power plant is potentially unlimited. Based on this, the NRC has only evaluated individual alternatives rather than combinations of alternatives in this GEIS. However, combinations of alternatives may be considered during plant-specific license renewal reviews.

The following sections describe alternative means of generating electricity or otherwise addressing electrical loads that could serve to replace the power produced by an existing

(a) The capacity factor is the ratio of the amount of electric energy produced by an electric generator over a given period of time to the amount of electric energy the same generator would have produced had it operated at its full, rated capacity over the same period of time.

nuclear power plant. These alternatives must be commercially viable on a utility scale and operational prior to the expiration of the reactor's operating license or be expected to become commercially viable on a utility scale and operational prior to the expiration of the reactor's operating license. As discussed in Chapter 1, the NRC does not engage in energy-planning decisions and makes no judgment as to which energy alternatives evaluated would be the most likely alternative in any given case.

The NRC relies on many sources of information to determine which alternatives are available and commercially viable. The U.S. Department of Energy's (DOE's) Energy Information Administration (EIA) maintains the official energy statistics of the Federal Government. Along with information from other sources, the NRC commonly uses information from EIA reports, including the *Electric Power Annual*, *Annual Energy Review*, *Renewable Energy Annual*, *Renewable Energy Trends in Consumption and Electricity*, *Annual Energy Outlook*, and *Assumptions to the Annual Energy Outlook* to identify alternatives to the proposed action (license renewal). The NRC will often consider the existing portfolio of electric generating technologies in the State or utility service area in which a reactor(s) is located, along with State and Federal policies that may promote or oppose certain alternatives. The NRC may also use EIA's State Energy Profiles as well as State, regional, and, in some cases, utility- or system-level assessments of energy resources and projections to identify alternatives for consideration.

In 2008, annual electric power generation decreased for the first time since 2001, dropping by 0.9 percent from 4,157 million megawatt-hours (MMWh) in 2007 to 4,119 MMWh in 2008. Generation by conventional sources dropped (coal by 1.5 percent, natural gas by 1.5 percent, and nuclear by 0.03 percent), while generation from all renewable sources except wood and wood-derived fuels increased. Wind energy represented the greatest change, increasing 60.7 percent from 34.5 MMWh in 2007 to 55.4 MMWh in 2008. Contributions to total electricity production in 2008 included: coal 1,985,801 MMWh (48.2 percent), petroleum 46,242 MMWh (1.1 percent), natural gas 882,981 MMWh (21.4 percent), other gases 11,707 MMWh (0.3 percent), nuclear 806,208 MMWh (19.6 percent), conventional hydroelectric 254,831 MMWh (6.0 percent), other renewables 126,212 MMWh (3.1 percent), and other miscellaneous sources 11,692 MMWh (0.3 percent) (DOE/EIA 2010a).

In the EIA's *Annual Energy Outlook 2010 with Projections to 2050* (DOE/EIA 2010b), the EIA projects a continued but modest nationwide increase in energy consumption and generating capacity throughout the 2050 forecast period. Reflecting the economic downturn that began in late 2007, total electricity generation dropped by 3 percent over the previous year. Nevertheless, despite gains in energy efficiency and advancements in energy conservation (including demand-side management programs), moderate growth in energy consumption (14 percent from 2008 to 2035, an annual growth rate of 0.5 percent) is forecasted, as is an increased reliance on renewable energy technologies. To meet the projected growth in demand and overcome the expected loss of 45 gigawatts (GW) of capacity from scheduled retirements, the EIA estimates that 250 GW of new generating capacity will be required between 2009 and 2035. Natural gas is expected to account for 46 percent of this new capacity, together with 37 percent from renewables, 12 percent from coal, and 3 percent from nuclear plants.

In the following sections, the NRC presents a variety of alternatives to license renewal. In Chapter 4, NRC compares the environmental impacts of alternatives to the environmental impacts of license renewal.

2.3.1 Fossil Fuel Alternatives

The EIA indicates that fossil fuels will likely continue to provide the bulk of commercial electric power generation through 2050. The EIA projects that natural-gas-fired (combined-cycle or combustion turbine technology) generation will account for the largest single share of new generating capacity (37 percent) (DOE/EIA 2010b). The growth rate for coal production will be markedly reduced from previous years. Projections for the amount of electricity produced from coal in the future vary widely across planning scenarios, due primarily to cost uncertainties associated with anticipated future environmental regulations such as cap-and-trade regulations for nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) and regulation of greenhouse gas (GHG) emissions, primarily carbon dioxide (CO_2). In the reference case, EIA projects coal-generated electricity to grow by only 12 percent, but to nevertheless be responsible for the largest share of electricity produced over the forecast period, dropping from 48 percent in 2008 to 44 percent in 2035 (DOE/EIA 2010b).

Advanced coal technologies will likely become increasingly important as regulations on power plant emissions evolve. Technologies often referred to as “clean coal technologies,” which include coal cleaning processes, coal gasification technologies, improved combustion technologies, and improved devices for capturing pollutants, will play an important role. Emissions controls and advanced combustion technologies will likely play an increasingly important role for other fossil-fuel power generating systems as well.

GHG controls may be required for future fossil fuel power plants. Though nationwide GHG limitations do not yet exist, regional-, State-, and local-level initiatives have begun to restrict CO_2 and other GHG emissions or to implement GHG-emissions-trading schemes. Fossil fuel alternatives—especially those burning coal, the most carbon-intensive of the fossil fuels—have the greatest exposure to risk from carbon regulation, and, in some areas, State-level permitting authorities have denied permits for new coal plants.

The technology needed for capture and removal of GHGs in fossil fuel emissions (primarily CO_2) will require additional development to become commercially viable. The infrastructure necessary to remove GHGs on a scale sufficient to support utility-scale power generation does not presently exist, though it is the subject of ongoing research. Citing performance guarantees by equipment manufacturers, DOE's National Energy Technology Laboratory (NETL) estimated that control technologies can remove up to 90 percent of CO_2 from waste gases at pulverized coal power plants, albeit with significant performance penalties. Consequences may include a reduction in overall thermal efficiency from 39.1 to 27.2 percent and a near doubling of the levelized cost of the electricity produced (NETL 2007). Additional costs would be incurred in cleaning the captured CO_2 to pipeline specifications and delivering it by pipeline to appropriate geologic repositories for permanent sequestration.

2.3.2 New Nuclear Power Plant Alternatives

The last nuclear power plant to come on line in the United States was Watts Bar in 1996. Since then, nuclear power generating capacity has only been increased through power uprates at existing plants. The EIA projects that nuclear capacity will increase from 100.6 GW in 2008 to 112.9 GW in 2035, including 4.0 GW of expansions at existing plants and 8.4 GW of new capacity (DOE/EIA 2010b).

Currently, four nuclear reactor designs have been certified, and seven additional designs are undergoing review. Certified designs include the 1,300 megawatt-electric (MWe) U.S. Advanced Boiling Water Reactor (10 CFR Part 52, Appendix A), the 1,300 MWe System 80+ Design (10 CFR Part 52, Appendix B), the 600 MWe AP600 Design (10 CFR Part 52 Appendix C), and the 1,100 MWe AP1000 Design (10 CFR Part 52, Appendix D).

Certification activities for other designs are ongoing, as are reviews of applications for early site permits (ESPs) and combined licenses (COLs). An ESP is not a license to build a nuclear power plant; however, it initiates a process to assess whether the proposed site is suitable for the construction of a nuclear power plant. The issuance of a COL authorizes the applicant to construct and operate a nuclear power facility at a specific site. On February 10, 2012, the NRC issued two COLs to Southern Nuclear Operating Company to construct and operate two new AP1000 reactors at the Alvin W. Vogtle Electric Generating Plant site in Waynesboro, GA (77 FR 12332). On March 30, 2012, the NRC issued two COLs to South Carolina Electric & Gas and Santee Cooper to construct and operate two new AP1000 reactors at the Virgil C. Summer Nuclear Station site in Jenkinsville, South Carolina (77 FR 21593).

2.3.3 Renewable Energy Alternatives

The NRC considers the following renewable energy alternatives for possible replacement power: hydroelectric, geothermal, wind (both land-based and offshore), biomass (energy crops, agricultural crop residues, and urban wood and forest wastes), refuse-derived biomass (municipal solid waste, refuse-derived fuel, and landfill gas), solar (thermal), solar (photovoltaic), and ocean wave and current. Combinations of renewable energy alternatives may be considered during plant-specific license reviews.

Few renewable energy alternatives are currently commercially employed in ways that could provide total replacement power for a nuclear power plant. However, this is likely to change. One of the major reasons for this is energy storage technologies are rapidly gaining in importance. As the amounts of power from variable renewable energy sources such as wind and solar increase, energy storage capability becomes an essential tool for temporally decoupling generation and demand. Energy storage can enhance the overall efficiency and value of intermittent renewable energy technologies as sources of reliable baseload power. Some energy storage options can also help to maintain grid stability through improved frequency management, and some may improve the usage and integration of smart grid technologies. Energy storage technologies are not generation sources but rather are complementary technologies that can take many forms, among them, electrochemical energy of batteries and capacitors, potential energy of pumped water and compressed air, kinetic energy of flywheels, and thermal energy of molten salt.

Most energy storage technologies are in the early stages of development, with very few examples of utility-scale application. The NRC has elected not to evaluate energy storage technologies as discrete alternatives to a nuclear reactor because they do not directly generate electricity, but NRC nevertheless intends to give appropriate consideration to the influence that energy storage technologies can have on its evaluations of the environmental impacts of alternative generating technologies in future license renewal reviews.

The EIA projects that total renewable electric generating capacity will increase sharply through 2035, primarily due to extensions of Federal investment and production tax credits in the American Recovery and Reinvestment Act of 2009, the promulgation of State Renewable Portfolio Standards (RPS),[b] anticipation of a National Renewable Energy Standard (RES), and advancements and efficiency improvements in renewable energy technologies. Non-hydroelectric renewable generation will account for 41 percent of this increase, with wind and biomass representing the largest portions of the projected increase. Wind is expected to increase from 1.3 percent of total generation in 2008 to 4.1 percent in 2035, while biomass grows from 0.9 percent in 2008 to 5.5 percent in 2035, with the majority of growth expected after 2015. Co-firing of biomass-derived fuels with fossil fuels is expected to represent a major portion of the projected increase. Growth in geothermal facilities is limited to only a few geographic areas with high-value geothermal resources, and widespread implementation of solar technologies is limited. Overall, renewable generation is expected to grow from a 9 percent share of total electricity production in 2008 to a 17 percent share in 2035 (DOE/EIA 2010b).

(b) As of January 2010, 30 States and the District of Columbia have promulgated an enforceable RPS or other laws and an additional five States have nonbinding renewable energy goals (DOE/EIA 2010b).

Environmental impacts of construction and operation of renewable energy alternatives are quite different from those of non-renewable alternatives. The NRC presents these impacts in Chapter 4. In general, however, resource areas with the greatest range of impacts include air quality, hydrology, and land use. Air quality impacts from hydroelectric, wind, solar, and ocean wave and ocean current generation methods would be negligible; however, biomass-fueled energy, for example, would emit air pollutants, some of them hazardous. Some geothermal technologies may also be sources of hazardous air pollutants. All renewable energy alternatives would rely on modest amounts of water, but those that would rely on conventional steam cycles to power turbine generators (biomass, geothermal, solar thermal) would have higher water demands, some which are comparable to those of non-renewable alternatives. All renewable energy alternatives would require land, although land requirements would be negligible for offshore wind and ocean wave and ocean current alternatives. Solar and conventional hydroelectric generators, for example, would require significant amounts of land. Brief overviews of renewable energy alternatives are provided in the following paragraphs.

2.3.3.1 Hydroelectric Energy

Currently, there are approximately 2,000 operating hydroelectric facilities in the United States. Hydroelectric technology operates by capturing the energy of flowing water and directing it to a turbine and generator to produce electricity. There are two fundamental hydropower facility designs: “run-of-the-river” facilities that simply redirect the natural flow of a river, stream, or canal through a hydroelectric facility, and “store-and-release” facilities that block the flow of the river by using dams that cause the water to accumulate in an upstream reservoir.

As of 2010, hydropower provided 80 percent of commercial electricity generated by all renewable alternatives (DOE/EIA 2010b). EIA projects that hydropower will remain the largest renewable energy source through the year 2035, growing by an annualized average of 0.7 percent over the period (DOE/EIA 2010b). However, the potential for future construction of large dams has diminished due to increased public concerns over flooding, habitat alteration and loss, and destruction of natural river courses. Additional demands for river water have also reduced water flow.

Large hydroelectric facilities constructed on major rivers can have peak power capacities as high as 10,000 MWe. However, river flow conditions and other circumstances and factors (e.g., spawning periods of anadromous fish) often require dam operators to divert river flow around power-generating turbines over various periods of time, thereby reducing the amount of power generated.

2.3.3.2 Geothermal Energy

Geothermal energy is energy in the form of heat contained below the earth's surface in hydrothermal zones (hot water or steam trapped in an aquifer), hot and dry geologic formations (referred to as hot dry rock or engineered geothermal systems [EGS]), or in geopressurized resources (hot brine aquifers existing under pressure). Thus far, hydrothermal sources are the only geothermal energy resources that have been in commercial use. Geothermal energy facilities have demonstrated capacity factors of 90 to 98 percent (DOE/EERE 2010).

The technical approaches to exploiting geothermal energy resources are quite similar. First, crews drill wells down to the heated resources. Next, the wells raise hot water or steam to the surface where the heat energy can be used to generate electricity. EGS differs in that crews must first fracture a hot, dry rock formation and then inject a heat transfer fluid (typically water). They then recover the heated fluid from the formation through the well and then use the heated fluid to produce steam—and subsequently electricity—in a conventional steam turbine generator (STG).

Most domestic geothermal resources exist in the western United States (see Figure D.10-16, Appendix D). To date, the greatest amount of electricity produced by geothermal technologies has occurred in California. In 2007, 13,000 GWh were produced by 43 geothermal plants located throughout that state, which, together with an additional 440 GWh of geothermal power produced in neighboring States and exported to California, represented approximately 4.5 percent of the electricity consumed in California over that period. The contribution of geothermal energy to electricity production in California has remained stable in recent years at 12,907 GWh in both 2008 and 2009 (4.2 percent and 4.4 percent, respectively, of total annual electricity consumed in California) (CEC 2010).

Geothermal reservoir mapping in the western States suggests there is still significant untapped potential. In 2008, the U.S. Bureau of Land Management and the U.S. Forest Service projected that 11 western States (Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming), Alaska, and Hawaii have the potential for approximately 5,540 MWe of additional commercial power generation development by 2015, with an additional potential of 6,660 MWe forecasted by 2025. Such capacity expansions would result in 110 additional geothermal power plants by 2015 and an additional 132 by 2025, with most expansions occurring in northern Nevada, California, and Idaho (BLM and FS 2008).[c] California State-level efforts identified 4,800 MWe of untapped geothermal resources capable of electricity production (CGEC 2010).

(c) In California, approximately 13,969,825 ac (5,657,791 ha) of the high-value geothermal resources lie beneath BLM-administered lands; an additional 13,467,992 ac (5,454,537 ha) are beneath National Forest System land administered by the Forest Service (BLM and FS 2008).

U.S. Geological Survey (USGS) assessments of geothermal capacities in the western States are also high. According to USGS, the 13 States listed above have 241 identified moderate-temperature (194–302°F [90–150°C]) and high-temperature (greater than 302°F [150°C]) geothermal resources with a power generating capacity potential of 9,057 MWe from identified geothermal resources, an additional mean generation capacity potential of 30,033 MWe from undiscovered geothermal resources,[d] and an additional 517,800 MWe from the application of EGS technology (USGS 2008). The USGS determined that California has the largest identified resource capacity (59.67 percent of identified resources), followed by Nevada (15.36 percent). California and Nevada also have the two largest shares of undiscovered resources with 37.8 percent and 14.5 percent, respectively. Nevada and California have the largest number of geothermal facilities under various stages of development with 60 projects in Nevada representing 3,323 MWe of additional capacity and 32 projects in California representing 1,939 MWe of additional capacity (GEA 2010).

Using current technologies (which, according to USGS, included EGS, where appropriate) and the exploitation of both identified and yet undiscovered resources, the USGS estimates that California and Nevada have the potential for additional geothermal power development on private and public lands of 9,282 MWe and 2,551 MWe, respectively (95 percent probability of development) (USGS 2008).

From a national perspective, the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007 both promote expanded reliance on geothermal energy, providing both tax incentives and DOE funding for technological research, development, and demonstration (RD&D). DOE anticipated that geothermal energy will rapidly increase in the near term, especially with technological advancements in EGS and a Federal production tax credit (PTC) of 2.0 cents/kWh in place (DOE/EERE 2010).[e]

2.3.3.3 Wind Energy

Wind resources exist throughout the United States and in offshore areas but are most prevalent in the upper Midwest and in western States (see Figure D.10-17 for wind resource distributions in the United States and in offshore areas, respectively). The most favorable resources for land-based wind farms are in rural or remote areas. If transmission facilities do not already exist, additional development costs and environmental impacts would result from the construction of electric transmission lines.

(d) Here, “undiscovered” means that existing conditions suggest accessible geothermal reservoirs are likely to be present, but exploration has yet to confirm the value or extent of such resources.

(e) The American Recovery and Reinvestment Act of 2009 extended the PTC through 2013.

Early wind turbine designs required the turbine's rotor to spin at very high speeds to produce power. This resulted in bird collisions and a considerable amount of aerodynamic noise. Advances in wind technology allow wind turbines to efficiently generate electricity at lower rotor speeds. Improvements in blade aerodynamics and advancements in power train components permit wind turbines to capture energy from lower wind speeds using slower blade rotations. At the current stage of wind energy technology development, wind resources of Category 3 or better[f] are required to produce utility-scale amounts of electricity. Land-based wind turbines have individual capacities as high as 3 MW, with the 1.67-MW turbine being the most popular size that was installed in 2008 (offshore wind turbines have capacities as high as 5 MW). Modern wind turbines have rotor diameters greater than 300 feet (100 meters) on towers that are hundreds of feet tall. The capacity factors of wind farms are primarily dependent on the constancy of the wind resource, and while offshore wind farms can have relatively high capacity factors due to high-quality winds throughout much of the day (resulting primarily from differential heating of land and sea areas), land-based wind farms typically have capacity factors lower than 40 percent. For maximum performance, turbines must be well separated from each other and from other ground features that could introduce turbulence, so utility-scale wind farms are typically spread across large areas. Remaining portions of land among wind turbine installations can be used for other purposes (typically agriculture), although some limitations exist for ground-intrusive activities that could affect buried power conductors and other buried components.

Offshore wind turbines are identical in appearance and function to their land-based counterparts. Typically, power is delivered from each turbine by underwater cable to a land-based substation. Currently no offshore wind farms exist in the United States, although some have been proposed. Offshore wind farms are operational in Europe, and are typically located on the outer continental shelf.

2.3.3.4 Biomass Energy

Biomass energy can be generated from a wide variety of fuels, including municipal solid waste (MSW), refuse-derived fuel, landfill gas, urban wood wastes, forest residues, agricultural crop residues and wastes, energy crops. Definitions of materials that qualify as biomass may vary in different States or regions depending on regulatory schemes or RPSs.

(f) By industry convention, wind resource values are categorized on the basis of the power density expressed in watts per square meter (W/m^2) and speed of the prevailing wind at an elevation of 160 feet (50 meters), and range from Category 1 with wind power densities of 200–300 W/m^2 (typically existing with constant wind speeds between 12.5 and 14.3 miles per hour (mi/hr) [5.8-6.4 meters per second (m/s)]) through Category 7 with power densities of 800–1,800 W/m^2 (wind speeds of 19.7–24.8 mi/hr [8.8–11.1 m/s]). Category 3 wind has a power density of 300–400 W/m^2 with wind speeds of 15.7–16.8 mi/hr (7.0–7.5 m/s).

Biomass resources are widely available throughout the United States (see Figure D.10-18). Biomass energy conversion is accomplished using a wide variety of technologies, some of which are similar in appearance and operation to fossil fuel plants, and include directly combusting biomass in a boiler or incinerator to produce steam, co-firing biomass along with fossil fuels (primarily coal) in boilers to produce steam, producing synthetic liquid fuels that are subsequently combusted, gasifying biomass to produce gaseous fuels that are subsequently combusted, and anaerobically digesting biomass to produce biogas. Synthetic fuel production, biomass gasification, and anaerobic digestion technologies have not been used to produce utility-scale electricity. Biogas is often consumed in combined heat and power plants with relatively small power generating capacities. To date, wood has been the most widely used biomass fuel for electricity generation, while coal-biomass co-firing and MSW combustion are also commercially feasible. While it is technically feasible to operate a biomass combustion plant on MSW or refuse-derived fuel, source material may not be reliable or consistent. Of the nearly 1,000 operating biomass power plants, the majority directly combust biomass while only a small number co-fire with coal (NREL 2006).

MSW combustors use one of three types of technologies: mass burn, modular, or refuse-derived fuel. Mass burning is currently the method used most frequently in the United States and involves no (or little) sorting, shredding, or separation. Consequently, toxic or hazardous components present in the waste stream are combusted, and toxic constituents are exhausted to the air or become part of the resulting solid wastes. Currently, approximately 87 waste-to-energy plants operate in 25 States, processing 28.7 million tons of trash annually and operating at capacity factors greater than 90 percent to generate approximately 2,720 MWe, or an average of 31.3 MWe per plant (IWSA 2007).

Landfill gas is another potential source of biomass energy for electric power production. Landfills in which organic materials are disposed represent the largest source of methane in the United States. Landfill gas composition varies depending on the type of waste. EPA estimates that every million tons of MSW buried in anaerobic conditions in sanitary landfills can produce approximately 432,000 cubic feet (12,200 cubic meters) per day of landfill gas. Landfill gas can be recovered from closed landfill cells and burned for electricity production in reciprocating internal combustion engines ranging in capacity from 100 kW to 3 MW, in turbines with capacities of 800 kW to 10.5 MW, or in microturbines with capacities of 30 kW to 250 kW (EPA 2010).

Collecting landfill gas is a relatively straightforward process that involves placing recovery wells and simple gas collection systems. Of the approximately 2,300 operating or recently closed landfills in the United States, 427 landfills are currently equipped with gas collection systems. In 2006, landfills produced enough gas to generate 10 billion kWh of electricity. An additional 560 landfills could be adapted to landfill gas-to-energy production (see Figure D.10-22). Since gas is produced continuously, landfill gas-to-energy plants can have capacity factors greater than 90 percent and can be relied upon as a source of baseload power.

2.3.3.5 Solar Power

Solar power technologies that are commercially viable for the production of electricity include solar thermal and photovoltaic. Solar thermal systems or concentrating solar power (CSP) systems are designed to concentrate the sun's heat energy by as much as 10,000 times to generate high-temperatures. Photovoltaic (PV) systems use semiconductors in solar cells that convert photons of solar energy to direct current (DC) electricity. Some PV designs also use concentrating devices to enhance power production by increasing the energy reaching a given solar cell. In recent years, solar power has enjoyed strong growth in many parts of the world. There is great interest in deploying these systems in the United States, especially in those portions of the six southwestern States with high-value solar resources (California, Nevada, Utah, Colorado, New Mexico, and Arizona), on lands controlled by the U.S. Department of Interior's Bureau of Land Management (BLM), and in States with solar "set-asides" in their RPSs.

Although the highest-value solar resources exist in the desert regions of the Southwest, solar resources of adequate quality to support utility-scale solar energy facilities are located in other parts of the country as well. Although both PV and CSP technologies have experienced technological advancements and enjoyed growth, including especially rapid growth of PV technologies in Germany, CSP appears to have a greater near-term potential to serve as baseload power. This is primarily because of currently existing opportunities to store thermal energy captured in a solar field for delayed production of electricity over time periods coincident with peak loads, irrespective of whether those peak load periods coincide with high-value incident solar radiation.[g]

While CSP relies on direct normal insolation (DNI), PV can respond to direct as well as reflected or refracted sunlight. Solar intensity varies throughout the lower 48 States, making the use of PV technology feasible—to varying extents—throughout the country. Nonetheless, the highest DNI values are found in the southwestern States, making that geographic region the preferred location for CSP facilities (see Figure D.10-26).

(g) Work is proceeding to equip PV systems with battery or fuel cell storage capabilities, thus improving the dispatchability of power; however, these technologies are in their infancy and are not currently being deployed at the utility scale in the United States.

CSP Technologies

Three CSP technologies have been developed for utility-scale power production: parabolic trough, power tower, and the Stirling heat engine. The parabolic trough and power tower both concentrate the sun's heat by reflecting it onto a container of heat-transfer fluid. The fluid, typically a high-boiling-point synthetic oil, is heated to temperatures as high as 1472°F (800°C) before being circulated to a conventional tube-type heat exchanger to make steam to drive a conventional STG. The Stirling heat engine concentrates the sun's heat on a closed container of hydrogen or helium gas, which expands to drive a piston whose linear motion is converted to angular momentum to drive a generator. Both parabolic trough and power tower facilities are operational at the utility scale.

CSP facilities can use molten salt to store heat for steam production at night and during cloudy periods, but to do so and still maintain their nameplate capacities, such CSP facilities must increase the size of the solar field. A CSP facility with six hours of thermal storage (considered to be the current practical limit) and operating at a capacity factor of approximately 48 percent would require a solar field over 3.5 times as large as the field size required to generate power at the facility's nameplate rating, or a "solar multiple" of 3.5 (SDRREG 2005). Thus, a 400-MWe CSP plant with six hours of thermal storage operating at an effective capacity factor of 48 percent would have a solar field of roughly 7,000 acres (2,833 hectares).

Both parabolic trough and power tower facilities use conventional steam cycles and thus have cooling demands similar to fossil-fuel power plants of equivalent capacities and overall thermal efficiencies.

PV Technologies

Various materials exhibit the "photovoltaic effect" and are capable of producing electricity from incident photons of solar energy. Solar cells have been developed using silicon (single crystal, polycrystalline, and amorphous silicon) and a variety of compounds such as cadmium telluride, copper-indium-gallium-selenide, and gallium arsenide. Among the silicon-based solar cells, single crystals exhibit the highest efficiency, but polycrystalline cells now represent the majority of the PV market. Although more expensive to produce, high-performance, multi-junction cells offer greater energy-conversion efficiencies and are currently the subject of most research into utility-scale applications. Many solar cell materials are now being manufactured as thin films, which have lower efficiencies than other types of PV technologies but typically can be made at lower cost. Unlike CSP technologies, PV systems do not require cooling water, although they may have substantial land requirements. Schematics of PV power systems appear in Figures D.10-24 and D.10-25.

2.3.3.6 Ocean Wave and Current Energy

A variety of ocean wave energy technologies have been considered. Point absorbers and attenuators allow waves to interact with a floating buoy. The wave motion is converted into mechanical energy to drive a generator. Overtopping devices trap some portion of an incident wave at a higher elevation than the average height of the surrounding sea surface, while terminators allow waves to enter a tube, compressing air that is then used to drive a generator.

In general, technologies that harness the energy of ocean waves are in their infancy and have not been used at utility scale. These technologies may become commercially viable in the near future. A point absorber facility, for example, has been proposed off the coast of Oregon. Similarly, feasibility studies and prototype tests for wave energy capture devices have been conducted for locations off the coasts of Hawaii, Oregon, California, Massachusetts, and Maine.

Ocean current energy technology is also in its infancy. Existing prototypes capture ocean current energy with submerged turbines that are similar to wind turbines. Although the functions of ocean turbines and wind turbines are similar (both derive power from moving fluids), ocean turbines have substantially greater power generating capacity since the energy contained in moving water is approximately 800 times greater than air. In relatively constant currents with average velocities of 3.5 miles per hour (mph) (5.6 kilometers per hr [km/h]) or variable tidal currents averaging 5.8 mph (9.3 km/h), ocean turbines can produce sufficient capacity factors for baseload demand (MMS 2007). Various ocean turbine designs are undergoing research, development, and demonstration.

2.3.4 Non-Generation Alternatives

As discussed in Section 2.3.1, various electric power generating technologies can be employed to replace the power provided by a nuclear power plant in a particular region of the country. The preceding sections have identified those technologies that the NRC considers to be viable candidates as alternatives. However, in addition to these generating options, alternatives that do not include the introduction of new electricity generating capacity also exist. Two such alternatives are purchased power from within or outside of a region, as well as energy conservation and energy efficiency measures (collectively, part of a range of demand-side management measures).

2.3.4.1 Purchased Power

Bulk electricity purchases currently take place within geographic regions established by the North American Electric Reliability Corporation (NERC), the authorized Electric Reliability Organization (ERO) for the United States. Also, interconnections exist between NERC regions that allow for power exchanges between the regions when necessary to satisfy short-term demand. The NRC recognizes the possibility that replacement power may be imported from outside a nuclear power plant's service area, which may or may not require importing power from another region. In most instances, importing power from distant generating sources would have little or no measurable environmental impact in the vicinity of the nuclear power plant; however, it could cause environmental impacts where the power is generated or anywhere along the transmission route. Importing power from outside a particular region or purchasing it from a generator in the same region are possible sources of replacement power.

Many factors influence power purchasing decisions, with respect to both technical feasibility and cost. The existing transmission grid may not support every possible power transfer agreement.

Incremental power transfer capacities have been established between grid segments both within and across NERC regions, and modest amounts of power routinely transfer across those points. Such capabilities were established to ensure overall grid stability and reliability under both routine and non-routine conditions. In contrast, long-term transfers of utility-scale power from outside of a given power plant's region may require modification of one or more existing transmission grid segments (as well as modifications to substations and power synchronization equipment) and could require construction of new transmission line segments. New transmission lines may be required for long-term purchased power from within the same NERC region, but the need for new transmission lines is highly situation-dependent. Further, efforts by transmission operators to provide a price signal for transmission congestion through locational-marginal pricing would, over the long run, provide an incentive for power purchases closer to the existing power plant or construction of new capacity nearer the existing power plant. In general, the more geographically distant the exporting source, the greater the likelihood that new or modified interconnecting transmission

North American Electric Reliability Corporation

For the purpose of ensuring continued reliability of electric service, the Energy Policy Act of 2005 (EPAct) authorized the creation of an independent, international Electric Reliability Organization (ERO) and directed the Federal Energy Regulatory Commission (FERC) to establish rules for the ERO as well as a process for certification. In July 2006, FERC approved the North American Electric Reliability Corporation's (NERC) application to become the ERO for the United States.

Established in 1968, NERC is a regulatory organization that develops and enforces reliability standards; monitors the bulk power system; assesses future adequacy; audits owners, operators, and users for preparedness; and educates and trains industry personnel. NERC is composed of eight Regional Reliability Councils (RRCs), each responsible for a specific geographic area. RRC membership typically includes investor-owned utilities; Federal power agencies; rural electric cooperatives; State, municipal, and provincial utilities; Canadian Crown corporations (only for some RRCs); independent power producers; power marketers; and end-use customers. These entities account for virtually all bulk electricity (i.e., electricity provided at 100 kV or higher) supplied in the United States, Canada, and a portion of Baja California Norte, Mexico. NERC's proposal to delegate enforcement authority for reliability standards to eight regional entities is pending before the Federal Energy Regulatory Commission.

line segments would be necessary. Power purchase agreements would also be used in emergency situations or to alleviate a capacity shortfall in the near term.

2.3.4.2 Conservation and Energy Efficiency Measures (Demand-Side Management Programs)

The need for alternative or replacement power can precipitate or invigorate conservation and energy efficiency efforts designed to either reduce electricity demand at the retail level or alter the shape of the electricity load. All such efforts are broadly categorized as demand-side management (DSM), although DSM can also include measures that increase energy consumption or cause consumers to switch from fuels like natural gas to electricity. Conservation and energy efficiency measures may be championed by the same company that operates a nuclear power plant when that company also serves retail customers. In other cases, the measures may be offered by other load-serving entities, State-based programs, third-party service providers and aggregators, or even transmission operators. Programs include, but are not limited to, incentives for equipment upgrades, improved codes and standards, rebates or rate reductions in exchange for allowing a utility to control or curtail the use of high-consumption appliances (like air conditioners) or equipment, training in efficient operation of building heating and lighting systems, direct payments in consideration for avoided consumption, or use of price signals to shift consumption away from peak times.

Data contained in the latest EIA Electric Power Annual Report (DOE/EIA 2010a) show that total peak load reductions due to DSM programs was 32,741 MW in 2008, an 8.2 percent increase from DSM savings of 2007. While the total costs of all DSM programs rose 22.9 percent from 2003 to 2008, peak load reductions over that period increased by an annualized growth rate of 6.17 percent.

EIA data show that historically, residential electricity consumers have been responsible for the majority of peak load reductions achieved by conservation and energy efficiency programs. However, participation in most conservation programs is voluntary, and the existence of a program does not guarantee that reductions in electricity demand would occur. Nevertheless, energy conservation programs in general can result in significant reductions in demand. Recent legislative actions in some States requiring the establishment of programs such as “net metering” and technological advances to the electric transmission network, the “smart grid,” have facilitated greater degrees of participation in energy conservation programs, especially among residential customers.

Conservation and energy efficiency programs may reduce overall environmental impacts associated with energy production. In a 2008 staff report, FERC outlined the results of the 2008 FERC Demand Response and Advanced Metering Survey (FERC 2008). Nationwide, approximately eight percent of retail electricity customers are enrolled in some type of demand-response program. The potential demand-response resource contribution from all U.S. demand-response programs is estimated to be close to 41,000 MW, or about 5.8 percent of U.S. peak demand. A national assessment of demand response potential as required by Section 529 of the Energy Independence and Security Act of 2007 was published by FERC in June 2009 (FERC 2009). The survey evaluated potential energy savings in five- and ten-year horizons for four development scenarios: Business As Usual, Expanded Business As Usual, Achievable Participation, and Full Participation, each representing successively greater demand-response program opportunities and successively increasing levels of customer participation. The greatest savings would be realized under the Full Participation scenario, with peak demand reductions of 188 GW by the year 2019, a 20 percent reduction of the anticipated peak load without any demand-response programs in place. Under the Achievable Participation scenario, reflecting a more realizable voluntary customer participation level of 60 percent, peak demand would be reduced by 138 GW by 2019, a 14 percent reduction.

While the energy conservation or energy efficiency potential in the United States is substantial, the NRC staff is aware of no cases where an energy efficiency or conservation program has been implemented expressly to replace or offset a large, baseload generation station. While the potential to replace a large baseload generator may exist in some locations, it is more likely that conservation and energy efficiency programs will not be evaluated in site-specific license renewal reviews as stand-alone alternatives but may play an important role in the evaluation of a combination of alternatives.

2.4 Comparison of Alternatives

This section provides a summary comparison of the environmental impacts of the proposed action and alternatives. Tables 2.4-1 through 2.4-5 provide an overview of the findings of the impact analyses (presented in Chapter 4) for the proposed action and alternatives, including the no-action alternative, replacement power alternatives (fossil energy, nuclear energy, and renewable energy), energy conservation, and power purchases. Impacts related to construction (Table 2.4-1), operations (Table 2.4-2), postulated accidents (Table 2.4-3), termination of nuclear power plant operations and decommissioning (Table 2.4-4), and the fuel cycle (Table 2.4-5) are provided. In each of these tables, important aspects of each alternative that serve as the basis of the assessment are identified as well as the magnitude of the anticipated impact in each resource area. Impacts are evaluated and compared in a general fashion. More detailed analyses incorporating relevant site-specific factors (as well as the future state of technology and, possibly, other reasonable alternatives) will be provided in each site-specific SEIS prepared to evaluate the environmental impacts of renewing a nuclear power plant's operating license.

Table 2.4-1. Environmental Impacts of Construction under the Proposed Action and Alternatives

	Assessment Basis and Nature of Impacts			
Proposed Action[(a)]	**No-Action Alternative**	**Fossil, Nuclear, and Renewable Energy Alternatives**	**Energy Conservation**	**Power Purchases**
Only minor construction projects (likely refurbishments) are associated with the proposed action. Original plant construction is not part of the proposed action.	No construction at the plant sites would occur if license renewal is denied. Construction could occur in other areas if new power plants or transmission facilities are needed to replace lost capacity. (Impacts from replacement power are addressed in the columns to the right.)	Major construction projects would be required to build replacement fossil, nuclear, or renewable energy generation capacity. Impacts would vary according to the specific alternative technology selected and site-specific resource conditions that would be reviewed under separate environmental review processes, depending on the activity's location and proponent. Impacts at brownfield sites would be smaller than at greenfield sites. Power may also be replaced by a portfolio of alternative technologies; in such cases, impacts would be additive among portfolio components, occurring at each facility commensurate with the technology and the amount of replacement power it provides.	Little or no construction would be associated with energy conservation programs implemented to offset lost generation capacity.	No construction would occur if available excess capacity is sufficient to offset losses. Construction could occur in those instances where expansions of the capacity of the alternative generation source to meet power purchase agreements or modifications to the transmission grid were required to bring the imported power to the load centers affected by reactor retirement.

(a) Refer to Table 2.1-1 for a more detailed presentation of the impacts of construction (likely refurbishments) under the proposed action. These impacts are discussed in detail in Chapter 4.

Table 2.4-2. Environmental Impacts of Operations under the Proposed Action and Alternatives

	Assessment Basis and Nature of Impacts			
Proposed Action[a]	**No-Action Alternative**	**Fossil, Nuclear, and Renewable Energy Alternatives**	**Energy Conservation**	**Power Purchases**
Continued operations under the proposed action would be comparable to what has occurred during the current license term.	Termination of plant operations would occur sooner than under the proposed action. After plant shutdown, some systems would remain in operation but at reduced levels. Operational impacts could occur in other areas if new power plants are needed to replace lost capacity. (Impacts from replacement power are addressed in the columns to the right.)	Operation of a new fossil energy, nuclear, or renewable energy facility would introduce new impacts to the facility site and vicinity. Impacts would vary according to site-specific resource conditions that would be reviewed under separate NEPA assessments. If lost power capacity is replaced with a portfolio of alternatives, impacts would be additive, occurring at each of the facilities within the portfolio based on the nature of the technology employed and commensurate with the amount of power produced. Impacts at brownfield sites may be less than at greenfield sites. Fossil energy alternatives would have similar operational impacts on the proposed action, nuclear, and some renewable alternatives (e.g., biomass), but would produce more air emissions. Nuclear energy alternatives would have similar operational impacts as fossil and some renewable technologies but would produce fewer air emissions than fossil and biomass technologies. Renewable technologies differ greatly in terms of operational impacts.	No new operational impacts are likely from energy conservation programs implemented to offset lost generation capacity. Existing operational impacts from current generation sources may be lessened if greater load reductions result.	Impacts would occur in areas where purchased power is produced. Impact magnitude would be incremental and reflective of the type of generating technology employed and the increase in the amount of power required to satisfy the power purchasing agreement.

(a) Refer to Table 2.1-1 for a more detailed presentation of the impacts of operations under the proposed action. These impacts are discussed in detail in Chapter 4.

Table 2.4-3. Impacts of Postulated Accidents under the Proposed Action and Alternatives

	Assessment Basis and Impact Magnitude			
Proposed Action[(a)]	**No-Action Alternative**	**Fossil, Nuclear, and Renewable Energy Alternatives**	**Energy Conservation**	**Power Purchases**
Postulated accidents associated with continued operations under the license renewal term include design-basis accidents and severe accidents. The impacts take into consideration the low probability of an accident occurring. Design-basis accidents would have a small impact. Severe accidents would likely have larger consequences than design basis accidents; however, the probability-weighted consequences (i.e., the probability of occurrence of the accident multiplied by the consequence if the accident occurred) would be SMALL for all plants.	Plant shutdown would occur sooner than under the proposed action. A reduction in accident risk would also occur sooner. Impacts could occur in other areas if new power plants are needed to replace lost capacity. (Impacts from replacement power are addressed in the columns to the right.)	Accidents associated with fossil energy facilities would have short-term, localized effects. Accidents associated with nuclear energy would be similar to those of the proposed action. Accidents associated with biomass facilities would be comparable to those of fossil energy facilities. Accidents associated with hydropower (e.g., dam collapse) could have large, far-reaching effects. Accidents associated with coal combustion residue handling and storage could also have large, far-reaching effects. Impacts from accidents associated with other renewable energy technologies would be localized and generally inconsequential.	No accidents are associated with energy conservation measures aside from occupational hazards for those who install or implement them.	Impacts would occur in areas where purchased power is produced. Nature and magnitude of the impact would depend on the technology used to produce the power and characteristics of the plant site. If power is purchased from existing generating facilities with excess capacity, little change in impact would be expected. Additional impacts may result from required expansions or modifications of transmission infrastructures.

(a) Refer to Table 2.1-1 for a more detailed presentation of the impacts of accidents under the proposed action. These impacts are discussed in detail in Section 4.9.1.2.

Table 2.4-4. Impacts of Termination of Nuclear Power Plant Operations and Decommissioning under the Proposed Action and Alternatives

Assessment Basis and Nature of Impacts				
Proposed Action[(a)]	**No-Action Alternative**	**Fossil, Nuclear, and Renewable Energy Alternatives**	**Energy Conservation**	**Power Purchases**
Termination of plant operations and decommissioning eventually would occur regardless of implementation of the proposed action. The proposed action would not contribute substantially to the impacts from the termination of plant operations and decommissioning.	The no-action alternative would not contribute to the impacts of termination of plant operations and decommissioning. Impacts would occur in other areas if new power plants are needed to replace lost capacity. (Impacts from replacement power are addressed in the columns to the right.)	Termination of plant operations and decommissioning of a fossil, nuclear, or renewable energy facility would result in short-term impacts during facility dismantlement and longer-term waste management impacts. Impacts would vary according to site-specific resource conditions. The NRC staff's analysis assumes that dams would remain in place for flood control after hydroelectric power generation ceases. Impacts at brownfield sites may be less than at greenfield sites.	No termination of operations and decommissioning impacts are anticipated to result from energy conservation programs implemented to offset lost generation capacity.	Because existing facilities would be used to produce purchased power, no termination of operations and decommissioning impacts would be associated with this alternative.

(a) Refer to Table 2.1-1 for a more detailed presentation of the impacts of decommissioning under the proposed action. These impacts are discussed in detail in Section 4.12.2.

Table 2.4-5. Impacts of the Fuel Cycle under the Proposed Action and Alternatives

	Assessment Basis and Nature of Impacts			
Proposed Action[b]	**No-Action Alternative**	**Fossil, Nuclear, and Renewable Energy Alternatives**	**Energy Conservation**	**Power Purchases**
During the license renewal term, the proposed action would result in the need for continued mining and milling of uranium; fuel fabrication; and storage, transport, and disposal of radioactive and other wastes.	The no-action alternative would result in a reduced need for nuclear fuel and a reduction in impacts associated with the uranium fuel cycle. Impacts associated with other fuel cycle(s) would occur if new power plants are needed to replace lost capacity. (Impacts from replacement power are addressed in the columns to the right.)	The fuel cycle of fossil energy alternatives includes the extraction of coal (mining) or natural gas (drilling and fracking); fuel clean-up; transport of extracted fuel; and storage, transport, and disposal of combustion waste. Impacts would depend on characteristics of extraction sites and fuels. The nuclear energy alternatives would have similar impacts to the proposed action. Of renewables, only certain biomass technologies (e.g., crop residues, forest products) have a fuel cycle *per se*. Biomass projects that involve growing, harvesting, and processing of plant materials would have impacts associated with producing and transporting biomass fuel and storage and disposal of combustion waste. Impacts would depend on the nature of the biomass being produced, the characteristics of areas used to produce fuel, and the technology used to convert the biomass to energy.	There is no fuel cycle associated with energy conservation.	The fuel cycle impacts associated with power purchases would depend on the mix of generating sources that are used to produce purchased power.

(a) Refer to Table 2.1-1 for a more detailed presentation of the impacts of operations under the proposed action. These impacts are discussed in detail in Section 4.12.1.

Further, each site-specific SEIS must analyze the impacts of the proposed action (license renewal) as well as a range of reasonable alternatives to provide replacement power. According to the President's Council on Environmental Quality, reasonable alternatives comprise "those that are practical or feasible from the technical and economic standpoint and using common sense" (46 FR 18026). Replacement power alternatives may require the construction of a new power plant and possibly the modification of the electric transmission grid. The new power plants would also have operational impacts that may or may not be equivalent in nature and/or extent to the operational impacts of the reactor for which license renewal is sought. Conversely, license renewal does not require major construction and operational impacts would not change beyond what is currently being experienced. Other alternatives that would not have construction or operational impacts include conservation and energy efficiency, delayed retirement, repowering, and purchased power.

Operational impacts of license renewal are comparable to replacement power alternatives and some renewable energy alternatives in some resource areas (e.g., socioeconomics), but quite different in other resource areas (air emissions, fuel cycle, land use, and water consumption). Some renewable energy alternatives (wind, ocean wave, and ocean current alternatives) have very few operational impacts, while others (biomass combustion and conventional hydropower) can have considerable operational impacts. Some renewable energy alternatives (wind and solar) have relatively low but regionally variable capacity factors while others (e.g., conventional hydropower and geothermal) can exhibit capacity factors at or near those of a nuclear power plant.

The proposed action and alternatives differ in other respects, including the consequences of accidents. The proposed action and new nuclear energy alternatives all may have low-probability but potentially high-consequence accidents in comparison to non-nuclear alternatives.

Termination of nuclear power plant operations and decommissioning impacts at existing nuclear power plant sites would eventually occur regardless of a decision to renew their licenses. Thus in this analysis, those impacts are not attributed to the proposed action, and the effects of the proposed action on the impacts from the termination of nuclear power plant operations and decommissioning are SMALL in all resource areas. Impacts from the decommissioning of a new nuclear power reactor would be similar to that of the existing reactor but would occur under a separate licensing action, including a separate NEPA assessment.

Fuel cycle impacts have been evaluated for license renewal and were found to be SMALL for all resource areas, except for offsite radiological impacts – collective impacts from other than the disposal of spent fuel and high-level waste, which are acceptable (See section 4.12.1.1, "Uranium Fuel Cycle" for information on this issue). Fossil-fueled alternatives may have larger fuel cycle impacts (mostly associated with land disturbance at fuel extraction sites), while other alternatives have no fuel-cycle impacts (renewable alternatives such as wind, wave, current, or solar alternatives do not have fuel cycles).

2.5 References

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3 Affected Environment

For purposes of the evaluation in this generic environmental impact statement (GEIS) revision, the “affected environment” is the environment that currently exists at and around operating U.S. commercial nuclear power plants. Because existing conditions are at least partially the result of past construction and operations at the plants, the impacts of these past and ongoing impacts and how they have shaped the environment are summarized here. Thus, it is this existing environment that comprises the environmental baseline against which potential environmental impacts of license renewal are evaluated. The impacts of license renewal that are presented in Section 4 are incremental to these baseline conditions, which include the effects of past and present actions at the plants.

Contents of Chapter 3

- Current nuclear power plant facilities and operations (Section 3.1)
- Existing conditions at operating nuclear power plants (including the impacts of past construction and operational effects) in the following environmental resource areas:
  - Land Use and Visual Resources (Section 3.2)
  - Meteorology, Air Quality, and Noise (Section 3.3)
  - Geologic Environment (Section 3.4)
  - Water Resources (Section 3.5)
  - Ecological Resources (Section 3.6)
  - Historic and Cultural Resources (Section 3.7)
  - Socioeconomics (Section 3.8)
  - Human Health (Section 3.9)
  - Environmental Justice (Section 3.10)
  - Waste Management and Pollution Prevention (Section 3.11)

3.1 Description of Nuclear Power Plant Facilities and Operations

3.1.1 External Appearance and Settings

Nuclear power plants contain a number of buildings or structures. Among them are containment or reactor building(s), turbine building(s), auxiliary buildings, vent stacks, meteorological tower(s), and cooling systems, particularly cooling towers. A plant site layout also includes large parking areas, security fencing, switchyards, water intake and discharge facilities, and transmission lines (see Section 3.1.6). While reactor, turbine, and auxiliary buildings are often clad or painted in colors that are intended to reduce or mitigate their visual presence, the heights of many of the structures, coupled with red and/or white safety lights, make plants visible from many directions. Typical heights of plant facilities are as follows: reactor buildings are 300 ft (90 m), turbine buildings are 100 ft (30 m), stacks are 300 ft (90 m), meteorological towers are 200 ft (60 m), natural draft cooling towers are higher than 500 ft (150 m), and mechanical draft cooling towers are 100 ft (30 m) tall. In addition, condensation from cooling towers is generally visible for many miles. Transmission line towers are between 70 ft (20 m) and 170 ft (50 m) in height, depending on the voltage being carried.

There are two types of power reactors used in the United States—boiling water reactors (BWRs) and pressurized water reactors (PWRs). All nuclear power plant sites are generally similar in terms of the types of facilities they contain. All plant sites contain a nuclear steam supply system. In addition, there are a number of common structures necessary for plant operation. However, the layout of buildings and structures varies considerably among the sites. For example, control rooms may be located in the auxiliary building, in a separate control building, or in a radwaste and control building. The following list describes typical structures located on most sites.

- *Containment or reactor building*. The containment or reactor building in a PWR is a massive concrete or steel structure that houses the reactor vessel, reactor coolant piping and pumps, steam generators, pressurizer, pumps, and associated piping. The reactor building structure of a BWR generally includes a containment structure and a shield building. The reactor containment building is a massive concrete or steel structure that houses the reactor vessel, the reactor coolant piping and pumps, and the suppression pool. It is located inside a somewhat less substantive structure called the shield building. The shield building for a BWR also generally contains the spent fuel pool and the new fuel pool.

  The reactor containment building for both PWRs and BWRs is designed to withstand natural disasters, such as tornados, hurricanes, and earthquakes. The containment building's ability to withstand such events and to contain the effects of accidents initiated by system failures constitutes the principal protection against releasing radioactive material to the environment.

- *Fuel building*. For PWRs, the fuel building has a fuel pool that is used to store and service spent fuel and prepare new fuel for insertion into the reactor. This building is connected to the reactor containment building by a transfer tube or channel that is used to move new fuel into the reactor and move spent fuel out of the reactor for storage.

- *Turbine building*. The turbine building houses the turbine generators, condenser, feedwater heaters, condensate and feedwater pumps, waste-heat rejection system, pumps, and equipment that support those systems. In BWRs, primary coolant is circulated through these systems, thereby causing them to become slightly contaminated. In PWRs, primary coolant is not circulated through the turbine building systems. However, it is not unusual for portions of the turbine building to become mildly contaminated because of leaks from the primary system into the secondary side during power generation at PWRs.

- *Auxiliary buildings*. Auxiliary buildings house support systems, such as the ventilation system, emergency core cooling system, laundry facilities, water treatment system, and waste treatment system. An auxiliary building may also contain the emergency diesel generators and, in some PWRs, the fuel storage facility. The facility's control room is often located in the auxiliary building.

- *Diesel generator building*. Often a separate building houses the emergency diesel generators if they are not located in the auxiliary building. The emergency diesel generators do not become contaminated or activated.

- *Pump houses*. Various pump houses for circulating water, standby service water, or makeup water may be onsite.

- *Cooling towers*. Cooling towers are structures designed to remove excess heat from the condenser without dumping the heat directly into water bodies, such as lakes or rivers. There are two principal types of cooling towers: mechanical draft towers and natural draft towers. Most nuclear plants that have once-through cooling do not have cooling towers associated with them. However, seven facilities with once-through cooling also have cooling towers that are used to reduce the temperature of the water before it is released to the environment.

- *Radwaste facilities*. Radioactive waste facilities may be contained in an auxiliary building or located in a separate solid radwaste building. For example, the radwaste storage facility may be a separate building.

- *Ventilation stack*. Many older nuclear power plants, particularly BWRs, have ventilation stacks to discharge gaseous waste effluents and ventilation air directly to the outside. These stacks can be 300 ft (90 m) tall or higher and contain monitoring systems to ensure that radioactive gaseous discharges are below fixed release limits. Radioactive gaseous effluents are treated and processed before being discharged out the stack.

- *Switchyard and transmission lines*. Plant sites also typically contain a large switchyard, where the electric voltage is stepped up and fed into the regional power distribution system. Electricity generated at the plant is carried off the site by transmission lines. Only those transmission lines that connect the plant to the switchyard where electricity is fed into the regional power distribution system (encompassing those lines that connect the plant to the first substation of the regional electric power grid) and power lines that feed the plant from the grid during outages are considered within the regulatory scope of license renewal environmental review and this GEIS.

- *Administrative, training, and security buildings*. Normally, the administrative, training, and security buildings are located outside the radiation protection zones; no radiological contamination is present; and radiation exposures are at general background levels.

- *Independent spent fuel storage installations (ISFSIs)*. An ISFSI is designed and constructed for the interim storage of spent nuclear fuel and other radioactive materials associated with spent fuel storage. ISFSIs may be located at the site of a nuclear power plant or at another location. The most common design for an ISFSI, at this time, is a concrete pad with dry casks containing spent fuel bundles. ISFSIs are used by operating plants that require increased spent fuel storage capability because their spent fuel pools have reached capacity (see Section 3.11.1.2).

Nuclear power plant site areas range from 84 ac (34 ha) to 30,000 ac (12,000 ha), with most sites encompassing 500 to 2,000 ac (200 to 800 ha). Larger land use areas are associated with plant cooling systems that include reservoirs, artificial lakes, and buffer areas.

Nuclear power plant sites are located in a range of political jurisdictions, including towns, townships, service districts, counties, parishes, and States. At more than 50 percent of the sites, the population density within a 50-mi (80 km) radius is fewer than 200 persons per square mile (77 persons per square kilometer), and at more than 80 percent of the sites, the density within 50 mi (80 km) is fewer than 500 persons per square mile (193 persons per square kilometer). Within the 50-mi (80-km) radius, State, Federal, and Native American lands are present to various extents. Typically, nuclear plant sites and their surrounding areas consist of flat to rolling countryside in wooded or agricultural areas. See Appendix C for summary descriptions of the characteristics of nuclear power plant sites and their surroundings.

3.1.2 Nuclear Reactor Systems

In the United States, all of the currently operating reactors used for commercial power generation are conventional (thermal) light water reactors (LWRs) that use water as a moderator and coolant. The two types of LWRs are PWRs and BWRs. Of the 104 operating LWRs, 69 are PWRs and 35 are BWRs (Figure 3.1-1 and Table 3.1-1). They are located at 65 sites in 31 States (NRC 2007a). Some of the reactors have undergone power uprates increasing their power levels. Uprate information is incorporated into Table 3.1-1, and other reactors are likely to undergo similar power uprates in the future.

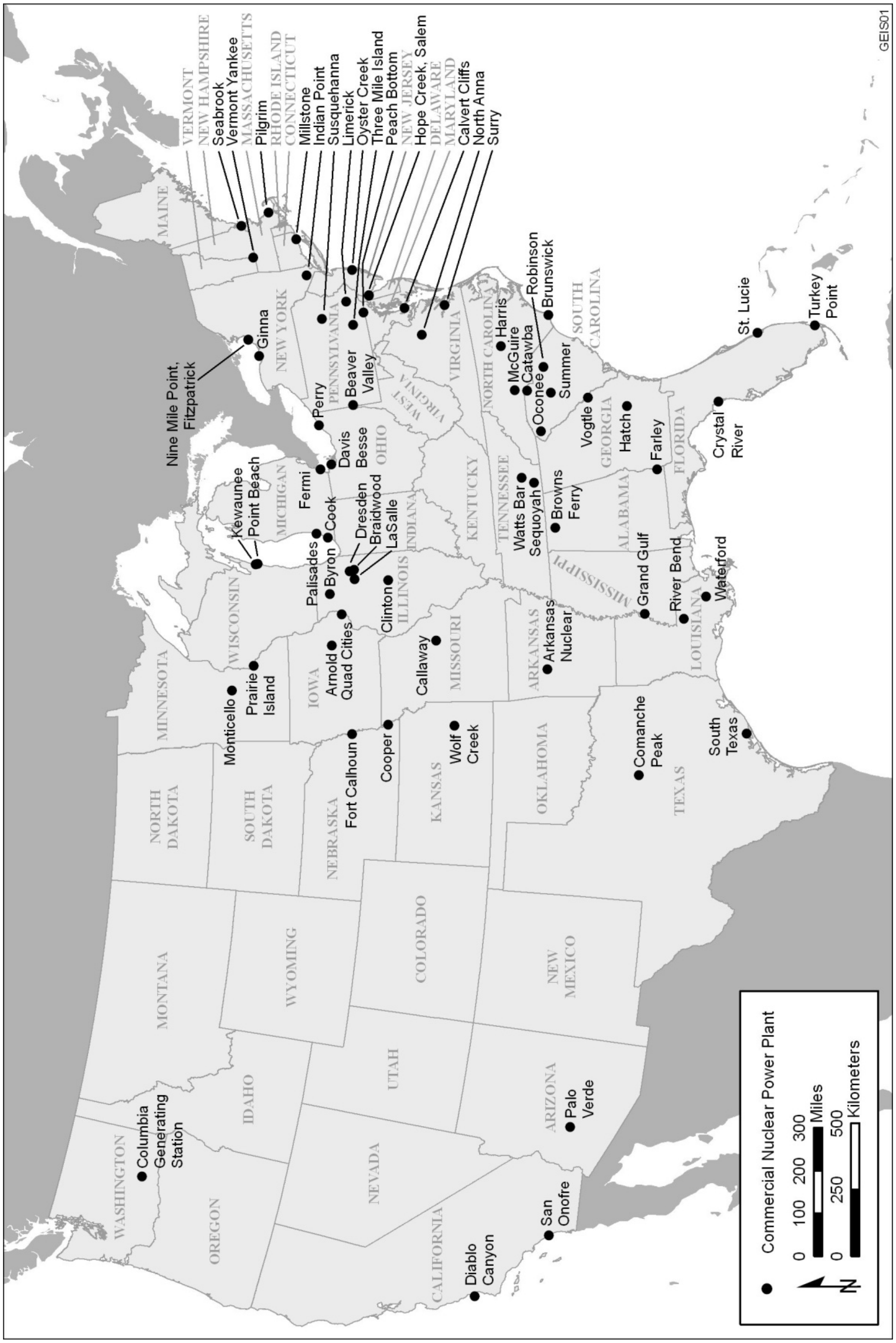

Figure 3.1-1. Operating Commercial Nuclear Power Plants in the United States

Table 3.1-1. Characteristics of Operating U.S. Commercial Nuclear Power Plants[(a)]

Plant	Unit	Year Operating License Granted	Year License Expires	Net Capacity (MWe)	Reactor Type[(b)]	Condenser Flow Rate (10^3 gpm)	Total Site Area (acres)	Nearest City	2000 Population within 50 mi
Arkansas Nuclear One	1	1974	2034	843	PWR	657	1,164	Little Rock, AR	267,664
	2	1978	2038	995	PWR	422			
Beaver Valley Power Station	1	1976	2036	892	PWR	480	453	Pittsburgh, PA	3,274,451
	2	1987	2047	846	PWR				
Braidwood Station	1	1987	2026	1,178	PWR	730	4,457	Joliet, IL	4,272,003
	2	1988	2027	1,152	PWR				
Browns Ferry Nuclear Plant	1	1973	2033	1,065	BWR	734	840	Huntsville, AL	872,478
	2	1974	2034	1,104	BWR				
	3	1976	2036	1,115	BWR				
Brunswick Steam Electric Plant	1	1976	2036	938	BWR	675	1,200	Wilmington, NC	361,872
	2	1974	2034	937	BWR				
Byron Station	1	1985	2025	1,164	PWR	632	1,398	Rockford, IL	1,300,282
	2	1987	2027	1,136	PWR				
Callaway Plant	1	1984	2024	1,190	PWR	530	5,228	Columbia, MO	491,072
Calvert Cliffs Nuclear Power Plant	1	1974	2034	873	PWR	1,200	2,108	Washington, D.C.	3,919,397
	2	1976	2036	862	PWR				
Catawba Nuclear Station	1	1985	2043	1,129	PWR	660	391	Charlotte, NC	2,041,465
	2	1986	2043	1,129	PWR				
Clinton Power Station	1	1987	2026	1,065	BWR	569	14,000	Decatur, IL	789,754
Columbia Generating Station	1	1984	2023	1,131	BWR	550	1,089	Spokane, WA	360,573
Comanche Peak Steam Electric Station	1	1989	2029	1,200	PWR	1,030	7,669	Fort Worth, TX	1,431,094
	2	1993	2033	1,150	PWR				
Cooper Nuclear Station	1	1974	2034	830	BWR	631	1,251	Lincoln, NE	156,157
Crystal River Nuclear Power Plant	3	1977	2016	838	PWR	680	4,700	Gainesville, FL	1,273,146
Donald C. Cook Nuclear Plant	1	1974	2034	1,009	PWR	800	650	South Bend, IN	1,447,303
	2	1977	2037	1,060	PWR				

Table 3.1-1. (cont.)

Plant	Unit	Year Operating License Granted	Year License Expires	Net Capacity (MWe)	Reactor Type[(b)]	Condenser Flow Rate (10^3 gpm)	Total Site Area (acres)	Nearest City	2000 Population within 50 mi
Davis-Besse Nuclear Power Station	1	1977	2017	893	PWR	480	733	Toledo, OH	2,617,550
Diablo Canyon Power Plant	1 2	1984 1985	2024 2025	1,122 1,118	PWR PWR	863	750	Santa Barbara, CA	836,031
Dresden Nuclear Power Station	2 3	1969 1971	2029 2031	867 867	BWR BWR	940 (once-through); 630 (mechanical draft cooling tower)	2,500	Joliet, IL	7,337,564
Duane Arnold Energy Center	1	1974	2034	640	BWR	290	500	Cedar Rapids, IA	613,736
Joseph M. Farley Nuclear Plant	1 2	1977 1981	2037 2041	851 860	PWR PWR	635	1,850	Columbus, GA	393,639
Enrico Fermi Atomic Power Plant	2	1985	2025	1,122	BWR	837	1,120	Detroit, MI	7,803,464
James A. FitzPatrick Nuclear Power Plant	1	1974	2034	852	BWR	353	702	Syracuse, NY	914,668
Fort Calhoun Station	1	1973	2033	478	PWR	360	660	Omaha, NE	852,717
R.E. Ginna Nuclear Power Plant		1969	2029	498	PWR	340	488	Rochester, NY	1,250,000
Grand Gulf Nuclear Station	1	1984	2024	1,297	BWR	572	2,100	Jackson, MS	357,525
Shearon Harris Nuclear Power Plant	1	1987	2046	900	PWR	483	10,744	Raleigh, NC	2,035,797
Edwin I. Hatch Nuclear Plant	1 2	1974 1978	2034 2038	876 883	BWR BWR	556	2,240	Savannah, GA	366,508
Hope Creek Generating Station	1	1986	2046	1,061	BWR	552	740	Wilmington, DE	5,999,588

Table 3.1-1. (cont.)

Plant	Unit	Year Operating License Granted	Year License Expires	Net Capacity (MWe)	Reactor Type[(b)]	Condenser Flow Rate (10^3 gpm)	Total Site Area (acres)	Nearest City	2000 Population within 50 mi
Indian Point Energy Center	2	1973	2013	1,020	PWR	840	239	White Plains, NY	16,806,454
	3	1976	2015	1,025	PWR				
Kewaunee Power Station		1973	2033	556	PWR	420	900	Green Bay, WI	1,585,415
LaSalle County Station	1	1982	2022	1,118	BWR	645	3,060	Joliet, IL	1,498,644
	2	1984	2023	1,120	BWR				
Limerick Generating Station	1	1985	2024	1,134	BWR	450	595	Reading, PA	7,651,537
	2	1990	2030	1,134	BWR				
McGuire Nuclear Station	1	1981	2041	1,100	PWR	675	577	Charlotte, NC	2,425,097
	2	1983	2043	1,100	PWR				
Millstone Power Station	2	1975	2035	884	PWR	523	500	New Haven, CT	2,868,207
	3	1986	2045	1,227	PWR	907			
Monticello Nuclear Generating Plant		1970	2030	572	BWR	292	1,250	Minneapolis, MN	2,740,995
Nine Mile Point Nuclear Station	1	1968	2029	621	BWR	250	900	Syracuse, NY	914,668
	2	1987	2046	1,140	BWR	580			
North Anna Power Station	1	1978	2038	981	PWR	940	1,043	Richmond, VA	1,614,983
	2	1980	2040	973	PWR				
Oconee Nuclear Station	1	1973	2033	846	PWR	680	510	Greenville, S.C.	1,226,479
	2	1973	2033	846	PWR				
	3	1974	2034	846	PWR				
Oyster Creek Nuclear Generating Station		1969	2029	619	BWR	115	800	Atlantic City, PA	4,243,462
Palisades Nuclear Plant		1972	2031	778	PWR	98	432	Kalamazoo, MI	1,287,558
Palo Verde Nuclear Generating Station	1	1985	2045	1,335	PWR	560	4,050	Phoenix, AZ	1,781,095
	2	1986	2046	1,335	PWR				
	3	1987	2047	1,235	PWR				
Peach Bottom Atomic Power Station	2	1973	2033	1,112	BWR	750	620	Lancaster, PA	5,270,600
	3	1974	2034	1,112	BWR				

Table 3.1-1. (cont.)

Plant	Unit	Year Operating License Granted	Year License Expires	Net Capacity (MWe)	Reactor Type[(b)]	Condenser Flow Rate (10^3 gpm)	Total Site Area (acres)	Nearest City	2000 Population within 50 mi
Perry Nuclear Power Plant	1	1986	2026	1,261	BWR	545	1,100	Euclid, OH	4,923,662
Pilgrim Nuclear Power Station	1	1972	2012	685	BWR	156	140	Boston, MA	4,629,116
Point Beach Nuclear Plant	1 2	1970 1972	2030 2033	512 514	PWR PWR	350	1,260	Green Bay, WI	1,622,052
Prairie Island Nuclear Generating Plant	1 2	1973 1974	2033 2034	551 545	PWR PWR	294	560	Minneapolis, MN	2,731,953
Quad Cities Nuclear Power Station	1 2	1972 1972	2032 2032	867 869	BWR BWR	970	817	Davenport, IA	656,527
River Bend Station	1	1985	2025	989	BWR	508	3,300	Baton Rouge, LA	866,314
H.B. Robinson Steam Electric Plant	2	1970	2030	710	PWR	448	6,020	Columbia, SC	809,582
St. Lucie Nuclear Plant	1 2	1976 1983	2036 2043	839 839	PWR PWR	491	1,130	West Palm Beach, FL	1,180,000
Salem Nuclear Generating Station	1 2	1976 1981	2036 2040	1,174 1,130	PWR PWR	1,100	700	Wilmington, DE	5,975,864
San Onofre Nuclear Generating Station	2 3 1	1982 1983 1967	2022 2023 2007	1,070 1,080	PWR PWR	797 797	84	Oceanside, CA	7,521,699
Seabrook Station	1	1990	2030	1,295	PWR	399	889	Lawrence, MA	6,932,660
Sequoyah Nuclear Plant	1 2	1980 1981	2020 2021	1,148 1,126	PWR PWR	522	525	Chattanooga, TN	954,430
South Texas Project Electric Generating Station	1 2	1988 1989	2027 2028	1,280 1,280	PWR PWR	907	12,350	Galveston, TX	402,902
Virgil C. Summer Nuclear Station	1	1982	2042	966	PWR	485	2,245	Columbia, SC	1,032,330
Surry Power Station	1 2	1972 1973	2032 2033	799 799	PWR PWR	840	840	Newport News, VA	2,387,353

Table 3.1-1. (cont.)

Plant	Unit	Year Operating License Granted	Year License Expires	Net Capacity (MWe)	Reactor Type[b]	Condenser Flow Rate (10^3 gpm)	Total Site Area (acres)	Nearest City	2000 Population within 50 mi
Susquehanna Steam Electric Station	1	1982	2042	1,149	BWR	968	1,173	Wilkes-Barre, PA	1,684,794
	2	1984	2044	1,140	BWR				
Three Mile Island	1	1974	2034	786	PWR	430	814	Harrisburg, PA	2,466,679
Turkey Point Nuclear Plant	3	1972	2032	693	PWR	624	2,400	Miami, FL	7,490,123
	4	1973	2033	693	PWR				
Vermont Yankee Nuclear Power Station	1	1973	2032	510	BWR	360	125	Holyoke, MA	1,513,282
Vogtle Electric Generating Plant	1	1987	2047	1,109	PWR	510	3,169	Augusta, GA	670,000
	2	1989	2049	1,127	PWR				
Waterford Steam Electric Station	3	1985	2024	1,150	PWR	975	3,000	New Orleans, LA	2,072,270
Watts Bar Nuclear Plant	1	1996	2035	1,123	PWR	410	1,170	Chattanooga, TN	1,044,454
Wolf Creek Generating Station	1	1985	2045	1,166	PWR	500	9,818	Topeka, KS	176,301

(a) The 1996 GEIS included a number of nuclear plants that are not being considered for license renewal and are not included in this table. They include the following plants:
Bellefonte: Never finished; mothballed in 1988.
Big Rock: Shut down in 1997; decommissioning complete in August 2006. Stored spent fuel is still onsite.
Haddam (Connecticut Yankee): Shut down in 1996; decommissioned in 2004. Stored spent fuel is still onsite.
Maine Yankee: Closed in 1997; decommissioned in 2005. Stored spent fuel is still onsite.
Millstone, Unit 1: Shut down in 1995; awaiting decontamination and dismantlement as part of decommissioning.
Rancho Seco: Shut down in 1989; still undergoing decommissioning.
Shoreham: Fully decommissioned in 1994; it never produced power.
Trojan: Closed in 1992; decommissioning completed in 2006. Stored spent fuel is still onsite.
Watts Bar, Unit 2: Construction halted in 1988, but approval to complete construction was approved in August 2007. Construction was to begin in 2007, with operation beginning in 2013.
Yankee Rowe: Shutdown in 1992; decommissioning completed in 2006.
Zion: Shut down in 1998, has been placed in safe storage (SAFSTOR), and decommissioning will begin in 2013.

(b) PWR = pressurized-water reactor; BWR = boiling-water reactor.

The nuclear fuel used in both types of reactors is uranium enriched to 2 to 5 percent in the uranium-235 isotope. The fuel is in the form of cylindrical uranium dioxide (UO_2) pellets, approximately 0.4 in. (1 cm) in diameter and 0.4 to 0.6 in. (1 to 1.5 cm) in height. The fuel pellets are stacked and sealed inside a hollow cylindrical fuel rod made of zircaloy, an alloy of zirconium. The fuel rods, also called fuel pins or fuel elements, are approximately 12 ft (3.6 m) long. They are bundled into fuel assemblies that generally consist of 15×15 or 17×17 rods for PWRs and 8×8 or 10×10 rods for BWRs. When new fuel is loaded into the reactors or spent fuel is removed from reactors, the fuel is handled as intact assemblies. Similarly, when spent fuel is stored onsite awaiting shipment offsite, the fuel assemblies remain intact.

Fission reactions that occur inside the fuel, primarily by the uranium-235 isotopes, are the source of thermal energy generated in a nuclear reactor. This energy is transferred to the coolant, which is ordinary water, circulating in the primary coolant system in LWRs. The vessel, which encloses the reactor, is part of the primary coolant system.

In PWRs, water is heated to a high temperature under pressure inside the reactor (Figure 3.1-2). The water is then pumped in the primary circulation loop to the steam generator. Within the steam generator, water in the secondary circulation loop is converted to steam that drives the turbines. The turbines turn the generator to produce electricity. The steam leaving the turbines is condensed by water in the tertiary loop and returned to the steam generator. The tertiary loop water flows to cooling towers where it is cooled by evaporation, or it is discharged directly to a body of water, such as a river, lake, or other heat sink (see Section 3.1.3). The tertiary loop is open to the atmosphere, but the primary and secondary cooling loops are not.

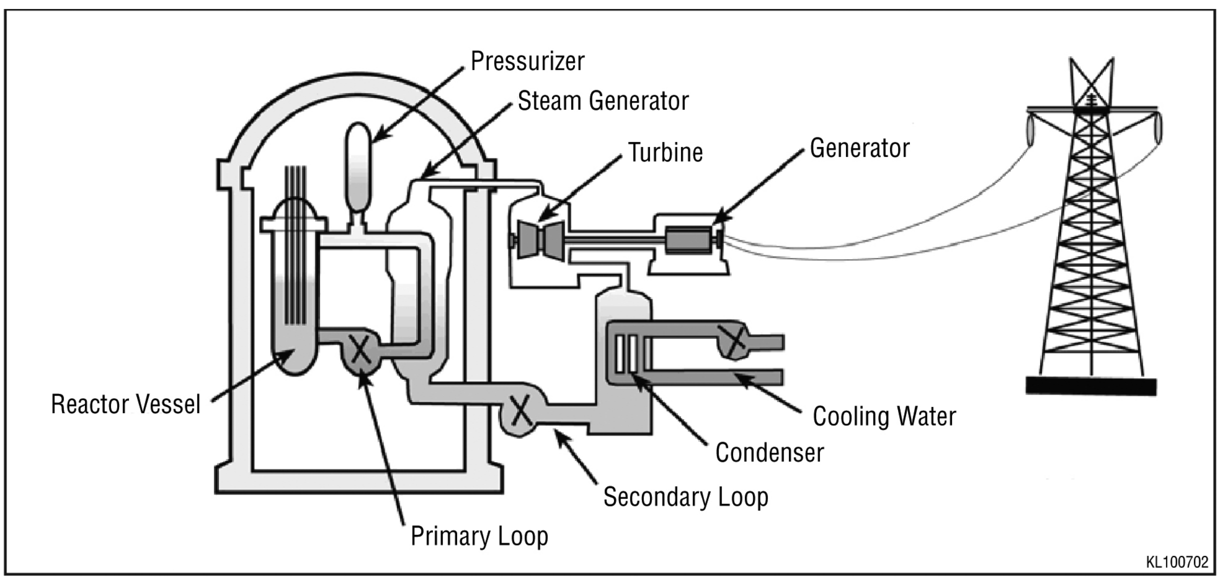

Figure 3.1-2. Pressurized Water Reactor (NRC 2002a)

BWRs generate steam directly within the reactor vessel (Figure 3.1-3). The steam passes through moisture separators and steam dryers and then flows to the turbines. Because it generates steam directly in the reactor vessel, the power generation system contains only two heat transfer loops. The primary loop transports the steam from the reactor vessel directly to the turbines, which generate electricity. The secondary coolant loop removes excess heat from the primary loop in the condenser. From the condenser, the primary condensate proceeds into the feedwater stage, and the secondary coolant loop removes the excess heat and discharges it to the receiving water body. As is the case for PWRs, the coolant water from the condenser is pumped to cooling towers or it is discharged directly to a water body.

3.1.3 Cooling Water Systems

The predominant use of water at a nuclear power plant is for removing excess heat generated in the reactor. The volumetric flow rate of water used for condenser cooling is a function of several factors, including the power rating of the plant and the increase in cooling water temperature from the intake to the discharge. The larger the plant, the greater the quantity of waste heat to be dissipated, and the greater the flow rate of cooling water required.

Table 3.1-2 shows some types of cooling systems used at the existing nuclear power plant sites. There are two major types of cooling systems for operating plants: once-through cooling

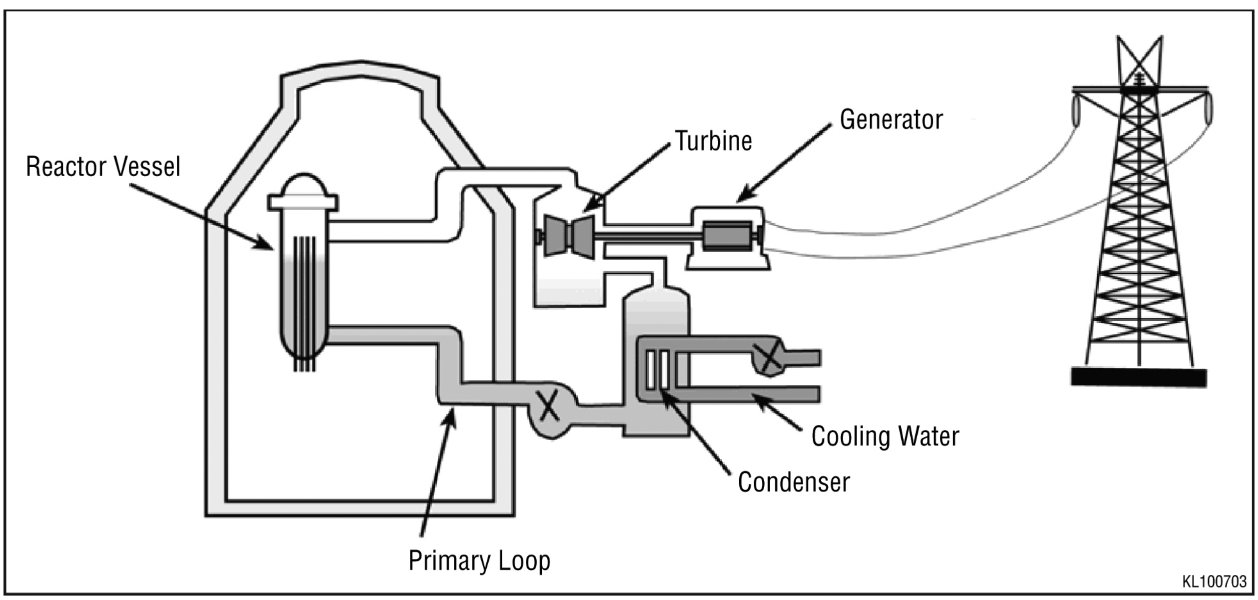

Figure 3.1-3. Boiling Water Reactor (NRC 2002a)

Table 3.1-2. Types of Cooling Systems Used at U.S. Commercial Nuclear Power Plants

Plant	State	Cooling System	Cooling Water Source
Coastal or Estuarine Environment			
Diablo Canyon	California	Once-through	Pacific Ocean
San Onofre Nuclear	California	Once-through	Pacific Ocean
Millstone	Connecticut	Once-through	Long Island Sound
Crystal River	Florida	Once-through	Gulf of Mexico
St. Lucie	Florida	Once-through	Atlantic Ocean
Turkey Point	Florida	Cooling canal	Biscayne Bay
Calvert Cliffs	Maryland	Once-through	Chesapeake Bay
Pilgrim	Massachusetts	Once-through	Cape Cod Bay
Seabrook	New Hampshire	Once-through	Atlantic Ocean
Hope Creek	New Jersey	Natural draft cooling towers	Delaware River
Oyster Creek	New Jersey	Once-through	Barnegat Bay
Salem	New Jersey	Once-through	Delaware River
Indian Point	New York	Once-through	Hudson River
Brunswick	North Carolina	Once-through	Cape Fear River
South Texas	Texas	Cooling pond	Colorado River
Surry	Virginia	Once-through	James River
Great Lakes Environment			
Cook	Michigan	Once-through	Lake Michigan
Fermi	Michigan	Natural draft cooling towers	Lake Erie
Palisades	Michigan	Mechanical draft cooling towers	Lake Michigan
FitzPatrick	New York	Once-through	Lake Ontario
Ginna	New York	Once-through	Lake Ontario
Nine Mile Point	New York	Unit 1: Once-through Unit 2: Natural draft cooling towers	Lake Ontario
Davis-Besse	Ohio	Natural draft cooling towers	Lake Erie
Perry	Ohio	Natural draft cooling towers	Lake Erie
Kewaunee	Wisconsin	Once-through	Lake Michigan
Point Beach	Wisconsin	Once-through	Lake Michigan

Table 3.1-2. (cont.)

Plant	State	Cooling System	Cooling Water Source
Freshwater Riverine or Impoundment Environment			
Browns Ferry	Alabama	Once-through (helper towers)	Tennessee River
Farley	Alabama	Mechanical draft cooling towers	Chattahoochee River
Palo Verde	Arizona	Mechanical draft cooling towers	Phoenix City Sewage
Arkansas	Arkansas	Unit 1: once-through Unit 2: natural draft cooling towers	Lake Dardanelle
Hatch	Georgia	Mechanical draft cooling towers	Altamaha River
Vogtle	Georgia	Natural draft cooling towers	Savannah River
Braidwood	Illinois	Cooling pond	Kankakee River
Byron	Illinois	Natural draft cooling towers	Rock River
Clinton	Illinois	Once-through (cooling pond)	Salt Creek
Dresden	Illinois	Cooling pond and optional mechanical draft cooling tower or once-through including residence time in pond and optional cooling towers	Kankakee River
LaSalle	Illinois	Cooling pond	Illinois River
Quad Cities	Illinois	Once-through	Mississippi River
Duane Arnold	Iowa	Mechanical draft cooling towers	Cedar River
Wolf Creek	Kansas	Cooling pond	Coffey County Lake
River Bend	Louisiana	Mechanical draft cooling towers	Mississippi River
Waterford	Louisiana	Once-through	Mississippi River
Monticello	Minnesota	Once-through and mechanical draft cooling towers	Mississippi River
Prairie Island	Minnesota	Once-through and mechanical draft cooling towers	Mississippi River
Grand Gulf	Mississippi	Natural draft cooling towers	Mississippi River
Callaway	Missouri	Natural draft cooling towers	Missouri River
Cooper	Nebraska	Once-through	Missouri River
Fort Calhoun	Nebraska	Once-through	Missouri River
Harris	North Carolina	Natural draft cooling towers	Buckhorn Creek
McGuire	North Carolina	Once-through	Lake Norman
Beaver Valley	Pennsylvania	Natural draft cooling towers	Ohio River
Limerick	Pennsylvania	Natural draft cooling towers	Schuylkill River

Table 3.1-2. (cont.)

Plant	State	Cooling System	Cooling Water Source
Peach Bottom	Pennsylvania	Unit 2: Once-through Unit 3: Once-through (mechanical draft cooling towers)	Conowing Pond
Susquehanna	Pennsylvania	Natural draft cooling towers	Susquehanna River
Three Mile Island	Pennsylvania	Natural draft cooling towers	Susquehanna River
Catawba	South Carolina	Mechanical draft cooling towers	Lake Wylie
Oconee	South Carolina	Once-through	Lake Keowee
H.B. Robinson	South Carolina	Cooling pond	Lake Robinson
Summer	South Carolina	Cooling pond	Monticello Reservoir
Sequoyah	Tennessee	Once-through and natural draft cooling towers	Chickamauga Lake
Watts Bar	Tennessee	Natural draft cooling towers	Chickamauga Lake
Comanche Peak	Texas	Once-through	Squaw Creek Reservoir
Vermont Yankee	Vermont	Once-through and mechanical draft cooling towers	Connecticut River
North Anna	Virginia	Once-through	Lake Anna
Columbia	Washington	Mechanical draft cooling towers	Columbia River

and closed-cycle cooling. In a once-through cooling system, circulating water for condenser cooling is obtained from a nearby source of water, such as a lake or river, passed through the condenser tubes, and returned at a higher temperature to the same water body (Figure 3.1-4a). Flow through the condenser for a 1,000-MWe plant during operations is typically 250,000 to 900,000 gpm (16 to 57 m^3/s) (NRC 1996). The waste heat is dissipated to the atmosphere mainly by evaporation from the water body and, to a much smaller extent, by conduction, convection, and thermal radiation loss.

In a closed-cycle system at an operating plant, the cooling water is recirculated through the condenser after the waste heat is removed by dissipation to the atmosphere, usually by circulating the water through large cooling towers constructed for that purpose (Figure 3.1-4b). The average for makeup water withdrawals for a 1000-MWe plant during operations is typically about 14,000 to 18,000 gpm (0.9 to 1.1 m^3/s) (NRC 1996). Recirculating cooling systems consist of natural draft or mechanical draft cooling towers, cooling ponds, lakes, reservoirs, or canals. Because the predominant cooling mechanism associated with closed-cycle systems is evaporation, much of the water used for cooling is consumed and is not returned to the water

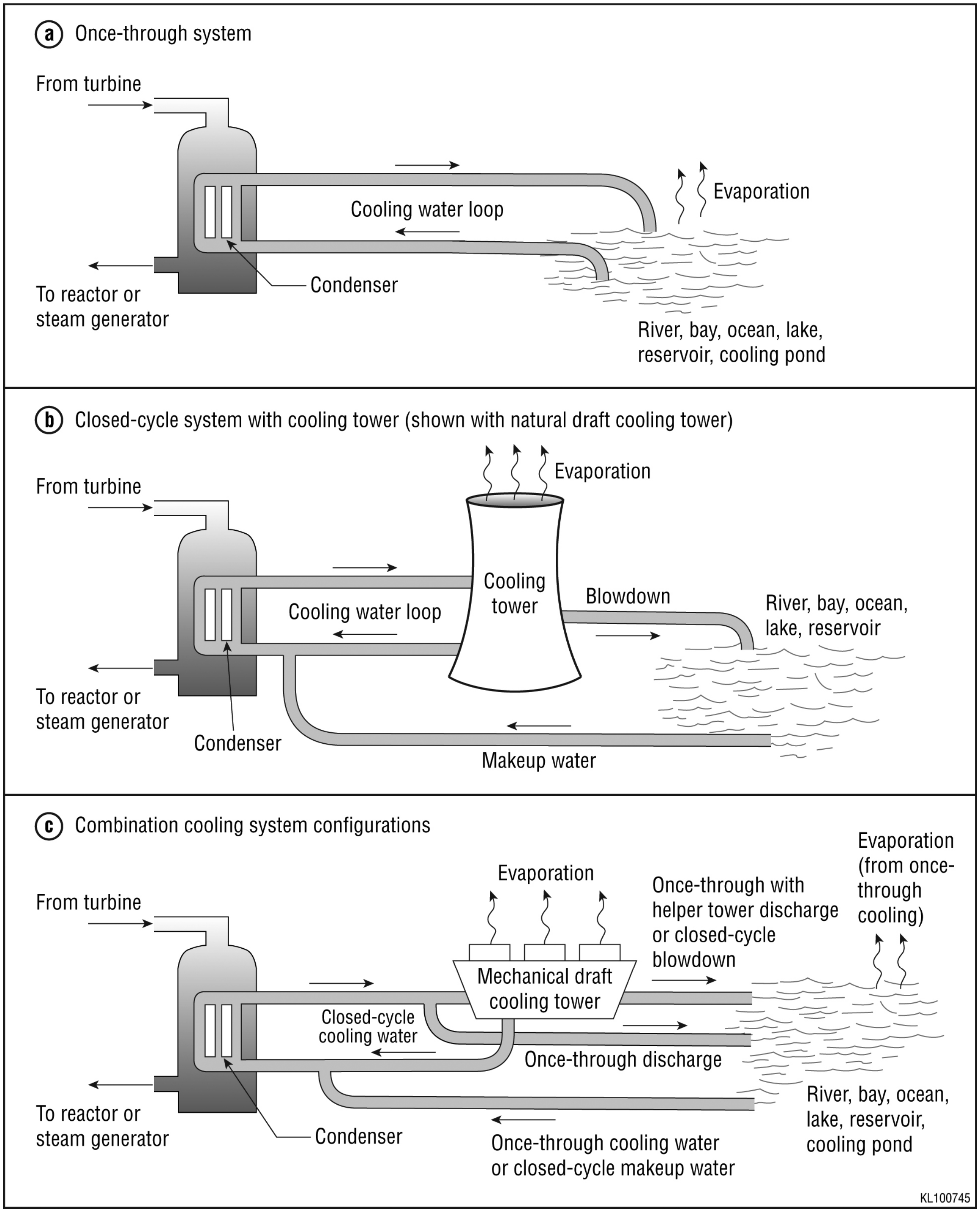

Figure 3.1-4. Schematic Diagrams of Nuclear Power Plant Cooling Systems

source. Blowdown (water that is periodically rinsed from the cooling system to remove impurities and sediment that may degrade performance) is typically released to a receiving body of surface water next to the plant.

Several nuclear plants use combination cooling systems that may be used in different configurations, especially during different times of the year (Figure 3.1-4c). Cooling towers may be included in a once-through system to cool the effluent prior to release to the receiving body of water. These are referred to as helper towers. Peach Bottom (NRC 2003d) has helper mechanical draft cooling towers that can receive up to 60 percent of the heated discharge, with the remainder of the water discharged as part of a traditional once-through system. Monticello (NRC 2006f) uses once-through cooling in the winter but has mechanical draft cooling towers for closed-cycle cooling in the summer. Dresden (NRC 2004a) is similar in that it relies on a cooling pond system in the fall, winter, and spring, but in summer switches to a once-through system that includes residence time in the cooling pond and also typically the use of helper mechanical draft cooling towers. Browns Ferry (NRC 2005a) uses mechanical draft cooling towers in helper mode. Vermont Yankee (NRC 2007f) is capable of operating in one of three modes: once-through, combined, or completely closed. The mode of operation is selected by the licensee to limit the thermal discharge to the Connecticut River to ensure compliance with the National Pollutant Discharge Elimination System (NPDES) permit requirements. In the combined mode, the plant operates both the closed cycle and the open (once-through) cycle systems, with the proportion of water running through each system varying depending on the temperature increase in the river water due to discharge from the plant.

All existing sites with two or three reactor units use the same cooling system for all units, except for two sites: Arkansas Nuclear One in Arkansas and Nine Mile Point in New York. These two sites use once-through cooling for one unit and closed-cycle for the other. Other cooling system types might be added to existing sites if new units are constructed.

For each type of cooling system, the configurations of the water intake and discharge structures vary to accommodate the source water body and minimize any impact to the aquatic ecosystem. The intake structures generally are located along the shoreline of the body of water and are equipped with fish-protection devices. The discharge structures are usually jets or diffusers and designed to promote rapid mixing of the effluent stream with the receiving body of water. Discharges of condenser cooling water (once-through systems) and blowdown water (closed-cycle systems) containing biocides and other chemicals used for corrosion control and other water treatment purposes are authorized by the States or the EPA under NPDES permits, which establish limits, as necessary, based on flow rates, chemical concentrations, and thermal changes.

In addition to removing heat from the reactor of an operating facility, cooling water is also provided to the service water system and to the auxiliary cooling water system. Service water is special-purpose water that may or may not be treated for use. The auxiliary cooling water systems include emergency core cooling systems, the containment spray and cooling system, the emergency feedwater system, the component cooling water system, and the spent fuel pool water systems. The volumetric flow rate of water required for these systems is usually less than 15 percent of the volume required for condenser cooling in once-through cooling. In closed-cycle cooling, the additional water needed is usually less than 5 percent of that needed for condenser cooling (NRC 1996).

In addition to surface water sources, some nuclear power plants use groundwater as a source for service, makeup, or potable water. Only Grand Gulf uses groundwater as a source of makeup water to the condenser cooling system. This plant employs a Ranney well collection system to draw groundwater from the Mississippi River alluvial aquifer.

3.1.4 Radioactive Waste Management Systems

During the fission process, a large inventory of radioactive fission products builds up within the fuel. Virtually all of the fission products are contained within the fuel pellets. The fuel pellets are enclosed in hollow metal rods (cladding), which are hermetically sealed to further prevent the release of fission products. However, a small fraction of the fission products escape from the fuel rods and contaminate the reactor coolant. The primary system coolant also has radioactive contaminants as a result of neutron activation. The radioactivity in the reactor coolant is the source of liquid, gaseous, and most of the solid radioactive wastes at LWRs. The following sections describe the basic design and operation of PWR and BWR radioactive waste treatment systems.

3.1.4.1 Liquid Radioactive Waste

Radionuclide contaminants in the primary coolant are the source of liquid radioactive waste in LWRs. The specific sources of these wastes, the modes of collection and treatment, and the types and quantities of liquid radioactive wastes released to the environment are similar in many respects in BWRs and PWRs. Accordingly, the following discussion applies to both BWRs and PWRs; distinctions are made only when important differences exist.

Liquid wastes resulting from LWR operation may be placed into the following categories: clean wastes, dirty wastes, detergent wastes, turbine building floor-drain water, and steam generator blowdown (PWRs only). Clean wastes include all liquid wastes with normally low conductivity and variable radioactivity. They consist of reactor-grade water, which is amenable to processing for reuse as reactor coolant makeup water. Clean wastes are collected from equipment leaks and drains, certain valve and pump seal leaks from which water was not collected in the reactor coolant drain tank, and other aerated leakage sources. Dirty wastes include all liquid wastes with moderate conductivity and variable radioactivity that, after processing, may be used as reactor coolant makeup water. Dirty wastes consist of liquid wastes collected in the containment building sump, auxiliary building sumps and drains, laboratory drains, sample station drains, and other floor drains. Detergent wastes consist principally of laundry wastes and personnel and equipment decontamination wastes and normally have low radioactivity. Turbine building floor-drain wastes usually have high conductivity and a low radionuclide content. In PWRs, steam generator blowdown can have relatively high concentrations of radionuclides, depending on the amount of primary-to-secondary leakage. Following processing, the water may be reused or discharged.

Each of these sources of liquid wastes receives varying degrees and types of treatment before being stored for reuse or discharged to the environment under the site NPDES permit. The extent and types of treatment depend on the chemical content of the waste; to increase the efficiency of waste processing, wastes with similar characteristics are batched before treatment.

Controls for limiting the release of radiological liquid effluents at each plant are described in the facility's Offsite Dose Calculation Manual (ODCM). Controls are based on (1) concentrations of radioactive materials in liquid effluents and (2) dose to a member of the public. Concentrations of radioactive material that are allowed to be released in liquid effluents to unrestricted areas are limited to the concentration specified in 10 CFR Part 20, Appendix B, Table 2.

The degree of processing, storing, and recycling of liquid radioactive waste has steadily increased among operating plants. For example, extensive recycling of steam generator blowdown in PWRs is now the typical mode of operation, and secondary side wastewater is routinely treated. In addition, the plant systems that process wastes are often augmented by commercial mobile processing systems. As a result, radionuclide releases in liquid effluent from LWRs have generally declined for most plants or remained the same over time.

3.1.4.2 Gaseous Radioactive Waste

The gaseous waste management system collects fission products, mainly noble gases, which accumulate in the primary coolant. A small portion of the primary coolant flow is continually diverted to the primary coolant purification, volume, and chemical control system to remove contaminants and adjust the coolant chemistry and volume. During this process, noncondensable gases are stripped and routed to the gaseous waste management system, which consists of a series of gas storage tanks. The storage tanks allow the short-half-life radioactive gases to decay, leaving only relatively small quantities of long-half-life radionuclides to be released to the atmosphere. Some LWRs currently use charcoal delay systems rather than gas storage tanks.

For BWRs, the sources of routine radioactive gaseous emissions to the atmosphere are the air ejector, which removes noncondensable gases from the coolant to improve power conversion efficiency, and gaseous and vapor leakages, which, after monitoring and filtering, are discharged to the atmosphere via the building ventilation systems.

PWRs have three primary sources of gaseous radioactive emissions: (1) discharges from the gaseous waste management system; (2) discharges associated with the exhaust of noncondensable gases at the main condenser if a primary-to-secondary system leak exists; and (3) radioactive gaseous discharges from the building ventilation exhaust, including the reactor building, reactor auxiliary building, and fuel-handling building.

The quantities of gaseous effluents released from operating plants are controlled by the administrative limits that are defined in the ODCM, which is specific for each plant. Controls are based on (1) the rate at which the gaseous effluent is released and (2) dose to a member of the public. The limits in the ODCM are designed to provide reasonable assurance that radioactive material discharged in gaseous effluents are not in excess of the limits specified in 10 CFR Part 20, Appendix B, thereby limiting the exposure of a member of the public in an unrestricted area.

3.1.4.3 Solid Radioactive Waste

Solid low-level radioactive waste (LLW) from nuclear power plants is generated from the removal of radionuclides from liquid waste streams, filtration of airborne gaseous emissions, and removal of contaminated material from various reactor areas. Liquid contaminated with radionuclides comes from primary and secondary coolant systems, spent fuel pools, decontaminated wastewater, and laboratory operations.

Solid waste is packaged in containers to meet the applicable requirements of 49 CFR Parts 171 through 177. Disposal and transportation are performed in accordance with the applicable requirements of 10 CFR Part 61 and 10 CFR Part 71, respectively.

Solid radioactive waste generated during operations is shipped to a LLW processor or directly to a LLW disposal site. Volume reduction may occur both onsite and offsite. The most common onsite volume reduction techniques are high-pressure compacting in waste drums, dewatering and evaporating wet wastes, monitoring waste streams to segregate wastes, and sorting. Offsite waste management vendors compact wastes at ultra-high pressures, incinerate dry active waste, separate and incinerate oily and organic wastes, and concrete-solidify resins and sludges before the waste is sent to a LLW disposal site.

Spent fuel contains fission products and actinides produced when nuclear fuel is irradiated in reactors, as well as any unburned, unfissioned nuclear fuel remaining after the fuel rods have been removed from the reactor core. Currently in the United States, the spent fuel is considered waste and is being stored at the reactor sites, either in spent fuel pools or dry storage facilities, also called independent spent fuel storage installations (ISFSIs) (see Section 3.11.1.2).

Mixed wastes, which contain both radioactive and hazardous components, are generally accumulated in designated areas onsite and then shipped offsite for treatment and disposal. Mixed wastes are regulated both by the EPA or the State under authority granted by the Resource Conservation and Recovery Act (RCRA) and by the NRC or the State under authority granted by the Atomic Energy Act (see Section 3.11.3).

3.1.5 Nonradioactive Waste Management Systems

Nonradioactive wastes from nuclear power plants include both hazardous and nonhazardous wastes. Hazardous wastes, as defined by RCRA Subtitle C, may include organic materials, heavy metals, solvents, paints, cutting fluids, and lubricating oils that have been used at a nuclear power plant, and, after use, declared to be waste. These wastes are generally accumulated in designated areas onsite and then shipped offsite for treatment and disposal. Certain hazardous waste streams may receive treatment at some sites. For example, waste oil is incinerated at some sites. Common treatment methods for these nonradioactive wastes include incineration, neutralization, biological treatment, and removal and recovery. All activities related to hazardous wastes—including storage, treatment, shipment, and disposal—are conducted pursuant to the regulations issued by the EPA or the State, if authorized, under RCRA (see Section 3.11.2).

There are also some routine or nonroutine releases from power plants that may have hazardous components, including boiler blowdown (continual or periodic purging of impurities from plant boilers), water treatment wastes (sludges and high-saline streams whose residues are disposed of as solid waste and biocides), boiler metal cleaning wastes, floor and yard drains, and stormwater runoff. With the exception of solid water treatment wastes, these releases would be regulated in accordance with each plant’s NPDES permit. Principal chemical and biocide waste sources include the following:

- Boric acid used to control reactor power and lithium hydroxide used to control pH in the coolant. These chemicals could be inadvertently released because of pipe or steam generator leakage.

- Sulfuric acid, which is added to the circulating water system to control scale.

- Hydrazine, which is used for corrosion control. It is released in steam generator blowdown.

- Sodium hydroxide and sulfuric acid, which are used to regenerate resins. These are discharged after neutralization.
- Phosphate in cleaning solutions.
- Biocides used for condenser defouling.

Other small volumes of wastewater are released from other plant systems depending on the design of each plant. These are discharged from such sources as the service water and auxiliary cooling systems, laboratory and sampling wastes, and metal treatment wastes. These waste streams are regulated and discharged in accordance with each plant's NPDES permit as separate point sources or are combined with the cooling water discharges.

Nonradioactive and nonhazardous wastes such as office trash are picked up by a local waste hauler and sent to a local landfill without any treatment. Sanitary wastes are treated at a sewage treatment plant that is located either onsite or offsite. If the treatment plant is offsite, the sanitary waste is either collected in septic tanks, tested for radioactivity, and sent offsite periodically or the sanitary waste may be tested for radioactivity and discharged directly to a publicly owned treatment works. Any effluent releases to surface water from onsite sewage plants are subject to NPDES permit limits.

3.1.6 Utility and Transportation Infrastructure

The utility and transportation infrastructure at nuclear power plants typically interfaces with public infrastructure systems available in the region. This infrastructure includes utilities, such as suppliers of electricity, fuel, and water, as well as roads and railroads used to gain access to the sites.

3.1.6.1 Electricity

Nuclear power plants generate electricity for other users; however, they also use electricity to operate. The amount of electrical power needed to run a 1,000-MWe nuclear power plant is relatively small when compared to the amount it generates. The plants use some of the power they generate; however, they also have connections to the electrical grid system to receive power from offsite sources. Offsite power is provided to run the engineered safety features and emergency equipment in case of a malfunction and interruption of power generation at the plant. The plants also have independent backup generators that run on diesel fuel. The backup generators are tested periodically and come on line automatically in case electrical power to the plant from internal generation and external sources is interrupted.

3.1.6.2 Fuel

An operating 1,000-MWe PWR contains approximately 220,000 lb (100 MT) of nuclear fuel in the form of UO_2 at any one time. Only about one-third of that fuel is replaced at every refueling. Assuming that the reactor is refueled once every 18 months, the amount of nuclear fuel needed (and also spent fuel generated) would be roughly 44,000 lb (20 MT) per year. Fresh fuel is brought to the site and stored at the site until needed.

In addition to nuclear fuel, a nuclear power plant needs a certain amount of diesel fuel to operate the emergency diesel power generators. To meet emergency demands, a certain quantity of diesel fuel is stockpiled on site in fuel storage tanks. Fuel is also needed for space heating, ventilating, and air conditioning (HVAC) purposes. Plants use a variety of energy sources for HVAC, including electricity, natural gas, or fuel oil. Some plants have waste oil incinerators onsite to burn their used oil. The heat generated by such an incinerator is used to heat buildings during winter.

3.1.6.3 Water

Systems designed to provide cooling water at nuclear power plants are described in Section 3.1.3. In addition to needing water for cooling, plants need water for sanitary reasons and for everyday use by the personnel (e.g., drinking, showering, cleaning, laundry, toilets, and eye washes). Plants generally rely on groundwater or, at times, on surface water bodies (e.g., nearby rivers and lakes) to obtain potable water. Because the plants are generally in rural areas away from population centers, they are often not connected to community water systems and are self-sufficient in meeting their water needs.

The quantity of water needed for cooling purposes was discussed in Section 3.1.3. The amount of water needed for sanitary reasons is generally much smaller than the amount needed for cooling. After use, the potable water is processed as part of the sanitary water treatment system. As described in Section 3.11.4, sanitary waste is either treated onsite, collected in septic tanks and then shipped offsite to be treated at a local sewage treatment plant, or discharged directly to a publicly owned treatment works.

3.1.6.4 Transportation Systems

All nuclear power plants are served by controlled access roads. In addition to the roads, many of the plants also have railroad connections for moving heavy equipment and other materials. Some of the plants that are located on navigable waters, such as rivers, Great Lakes, or oceans, have facilities to receive and ship loads on barges.

Trucks are the most common mode of transportation for delivering materials to and from the sites. Deliveries are accepted at and shipments are made from designated areas on the sites under controlled conditions and by following established procedures. Workers generally use their personal vehicles to commute to work. Visitors use passenger cars or light pickup trucks to get to and from the sites. There are parking areas available on every site for workers and visitors. There is also a network of roads and sidewalks for vehicles and pedestrians on each site.

3.1.6.5 Power Transmission Systems

Each nuclear power plant is connected to an independent regional electrical power distribution grid. Power transmission systems consist of switching stations (or substations) and the transmission lines needed to transfer electrical power from the nuclear plant to the regional electrical power distribution grid (see Section 3.1.1). Only those transmission lines that connect the power plant to the switchyard where electricity is fed into the regional distribution system (encompassing those lines that connect the nuclear plant to the first substation of the regional electric power grid) and power lines that feed the plant from the grid during outages are considered within the regulatory scope of license renewal environmental review and this GEIS.

The original final environmental statements (FESs) for the construction and operation of a nuclear power plant also evaluated the impacts of constructing and operating transmission lines needed to connect the nuclear plant to the regional electrical power distribution grid. Since construction, many of these transmission lines have been incorporated into the regional electrical power distribution grid. In many cases, these transmission lines are no longer owned or managed by licensees and would remain energized regardless of a license renewal decision. These transmission lines are outside of the scope of this GEIS. This is a departure from the *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (GEIS), NUREG-1437 (1996 GEIS)[a] (NRC 1996) and the supplemental environmental impact statements (SEISs) prepared to date. Those reviews considered the operational effects of the transmission lines needed to connect the plant to the grid at the time of nuclear power plant construction.

Switching stations transfer electrical power from generating sources to power lines and regulate the operation of the power system. Transformers in switching stations convert the generated voltage to voltage levels appropriate for the power lines. Equipment for regulating system operation includes switches, power circuit breakers, meters, relays, microwave communication equipment, capacitors, and a variety of other electrical equipment. This equipment meters and controls power flow; improves the performance characteristics of the generated power; and

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(a) Any reference in this document to the 1996 GEIS includes the two-volume set published in 1996 and Addendum 1 to the GEIS published in 1999.

protects generating equipment from short circuits, lightning strikes, and switching surges that may occur along the electrical power transmission lines. Switching stations occupy onsite land areas generally two to four times as large as those areas occupied by the reactor and generator buildings, but they are generally not as visible as other power plant structures.

3.1.7 Nuclear Power Plant Operations and Maintenance

Nuclear power reactors are capable of generating electricity continuously for long periods of time. However, they operate neither at maximum capacity nor continuously for the entire term of their license. Plants can typically operate continuously for periods of time ranging from 1 year to 2 years on a single fuel load.

Maintenance activities are routinely performed on systems and components to help ensure the safe and reliable operation of the plant. In addition, inspection, testing, and surveillance activities are conducted throughout the operational life of a nuclear power plant to maintain the current licensing basis of the plant and ensure compliance with Federal, State, and local requirements regarding the environment and public safety.

Nuclear power plants must periodically discontinue the production of electricity for refueling, periodic in-service inspection (ISI), and scheduled maintenance. Refueling cycles occur approximately every 12 to 24 months. The duration of a refueling outage is typically about 1 to 2 months. Enhanced or expanded inspection and surveillance activities are typically performed at 5- and 10-year intervals. These enhanced inspections are performed to comply with NRC and/or industry standards or requirements, such as the American Society of Mechanical Engineers Boiler and Pressure Vessel Code. Five-year ISIs are scheduled for the 5th, 15th, 25th, and 35th years of operation, and 10-year ISIs are performed in the 10th, 20th, and 30th years. For economic reasons, many of these activities are conducted simultaneously (e.g., refueling activities typically coincide with the ISI and maintenance activities).

Many plants also undertake various major refurbishment activities during their operational lives. These activities are performed to ensure both that the plant can be operated safely and that the capacity and reliability of the plant remain at acceptable levels. Typical major refurbishments that have occurred in the past include replacing PWR steam generators, reactor vessel heads, BWR recirculation piping, and rebuilding main steam turbine stages. The need to perform major refurbishments is plant-specific and depends on factors such as design features, operational history, and construction and fabrication details. The plants may remain out of service for extended periods of time (e.g., several months) while these major refurbishments are made. Outage durations vary considerably, depending on factors such as the scope of the repairs or modifications undertaken, the effectiveness of the outage planning, and the availability of replacement parts and components.

Each nuclear power plant may be part of a utility system that may own several nuclear power plants, fossil-fired plants, or other means of generating electricity. An onsite staff is responsible for the actual operation of each plant, and an offsite staff may be headquartered at the plant site or some other location. Typically, 800 to 2,300 people are employed at nuclear power plant sites during periods of normal operation, depending on the number of operating reactors located at a particular site. The permanent onsite workforce is usually in the range of 600 to 800 people per reactor unit. However, during outage periods, the onsite workforce typically increases by 200 to 900 additional workers. The additional workers include engineering support staff, technicians, specialty crafts persons, and laborers called in both to perform specialized repairs, maintenance, tests, and inspections, and to assist the permanent staff with the more routine activities carried out during plant outages.

3.2 Land Use and Visual Resources

3.2.1 Land Use

Nuclear power plants are large industrial complexes with land requirements generally amounting to 100 to 125 ac (40 to 50 ha) for the reactor containment building, auxiliary buildings, cooling system structures, administration and training offices, and other facilities (e.g., switchyards, security facilities, and parking lots). Areas disturbed during construction of the power plant generally have been returned to prior uses or were ecologically restored when construction ended. Site areas range from 84 ac (34 ha) for the San Onofre plant in California to 14,000 ac (5,700 ha) for the Clinton plant in Illinois (Table 3.1-1). Almost 60 percent of plant sites encompass 500 to 2,000 ac (200 to 800 ha), with 28 site areas ranging from 500 to 1,000 ac (200 to 400 ha) and an additional 12 sites encompassing 1,000 to 2,000 ac (400 to 800 ha). Larger land areas are often associated with elaborate man-made closed-cycle cooling systems that include cooling lagoons, spray canals, reservoirs, artificial lakes, and buffer areas.

While many utilities use the land for the sole purpose of generating electricity, other utilities allow other uses for the land. Some sites lease land for agricultural and forestry production, promote their ecology nature centers and preservation areas, allow recreational use, and permit cemetery and historical site access. Most sites have closed their visitor centers as a result of security concerns after September 11, 2001. Sites have improved their security fencing, altered their landscaping to enhance visibility from the plant, reduced site access, and increased signage detailing site access and restrictions. Some sites have constructed onsite dry cask storage facilities for spent fuel.

The land cover and land use percentages at each site depend on the total site area and amount of land required for electricity generation. Land cover on sites is often designated within the land use “resource-oriented” classification system, which includes urban or built-up land, agricultural land (e.g., cropland, pasture, orchards, nurseries, fields, and fallow lands), rangeland, forest land, water, wetland (e.g., marshes and swamps), and barren land (e.g., beaches and gravel pits). Land cover designations at other sites use visually descriptive categories that include open areas (e.g., fields, cemeteries), forested areas, scrub forest, deciduous forest, hardwood forest, beach, wetlands, open water (e.g., ponds, streams, lakes, and canals), natural lands, recreational lands, and parking areas.

Land use within transmission line rights-of-way (ROWs) is both precluded and restricted under the easement rights acquired by the utility from private landowners or from local, State, or Federal governments. Land use within cleared ROWs often, but not always, differs from that in adjacent areas. Land cover within ROWs is managed through a variety of oversight and maintenance procedures so that vegetation growth and building construction do not interfere with power line operation and access. Land use within ROWs is limited to activities that do not endanger line operation and can include recreation, off-road vehicle use, grazing, agricultural cultivation, irrigation, recreation, roads, and environmental conservation and wildlife areas.

One of the siting criteria for nuclear power plant sites was access to rail or water transport so that rail or barge deliveries of reactor vessels and other large operating equipment could be received. The rail spurs and barge docking facilities still remain at many sites and are used occasionally. Because of the large number of workers commuting daily to and from the site, a quality road network connecting the site to urban locations was and continues to be essential.

Information on land cover within 5 mi (8 km) of commercial nuclear power plants is summarized in Table 3.2-1. The land cover types in the vicinity of each plant site are presented in Appendix C. For all NRC regions, most of the cover near plants is undeveloped or agricultural land, or open water. There are differences in land use and land cover in the four NRC regions. In Region I (Northeast) and Region II (Southeast), more than two-thirds of the area surrounding most plants is open water, forest, and wetlands. Region III (northern Midwest) plants are mostly surrounded (80 percent) by agricultural land, open water, and forests. In Region IV (West and Southern Midwest), plants are surrounded (77 percent) by agricultural land, shrub/scrub land, forests, herbaceous cover, and wetland.

Section 307(c)(3)(A) of the Coastal Zone Management Act of 1972 (16 USC 1456) requires that license renewal applicants certify that the proposed Federal license renewal in a coastal zone or coastal watershed boundary, as defined by each State participating in the National Coastal Zone Management Program, is consistent with the enforceable policies of that State's Coastal Zone Management Program. States define their coastal zone boundaries by using a variety of parameters, such as the entire State, county or county-equivalent boundaries, political features (e.g., town boundaries), and geographic features (adjacency to tidal waters). Applicants must coordinate with the State agency that manages the State Coastal Zone Management Program

Table 3.2-1. Land Cover within a 5-Mile Radius of U.S. Commercial Nuclear Power Plants

	Percent of Land Cover Type in NRC Region				
Land Cover Classes	**Region I**	**Region II**	**Region III**	**Region IV**	**Overall**
Open water	31.7	20.6	24.6	14.9	23.0
Undeveloped land					
Barren land	0.7	0.7	0.3	0.3	0.5
Forest (deciduous, evergreen, and mixed)	30.6	35.9	14.6	13.3	23.6
Wetlands	8.4	13.4	5.9	10.3	9.5
Herbaceous	0.3	5.4	3.7	11.5	5.2
Shrub/scrub	0.8	2.3	0.2	18.3	5.4
Total undeveloped land	40.8	57.7	24.7	53.7	44.2
Developed land					
Agriculture (cultivated crops and hay/pasture)	15.6	14.2	40.4	23.7	23.5
Developed open space	5.2	4.9	5.0	3.6	4.7
Low- to high-density developed land	6.7	2.7	5.2	4.0	4.7
Total developed land	27.5	21.8	50.6	31.3	32.9
Total	100	100	100	100	100

Source: USGS 2007

to obtain a determination that the proposed nuclear plant license renewal would be consistent with their program.

The population densities in the vicinity of nuclear plants and the distances of plants from a medium- or large-sized metropolitan center vary among sites. Most sites are not very remote (i.e., they are not more than about 20 mi (32 km) from a community of 25,000 people or 50 mi (80 km) from a community of 100,000 people). During the period from 1960 to 1980, with utility and local government activities actively encouraging growth (Metz 1983), commercial, industrial, recreational, and industrial land uses tended to expand in the 10-mi (16-km) radius around nuclear plants at the expense of agriculture. New major highways, expanded municipal services, proximity to major urban areas, recreation facilities, and low taxes are indirect factors that promoted population and industrial growth. In some instances, the roads and water lines built for plant purposes encouraged area growth because they were available for other users. In many communities, recent changes in the legislation and tax codes on electricity generation in several States have resulted in significant reductions in the tax revenue stream from nuclear power plants.

Some form of land use control exists in nearly every local jurisdiction that adopted a comprehensive land use or master plan to control residential and commercial developments and preserve shrinking agriculture areas.

For example, some communities enacted laws to specifically regulate land use density around nuclear power plants (e.g., in recognition of natural resources, infrastructure constraints, or the population's generally anti-growth attitude since the 1940s). An inadvertent buffering of the Crystal River plant in Florida was caused by the host county's industrial zoning around two contiguous large coal-fired power plants that excluded residential development.

The residential settlement patterns of nuclear power plant workers are well established. Area population-driven and tax-driven indirect impacts on land use development have occurred in local jurisdictions and service districts that receive tax payments from the owners of the nuclear power plant. The manner in which offsite land use has changed during plant operations has been directly related to the influence of tax payments to the communities' total tax revenue and the controls and plans approved and enacted to steer and manage growth and land use changes. A case study of land use changes that resulted from the operation of seven nuclear power plants that was conducted for the 1996 GEIS determined that impacts were SMALL at two sites, MODERATE at four sites, and significant at one site depending on the local jurisdiction's ability to provide the public services necessary to support substantial industrial development. Impacts at the Wolf Creek plant in Kansas were determined to be potentially significant if the plant was shut down. Property tax payments allowed host Coffey County to lower its property taxes and upgrade its provision of municipal services as well as purchase industrial buildings and machinery. The county was able to lease them back at a discount on a lease-purchase basis, thereby successfully encouraging industrial and commercial development in the area (NRC 1996).

3.2.2 Visual Resources

Aesthetic resources are related to physical elements that represent pleasing sensory stimuli and include natural and man-made landscapes and the ways in which the two are integrated. Nuclear power plants—particularly those with natural draft cooling towers—stand out from their backgrounds. Their site features (Section 3.1.1) are often visible from neighborhoods, roads, and recreation-based water bodies over a wide area. While plant structures can be visible from as far away as 10 mi (16 km), most structures are typically partially obscured because of the large size (distance) of the site and by changes in site topography, buildings next to the site, and vegetation. Cooling towers at a site can draw attention to the plant's existence because vapor plumes can rise more than 5,000 ft (1,500 m) above the towers and can extend as much as 9 mi (14 km) downwind. These plumes, although visible only under certain meteorological and seasonal conditions, extend the plant-related viewshed considerably beyond that of a tower alone.

During the current operating license term, most nuclear power plants have employed a variety of mitigation measures to decrease the visual intrusion of plant structures, including the choice of exterior cladding and paint colors to blend with surroundings, use of nonreflective surfaces, strategic placement of tree plantings and landscaping, and structure placement. In some instances, as a result of security requirements, landscaping was reduced and exterior lighting was increased. Federal regulations require that tall structures, including reactor containment buildings, cooling towers, stacks, and meteorological towers, be fitted with arrays of lights to alert aircraft pilots of their presence. Often these structures can be visible for miles away, depending on the amount of topographic and vegetation screening.

Because nuclear power plants are frequently sited near water bodies, views of the facilities and their associated transmission lines often intrude into recreational, historic, or scenic areas. To date, most of the visual impact from transmission lines has been associated with crossings of rivers, wetlands, wildlife areas, roads, lakes, cemeteries, and battlefields. Various design, engineering, siting, construction, and metallic surface treatments have been used to mitigate these conflicts.

3.3 Meteorology, Air Quality, and Noise

3.3.1 Meteorology and Climatology

The NRC requires that basic meteorological information be available for use in assessing (1) the environmental effects of radiological and nonradiological emissions and effluents resulting from the construction or operation of a nuclear power plant and (2) the benefits of design alternatives. All nuclear power plants in the United States have a required onsite meteorological monitoring program to provide the data needed to determine dispersion conditions in the vicinity of the plant for assessment of safety and environmental factors. These data are used with air dispersion models to assess and protect public health, safety, and property during plant operations (NRC 2007b).

The most recent update to NRC Regulatory Guide 1.23, which covers meteorological monitoring programs for nuclear power plants, provides new guidance for onsite meteorological measurements at stationary licensed power reactors. The guidance covers the siting of instruments to provide representative measures at plant sites, the accuracy and range of specified measured parameters, and special considerations for plants located near influences of complex terrain (e.g., coastal areas, hills of significant grade or valleys), among other criteria and specifications.

Onsite meteorological conditions at commercial nuclear power plants are monitored at primary fixed meteorological towers with instrumentation at two levels (e.g., 10 and 60 m), and, if necessary, one additional higher level on the tower to better represent dispersion of elevated releases from stacks. A secondary onsite tower is typical at many installations as a backup if primary tower measures fail. Basic meteorological measurements from tower instruments at these levels include: (1) wind speed and direction from at least two levels, (2) temperature for an ambient reading at 33 ft (10 m) and to determine deltas or change with height and (3) precipitation, which is typically measured near ground level by the tower base. Supplemental measures can include moisture at 33 ft (10 m), and, if applicable, incoming solar and net radiation, barometric pressure, soil temperature, and moisture at the top of the cooling tower. Atmospheric stability is determined from temperature differences at the two lowest levels on the tower. If a backup tower is present, measurements include wind speed and direction and horizontal wind direction variation, usually taken at one level.

Weather conditions at each of the plants can be quite variable depending on the year, season, time of day, and site-specific conditions, such as whether the site is near coastal zones or located in or near terrain with complex features (e.g., steep slopes, ravines, valleys). These conditions can be generally described by climate zones according to average temperatures. On the basis of temperature alone, there are three major climate zones: polar, temperate, and tropical. Within each of the three major climate zones, there are marine and continental climates. Areas near an ocean or other large body of water have a marine climate. Areas located within a large landmass have a continental climate. Typically, areas with a marine climate receive more precipitation and have a more moderate climate. A continental climate has less precipitation and a greater range in climate. Regional or localized refinements in climate descriptions and assessments can be made by considering other important climate variables and climate-influencing geographic variables, such as precipitation, humidity, surface roughness, proximity to oceans or large lakes, soil moisture, albedo, snow cover, and associated linkages and feedback mechanisms. Localized microclimates can be defined by considering factors such as urban latent and sensible heat flux and building-generated turbulence. Both national and regional maximum and minimum average annual temperature and precipitation climatologies over the 30 years from 1971 through 2000 are summarized in Section D.2 in Appendix D.

The intensities of historical tornado events are recorded and archived by the National Climatic Data Center (NCDC) (NOAA 2007). Table 3.3-1 provides the current enhanced Fujita (EF) scale next to the original Fujita (F) scale, adjusted to represent peak winds averaged over

Table 3.3-1. Fujita Tornado Intensity Scale

Intensity	Description of Damage	Original Fujita Scale (3-s gust) (mph)	Operational Enhanced Fujita Scale (3-s gust) (mph)
F0/EF0	Light	45 to 78	65 to 85
F1/EF1	Moderate	79 to 117	86 to 110
F2/EF2	Considerable	118 to 161	111 to 135
F3/EF3	Severe	162 to 209	136 to 165
F4/EF4	Devastating	210 to 261	166 to 200
F5/EF5	Incredible	262 to 31	>200

Source: Texas Tech University 2006

3 seconds, which are used to identify a tornado event's intensity. The number of recorded tornado events or strikes having intensities greater than or equal to EF2 (wind speeds ranging from 111 to 135 miles per hour or mph [50 to 60 m/s], with 3-second gusts, EF scale) in the three regions (Western, Central, and Eastern) of the continental United States over approximately the last 50 years (1950 through August 2003) are shown in Figure 3.3-1. The size of each square in the figure is 1 degree of latitude per side and represents an area of approximately 5000 mi^2. The EF scale (Texas Tech University 2006) is based on the highest wind speed estimated in the tornado path with maximum 3-second average wind gusts within the range specified for each EF intensity level. The range in damage to structures in the EF2 through EF5 range is described as considerable to incredible, and the damage depends highly on the building's structural design. Computer programs were used to analyze NCDC data, and tornado strike probabilities were estimated for the three U.S. regions: Western, Central, and Eastern (NRC 2006a). The expected value structure strike probabilities were estimated to range from 1.7 chances of a strike in 100,000 tornado events in the Western region to 35.8 chances in 100,000 in the Central region. Figure 3.3-2 provides estimates of the expected maximum tornado wind speeds with a 1 in 100,000 chance of occurrence. Approximately 48 percent of the rated licensed reactor capacity is located in the Eastern region, 41 percent is in the Central region, and 11 percent is in the Western region.

Within the context of the normal variations in weather, including severe weather, NRC recognizes the implications of global climate change as affected by the contribution of man-made greenhouse gas (GHG) emissions. Based on findings to date published by the Intergovernmental Panel on Climate Change (IPCC), impacts from warming of the climate system include expansion of sea water volume; decreases in mountain glaciers and snow cover

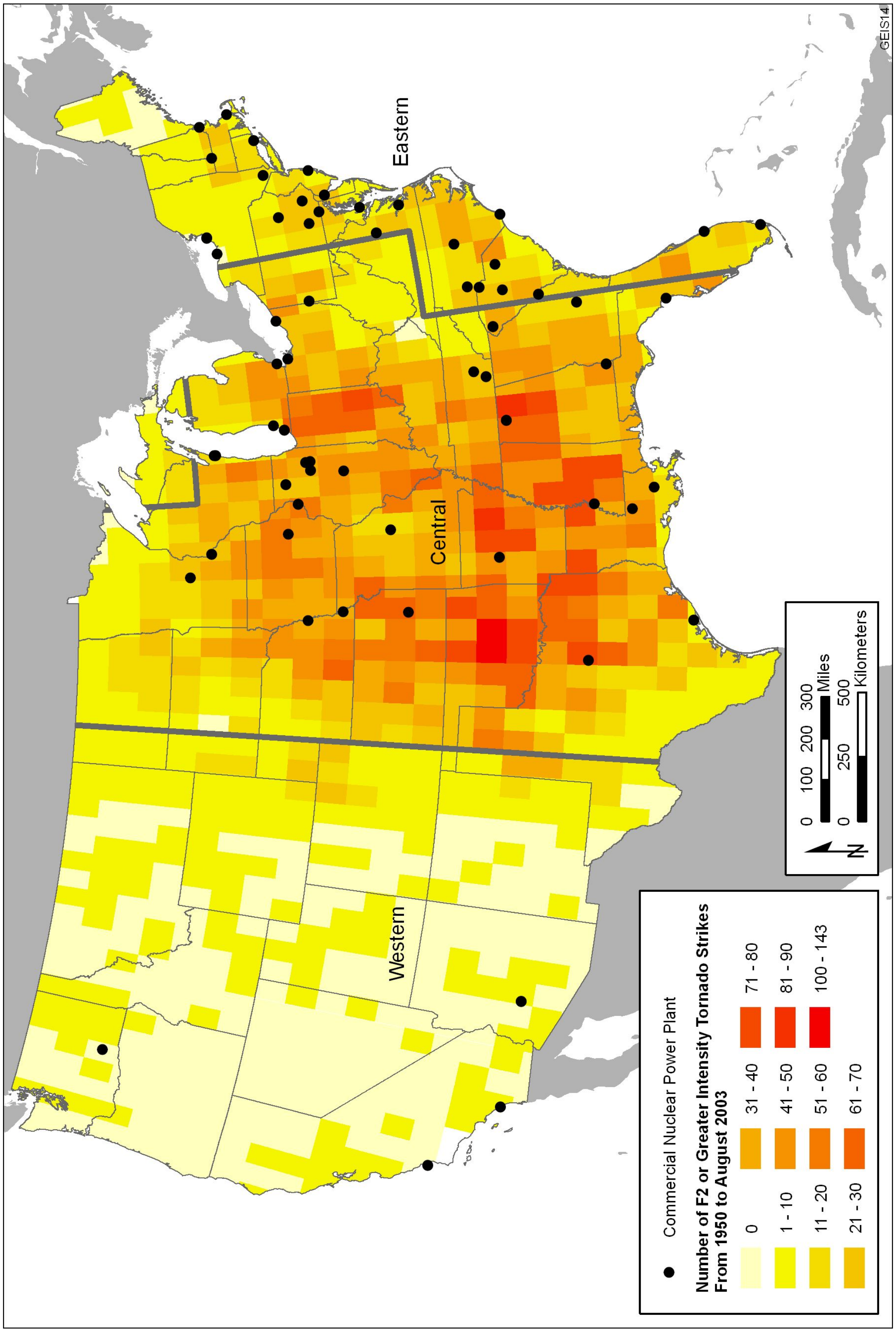

Figure 3.3-1. Distribution of Tornado Strikes with Intensities of F2 or More over the Contiguous United States by One Degree of Latitude and Longitude Boxes (1950 through August 2003) (Adapted from Figure 2-2 in NRC 2006a)

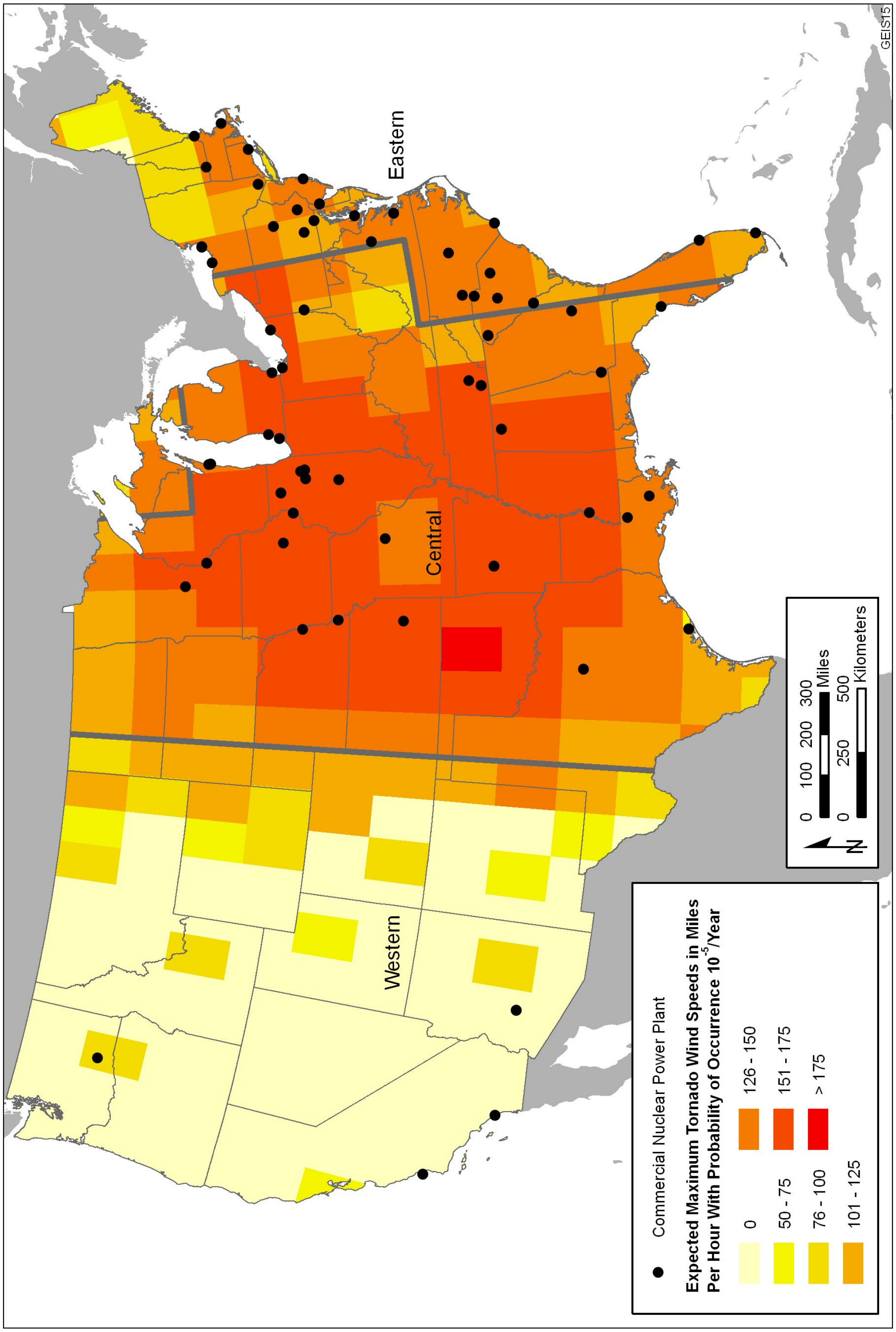

Figure 3.3-2. Expected Maximum Tornado Wind Speed with a Probability of One in 100,000 of Occurring over the Contiguous United States by Two Degrees of Latitude and Longitude Boxes (Adapted from Figure 5-8 in NRC 2006a)

resulting in sea level rise; changes in arctic temperatures and ice; changes in precipitation, ocean salinity, and wind patterns; and changes in extreme weather (IPCC 2007).

Consistent with the IPCC, the U.S. Global Change Research Program (USGCRP) has concluded that warming of the climate is unmistakable and is due primarily to human-induced emissions of heat-trapping gases. As summarized by the USGCRP, climate-related changes have already been observed globally and in the continental United States. These include increases in air and water temperatures, reduced frost days, increased frequency and intensity of heavy downpours, a rise in sea level, and reduced snow and ice cover. A longer ice-free period on lakes and rivers, lengthening of the growing season, and increased water vapor in the atmosphere have also been observed. Over the past 30 years, temperatures have risen faster in winter than in any other season, with average winter temperatures in the Midwest and northern Great Plains increasing more than 7ºF (3.9ºC). Temperatures are projected to rise more in the future. In the Northeast, the annual average temperature has increased by 2°F (1.1ºC), with winter temperatures rising twice this much. In the Southeast, average temperatures have increased by 1.6ºF (0.9ºC) while annual precipitation has declined by about 8 percent. Regionally-averaged temperatures across the Northwest have risen by about 1.5°F (0.8ºC) over the past century, but with some areas experiencing increases up to 4°F (2.2 ºC). Average temperatures across the Southwest have risen by about 1.5°F (0.8ºC) in the last 30 years alone. Nationally, annual precipitation has increased by about 5 percent over the past 50 years, but with a broad decline in precipitation across the Southeast and in parts of the Northwest and Southwest, and observed changes in precipitation patterns elsewhere. Projections of future precipitation generally indicate that northern areas will become wetter, and southern areas, particularly in the West, will become drier. For coastal areas in particular, likely climate implications include more intense hurricanes with related increases in wind, rain, and storm surges. Taken together, these changes will nationally affect human health, water supply, agriculture, coastal areas, and many other aspects of society and the natural environment (USGCRP 2009).

The contribution of nuclear power plant operations to GHG emissions are discussed in Section 3.3.2 below.

3.3.2 Air Quality

Air emissions related to criteria air pollutants and volatile organic compounds (VOCs) (a precursor of ozone [O_3]) are released to the atmosphere from ancillary non-nuclear facilities at nuclear power plants. These emissions include criteria air pollutants such as particulate matter (PM) with a mean aerodynamic diameter of 10 μm or less (PM_{10}), PM with a mean aerodynamic diameter of 2.5 µm or less ($PM_{2.5}$), sulfur dioxide (SO_2), nitrogen oxides (NO_x),[b] carbon monoxide (CO), and lead (Pb), and VOCs.

The facilities that contribute emissions include backup diesel generators, boilers, fire pump engines, and cooling towers. The emissions from these facilities (and, if applicable, emissions from the incineration of any waste products) must comply with State and local regulatory air quality permitting requirements. Because nuclear power plant ancillary facilities are generally low emitters of criteria air pollutants and VOCs, the impact on potential ambient air quality is minimal. However, special permit conditions may be applicable under various regulatory jurisdictions for facilities located in EPA-designated nonattainment areas.

The EPA has set National Ambient Air Quality Standards (NAAQS) for six criteria pollutants, including SO_2, nitrogen dioxide (NO_2), CO, O_3, PM_{10}, and $PM_{2.5}$, and Pb, as shown in Table 3.3-2. Primary NAAQS specify maximum ambient (outdoor air) concentration levels of the criteria pollutants with the aim of protecting public health with an adequate margin of safety. Secondary NAAQS specify maximum concentration levels with the aim of protecting public welfare. The NAAQS specify different averaging times as well as maximum concentrations. Some of the NAAQS for averaging times of 24 hours or less allow the standard values to be exceeded a limited number of times per year, and others specify other procedures for determining compliance. States can have their own State Ambient Air Quality Standards (SAAQS). SAAQS must be at least as stringent as the NAAQS and can include standards for additional pollutants. If a State has no standard corresponding to one of the NAAQS, the NAAQS apply.

An area where criteria air pollutants exceed NAAQS levels is called a nonattainment area. Previous nonattainment areas where air quality has improved to meet the NAAQS are redesignated maintenance areas and are subject to an air quality maintenance plan.

The currently designated nonattainment areas (as of August 30, 2011)[c] for each criteria air pollutant (8-hour O_3, PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO, and Pb) and their relative locations with

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(b) NO_x is not a criteria pollutant, but emissions are typically reported in terms of NO_x. Nitrogen dioxide (NO_2) is the component of NO_x that is a criteria pollutant, but emissions of NO_2 are not typically reported.

(c) Nonattainment area designations are ever-changing and redesignations are expected due to EPA's recent standard revisions for PM_{10} and $PM_{2.5}$ (effective December 18, 2006), 8-hour O_3 (effective May 27, 2008), Pb (effective January 12, 2009),1-hour SO_2 (Effective August 23, 2010), and 1-hour NO_2 (effective April 12, 2010). Please refer to the latest EPA Green Book for the most updated nonattainment and maintenance area designations (Available URL: http://www.epa.gov/oaqps001/greenbk/).

Table 3.3-2. National Ambient Air Quality Standards (NAAQS)

Pollutant[a]	Averaging Time	NAAQS[b] Value	NAAQS[b] Type[c]
SO_2	1-hour	75 ppb	P
	3-hour	0.5 ppm	S
NO_2	1-hour	100 ppb	P
	Annual	0.053 ppm (53 ppb)	P, S
CO	1-hour	35 ppm	P
	8-hour	9 ppm	P
O_3	8-hour	0.075 ppm	P, S
PM_{10}	24-hour	150 µg/m^3	P, S
$PM_{2.5}$	24-hour	35 µg/m^3	P, S
	Annual	15 µg/m^3	P, S
Pb	Rolling 3-month	0.15 µg/m^3	P, S

(a) Notation: CO = carbon monoxide; NO_2 = nitrogen dioxide; O_3 = ozone; Pb =lead; $PM_{2.5}$ = particulate matter ≤ 2.5 µm; PM_{10} = particulate matter ≤ 10 µm; and SO_2 = sulfur dioxide.
(b) Refer to 40 CFR Part 50 or EPA (2011c) for detailed information on attainment determination and reference method for monitoring.
(c) P = Primary standard whose limits were set to protect public health; S= Secondary standard whose limits were set to protect public welfare.
Source: EPA 2011c

respect to operating nuclear power plants are shown on the maps in Figures 3.3-3 through 3.3-9. There are currently more than 30 operating plants located within or adjacent to counties with designated nonattainment areas.

The operation of wet cooling towers results in the emission of salt and other inorganic and/or organic particles to the air. These releases are called drift emissions. Salt is the dominant drift component—being typically greater than 70 percent of the total suspended PM released—for coastal plants with wet towers that use seawater as the coolant. Drift emissions from cooling towers are also associated with deposits on downwind surfaces (e.g., vegetation, automobiles, and structures), known as drift deposition, and a resulting increase in downwind PM concentrations. The magnitude and pattern of these impacts could include both near-field and far-field receptors. The degree of impacts would depend on a number of factors, such as the size of the particles, the steam condenser flow rate or throughput, and the type and height of the cooling tower.

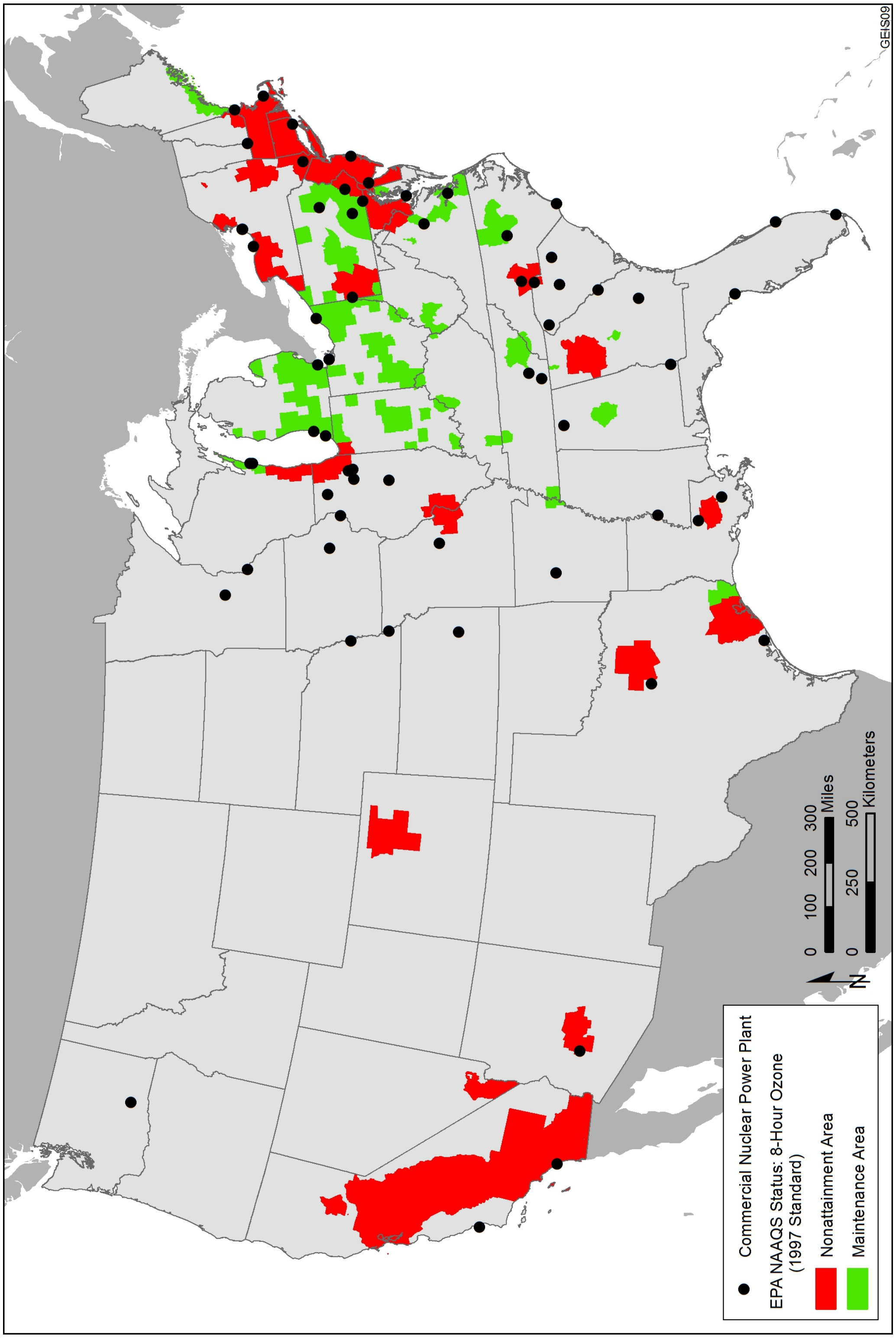

Figure 3.3-3. Locations of Operating Nuclear Plants Relative to EPA-Designated 8-Hour Ozone Nonattainment and Maintenance Areas, as of August 30, 2011 (Adapted from EPA 2011b)

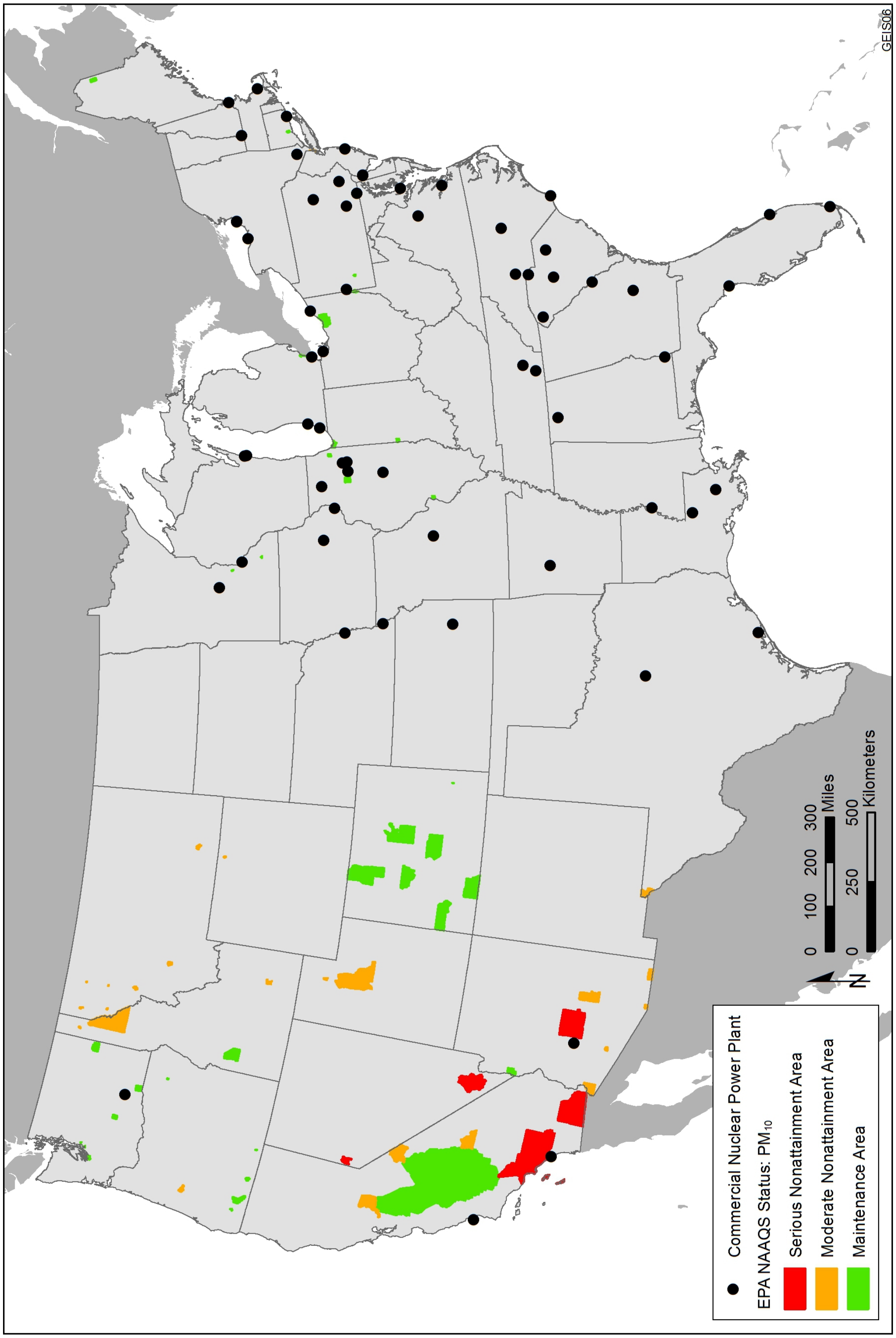

Figure 3.3-4. Locations of Operating Nuclear Plants Relative to EPA-Designated PM_{10} Nonattainment and Maintenance Areas, as of August 30, 2011 (Adapted from EPA 2011b)

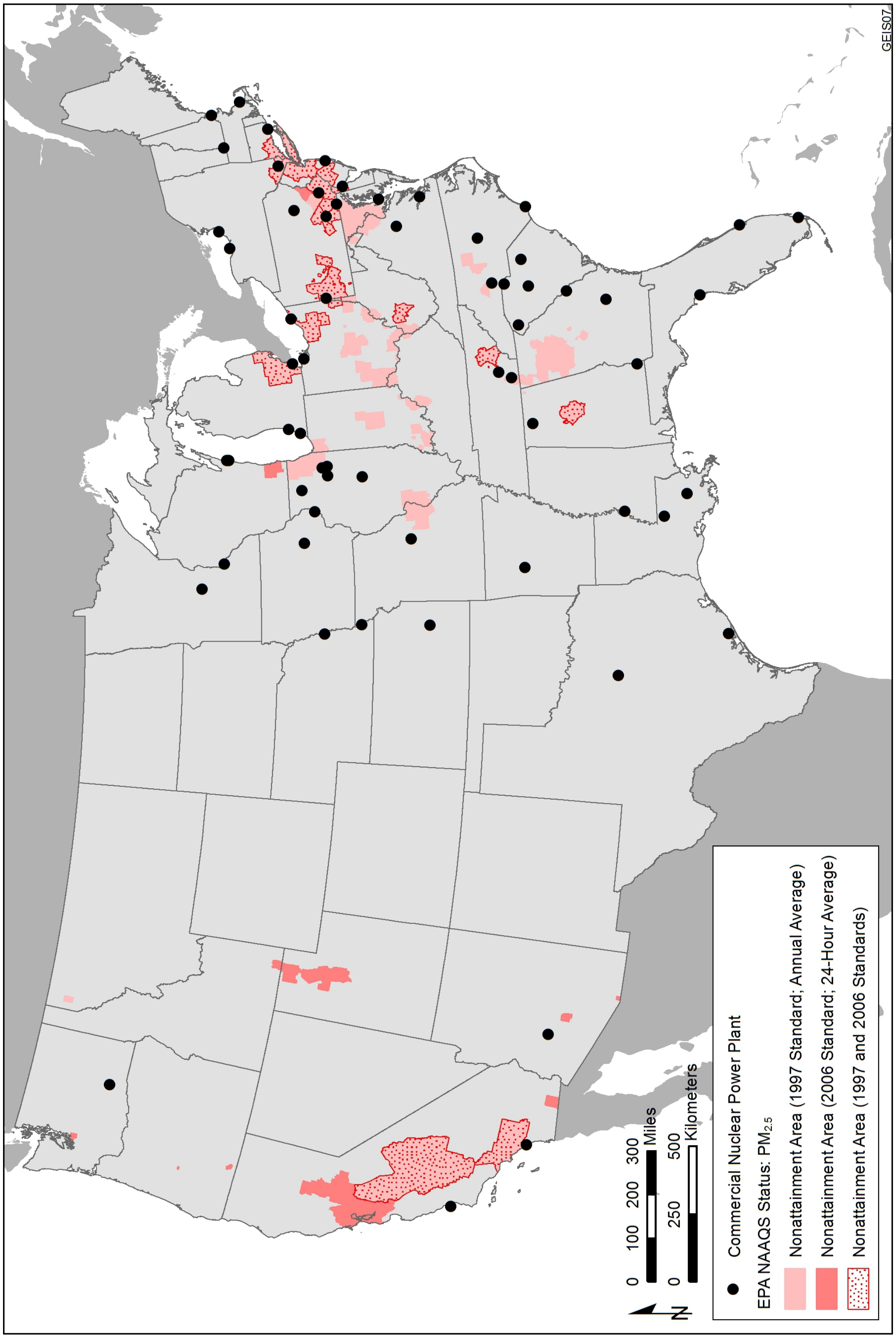

Figure 3.3-5. Locations of Operating Nuclear Plants Relative to EPA-Designated $PM_{2.5}$ Nonattainment Areas, as of August 30, 2011 (Adapted from EPA 2011b)

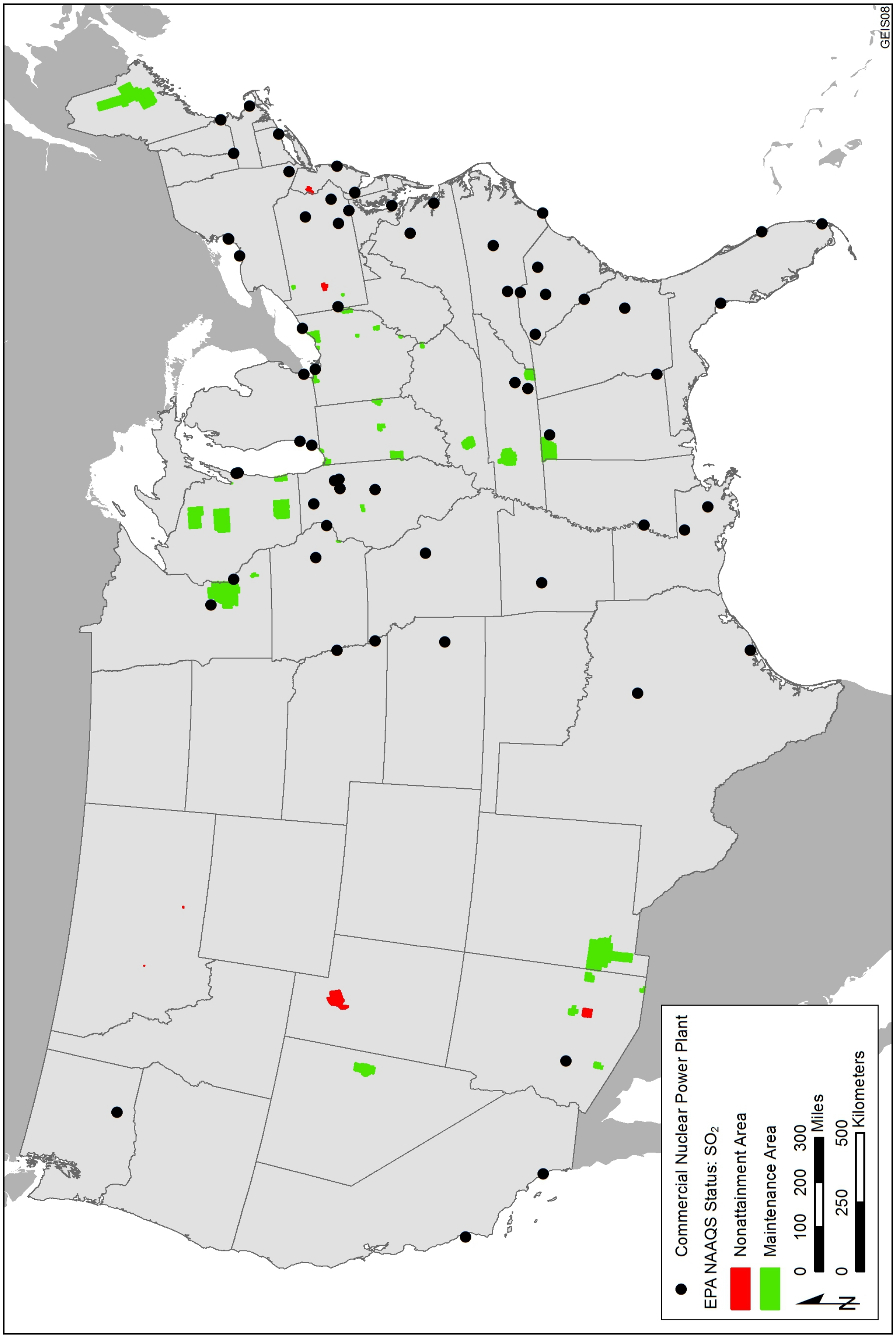

Figure 3.3-6. Locations of Operating Nuclear Plants Relative to EPA-Designated SO_2 Nonattainment and Maintenance Areas, as of August 30, 2011 (Adapted from EPA 2011b)

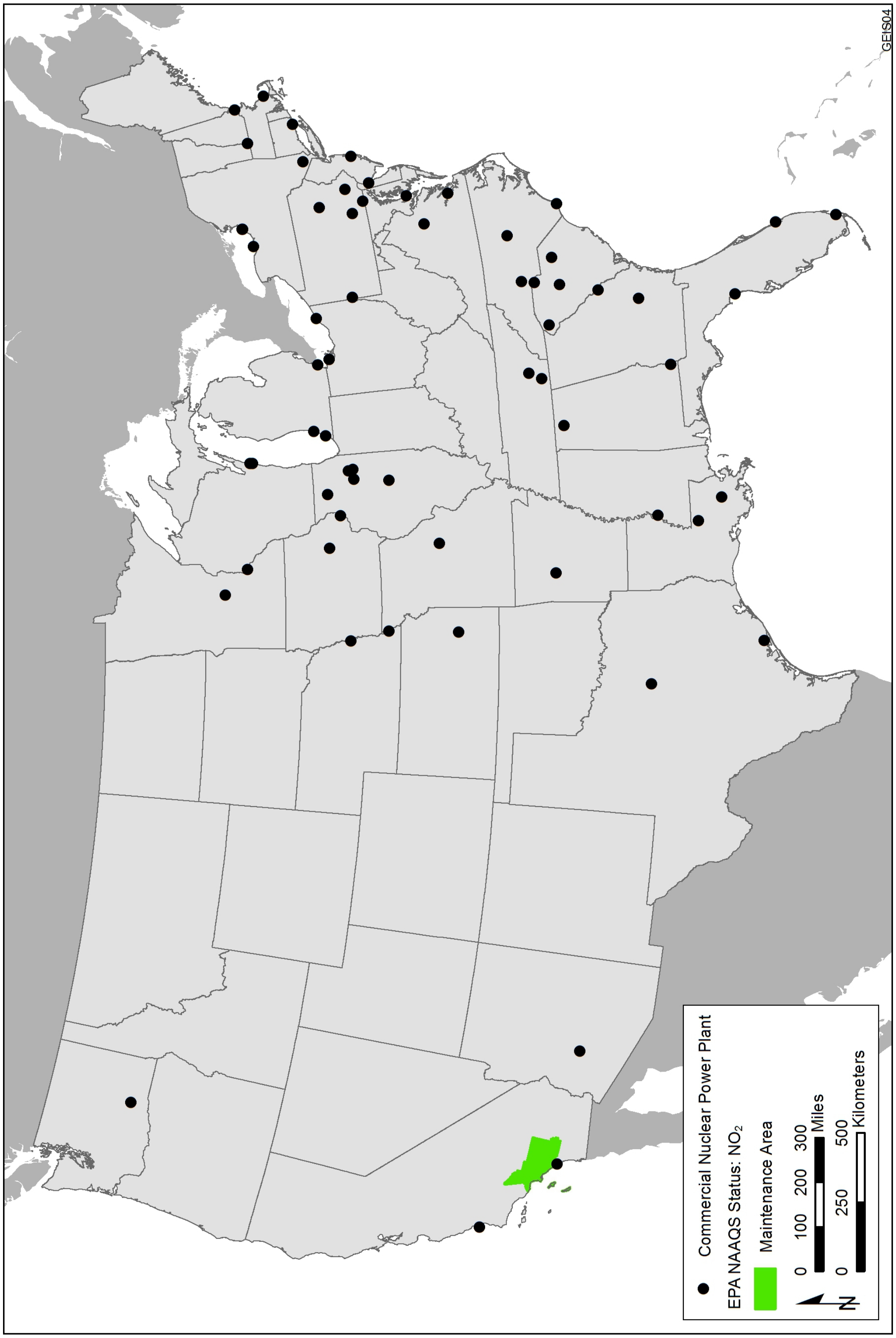

Figure 3.3-7. Locations of Operating Nuclear Plants Relative to EPA-Designated NO_2 Nonattainment and Maintenance Areas, as of August 30, 2011 (Adapted from EPA 2011b) (Note: There are currently no nonattainment areas for NO_2 in the United States.)

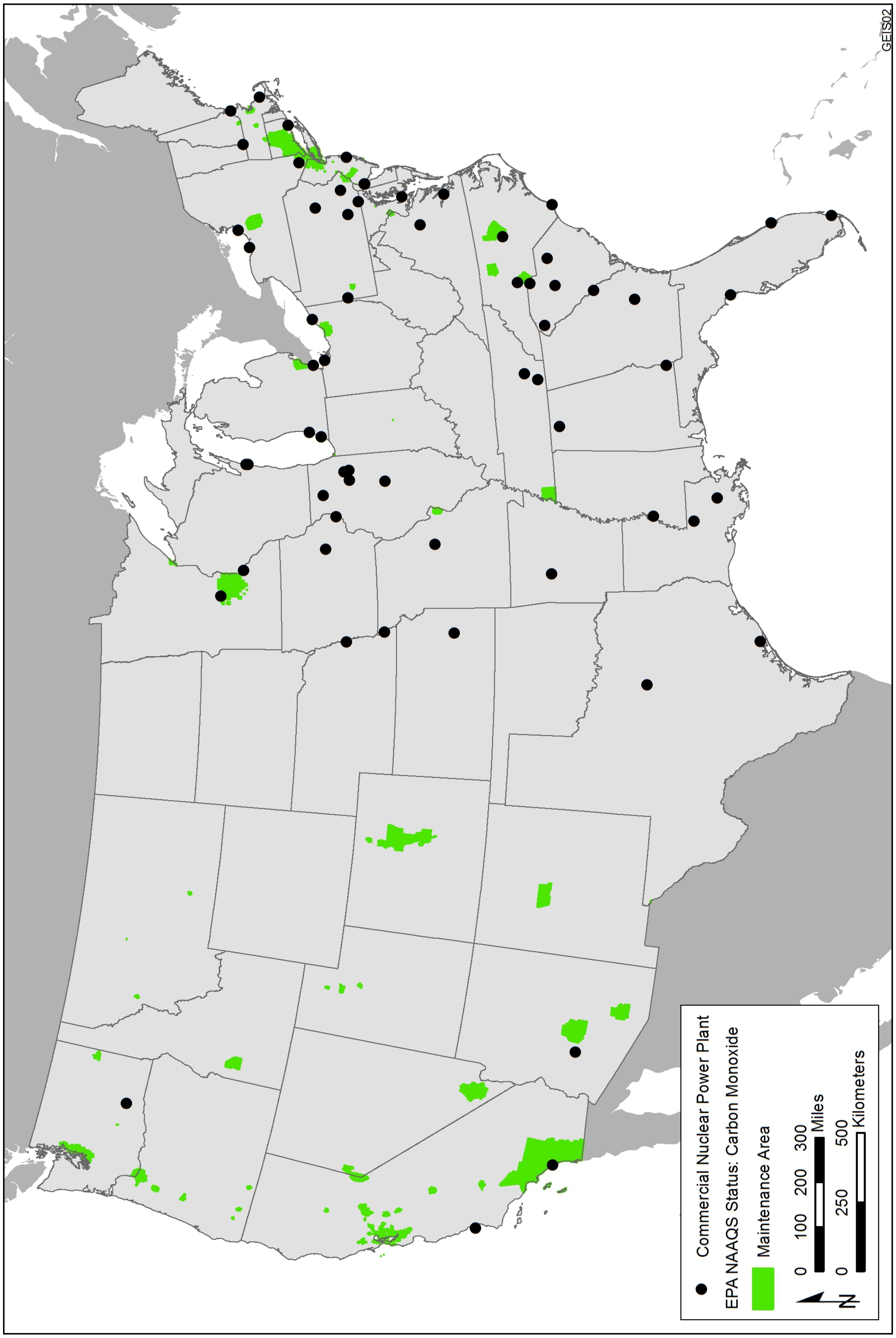

Figure 3.3-8. Locations of Operating Nuclear Plants Relative to EPA-Designated CO Nonattainment and Maintenance Areas, as of August 30, 2011 (Adapted from EPA 2011b) (Note: There are currently no nonattainment areas for CO in the United States.)

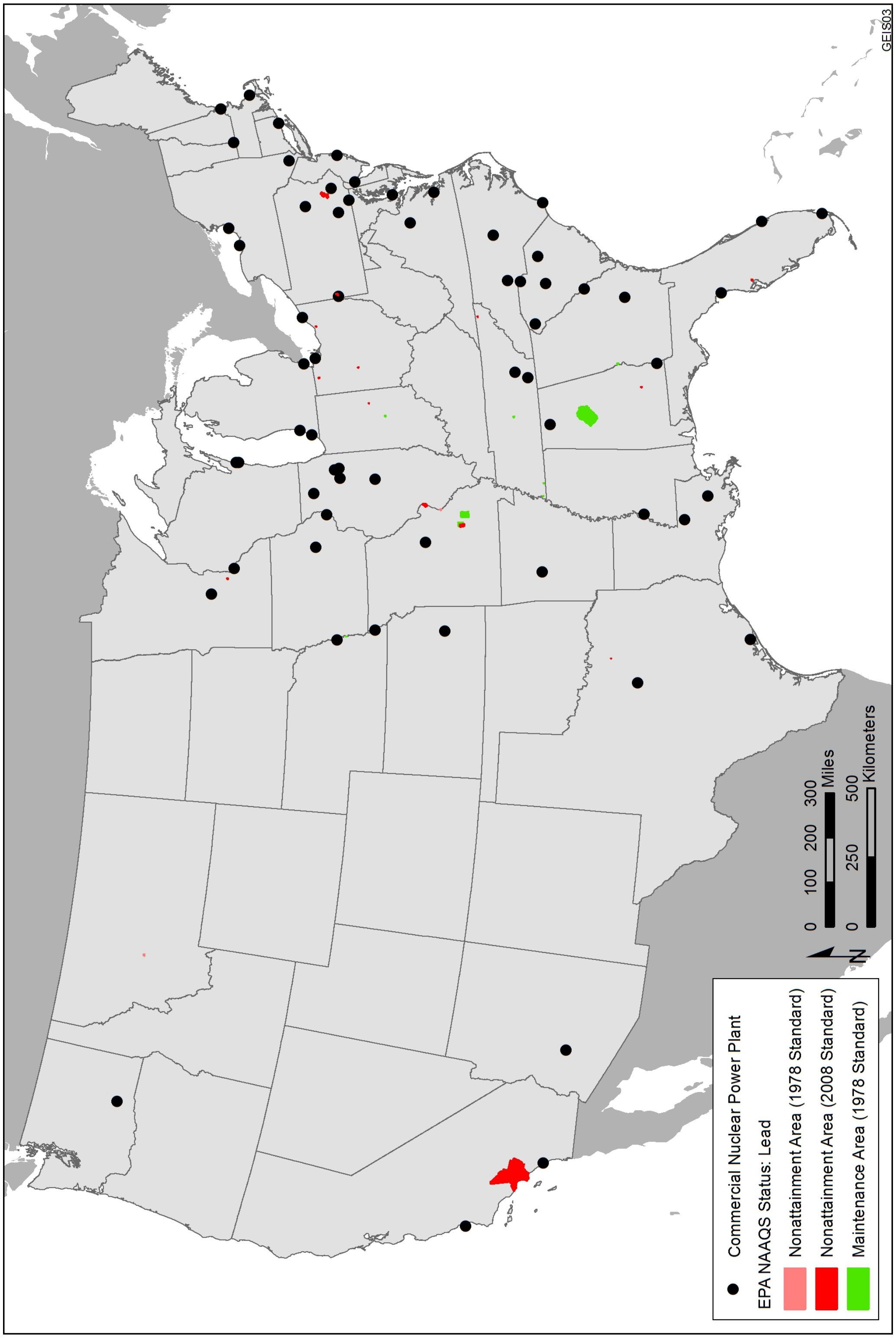

Figure 3.3-9. Locations of Operating Nuclear Plants Relative to EPA-Designated Pb Nonattainment and Maintenance Areas, as of August 30, 2011 (Adapted from EPA 2011b)

Cooling tower particulate emissions are formed entirely as secondary particles from evaporation of wet tower drift droplet releases to the atmosphere. Because the drift droplets generally contain the same chemical impurities (primarily dissolved solids) as those in the cooling water circulating through the tower, these impurities wind up in the drift that escapes the tower. Large drift droplets settle out of the tower's exhaust air stream and are deposited on surfaces near the tower. This process can lead to wetting, icing, and salt deposition and can cause related problems, such as damage to equipment or vegetation. Other drift droplets may evaporate and form mixed chemical particles from water-soluble materials (total dissolved solids or TDS), such as sea salt, and water-insoluble (total suspended solids or TSS) droplet-encapsulated particles (Pruppacher and Klett 1980) that are transported in the air as suspended PM before being deposited on surfaces downwind. Both PM_{10} and $PM_{2.5}$ are generated when the drift droplets evaporate and leave fine PM formed by the crystallization of dissolved solids. Dissolved solids found in cooling tower drift can consist of salt compounds (e.g., sodium chloride [NaCl], sodium nitrate [$NaNO_3$], ammonium sulfate [$(NH_4)_2SO_4$] and other mineral matter, corrosion inhibitors, and biocides.

The magnitude of drift-related PM_{10} and $PM_{2.5}$ emissions from wet towers depends on several conditions and parameters, such as the makeup water composition, concentrations of TDS (organic matter, biocides, corrosion inhibitors, sodium chloride), steam condenser flow rate, drift eliminator efficiency, number of cooling towers/cells, and annual hours of operation. In comparison, drift emissions from cooling tower systems using seawater are over 7 times greater than those from systems supplied with freshwater makeup feeds, if everything else is held constant. However, one plant (Palo Verde in Arizona) uses makeup water derived from the Phoenix City Sewage Treatment Plant. Reported emission data indicate that wastewater treatment at this facility is good. The associated drift emissions from the six mechanical draft cooling towers at the Palo Verde plant are estimated at 7.7 and 6.4 lb/hr (3.5 and 2.9 kg/hr) for PM_{10} and $PM_{2.5}$, respectively (MCAQD 2006). These emissions are relatively small and typical for a well-controlled cooling tower using a water supply with low TDS concentration levels. Palo Verde's cooling tower operates in compliance with operating permit conditions issued by the Maricopa County Air Quality Department and is located in neither a PM_{10} nor $PM_{2.5}$ nonattainment area.

There is only one plant, Hope Creek in New Jersey, that uses high-salinity water (from the Delaware River Estuary) as the reactor coolant in a natural draft cooling tower. On the basis of recent air quality modeling conducted in support of an extended power uprate from about 3,300 to about 3,800 megawatts-thermal (MWt), the analysis of drift emissions and air impacts from Hope Creek's natural draft cooling tower was assessed (NRC 2007b). The analysis showed that the upgrade would increase the particulate cooling tower drift emissions from the current rate of 29.4 lb/hr (13.3 kg/hr) to an average rate of 35.6 lb/hr (16.1 kg/hr, with a maximum of 42.0 lb/hr [19.1 kg/hr]). Particulates (primarily salts) from the cooling tower are primarily PM_{10}. Although smaller suspended drift particles would also likely be generated from evaporation of cooling tower plume droplets, estimates of the size distribution of generated drift particles to determine the $PM_{2.5}$ fraction were not made. The NRC determined that the estimated increase in particulate emissions would exceed the New Jersey Department of Environmental Protection's (NJDEP's) regulatory maximum hourly emission limit of 30 lb/hr (13.6 kg/hr) for particulates (NJDEP 1998). However, the NJDEP's Bureau of Technical Services reviewed the air quality modeling conducted in support of the proposed power uprate and determined that the cooling tower emissions would not exceed the NAAQS for PM_{10} or New Jersey's Ambient Air Quality Standards for PM_{10}. On the basis of this determination, the NRC concluded that there would be no significant particulate emission impacts associated with the Hope Creek Plant's cooling tower at the associated higher makeup water throughput necessary to sustain the higher requested plant operating loads. On June 13, 2007, NJDEP issued its final Title V air permit for the Hope Creek cooling tower, authorizing a variance to the plant's air operating permit with an hourly emission rate of 42 lb/hr (19.1 kg/hr) (NJDEP 2007). In addition, a prevention of significant deterioration (PSD) applicability determination by the EPA concluded that the requested power uprate would not result in a significant increase in emissions and would not be subject to PSD review (NJDEP 2007). Further regulatory review was not required since the Hope Creek plant is located in an attainment area for PM_{10}.

Although there is the potential for some air quality impacts to occur as a result of equipment and cooling tower operations, even in the worst case situation (Hope Creek), the impacts would be considered small, at least in part because of the fact that licensees would be required to operate within State permit requirements.

Nuclear power plants also emit GHGs that contribute to climate change, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from fuel combustion. In general, GHGs are those gaseous constituents of the atmosphere, both natural and anthropogenic (man-made), that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapor (H_2O) and CO_2, N_2O, CH_4, and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely man-made GHGs in the atmosphere, including halocarbons and other chlorine- and bromine-containing substances (IPCC 2007).

However, total GHG emissions from nuclear power plants are typically very minor, because such plants, by their very nature, do not normally burn fossil fuels to generate electricity. As a result, for most plants, GHG emissions would be expected to fall below EPA's mandatory reporting threshold of 25,000 metric tons CO_2 equivalent per year (74 FR 56264), although comprehensive data in this regard for the entire fleet of 104 nuclear power plants is currently lacking.

Other GHG sources from nuclear power plants may include man-made fluorinated compounds. These include hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) contained in refrigerants and used in other industrial applications, and sulfur hexafluoride (SF_6). The present contribution of these gases to the total global effect of all man-made GHGs is small; however, because of their extremely long lifetimes, many of them will continue to accumulate in the atmosphere as long as emissions continue. In addition, many of these gases have a high global warming potential relative to CO_2, and the usage of HFCs has been growing rapidly in industrial applications since they are the primary substitutes for ozone-depleting substances (ODSs), which are being phased out under the Montreal Protocol on Substances that Deplete the Ozone Layer (EPA 2011a). Nevertheless, the gas SF_6 is particularly relevant to the nuclear power industry by virtue of its use in electric power transmission and distribution applications.

The largest use of SF_6 in the United States and worldwide is as a dielectric (insulating) gas and electrical interrupter in equipment that transmits and distributes electricity. This colorless, odorless gas has been employed by the electric power industry in the United States since the 1950s because of its dielectric strength and electric arc-quenching characteristics. It can be found in substations, circuit breakers, and other switchgear. The gas has replaced flammable insulating oils in many applications and allows for more compact substations. Fugitive emissions of SF_6 can escape from gas-insulated substations and switchgear through seals, especially from older equipment. The gas can also be released during equipment manufacturing, installation, servicing, and disposal (EPA 2011a). Further, SF_6 is the most potent greenhouse gas that has been studied, with a global warming potential of 23,900 times that of CO_2 over a 100-year time horizon. In addition, SF_6 has an extremely long atmospheric lifetime of about 3,200 years, resulting in irreversible accumulation in the atmosphere once emitted (IPCC 2007) (EPA 2011a).

Transmission lines have been associated with the production of minute amounts of O_3 and NO_x. These pollutants are associated with corona—the breakdown of air that is very near high-voltage conductors. Corona is a phenomenon associated with all energized transmission lines. Under certain conditions, the localized electric field near an energized conductor can be sufficiently concentrated to produce a tiny electric discharge that can ionize air close to the conductors (EPRI 1982). This partial discharge of electrical energy is called corona discharge, or corona. Corona is most noticeable for higher-voltage lines during rain or fog conditions. In addition to the small quantities of O_3 and NO_x that form, other manifestations of corona events include energy loss, interference with radio or television transmission, and ambient noise (see Section 3.3.3). Typically, corona interference with radio and television reception is not a design problem. Interference levels in both fair and rainy weather are extremely low at the ROW edge for 230-kV and lower transmission lines, and they usually meet or exceed the reception guidelines of the Federal Communications Commission (FCC). Through the years, line designs that greatly reduce corona effects have been developed. Because transmission line emissions associated with corona discharge are so small when compared with emissions from other sources of air pollution (e.g., ozone precursors from automobiles, power plants, and large industrial boilers), these emissions are not a regulated source of air pollution in the United States.

Airborne radiological releases during normal plant operation and associated doses to downwind populations are discussed in Section 3.9.

3.3.3 Noise

The principal sources of noise from nuclear power plant operations are natural draft and mechanical draft cooling towers, transformers, and loudspeakers. Other occasional noise sources may include auxiliary equipment (such as pumps to supply cooling water) and corona discharge. Generally, these plant noise sources are not perceived by a large number of people offsite because the level of noise from the surrounding community and highway is high (60 to 65 dBA) (FICN 1992). In rural or low-population areas, where background noise levels are in a range of 35 to 45 dBA, plant noises are more noticeable.

In most cases, the sources of noise are far enough away from sensitive receptors outside plant boundaries that the noise is attenuated to nearly ambient levels and is scarcely noticeable. However, during the original license application process, some sites identified sensitive receptors near plant boundaries that would experience noise greater than 10 dBA above ambient levels. Those levels would increase the difficulty in communicating by speech outdoors, requiring people to speak louder to be heard. In no case is the offsite noise level from a plant sufficient to cause hearing loss.

There are no Federal regulations for public exposures to noise. When noise levels are below the levels that result in hearing loss, impacts have been judged primarily in terms of adverse public reactions to noise. The Department of Housing and Urban Development (24 CFR 51.101(a)(8)) uses day-night average sound levels of 55 dBA, recommended by EPA as guidelines or goals for outdoors in residential areas (EPA 1974). However, noise levels are considered acceptable if the day-night average sound level outside a residence is less than 65 dBA.

Natural draft and mechanical draft cooling towers emit noise of a broadband nature, whereas transformers emit a humming noise of a specific tonal nature at twice the normal voltage or current cycle (core expansion and contraction twice its 60 Hz cycle) with a vibration or noise harmonic of 120 Hz. This is called the fundamental noise frequency. Transformer noise originates almost entirely in the reactor core as a result of the restrictive effects of steel on the generated magnetic field, a phenomenon called magnetostriction, which causes the core and its clamps to vibrate (Ellingson 1979). Since the core is not symmetrical and the magnetic effects do not behave in a simple way, the resultant noise is not pure in tone. This is the noise or vibration produced. The noise radiated by transformers is primarily composed of discrete tones at even harmonics of line frequency (e.g., 120, 240, 360 Hz) when the line frequency is 60 Hz (Vér and Beranek 2006).

Loudspeakers emit noise at audible frequencies, generally below 5,000 Hz. Because of the broadband character of the noise at cooling towers, the noise associated with the towers is less obtrusive and is largely indistinguishable from the noise from transformers or loudspeakers. Transformer noise is distinct because of its specific low frequencies. The low frequencies are not attenuated with distance and intervening materials as much as higher frequencies are; thus, low frequencies are more noticeable and obtrusive. However, at most sites employing cooling towers, transformer noise is masked by the broadband cooling tower noise.

Cooling tower and transformer noise from existing equipment does not change appreciably during the time when the plant is operating, nor does the crackling sound of transmission lines during storms. Increases or decreases in site noise levels can occur when equipment is upgraded or modified to meet life-cycle maintenance requirements or when the power level is uprated.

Transmission lines can generate a small amount of sound energy during corona activity. During corona events (see Section 3.3.2), the ionization of the air that surrounds conductors of the high-voltage transmission lines, which is caused by electrostatic fields in these lines, generates impulse corona currents. When the voltage on a particular phase is high enough, a corona burst occurs, and a noise is generated. This noise occurs primarily on the positive power line voltage wave and is referred to as positive corona noise (Maruvada 2000). Although conductors are designed to minimize corona discharges, surface irregularities caused by damage, insects, raindrops, or contamination may locally enhance the electric field strength enough for corona discharges to occur (D'Amore 1985). This audible noise from the line can barely be heard in fair weather on higher-voltage lines. During wet weather, water drops collect on the conductor and increase corona activity so that a crackling or humming sound may be heard near the line. This noise is caused by small electrical discharges from the water drops.

3.4 Geologic Environment

The geologic environment of a nuclear power plant site encompasses the physiographic or physical setting in which the plant has been constructed and the associated geologic strata and soils that comprise the site. Large-scale geologic hazards are a condition of the geologic environment and include geologic faulting and earthquakes that comprise a site's seismologic setting.

Nuclear power plants are located in a variety of physiographic provinces, though most nuclear plants are located in the Atlantic Coastal Plain and Central Lowlands provinces. Each physiographic province consists of a regional geologic terrain with a broadly similar structure and character. However, within each province, the local geology may differ significantly from the regional conditions. The geologic setting of each plant is therefore a site-specific function of the local geology rather than the physiographic province in which it is located. Plants are located in a wide variety of settings, including uplands along rivers, glaciated till plains, Great Lakes shorelines, and coastal sites. As a result, the geologic strata on which plants have been sited and constructed ranges from variably textured, interbedded, unconsolidated to semi-consolidated sediments of relatively recent age (i.e., less than 11,700 years before present), to thick sequences of sedimentary rock (e.g., sandstone, shale, siltstone) of varying age, to massive crystalline igneous and metamorphic rocks (e.g., granitic and gneissic rocks) as old as Precambrian (i.e., greater than 540 million years before present). All safety-related structures (e.g., seismic category 1 structures) at nuclear power plants are founded either on competent bedrock, engineered compacted strata, concrete fill, and/or structural backfill in order to ensure that no safety-related facilities are constructed in potentially unstable materials.

Soils across a plant site come from the disintegration of parent materials (i.e., bedrock or sediments) and interaction with the atmosphere and biological action, and can develop distinct horizons or layers with varying properties and uses. Soils and subsoils at nuclear plant sites vary in terms of their geotechnical properties, such as shear-strength, shrink-swell potential, cut-slope stability, and erodibility, relative to site construction projects and their hydraulic properties relative to the movement of infiltration, groundwater, and contaminants. Depending on the nuclear plant's location and design, riverbanks or coastlines may need to be protected to prevent erosion, especially at water intake or discharge structures.

The soil resources available at each power plant are site-specific in terms of their potential erodibility and their potential use for agricultural activities and vary spatially on the basis of the distribution of different soil types on the site. Many of the plants in the Midwest, Great Plains, East, and Southeast (with the exception of plants in Florida) are located in areas with soils that are designated prime farmland (USDA 2001). Prime farmland soil has the best combination of physical and chemical characteristics for growing crops and is potentially subject to the Farmland Protection Policy Act of 1981 (FPPA) (7 USC 4201 et seq.) and its implementing regulations (7 CFR Parts 657 and 658). Other important farmland soils potentially subject to the FPPA include unique farmlands as well as farmlands designated as having statewide or local importance. Farmland subject to FPPA regulation does not have to be currently used for cropland. It can be forest land, pastureland, cropland, or other land, but not water or urban built-up land. Nuclear plants in Florida and in Western States are generally not located near prime or other important farmland. At some nuclear plant sites (e.g., Cooper and Harris), undeveloped or restored portions of the nuclear plant site are leased for agricultural use including timber production. However, some land areas may not be available for leasing if they are within a nuclear plant's security zone.

The geologic resources in the vicinity of each nuclear plant, including rock, mineral, or energy rights and assets, vary with the location and may support extraction industries. These industries may include sand and gravel pit operations or quarrying for crushed stone. In general, there is little if any interaction between plant operations and local extraction industries, although some nuclear plants may purchase materials for landscaping and site construction from local sources. Commercial mining, or quarrying, or drilling operations are not allowed within site boundaries.

Another aspect of the geologic environment is the seismic setting. The NRC has well established design criteria and standards that are used as the basis for the construction of all commercial nuclear power plants in the United States. These include ensuring the ability to withstand environmental hazards, such as earthquakes and flooding, without loss of capacity to perform their safety functions. Specifically, the NRC requires that safety-related structures, systems, and components be designed to take into account the most severe natural phenomena historically reported for the site and surrounding area. With regard to earthquakes in particular, existing U.S. nuclear power plants were designed and built to withstand the ground-shaking level considered appropriate for its location, given the possible earthquake sources that may affect the site.

U.S. nuclear power plants were originally sited using geologic and seismic criteria set forth in 10 CFR 100.10(c)(1) and 10 CFR Part 100, Appendix A, and designed and constructed in accordance with 10 CFR Part 50, Appendix A. The regulations require that plant structures, systems, and components important to safety be designed to withstand the effects of natural phenomena, including earthquakes and other natural phenomena, without loss of capability to perform safety functions. Site-specific design bases for seismic protection are prescribed by a nuclear power plant's Final Safety Analysis Report/Updated Final Safety Analysis Report (FSAR/UFSAR) and by applicable technical specifications. Nuclear power plants licensed after January 10, 1997, are subject to the more rigorous geologic and seismic site acceptability and design criteria established in 10 CFR 100.20 and 100.23, and 10 CFR Part 50, Appendix S. Detailed investigations of the proposed site and regional geologic environment are required to include an analysis of all historic earthquakes with the potential to affect the nuclear power plant site and power plant operations. Locations for nuclear power plants are also evaluated for the presence of geologic faults including those considered to be capable of generating earthquakes, predicted earthquake ground motions in order to establish the plant's safe shutdown earthquake, the potential for the nuclear plant to be exposed to seismically induced floods and water waves, and characterization of the nature and behavior of the surficial geologic materials and subsurface materials and their engineering properties. In addition, spent fuel pools are designed with reinforced concrete so that they may remain operable through the largest historic earthquake that has or is expected to occur in the area.

The U.S. Geological Survey regularly updates its seismic hazard mapping products for the United States (see, for example, USGS 2011a,b). Currently, as measured in terms of predicted earthquake-produced peak horizontal ground accelerations with a 10 percent probability of exceedance in 50 years (i.e., corresponding to a return time of about 500 years), most nuclear power plants are located in seismically low-hazard areas, with peak accelerations of 0 to 10 percent of gravity. However, the two California plants—Diablo Canyon and San Onofre—are in locations with predicted peak ground acceleration of approximately 25 to 30 percent of gravity. These plants have been designed to safely withstand the seismic effects associated with earthquakes with epicenters at various locations and at various depths, magnitudes, and ground accelerations (AEC 1973; Southern California Edison 2007).

Moreover, the state of knowledge regarding geologic conditions and seismology and seismic hazards at nuclear power plant sites may have changed since construction. Although such discoveries are expected to be rare, new seismological conditions include the identification of previously unknown geologic faults. For example, a strike-slip fault was discovered approximately 1 km (0.6 mi) offshore of the Diablo Canyon Power Plant in 2009 (NRC 2009). Changes in potential seismic hazards are not within the scope of the license renewal environmental review, except, where appropriate, during the analysis of severe accident mitigation alternatives, because any such changes would not be the result of continued operation of the nuclear power plant. Seismic design issues are considered during site-specific safety reviews and, more specifically, are addressed on an ongoing basis through the reactor oversight process and other NRC safety programs, such as the Generic Issues Program, which are separate from the license renewal process. When new seismic hazard information becomes available, the NRC evaluates the new information, through the appropriate program, to determine if any changes are needed at one or more existing plants.

3.5 Water Resources

Water resources comprise all forms of surface water and groundwater occurring in the vicinity of nuclear power plants. Surface water encompasses all water bodies that occur above the ground surface, including rivers, streams, lakes, ponds, and other features, such as man-made reservoirs or other impoundments. Groundwater is water that is below the ground surface within a zone of saturation, with the uppermost groundwater surface comprising the water table. Groundwater comprises water that originated naturally as recharge from precipitation (e.g., rain or the melting of snow, sleet, or hail) or artificially as recharge from activities such as irrigation, industrial processing, and wastewater disposal, and water destined to return to the surface through discharge to springs and baseflow into rivers and streams, evaporation from shallow water table areas, or human activity involving wells or excavations. Aquifers are subsurface formations capable of yielding a significant amount of groundwater to wells or springs. Lesser amounts of groundwater may also occur in areas above the saturated zone in the form of relatively small and isolated lenses of groundwater known as “perched” groundwater.

Potential water uses, from either surface water or groundwater sources, include drinking and sanitary purposes, irrigation, maintenance of terrestrial and aquatic resources, recreation, and, of critical importance to all nuclear plants, industrial cooling and other applications. Demands for water are not restricted to freshwater (i.e., generally water with a total dissolved solids [TDS] level of less than 1,000 mg/L) but can also be met, for certain uses, by brackish (i.e., TDS level of about 1,000 to 35,000 mg/L) and saltwater (saline) sources, including for industrial cooling applications. As such, nuclear power plants are located in a range of settings with respect to water resources availability. In point, 16 of the 65 currently licensed nuclear power plants are located in estuarine or coastal areas, 10 plants are located on or near the Great Lakes, 35 plants are located on rivers and/or with associated impoundment (e.g., reservoirs), 3 plants are located on or near large, free-flowing river corridors, and 1 plant is located at an inland location with no nearby perennial surface water bodies (see also Table 3.1-2 and Section 3.5.1.1 below).

Earth’s water is always in movement, and the natural water cycle, also known as the hydrologic cycle, describes the continuous movement of water on, above, and below the surface of the Earth. It is the movement of water from surface water, groundwater, and vegetation to the atmosphere and back to the Earth in the form of precipitation. Natural waters are normally replenished by precipitation. However, the availability of water resources is being reduced and their distribution is changing due to human activity and natural forces. This is further aggravated by global climate change and variations in natural conditions. Impacts within the hydrologic cycle can be observed in precipitation patterns, infiltration to groundwater, surface runoff, stream flow, and other natural features.

Water quality of surface water bodies and groundwater in the vicinity of and within the watersheds where nuclear power plant sites are located is influenced by a wide range of activities that are often unrelated to and far removed from nuclear power plant operations. Urbanization and development increases the amount of impervious surface coverage, such as roads and sidewalks, and reduces the natural terrain and pervious surfaces, including woodlands, meadow, and prairie lands. These alterations result in higher runoff velocities while reducing or eliminating the ability for infiltration, which also reduces groundwater recharge. Pervious areas associated with urbanization and development, such as landscape and recreational areas, contribute to increased surface runoff because they are typically uniformly graded and sparsely vegetated. Increased runoff is also thermally warmer than precipitation falling on natural terrain, and can carry pollutants entrained from sources of contamination on the land surface and which may have otherwise been filtered through natural processes. As a result, changes in surface runoff velocities and volumes have the potential to result in surface water quality impacts, including changes in receiving water chemical and thermal characteristics. Additionally, increases in runoff lead to streamside erosion, loss of topsoil, and other hydrologic changes leading to an increased flooding potential of downstream areas. These changes can occur in some watersheds despite design guidelines and regulations implemented by local, State, and Federal agencies to manage runoff rates associated with development.

Typical pollutants carried in stormwater runoff include sediment, nutrients, debris, bacteria, and household hazardous substances. Nutrient additions, whether from fertilizer additions to landscaped lawns in urban and suburban areas or from croplands in agricultural areas, add to the pollutant loading and can have negative effects on water quality, terrestrial communities, and aquatic life (see Section 3.6). Atmospheric deposition of pollutants is also a substantial contributor to water quality degradation in “downwind” regions and particularly in urbanized areas. Nuclear power plant operations can contribute to water quality and hydrologic changes by increasing stormwater runoff, adding to nutrient discharges from sewage treatment, and through effluent discharges from industrial cooling systems. The additional runoff volume results in a total increase in deposited pollutants from impervious surface and industrial yards. Cooling system discharges typically contain cooling water treatment chemicals (e.g., corrosion inhibitors and biocides) (see also Section 3.5.1.2 below). Such chemical constituents when released to receiving water bodies have the potential to impact aquatic organisms. Thermal pollution is an additional pollutant that warms a receiving water body from both stormwater runoff and industrial cooling discharges. Within a watershed, these conditions are exacerbated by basin-wide deforestation and stripping of streamside vegetation in urban, suburban, and even in agricultural areas due to the associated reduction in runoff and pollutant attenuation.

The collection of these pollutants from all sources in receiving waters can result in waters that are unable to meet the water quality standards and desired uses set by States, territories, or authorized Tribes. Those water bodies that do not meet the standard are listed as impaired water bodies and require additional monitoring and more stringent effluent limits being imposed on industrial and other dischargers under Section 303(d) of the Clean Water Act. In the United States, there are approximately 41,000 listed impaired water bodies. The top pollutants contributing to impairment are pathogens (e.g., coliform bacteria), sediment, nutrients, and organic enrichment/oxygen depletion (EPA 2012).

Finally, groundwater quality, whether in shallow, unconfined aquifers comprised of unconsolidated sediments or bedrock aquifers, may be impacted by many of the sources previously described. Fertilizers, chemicals, and petroleum products can degrade groundwater quality by infiltration into soil, subsoils, and into the water table. Subsurface sources of pollution may be from broken sewage pipelines, stormwater and/or combined sanitary sewers, as well as cracks or failures of underground storage tanks. At nuclear power plant sites and other industrial facilities, groundwater quality has been impacted by inadvertent releases including spills and leaks of petroleum products and radionuclides, predominately tritium, from plant systems.

Within the context of the information discussed above, the following sections discuss the effects of past and current nuclear power plant operations on water resources, including relevant regulatory considerations.

3.5.1 Surface Water Resources

The dominant water requirement at most nuclear power plants is cooling water, which, in most cases, is obtained from surface water bodies. For this reason, most plants are located near suitable supplies of surface water, such as rivers, reservoirs, lakes, the Great Lakes, oceans, bays, or manmade impoundments, as described above. An exception is the Palo Verde plant in Arizona, which relies on treated municipal wastewater for cooling. Because of the interaction between power plants and surface water, issues arise in terms of both usage and quality. These are discussed in separate sections below.

3.5.1.1 Surface Water Use

Nuclear power plants withdraw large amounts of surface water to meet a variety of plant needs, especially for condenser cooling (Section 3.1.3). The commercial nuclear power plants considered in the 1996 GEIS are compared in Table 3.5-1 in terms of their condenser flow rates, when normalized to energy production. Included in the table are two plants (Nine Mile

Table 3.5-1. Overall Condenser Cooling Water Flow Rate and Consumptive Water Loss Rate per 1,000 MWe

Cooling System[(a)]	Number of Sites	Condenser Cooling Water Flow Rate per 1,000 MWe in gpm (m^3/s)[(b)]	Average Consumptive Water Loss per 1,000 MWe in gpm (m^3/s)[(c)]
Pond and/or canal	6	300,000 to 650,000 (19 to 41)	9,300 (0.59)
Mechanical draft cooling tower	8	140,000 to 760,000 (9 to 48)	14,000 (0.89)
Natural draft cooling tower	19	170,000 to 760,000 (11 to 48)	13,000 (0.82)
Once-through cooling	37	250,000 to 900,000 (16 to 57)	8,100 (0.51)
Once-through cooling with tower	6	220,000 to 680,000 (14 to 43)	Not available

(a) For cases of multiple reactors per site, the water use was combined if the reactors used the same type of cooling system. If multiple reactors at a site used different cooling systems (Nine Mile Point Nuclear Station and Arkansas Nuclear One), water use for each system was tallied separately.
(b) Source: NRC (1996).
(c) Source: Giusti and Meyer (1977). Note that Giusti and Meyer calculated consumptive use for a different set of plants.

Point and Arkansas) that have two reactors each: one with a cooling tower and one with a once-through system. These were tallied separately in the table. The condenser flow rates are similar in magnitude for the various types of cooling systems. Although plants in warmer geographical locations might be expected to have higher water requirements for cooling, a comparison of the locations of the plants and the normalized water use by their cooling systems suggests there is not a correlation between high water use and warmer climate. Design factors are likely responsible for the overlapping ranges in condenser flow rates.

For closed-cycle cooling systems featuring cooling towers, the amount of water consumed equates approximately to the amount of water lost through evaporation and drift. In this type of cooling system, the condenser flow rate is much larger than the withdrawal rate from a surface water body, and this withdrawal rate is essentially the water consumption rate of the system. For once-through cooling systems, the condenser flow rate is nearly equal to the surface water withdrawal rate, and the consumption rate is much less since water is returned directly to the surface water body and undergoes less evaporation than in a cooling tower.

Cooling towers consume water at 13,000 to 14,000 gpm (0.82 to 0.88 m^3/s), normalized to 1,000 MWe, as a result of evaporation and drift (Table 3.5-1) (Giusti and Meyer 1977). Additional water requirements offset the blowdown returned to the surface water body. Water withdrawal for plants with closed-cycle cooling systems is 5 to 10 percent of the withdrawal for plants with once-through cooling systems, with much of this water being used for makeup of water lost to evaporation (NRC 1996). An estimate of typical makeup water needs for plants having closed-cycle cooling, normalized to a 1,000 MWe reactor, is about 14,000 to 18,000 gpm (0.9 to 1.1 m^3/s) for all makeup needs (NRC 1996). This range of makeup water requirements includes not only the consumed water but also the offset of blowdown, which is returned to the surface water body. Variation in water use among plants results from the design of the cooling tower, concentration factor of recirculated water, climate at the site, plant operating conditions, and other plant-specific factors.

Once-through cooling systems are somewhat more common than closed-cycle systems (Table 3.5-1). For once-through systems, the water withdrawn is returned to the surface water body with less consumptive loss (8,100 gpm or 0.51 m^3/s) per 1,000 MWe because there is less evaporation than that associated with cooling towers (Giusti and Meyer 1977). The withdrawal rate from the surface water body, however, is much higher than that of a closed-cycle system (e.g., in Table 3.5-1, compare the condenser flow rates needed for once-through systems [which correspond to their surface water withdrawals] with the consumptive losses of closed-cycle systems [which correspond to their makeup water requirements] and, therefore, their surface water withdrawals). The thermal discharge from once-through cooling systems is generally higher than that from cooling towers, as discussed below.

Additional operational surface-water-related needs at power plants include service water, auxiliary system supplies, and radioactive waste systems. These needs combined are small relative to the flow needed for condenser cooling (NRC 1996).

Nuclear plant water usage must comply with State, local, and regional regulations regarding water supply. Most States require permits regulating surface water usage.

For plants relying on river water, consumptive water losses reduce surface water supplies for other users downstream. In areas experiencing water availability problems, nuclear power plant consumption could conflict with other existing or potential uses (e.g., municipal and agricultural water withdrawals) and instream uses (e.g., adequate instream flows to protect aquatic biota, recreation, and riparian communities). Water availability issues have not been generally noted in past license renewal evaluations and are likely to occur only during times of extended drought. Both water availability and water temperature are important factors in maintaining operations at power plants. In August 2007, a heat wave resulted in high river water temperatures at the Browns Ferry plant in Alabama (*Huntsville Times* 2007). Because of the reduced capability of the river water to cool the condensers, one of the plant's three reactors was shut down, while operations at its other two reactors were cut by 25 percent. In summer 2006, the Quad Cities plant in Illinois had to reduce operations because the Mississippi River was warm, and other plants in Illinois and Minnesota had to cut back as a result of drought effects (Nuclear Information and Resource Service 2007). High surface water temperature at the intake does not represent an impact on the environment but rather an effect of the natural conditions on operations.

3.5.1.2 Surface Water Quality

Discharges from the circulating cooling water system account for the largest volumes of water and usually the greatest potential impacts on water quality and aquatic systems, although other systems may also contribute heat and chemical contaminants to the effluent. Provisions of the Clean Water Act (CWA) regulate the discharge of pollutants into waters of the United States. The CWA requires that all facilities which discharge pollutants from any point source into waters of the United States obtain an NPDES permit. An NPDES permit is

Clean Water Act

- Section 402 authorizes the NPDES permit program that controls water pollution by regulating point sources, including cooling water discharge from electricity-generating plants that discharge pollutants into waters of the United States.
- Section 316(a) allows for a variance from thermal discharge standards in an NPDES permit if the variance is more stringent than necessary to assure the propagation of a balanced, indigenous population. The alternate thermal effluent limitation is only good for the term of the NPDES permit (5 years), and the facility must reapply each permit term for the permitting authorities review and approval.
- Section 316(b) requires that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact.

developed with two levels of controls: technology-based limits and water quality-based limits. NPDES permit terms may not exceed 5 years, and the applicant must reapply at least 180 days prior to the permit expiration date. EPA is authorized under the CWA to directly implement the NPDES program; however, EPA has authorized many States to implement all or parts of the national program. Conditions of discharge for each plant are specified in its NPDES permit issued by the State or EPA. CWA Section 401 requires an applicant for a Federal license to conduct activities that may cause a discharge of regulated pollutants into navigable waters to provide the licensing agency with water quality certification from the State. This certification implies that discharges from the project to be licensed will comply with CWA requirements, as applicable, including that the project will not cause or contribute to a violation of State water quality standards. If the applicant has not received Section 401 certification, the NRC cannot issue a license unless that State has waived the requirement. The NRC recognizes that some NPDES-delegated States explicitly integrate their 401 certification process with NPDES permit issuance.

Thermal Effluents and Withdrawal of Cooling Water from Surface Water Bodies

NPDES permits for nuclear power plants impose temperature limits for effluents (which may vary by season) and/or a maximum temperature increase above the ambient water temperature (referred to as “delta-T,” which also may vary by season). Other aspects of the permit may include the compliance measuring location and restrictions against plant shutdowns during winter to avoid drastic temperature changes in surface water bodies.

The area affected by heated releases to surface water bodies (the thermal plume) varies with site-specific conditions (e.g., discharge temperature, discharge rate, discharge structure location and design, flow of the surface water body, and temperature of the surface water body). A plume may be assessed in the field through plume mapping or dye tracing. Generally, the use of cooling towers decreases the thermal influence of a plant (e.g., NRC 2006b).

Sections 316(a) and 316(b) of the CWA are relevant to the operation of a nuclear power plant cooling system. Facilities may apply for a thermal variance from their NPDES temperature limitation under Section 316(a) of the CWA. The facility must be able to demonstrate that the required variance is more stringent than necessary to assure the propagation of a balanced, indigenous population (40 CFR Part 125, Subpart H) in order to receive an alternative thermal effluent limitation. The alternate thermal effluent limitation is only good for the term of the NPDES permit (5 years), and the facility must reapply each permit term for the permitting authorities review and approval. Section 316(b) of the CWA requires that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing impingement and entrainment of aquatic organisms and is also regulated under the NPDES program.

Three rulemaking phases address cooling water intake structures. Phase I (enacted in December 2001) is for new facilities (40 CFR 125.83) with a design intake flow greater than 2 million gallons per day (MGD) (7.6 million L/d) and that use at least 25 percent of water withdrawn used for cooling purposes (40 CFR Part 125, Subpart I). Phase II (enacted in July 2004) applies to existing large electric generating facilities with a design intake flow of 50 MGD (189 million L/d) or more and that use at least 25 percent of the water withdrawn for cooling purposes (40 CFR Part 125, Subpart J). The Phase II Rule was suspended on July 9, 2007, after several of its key provisions were remanded by the U.S. Court of Appeals. Phase III (enacted June 2006) established national standards for new offshore and coastal oil and gas extraction facilities with a design intake flow greater than 2 MGD (7.6 million L/d) and that use at least 25 percent of water withdrawn used for cooling purposes (40 CPR Part 125, Subpart N).

Existing facilities with a cooling water intake structure that are not currently subject to a national rule require Section 316(b) NPDES permit conditions that reflect best technology available for minimizing adverse environmental impact on a case-by-case, best professional judgment basis (40 CFR 125.90(b) and 401.14).

Other Effluents

Liquids containing chemicals and other parameters are discharged to surface water from nuclear power plants, as discussed in Section 3.1.4.1. The concentrations and flow rates of the liquids vary with activities involving the systems associated with floor drains, blowdown, laundries, decontamination, and other facilities. The liquids may also undergo treatment before reuse or discharge. These effluents are regulated under the plant's NPDES permit. As part of the permitting process, concentration limits are established, and monitoring takes place at specific outfalls or other monitoring locations. The frequency of sampling is also covered by permit. EPA or authorized State agencies also provide the reporting requirements, and they may post results on a publicly accessible Web site. Noncompliance issues may range from administrative matters to exceedances of concentration, temperature, or flow limits. The exceedance of a parameter limit will trigger the permitting agency to review the history and magnitude of exceedance recurrences. Actions may include reviewing the permit for appropriate parameter levels, setting a compliance schedule for the applicant, assessing fines, and, in a worst case scenario, withdrawing a permit and disallowing the legal ability to discharge.

Sanitary sewage wastes are treated before their release to the environment to minimize environmental impacts. The treatment may be through discharge to a municipal wastewater treatment system, an onsite wastewater treatment plant, or an onsite septic system. In cases where nonradioactive sanitary or other wastes cannot be processed by onsite wastewater treatment systems, the wastes are collected by independent contractors and trucked to offsite treatment facilities. Waste collection and offsite disposal can occur during a planned outage, when portable toilets may be required to accommodate the additional workforce. Water quality issues related to sanitary waste treatment include the adequacy of the wastewater treatment capacity for handling the increased flow and loading associated with operational changes to the plant, emission of phosphates from onsite laundries, suspended solids, coliform bacteria from sewage treatment discharges, and other effluents that cause excessive biochemical oxygen demand. State regulators are typically involved in site inspections, review of monitoring reports, and handling of any violations.

The control of biological pests is critical to maintaining optimum system performance and minimizing operating costs. Consequently, many nuclear power plant cooling systems are periodically treated with molluscides to control the Asiatic clam (*Corbicula fluminea*) and the zebra mussel (*Dreissena polymorpha*), which are generally found in the portions of the cooling system where water temperatures are ambient rather than heated.

Biocides also are commonly used in cooling towers, although they may also be used in once-through systems or cooling ponds (Veil et al. 1997). Discharge of these chemicals to the receiving body of water can have toxic effects on aquatic organisms. Chlorine is commonly used as a biocide at nuclear power plants and represents the largest potential source of chemically toxic release to the aquatic environment. It may be injected at the intake or targeted at various points (such as the condensers) on an intermittent or continuous basis. Chlorine gas, which was commonly used in the past, has been replaced by many users with other forms, such as bleach (sodium hypochlorite) (Veil et al. 1997). Bromide compounds have been used increasingly in recent years, either in place of or in addition to chlorine treatments. Dechlorination may occur prior to discharge. Non-oxidizing biocides used to control zebra mussels and other organisms include quaternary ammonia salts, triazine, glutaraldehyde, and other organic compounds.

Most plants have a storm water management plan, with the parameter limits of the storm water outfalls included in the NPDES permit. Plants may also have a spill prevention, control, and countermeasures plan that contains information on potential liquid spill hazards and the appropriate absorbent materials to use if a spill occurs.

3.5.1.3 Hydrologic Changes and Flooding

As described in Section 3.5, urbanization of watersheds in which nuclear power plants operate increases the amount of impervious surface coverage resulting in water quality impacts and changes in the hydrologic characteristics of the watershed. Urbanization has a direct correlation to the degradation of natural receiving streams. The higher the percentage of the impervious surface coverage in a watershed, the higher the flow velocity and volume in receiving water bodies. Increases in stream flow erode natural stream banks and scour natural vegetation from littoral zones, while also adding to higher flow volume and increased potential for flooding. A flood is the occurrence when, under high water level and/or flow conditions, water overflows the natural or artificial bank of the water body. The floodplain or zone defines the extent of the land areas covered by the overflowing water. Floods can occur at any time, but weather patterns, terrain, land use coverage, and other factors influence when and where floods happen, as well as their frequency and severity. For example, the western United States can experience flooding due to cyclones in the winter and early spring; the streams in the southwest United States can experience flashflooding due to thunderstorms in late summer and fall; frontal storms in the northern and eastern United States can cause floods during the winter and spring; and the southeastern United States experiences flooding due to tropical storms, such as hurricanes, during the late summer and fall.

Flood zone boundaries are determined based on the predicted recurrence interval of flooding and the extent of the land area inundated through the use of analytical modeling and field observations. The recurrence interval is the average number of years between floods of a certain size. For instance, the 100-year flood, on average, would occur once every 100 years. However, statistically there is a 1 in 100 chance that the 100-year flood will occur in any given year.

Flood zones are dynamic and change over time due to natural forces. Further, changes in urbanization increase runoff and changes in weather patterns increase the intensity of precipitation events. In some instances, land areas that were not previously within a flood zone have been reclassified as being within one after nearby river elevations and flood potential were reanalyzed. On large rivers, dams have been shown to reduce flooding. Flood control dams, such as on multi-use reservoirs, are designed to release water flow at a controlled rate and allow water to back up in a reservoir when, typically under storm events, the inflows exceed the predetermined outflow rate. This prevents high flows from reaching streams that would otherwise flood, and allows water flow to bypass communities without flooding them.

Currently operating nuclear power plants were originally sited in consideration of the hydrologic siting criteria set forth in 10 CFR 100, and designed and constructed in accordance with 10 CFR Part 50, Appendix A. The regulations require that plant structures, systems, and components important to safety be designed to withstand the effects of natural phenomena including flooding, without loss of capability to perform safety functions. Site-specific design bases for flood protection are prescribed by a nuclear power plant’s FSAR/UFSAR and by applicable technical specifications. Acceptable protection for floods includes levees, seawalls, floodwalls, or breakwaters. If new information or operating experience relating to flooding becomes available, the NRC evaluates the new information to determine if any changes are needed at existing plants. Flood protection issues are considered during site-specific safety reviews and, more specifically, are addressed on an ongoing basis through the reactor oversight process and other NRC safety programs, which are separate from the license renewal process.

3.5.2 Groundwater Resources

Some nuclear power plants also use groundwater as a source of water for some of their operational needs. The rate of usage varies greatly among the plants. Many plants use groundwater only for the potable water system and require less than 100 gpm (0.006 m^3/s). At some plants, the original construction required dewatering of a shallow aquifer by using pumping wells or a drain system. Some plants operate dewatering systems to lower the water table near buildings. This is accomplished either by pumping or by having footing drains along foundations. Groundwater may also be used for sanitary uses or landscaping, and it may undergo processing to be used for makeup or service water systems. Groundwater usage regulations vary considerably from State to State, and State allocation permits are typically required.

At the Grand Gulf plant in Mississippi, large-diameter wells with radial collector arms known as Ranney wells are used to withdraw groundwater along the Mississippi River at relatively high rates. They are installed in alluvial aquifers along rivers to obtain a mixture of groundwater and surface water through induced infiltration. At Grand Gulf, the average groundwater pumping rate by their well systems was higher than 21,000 gpm (1.3 m^3/s) in 2001 (System Energy Resources, Inc. 2005). The water withdrawn at Grand Gulf may be used as makeup, service, potable, or sanitary water or for landscaping or fire protection.

The quality of groundwater may be affected by operations at nuclear power plants. Water from cooling ponds may seep into the underlying surficial aquifer. Activities at power plants typically include general industrial practices, such as the storage and use of hydrocarbon fuels (diesel and/or gasoline), solvents, and other chemicals. These practices have the potential to contaminate soil and groundwater, and, at some plants, this contamination has occurred. Examples from plant-specific SEISs include leakages or spills of gasoline (with methyl tertiary butyl ether, or MTBE) at fuel tank storage areas, spills of fuel at transfer or filling stations, solvent leakages from storage area drums, spilled or sprayed solvents, and underground line leaks of hydraulic oil or diesel fuel (e.g., NRC 2006b, 2007c). These incidents involved regulatory oversight under State regulations for hydrocarbons and under RCRA for other chemicals, and offsite groundwater users were not affected.

Radionuclide releases, primarily tritium, to groundwater has raised concern in recent years because of inadvertent releases at the Indian Point, Braidwood, Callaway, Dresden, Byron, and Palo Verde plants (NRC 2007d). The NRC (2006c) has examined the matter and noted the leaks are generally not observable because they are underground and because plants are not required to have onsite groundwater monitoring wells unless an onsite well is used for drinking water or irrigation water. Even so, NRC licensees are required to survey, evaluate, document, and report the hazard of known spills or leaks of radioactive material. The NRC has reporting requirements based on the amount of radioactivity released; thus any large spills or leaks will be reported. Additionally it is important to note that all plants are required to submit an annual report, which is publically available, to the NRC that summarizes the types and quantities of radioactive material released into the environment.

In response to discoveries of underground radionuclide releases at nuclear power plants, the Nuclear Energy Institute (2007a), which represents the nuclear industry on policy issues, developed the Ground Water Protection Initiative. Each plant voluntarily committed to have an action plan to develop site-specific groundwater protection program in place by July 31, 2006. These programs cover the assessment of plant systems and components, site hydrogeology, and implementation of groundwater monitoring programs. To monitor the actions of the nuclear industry, the NRC updated its inspection procedure to include this issue as part of its routine radiological inspection at all nuclear power plants.

3.6 Ecological Resources

A wide variety of ecological resources exist at and in the vicinity of operating nuclear power plants across the United States. This section presents an overview of those resources. Terrestrial resources (including wetlands and floodplains, which are transitional areas between terrestrial and aquatic systems); aquatic resources; and special status species and habitats are discussed in Sections 3.6.1, 3.6.2, and 3.6.3, respectively. This section summarizes the effects of past activities, including construction and current operations at plant sites.

3.6.1 Terrestrial Resources

Operating commercial nuclear power plants are located in 31 States across the continental United States. These power plants have been sited in a wide variety of terrestrial habitat types. For the purposes of this analysis, terrestrial ecological resources in the vicinity of nuclear power plants are described in terms of upland vegetation and habitats, floodplain and wetland vegetation and habitats, and wildlife. Section 3.6.3.1 discusses special status terrestrial species and habitats.

3.6.1.1 Upland Vegetation and Habitats

Terrestrial vegetation and habitats include forests, grasslands, and shrublands. These habitats were affected by the initial construction of nuclear power plants, normal operations associated with nuclear power plants, and successional changes occurring within vegetation communities. In general, the level of land management varies by area at a nuclear power plant. See Section 3.2.1 for a general description of land use at a nuclear power plant.

Impacts on terrestrial vegetation and habitats can result from a number of activities or processes during normal operations at a nuclear power plant. Since startup of operations, areas on the nuclear plant sites within the security fence have typically been maintained as modified landscapes, but they may also include disturbed early successional habitats or areas of relatively undisturbed habitat. Maintenance of portions of the site by mowing and herbicide or pesticide application keeps the diversity of plant species at a reduced level. Native plant species are often replaced by cultivated varieties or weedy species tolerant of disturbance. Areas of the plant site outside the security fence may include natural areas, such as forest or shrubland, in various degrees of disturbance.

Terrestrial habitats near nuclear plants can be subject to radiological releases under normal plant operations. These habitats are exposed to small amounts of radionuclides that result from the deposition of particulates released from power plant vents during normal operations. Releases typically include noble gases (which are not deposited), tritium, isotopes of iodine, and cesium, and they may also include carbon-14, strontium, cobalt, and chromium. Exposure to these radionuclides results in a dose rate to terrestrial plants of much less than 0.1 rad/d (0.001 Gy/d).[d] This rate is considerably lower than 1.0 rad/d (0.01 Gy/d), which is the DOE guideline level for impacts on terrestrial plant species (DOE 2002). Radionuclides, such as tritium, and other constituents in cooling water systems, such as biocides, that enter shallow groundwater from cooling ponds can be taken up by terrestrial plant species.

Terrestrial habitats near plants with closed-cycle cooling water systems are subject to the deposition of cooling tower drift particulates (including salt); the deposition of water droplets on vegetation from drift; structural damage from freezing vapor plumes; and increased humidity from cooling towers and cooling ponds. Small amounts of particulates from cooling towers are dispersed over a wide area, with particulates from natural draft towers being dispersed over a larger area and at a lower deposition rate than those from mechanical draft towers (NRC 1996). However, most of the deposition from cooling towers occurs in relatively close proximity to the towers. Generally, deposition rates are below those that are known to result in measurable adverse effects to plants, and no deposition effects on agricultural crops or plant communities have been observed at most of the power plants. However, exceptions have been observed at some nuclear plants (NRC 1996). Impacts from icing, when they have occurred, have been minor and localized near cooling towers.

Effects of nuclear power plant operations on terrestrial habitats also include the effects of transmission line ROWs and their maintenance. ROW management typically includes the periodic cutting of tall woody vegetation and use of herbicides. Management activities and transmission line repair occasionally result in the erosion of exposed soils where vegetation is

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(d) Dose rates were calculated on the basis of media concentrations provided in nuclear power plant radiological monitoring reports (see Section D.5 in Appendix D).

removed or where soils are disturbed by equipment. However, based on the scope of the power transmission system described in Section 3.1.6.5, in-scope transmission lines and structures are expected to occur primarily on developed portions of sites and would include only the short lengths of transmission lines that run from the plant to the nearest substation.

3.6.1.2 Floodplain and Wetland Vegetation and Habitats

Floodplains occur as lowlands along rivers and coastlines near many nuclear plants. They are typically identified as areas that have a chance of at least 1 percent of flooding in any given year; these are also described as 100-year floodplains. Activities related to nuclear plant construction and operations that have occurred in floodplains include the construction and maintenance of cooling water intakes and outfalls and transmission line ROWs. Activities undertaken by Federal agencies are regulated under Executive Order 11988, *Floodplain Management*. One requirement of this order is for Federal agencies to restore and preserve the natural and beneficial values served by floodplains. Floodplain values include attenuation of the extent of flooding, which supports wetlands, fish, and wildlife.

A wide variety of wetland types occur near nuclear power plants. These include riverine, palustrine, lacustrine, estuarine, and marine wetland types as described by the U.S. Fish and Wildlife Service (USFWS) (Cowardin et al. 1979) for the National Wetlands Inventory (NWI). Most nuclear plants have wetlands nearby (within a radius of 5 mi), and wetlands cover an average of 3 percent of the land area near the plants, as mapped by the NWI (USFWS 2007a). The National Land Cover Database (USGS 2007) and New Jersey State database were used for the sites that were lacking digital NWI data. Wetlands exclude deepwater habitats, which are permanently flooded coastal areas and which occupy, on average, 10 percent of the area within 5 mi of the plants. The proportion of wetlands and deepwater habitats within 5 mi (8 km) of nuclear plants is presented in Table D.5-3 in Appendix D.

Wetland Types That Occur near Nuclear Power Plants

- ***Riverine wetlands*** are contained within a channel that has moving water, at least periodically, and they lack persistent vegetation.
- ***Palustrine wetlands*** primarily support trees, shrubs, or persistent emergent plants, or they can be small (generally under 20 ac or 8 ha), shallow wetlands lacking such plant communities.
- ***Lacustrine wetlands*** are large or deep bodies of water that lack persistent vegetation.
- ***Estuarine wetlands*** occur near land with access to the ocean, are influenced by tides, and are diluted to a variable extent by freshwater.
- ***Marine wetlands*** are exposed to open ocean waves and currents and may be slightly diluted by freshwater.

Source: Cowardin et al. 1979

Wetlands were affected by the initial plant construction and various aspects of plant operation during the period of the initial plant operating license. These effects included those associated with facility construction, transmission line ROW construction and maintenance, the construction and operation of cooling systems, and stormwater management. Effects to wetlands from construction activities and stormwater runoff often include changes in vegetative plant community characteristics, altered hydrology, decreased water quality, and sedimentation (Wright et al. 2006; EPA 1996). Wetland losses occurred during the construction of many nuclear power plants. For example, construction of the Oyster Creek plant in New Jersey resulted in the loss of 200 acres of several types of wetlands (AEC 1974). However, at plants using cooling ponds, new wetland habitats may form along the margins of those ponds such as can be found along portions of the Robinson Reservoir, the Robinson nuclear plant cooling pond (NRC 2003b), and Parr Reservoir used for storage exchange and makeup water for the Summer plant cooling pond (NRC 2004b). Forested wetlands in ROWs are converted to scrub/shrub or emergent wetland types when trees are removed, and ROW management programs maintain the ROW in these habitat types. The operation of heavy equipment in wetlands during ROW maintenance or transmission line repair can damage or compact wetland soils and vegetation and may promote the establishment of invasive species (BPA 2000).

The operation of cooling water intake and discharge systems can increase the salinity of stream segments, as has occurred at the Oyster Creek plant (NRC 2007c), or expose wetland habitats to thermal impacts and contaminants in discharged cooling water or cooling tower blowdown. The maintenance of intake or discharge structures may damage wetland habitats, and the disposal of dredged sediments may affect wetlands. Maintenance activities on the plant sites or ROWs may also result in chemical or fuel spills that may affect wetlands. Contaminants that enter groundwater may affect wetlands that receive groundwater discharge. Executive Order 11990, *Protection of Wetlands*, requires Federal agencies not only to minimize the destruction, loss, or degradation of wetlands while they are conducting their activities but also to preserve and enhance the natural and beneficial values of wetlands. Many activities that occur in wetlands are regulated under Section 404 of the CWA. Actions that result in the discharge of dredge or fill material into wetlands that are under the jurisdiction of the CWA require a permit from the U.S. Army Corps of Engineers (USACE).

3.6.1.3 Wildlife

Wildlife populations on and in the vicinity of nuclear power plants have also been affected by plant construction and operations. The initial construction of the plants and transmission line ROWs reduced the available terrestrial habitat at sites; habitat losses in many cases total hundreds of acres. Because habitats along transmission line ROWs are maintained in a modified condition, the wildlife communities they support are different than those found in undisturbed habitats. Some predator species, such as skunks and raccoons, more readily use ROW habitats, and ROWs may therefore provide a means for new or easier access to some areas, thereby affecting populations of prey species (Evans and Gates 1997; Crooks and

Soulé 1999). Wildlife species in the vicinity of transformers or cooling towers are exposed to elevated noise levels that disrupt behavior patterns. Wildlife species near transmission lines are exposed to electromagnetic fields. However, there is currently a lack of conclusive evidence that biological systems are affected by electromagnetic fields (see Section 3.9.4). Atmospheric or surface water releases can result in the exposure of wildlife to contaminants. Wildlife is exposed to small amounts of radionuclides from the deposition of particulates released from power plant vents during normal operations. Exposure of upland and riparian wildlife to these radionuclides results in a dose rate of much less than 0.1 rad/d (0.001 Gy/d), which is the guideline for protection of riparian and terrestrial wildlife (DOE 2002).[e] This rate is considerably lower than rates known to result in measurable impacts.

Plant structures such as natural draft cooling towers, meteorological towers, and transmission lines create collision hazards for migratory and local bird species. Monitoring of bird collisions has been done at several nuclear plants with natural draft cooling towers. The results of those monitoring efforts indicate that cooling towers at nuclear power plants do cause some collision mortality for migrating songbird species; however, these deaths represent only a fraction of the total annual bird collision mortality from all man-made sources. See Section 4.6.1.1 for a detailed description of bird collision mortality at nuclear power plants.

There are no reports of relatively high collision mortality occurring at the transmission lines associated with nuclear power plants in the United States. The length of these lines is considerably less than the total 500,000 mi (800,000 km) of transmission lines estimated within the United States (Manville 2005). Although the data are not available, transmission lines associated with nuclear power plants are likely responsible for only a small fraction of total bird collision mortality associated with transmission lines nationwide. See Section 4.6.1.1 for a detailed description of bird collision mortality at nuclear power plants.

Cooling system intakes can create an impingement hazard for waterfowl, and water demands for cooling can create water-use conflicts with wildlife. At the Nine Mile Point plant in New York, for example, approximately 100 greater scaup (*Aythya marila*) and lesser scaup (*Aythya affinis*) ducks were impinged at the cooling water intake structure in 2000 while feeding on zebra mussels during reverse flow conditions for deicing of the structure (NRC 2006d). As a result of this incident, the Nine Mile Point Intake structures now undergo annual cleaning to remove zebra mussels (the food source), and reverse flow conditions are scheduled during periods when diving duck feeding is limited (NRC 2006d). The potential for water use conflicts at the Wolf Creek plant in Kansas can occur during drought conditions as makeup water for the cooling lake is withdrawn from the Neosho River, resulting in reduced flows (NRC 2008). Riparian communities along the Neosho River can be degraded or lost by reduced flows.

(e) Dose rates were calculated based on information provided in nuclear power plant radiological monitoring reports (see Section D.5 in Appendix D).

Wildlife associated with these riparian habitats can subsequently be affected by reductions in habitat quality or extent.

Species that occupy onsite habitats are exposed to a variety of factors associated with plant operations and maintenance. The maintenance required for landscaped areas generally keeps the diversity of wildlife located there less than it is in surrounding habitats. Wildlife species occurring on the sites within the security areas are typically limited by the low quality of the habitat and generally include common species adapted to industrial developments.

3.6.2 Aquatic Resources

Nuclear power plants are usually located near relatively large water bodies, such as major rivers and reservoirs, the Great Lakes, and estuarine and marine coastal areas, because of the amount of water that is needed to meet cooling system demands (Table 3.1-2). In the few cases where a power plant is located near small streams (e.g., the Summer plant in South Carolina and the Clinton plant in Illinois), the streams have been impounded to create cooling lakes. The water bodies in the vicinity of the power plants contain a complex assemblage of habitats and species that may be affected by a plant's cooling system and by maintenance of the transmission line ROWs. The following text presents an overview of the habitats and aquatic biota in the vicinity of nuclear power plants, followed by an overview of the effects of existing power plant operations on aquatic resources.

3.6.2.1 Description of Aquatic Resources near Nuclear Power Plants

This section presents an overview of the aquatic habitats and biota that occur in the vicinity of nuclear power plants. Emphasis is placed on the major ecosystem types (i.e., freshwater rivers, reservoirs, and lakes and coastal estuarine and marine systems) and major groups of aquatic biota (i.e., fish, other aquatic vertebrates, macroinvertebrates, zooplankton, phytoplankton, and macrophytes). An overview of the effects of existing power plant operations on aquatic resources is provided in Section 3.6.2.2. A discussion of threatened and endangered aquatic species, marine mammals, and essential fish habitat is provided in Section 3.6.3.2.

Aquatic Habitats

The aquatic ecological communities that occur in the vicinity of U.S. nuclear power plants are very diverse because of the differences in their geographies and habitat types and in the physical and chemical conditions of the water bodies located near them. The geographical setting, physical conditions (e.g., substrate type, temperature, turbidity, and light penetration), chemical factors (e.g., dissolved oxygen levels and nutrient concentrations), biological interactions (e.g., competition and predation), seasonal influences, and man-made modifications and actions all interact to influence the types of species present and the nature of the aquatic community in a particular aquatic ecosystem. Nuclear plants use freshwater, estuarine, and marine ecosystems as their cooling water sources, except for the Palo Verde plant, which uses Phoenix City sewage effluent (Table 3.1-2).

Freshwater systems can be broadly categorized as lentic or lotic, depending on the degree of water movement. Lentic systems refer to water bodies that have standing or slow-flowing water, such as that found in ponds, lakes, reservoirs, and some canals. Most lentic habitats stratify during summer (monomictic) or during summer and winter (dimictic). Lotic habitats generally have a measurable velocity and include natural rivers and streams and also some artificial waterways. Most lotic habitats do not generally stratify (Morrow and Fischenich 2000). Although some freshwater aquatic species occur in both lentic and lotic habitats, many species are adapted to the physical, chemical, and ecological characteristics of one system or the other, and the overall ecological communities present within these aquatic ecosystem types will differ for a given region of the country.

Species composition and ecological conditions within riverine environments are largely determined by the geographic area, gradient of the river bed, velocity of the current, and source of nutrients and organic matter at the base of the food chain. Thus, ecological communities in rivers become altered if the river is impounded, with the degree of alteration depending on the degree to which various physical and chemical conditions are affected. Environmental threats to rivers include depletion of water, dams that alter flow and temperature characteristics and can block the upstream or downstream movement of aquatic organisms, chemical pollution, and the introduction of nonnative species.

Aquatic Ecosystem Types

- ***Freshwater:*** Waters that contain a salt concentration of less than 1 percent.
  - ***Lentic:*** Standing or slow-flowing fresh water (e.g., lakes and ponds).
  - ***Lotic:*** Flowing fresh water with a measurable velocity (e.g., rivers and streams).
- ***Marine:*** Waters that contain a salt concentration of about 3 percent (e.g., ocean overlying the continental shelf and associated shores).
- ***Estuarine:*** Coastal bodies of water, often semi-enclosed, which have a free connection with marine ecosystems (e.g., bays, inlets, lagoons, and ocean-flooded river valleys). In these areas, freshwater merges with marine waters; salinity concentrations vary spatially and temporally due to location and tidal activity.

Major rivers that serve as cooling water sources include the Mississippi River (Minnesota, Illinois, Mississippi, and Louisiana; six plants), Missouri River (Nebraska and Missouri; three plants), Susquehanna River (Pennsylvania; three plants), Delaware River (New Jersey; two plants), Hudson River (New York; one plant), and Columbia River (Washington; one plant) (Table 3.1-2). Some power plants that use rivers for cooling are located on sections of rivers that have been impounded to slow the rate of flow and create pooled areas in the vicinity of cooling water withdrawal or discharge structures. These sections are not as clearly lentic in nature as are reservoirs.

Lentic ecosystems can be broadly divided into littoral, pelagic, and profundal habitat zones on the basis of water depth and light penetration in the water. Littoral habitats refer to nearshore shallower waters where sufficient light reaches the bottom so that rooted plants are able to grow. Pelagic habitats include open offshore waters where light intensity is great enough for photosynthesis to occur. Profundal habitats are found in deep-water areas that are beyond the depth at which light penetration is great enough to support photosynthesis (Armantrout 1998). The ecological communities that inhabit these zones differ, reflecting the preferences and tolerances of aquatic species at various life stages for the physical and chemical conditions that exist. Within the United States, 10 nuclear power plants use water from natural lakes for cooling (Table 3.1-2): Lake Erie (Ohio and Michigan; three plants), Lake Michigan (Michigan and Wisconsin; four plants), and Lake Ontario (New York; three plants).

The species diversity and biomass of fish are greater in the nearshore than in the offshore areas of the Great Lakes (Edsall and Charlton 1997). The nearshore areas offer a variety of habitat conditions (e.g., morphometric features, current velocities, substrates, and aquatic vegetation) that provide conditions that are optimal to most species of fish in the Great Lakes for at least some portion of their life cycle. Of 139 Great Lakes fish species reviewed by Lane et al. (1996, as reported in Edsall and Charlton [1997]), all but five species (four species of deepwater ciscoes [*Coregonus* spp.] and the deepwater sculpin [*Myxocephalus thompsoni*]) use waters less than 33 ft (10 m) deep for nursery habitat. Some of the threats to the ecological integrity of the Great Lakes are reviewed in Beeton (2002); they include eutrophication (nutrient enrichment), land-use changes, overfishing, invasive species, and pollution (Beeton 2002). Constraints have been implemented in recent years to reduce nutrient inputs and control land use changes, such as shoreline alteration and destruction of wetlands. Invasive species have become a major problem as nonindigenous species gain access to the Great Lakes. Examples of invasive nonnative aquatic organisms that have become established in the Great Lakes include the round goby (*Neogobius melanostomus*), zebra mussel (*Dreissena polymorpha*), spiny waterflea (*Bythotrephes cederstroemi*), and quagga mussel (*Dreissena bugensis*). The introduction of such species can result in changes to native ecological communities (Dermott and Kerec 1997). These threats to the integrity of the Great Lakes are likely to continue (Beeton 2002).

Reservoirs refer to areas of rivers or streams that are impounded by a dam or water control structure such that they have become physically, chemically, and ecologically more similar to lakes instead of the lotic system from which they are formed (Armantrout 1998). In the United States, 14 nuclear power plants use water from reservoirs for cooling (Table 3.1-2). Fish species that thrive in the habitat conditions that exist within a given reservoir are often stocked and managed to support recreational fisheries.

Brackish to saltwater estuarine and marine ecosystems occur along the coastlines of the United States. General habitat types found within these ecosystems include the mouths of rivers, tidal streams, shorelines, salt marshes, beaches, mangroves, submerged aquatic vegetation, coral reefs, and open water. Estuaries are particularly important as staging points during the migration of certain fish species (e.g., salmon and eels), giving them time to form schools and to physiologically adjust to the changes in salinity. Many marine fish and invertebrate species use estuaries for spawning or as places where young fish can feed and grow before moving to other marine habitats. Estuarine and marine habitats support important commercial or recreational finfish and shellfish species. In the United States, 16 nuclear power plants use water from estuarine or marine environments (Table 3.1-2).

Aquatic Organisms

A great diversity of aquatic organisms could be affected by nuclear plant operations. Power plant effects can be analyzed by studying representative important species (e.g., indicator species or species groups). McLean et al. (2002) identified the following representative important species:

- Species sensitive to adverse harm from plant operations (e.g., thermally sensitive species);
- Species that use the local area for spawning or nursery grounds (including those species that migrate past the plant to spawn);
- Species of commercial or recreational value;
- Species that are habitat formers and critical to the functioning of the local ecosystem;
- Species that are important links in the local food web;
- Rare, threatened, or endangered species; and
- Potential nuisance species likely to be enhanced by plant operations.

<u>Fish</u>

Fish can be characterized as freshwater, estuarine, marine, and migratory (e.g., anadromous and catadromous) species. The first three categories are based on salinity regimes, whereas the migratory category is composed of reproductively specialized fish that migrate between freshwater and saltwater (or vice versa) to reproduce (Murdy et al. 1997). Murdy et al. (1997) defined freshwater fish as those that usually inhabit waters with a salinity of less than 0.5 parts per thousand (ppt) (although some species can tolerate a salinity as high as 10 ppt); estuarine fish as those that inhabit tidal waters with salinities that range between 0 and 30 ppt; and marine fish as those that typically live and reproduce in coastal and oceanic waters with salinities that are more than 30 ppt. Anadromous species migrate from the ocean waters to freshwater to spawn, while the opposite situation occurs for catadromous species. Anadromous species include sturgeons, clupeids, salmonids, smelts, striped bass (*Morone saxatilus*), and the sea lamprey (*Petromyzon marinus*). Within the United States, the only catadromous species is the American eel. For some species, migratory movements may be confined within a freshwater system (e.g., species tend to move to upstream areas for spawning) or in the ocean (e.g., species tend to move northward as waters warm and southward as they cool). A few species such as the tarpon (*Megalops atlanticus*) move freely between fresh and marine waters for purposes not related to spawning (Lagler et al. 1962). Many of the fish species that occur in the vicinity of the power plants are of considerable commercial and/or recreational importance, while others serve as forage for those species.

Fish have developed various regulatory mechanisms to maintain their overall performance at a wide range of body temperatures as a result of being subjected to large diurnal or seasonal changes in water temperature (Claireaux et al. 2006). Nevertheless, freshwater fish can be classified as coldwater, coolwater, or warmwater species. Coldwater fish (e.g., trout and salmon) have an upper lethal temperature of about 77°F (25°C), warmwater species (e.g., gizzard shad [*Dorosoma cepedianum*], common carp [*Cyprinus carpio*], largemouth bass (*Micropterus salmoides*], and sunfish [*Lepomis* spp.]) have an upper lethal limit as high as 97°F (36°C), and coolwater species have upper lethal temperature limits similar to or slightly lower than those of warmwater species (e.g., freshwater drum [*Aplodinotus grunniens*], yellow perch [*Perca flavescens*], smallmouth bass [*Micropterus dolomieu*], walleye [*Sander vitreus*], and sauger [*S. canadensis*]), but they usually require cooler average temperatures during their growing season (Morrow and Fischenich 2000). Preferred summer temperatures are below 59°F (15°C) for coldwater species, 70 to 77°F (21 to 25°C) for coolwater species, and 81 to 88°F (27 to 31°C) for warmwater species (Magnuson et al. 1979). As summarized by Armour (1991), the highest average mean weekly temperatures tolerated by coldwater, coolwater, and warmwater fish species are 72°F (22°C), 84°F (29°C), and 86°F (30°C); while their respective spawning temperatures are less than 55°F (12.8°C), 40 to 60°F (4.4 to 15.6°C), and above 60°F (15.6°C).

The swimming performance of fish is influenced by temperature. Maximum swimming speed and endurance peak at an optimum temperature, are reduced at low temperatures, and decrease as temperatures approach the upper thermal limit (Claireaux et al. 2006). Many of the marine fish species have buoyant eggs, while most stream fish have eggs that are heavy and sink (demersal). Most demersal eggs are also, at least temporarily, adhesive (Lagler et al. 1962). Most marine fish species have high fecundity (e.g., a female may produce thousands to millions of eggs per year); while most freshwater fish produce hundreds to thousands of eggs per year. However, newly hatched larvae undergo mortality rates of 5 to 30 percent per day as a result of predation, starvation, disease, pollution, and other causes (Batty and Blaxter 1992).

Other Aquatic Vertebrates

In addition to fish, other vertebrate species can be present in the aquatic ecosystems near nuclear plants. These include sea turtles, American crocodile (*Crocodylus acutus*), waterfowl, seals, and the West Indian manatee (*Trichechus manatus*). The effects that power plant operations have had on these species are discussed in Section 4.6.1.2.

Aquatic Macroinvertebrates

Aquatic macroinvertebrates include a diverse range of taxa, including immature and adult insects, crustaceans, mollusks, and worms. They can occur on a variety of substrates, plants, debris, and submerged portions of manmade structures and within the water column (Fremling and Drazkowski 2000). Macroinvertebrates control key ecosystem processes, such as primary production, decomposition, nutrient regeneration, water chemistry, and water clarity. High densities of macroinvertebrates can be attained, as exemplified by midge (Chironomidae) larvae—4,650/ft^2 (50,000/m^2); Asiatic clams (*Corbicula fluminea*)—2,325/ft^2 (25,000/m^2); and zebra mussels (*Dreissena polymorpha*)—46,500/ft^2 (500,000/m^2) (GSMFC 2005; Pennak 1953; Sprecher and Getsinger 2000).

Mussels are planktivores and are prey items for some fish and other vertebrates. They depend on good water quality and physical habitat conditions and on an environment that will support populations of their host fish species. Williams et al. (1993) reported the nearly 300 native freshwater mussels in the United States and Canada, nearly 72 percent are considered endangered, threatened, or of special concern; almost 5 percent are of undetermined status; and less than 24 percent are considered stable. Mussels occur in the vicinity of most plants that use freshwater as a cooling water source.

In addition to native freshwater mussels, several species of mussels and clams have been introduced to the United States and have reached nuisance levels. Most notable among these are the Asiatic clam and the zebra mussel. These species can alter trophic and nutrient dynamics of aquatic ecosystems and displace native mussels. The ability of Asiatic clams and zebra mussels to clog water systems makes them a serious and costly problem for utilities (Morgan et al. 2003). Densities of zebra mussels can be as high as 78,000/ft^2 (840,000/m^2) in utility water pipes (IDNR undated). Many of the nuclear plants have programs in place to monitor for these species, and, as appropriate, to control them, usually using biocides.

Zooplankton

Zooplankton is the animal component of the plankton community and includes protozoans, crustaceans, and the drifting larvae of fish and macroinvertebrates. Rotifers, cladocerans, and copepods are primary components of the zooplankton community in freshwater ecosystems. The zooplankton of estuarine and marine ecosystems include eggs, larvae, juveniles, and/or adults of anemones, jellyfish, bristleworms, sea urchins, starfish, copepods, isopods, amphipods, shrimp, crabs, lobsters, bryozoans, and mollusks. Ichthyoplankton (fish eggs and larvae) are a seasonal component of the zooplankton in all aquatic ecosystems. Zooplankton is an important link between phytoplankton and fish or other secondary consumers.

Phytoplankton and Aquatic Macrophytes

Phytoplankton is an important food source for some invertebrate and fish species and is important for carbon fixation (converting carbon dioxide to organic materials via photosynthesis). Periphyton (algae attached to solid submerged objects) includes species of diatoms and other algae that grow on natural or artificial substrates. These species can become planktonic as a result of scouring or other actions that separate individuals from their substrate. Components of the phytoplankton include green algae (Chlorophyta), bluegreen algae (Cyanophyta), and golden brown algae (Chrysophyta). Brown algae and kelp (Phaeophyta) and red algae (Rhodophyta) also occur in marine waters. Diatoms (Bacillariophyta) are a major component of the phytoplankton in many aquatic systems. Macrophytes can stabilize sediments, act as important links in nutrient cycling, provide shelter and protection for animal communities, and provide important nursery areas (Hall et al. 1978). Factors that affect the distribution and condition of submersed aquatic vascular plants include weather and hydrology, sedimentation, suspended solids and water clarity, and consumption and disturbance by fish and wildlife (USGS 1999).

3.6.2.2 Overview of the Effects of Existing Nuclear Plant Operations on Aquatic Resources

During the initial license period, the operations of nuclear plants had effects on aquatic resources. The withdrawal of cooling water affected aquatic organisms by means of impingement and entrainment. Impingement occurs when organisms (e.g., fish, shellfish [e.g., shrimp, crabs, and crayfish], and, more rarely, sea turtles, birds, and marine mammals) are held against the intake screen or netting

Impingement

Impingement is the entrapment of all life stages of fish and shellfish on the outer part of an intake structure or against a screening device during periods of water withdrawal (40 CFR 125.83).

Entrainment

Entrainment is incorporation of all life stages of fish and shellfish with intake water flow entering and passing through a cooling-water intake structure and into a cooling water system (40 CFR 125.83).

placed within intake canals. Entrainment occurs when smaller organisms (e.g., phytoplankton, zooplankton, and the planktonic eggs and larvae of fish and shellfish) pass through the intake screens and travel through the entire condenser cooling system. Aquatic organisms that might otherwise avoid impingement by swimming away may enter and become entrapped in enclosed cooling water intake canals that hinder escape.

> ***Thermal Shock***
>
> ***Heat Shock:*** Acute thermal stress caused by exposure to a sudden elevation of water temperature that adversely affects the metabolism and behavior of an organism and can lead to its death.
>
> ***Cold Shock:*** Acute thermal stress caused by exposure to a sudden decrease of water temperature that adversely affects the metabolism and behavior of an organism and can lead to its death.

Temperature can have an effect on most biochemical, physiological, and life history activities of aquatic organisms (Beitinger et al. 2000). Thermal effects on aquatic biota can result from heat shock; cold shock; interference with fish migration; premature emergence of aquatic insects; enhanced susceptibility to parasitism, predation, and disease; stimulation of nuisance organisms; gas bubble disease; and lower dissolved oxygen level (NRC 1996). Nuclear power plants also affect aquatic organisms through thermal and chemical releases (NRC 1996). In addition, radionuclides are released into aquatic systems. Radionuclides can be environmentally significant as they have a strong tendency to adsorb onto particles (e.g., suspended and settled solids), can accumulate in biological organisms, or can be concentrated through trophic transfers (Jones and McLean 2005).

The impact from any type of power plant on aquatic resources can be difficult to determine because biotic populations also respond to changes in environmental conditions (EPA 2002). Table 3.6-1 lists various characteristics of power plants, water bodies, and aquatic species that influence the effects of impingement, entrainment, or thermal or chemical discharge on aquatic resources.

Chemical effects on aquatic biota can occur from exposure to biocides and other contaminants (e.g., heavy metals such as copper, zinc, and chromium that may be leached from condenser tubing and other heat exchangers). Blowdown from closed-cycle cooling systems can contain concentrated levels of constituents present in the makeup water, residual biocides, process contaminants, and other chemicals added for controlling corrosion or deposits (Veil et al. 1997). Radionuclides are released to aquatic systems at or below permitted levels at nuclear power plants.

Table 3.6-1. Factors That Influence the Impacts of Nuclear Power Plant Operation on Aquatic Resources

Power Plant Factors	Ecosystem Factors
• Intake and discharge location (e.g., distance from shoreline and to each other) and type (e.g., size and operation) • Intake depth and approach velocities • Proximity to areas of biological concern (e.g., spawning and rearing habitats) • Fish protection technologies (e.g., intake screen design, fish diversion/avoidance systems, screen wash return systems) • Timing, duration, frequency, and quantity of water withdrawal • Ratio of cooling water intake to source water flow • Water temperature change and duration in cooling system • Biocide use • Corrosive potential of condenser tubing • Type of cooling system (e.g., once through, combination cycle, closed cycle, cooling lake, or canal) • Thermal plume characteristics (e.g., cross-sectional area of elevated discharge temperatures)	***Abiotic Factors*** • Type of water body (e.g., riverine, lacustrine, estuarine, marine) • Ambient water temperatures • Ambient water quality (e.g., salinity, dissolved oxygen, pollutant levels) • Current or tidal conditions • Direction and rate of ambient flows ***Biological Factors*** • Spatial and temporal distributions • Abundance or density • Habitat preference • Ability to detect and avoid intake • Swimming speeds • Body size • Age and developmental stage • Physiological tolerance (e.g., temperature, dissolved oxygen, and salinity) • Reproductive strategy • Mode of egg and larval dispersal • Generation time • Condition and health

Source: EPA 2002; NRC 1996

3.6.3 Special Status Species and Habitats

A variety of Federal and State Acts protect certain species and habitats. Federally listed threatened and endangered species are protected under the Endangered Species Act of 1973, while State-listed species are protected under provisions of various State regulations. Prior to the initial construction of the power plants and transmission line ROWs built after 1973, the NRC consulted with the USFWS or the National Marine Fisheries Service (NMFS), as appropriate, to determine the presence of any Federally listed species or critical habitat at or near sites and assess the potential for impacts from the construction and operation of plants or associated transmission lines. Before the Endangered Species Act was enacted, consultation was not required; however, rare species or habitats were often considered in project planning. Any ongoing or proposed activity associated with the operation or maintenance of existing nuclear power plants during the license renewal term that has the potential to affect a listed species requires the initiation of consultation under Section 7 of the Endangered Species Act with the USFWS for terrestrial and freshwater species or the NMFS for marine and anadromous species. Federally managed marine and anadromous fishery resources, including essential fish habitat, are protected under the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act; 16 USC 1801 et seq.). Marine mammals are protected under the Marine Mammal Protection Act (MMPA; 16 USC 1361 et seq.), which establishes a Federal responsibility to conserve marine mammals. Both the Magnuson-Stevens Act and MMPA are administered by the NMFS.

Terms Related to Threatened, Endangered, and Protected Species and Habitats

- ***Endangered Species:*** Animal or plant species in danger of extinction throughout all or a significant portion of its range.
- ***Threatened Species:*** Animal or plant species likely to become endangered within the foreseeable future throughout all or a significant portion of its range.
- ***Candidate Species:*** Animal or plant species for which the USFWS or NMFS has on file sufficient information on vulnerability and threats to support a proposal to list it as endangered or threatened.
- ***Proposed Species:*** Animal or plant species that is proposed in the *Federal Register* to be listed under Section 4 of the Endangered Species Act.
- ***Critical Habitat:*** Specific geographic areas, whether occupied by a listed species or not, that are essential for its conservation and that have been formally designated by rule published in the *Federal Register*.
- ***Essential Fish Habitat:*** Those waters and substrates needed by Federally managed marine and anadromous fish for spawning, breeding, feeding, or growth to maturity.

Many listed species occur in the vicinity of U.S. commercial nuclear plants. Sackschewsky (1997) reported that there were 484 Federally listed threatened, endangered, proposed, or candidate species potentially occurring near one or more of the 75 nuclear reactor sites (including sites that have now been shut down or decommissioned). In a follow-up report, 452 species[f] were identified at 63 sites for which data were available (the Pilgrim and Seabrook plants were not included); critical habitat for 18 species was identified near the facilities (Sackschewsky 2004). The number of species by taxonomic group is given in Table 3.6-2. Although a number of species were identified for most nuclear plants, the probability of occurring at sites was considered low for most species. At the time of the study, there were 59 known occurrences of listed species on nuclear plant sites. Some of the known

(f) Five species that were included in this report have been removed from the list of threatened and endangered species: the Arizona agave (*Agave arizonica*), bald eagle (*Haliaeetus leucocephalus*), cactus ferruginous pygmy-owl (*Glaucidium brasilianum cactorum*), Eggert's sunflower (*Helianthus eggertii*), and gray wolf (*Canis lupus*) in the western Great Lakes and Minnesota.

Table 3.6-2. Number of Endangered Species Act-Listed Species That Could Occur near Operating Nuclear Power Plants

Taxonomic Group	No. of Species
Plants	218
Clams	58
Snails	12
Crustaceans	8
Insects and arachnids	16
Fish	44
Amphibians	9
Reptiles	21
Birds	32
Mammals	34
Total	**452**

Source: Sackschewsky 2004

or potentially occurring species may have been affected by the construction and subsequent operation of the plants, with effects similar to those described in Sections 3.6.1 and 3.6.2.

The USFWS maintains a threatened and endangered species system (TESS) Web site (USFWS 2007b) for all Federally listed species (as well as proposed and candidate species), which has lists organized by State, taxonomic group, species with critical habitats and recovery plans, and so forth.

3.6.3.1 Terrestrial Threatened, Endangered, and Protected Species

Nuclear plants known to support listed terrestrial species on the site or along transmission line ROWs generally maintain monitoring programs to identify changes in populations or report impacts to the USFWS and State agencies. Factors that could affect listed terrestrial species include construction-related habitat loss, cooling tower drift, operation and maintenance of cooling systems, transmission line ROW maintenance, avian collisions with cooling towers and transmission lines, exposure to radionuclides, and site operations and maintenance.

In cases where there have been concerns regarding potential impacts on listed species from plant operation, mitigation has been implemented. For example, the bald eagle (*Haliaeetus leucocephalus*), which was listed by the USFWS as a threatened species until August 2007, occurs near many nuclear plants. At the Monticello plant in Minnesota, a bald eagle nest is located on one of its transmission towers. Flight diverters were installed on transmission lines associated with the Monticello plant to reduce the potential for avian collisions, thereby reducing the likelihood of impacts on bald eagles (NRC 2006f). At the Calvert Cliffs plant in Maryland, restrictions are placed on activities (such as timber harvest) within 0.25 mi (0.4 km) of active bald eagle nests. The cooling canals at the Turkey Point plant in Florida support a breeding population of the American crocodile (*Crocodylus acutus*). The cooling canal system, including freshwater ponds between canals, is managed to provide suitable habitat for all life stages of the crocodile (NRC 2002b).

Listed plant species occur along transmission line ROWs associated with many of the nuclear plants. The open canopy maintained in the ROWs provides habitat conditions required by many of these species. However, these species could be adversely affected by ROW management or line maintenance activities. Individuals could be affected by mowing, cutting, equipment or vehicle operation, and herbicide applications. Many nuclear plants have developed ROW management programs in cooperation with the USFWS or State resource agency. Management activities are designed to avoid impacts on these species and maintain habitat conditions conducive to the survival of these populations. For example, at the Brunswick Nuclear Plant in North Carolina, the golden sedge (*Carex lutea*), Cooley's meadowrue (*Thalictrum cooleyi*), and rough-leaf loosestrife (*Lysimachis asperulaefolia*), all listed by the USFWS as endangered, occur within transmission line ROWs. These populations are managed in cooperation with the State of North Carolina, and vegetation management practices have been adopted to protect these species (NRC 2006e).

ROW management efforts at the St. Lucie plant in Florida provide and maintain habitat for the Florida scrub jay (*Aphelocoma coerulescens*) and other species that prefer open shrubby habitat (NRC 2003a). A small number of bald eagles were killed by collisions with the Rock Creek transmission line associated with the Quad Cities plant in Illinois, at the Mississippi River crossing; however, the impact on the local population was considered small (NRC 2004c).

3.6.3.2 Aquatic Threatened, Endangered, and Protected Species, Marine Mammals, and Essential Fish Habitat

The potential for Federally and State-listed aquatic species to occur in the vicinity of specific nuclear power plants depends on the distribution and habitat preferences of the listed species and the specific water bodies and habitat types that are present on or near the power plant. Species that occur in aquatic habitats with enough water to support power plant cooling water needs (e.g., large rivers and lakes, estuaries, and inshore marine areas) are more likely to be affected by power plant operations than species that occur in smaller bodies of water that would not be capable of providing sufficient cooling water (EPA 2002). Listed aquatic species would generally be considered less likely to be present in constructed habitats, such as cooling ponds, that historically would not have provided suitable habitat and that do not provide ready connections to more natural habitats from which colonization or immigration could occur.

Examples of listed freshwater fish species that have been identified as occurring in the vicinity of nuclear power plants include the pallid sturgeon (*Scaphirhynchus albus*), which occurs in the Missouri River near the Fort Calhoun plant in Nebraska (NRC 2003c), and the Neosho madtom (*Noturus placidus*), which may inhabit streams in the immediate vicinity of the Wolf Creek plant in Kansas (Sackschewsky 2004). None of the operating nuclear power plants or their transmission lines are located in areas designated as critical habitat under the Endangered Species Act for Federally listed aquatic species.

North America has the highest diversity of freshwater mussels in the world. Williams et al. (1993) reported that about 72 percent of North American mussel species are considered endangered, threatened, or of special concern as a result of habitat destruction and reduced water quality (Williams et al. 1993). This high percentage of imperiled species is reflected in the large numbers of listed mussel species that could occur in the vicinity of nuclear power plants that obtain cooling water from freshwater aquatic habitats. Sackschewsky (2004) identified 32 nuclear plants where listed mussel species could occur. There was the potential for more than 20 listed mussel species to occur in the immediate vicinity of three of these plants (Browns Ferry, Sequoyah, and Watts Bar) (Sackschewsky 2004).

A number of listed fish, shellfish, and sea turtles occur in the vicinity of nuclear plants located on estuaries and marine habitats. Some marine mammals (e.g., seals and the West Indian manatee), which, depending on the species, may be protected under Endangered Species Act Section 7 or under the MMPA, occur in the vicinity of some coastal plant sites. Federally listed estuarine and marine fish species that are known to occur in the vicinity of nuclear plants include shortnose sturgeon (*Acipenser brevirostrum*) and smalltooth sawfish (*Pristis pectinata*). Although the West Indian manatee occurs in the vicinity of the Turkey Point plant in Florida, it has not been found in the cooling water canals and is considered unlikely to be affected by operations of the plant (NRC 2002b). The West Indian manatee also occurs in the vicinity of the Crystal River plant in Florida, and in the heated effluent of other non-nuclear power plants in Florida (Laist and Reynolds 2005).

In addition to those marine mammals protected under the Endangered Species Act, marine mammals are also protected under the MMPA. The MMPA gives the NMFS the responsibility for managing cetaceans (porpoises and whales) and pinnipeds (seals, fur seals, and sea lions). The USFWS is responsible for managing all other marine mammals, including the sea otter, walrus, polar bear, dugong, and manatee. The MMPA prohibits, with certain exceptions, the “take” (i.e., harming) of marine mammals in U.S. waters. Concerns about the potential impacts of nuclear power plants on marine mammals have been expressed for only a small number of plants, and typically, intake structures and discharge systems are modified to reduce the potential for harming marine mammals. In cases where there is a potential for small numbers of marine mammals to be inadvertently affected by plant operations, the NMFS or the USFWS may allow the unintentional take of up to a certain number of individuals. For example, a letter of authorization (LOA) under the MMPA was issued by the NMFS for the unintentional take of small numbers of seals incidental to operations of the cooling water intake system at the Seabrook plant in New Hampshire (67 FR 61, January 2, 2002). That LOA specified that up to 20 harbor seals (*Phoca vitulina*) and up to a combined total of four gray (*Halichoerus grypus*), harp (*Pagophilus groenlandicus*), and hooded seals (*Cystophora cristata*) may be taken annually (LOAs are subject to periodic renewal). As part of the take authorization, the licensee of the Seabrook plant is required to monitor the intake facilities for seals and report the impingement of any seals to the NMFS. No seals have been impinged at the Seabrook plant since the installation of seal deterrent barriers in August 1999 (see 67 FR 61).

Under the Magnuson-Stevens Act, the NMFS is responsible for the management of commercial and recreational fisheries within the Exclusive Economic Zone (EEZ) of the United States, which includes marine waters that extend seaward for up to 200 nautical miles from State-managed coastal waters. The Magnuson-Stevens Act calls for the description, identification, and management of essential fish habitat (EFH) to help conserve and manage Federal fishery resources. EFH is defined as those waters and substrates that are necessary to fish for spawning, breeding, feeding, or growth to maturity. The Magnuson-Stevens Act established Fishery Management Councils and requires them to describe and identify EFH in their respective regions and to specify actions to conserve and enhance that EFH. The Magnuson-Stevens Act also requires Federal agencies to consult with NMFS on activities that may adversely affect the EFH designated in fishery management plans.

In addition to designating EFH, the NMFS requires Fishery Management Councils to identify habitat areas of particular concern (HAPCs) within fishery management plans. These HAPCs are discrete subsets of EFH that provide important ecological functions or are especially vulnerable to degradation. Councils may designate a specific habitat area as an HAPC on the basis of the (1) importance of the ecological function provided by the habitat; (2) extent to which the habitat is sensitive to human-induced environmental degradation; (3) whether, and to what extent, development activities are or will be stressing the habitat type; or (4) the rarity of the habitat type. While the HAPC designation does not confer additional protection for or restrictions on an area, it can help prioritize conservation efforts.

Fishery management plans for Federally managed species are typically prepared by the appropriate regional Fishery Management Council(s) and submitted to the NMFS for review, approval, and implementation. Because some of these Federally managed fish and invertebrate species use coastal habitats (e.g., estuaries, coastal rivers, submerged aquatic vegetation, salt marshes, coral reefs, rocky intertidal areas, and hard or live bottom areas) during their lives, some coastal habitats outside of the EEZ have been designated as EFH for one or more managed species. Because of this, some activities on land and in the water have a potential to alter, damage, or destroy EFH components, thereby affecting the fishery resources that use them. Thus, operations of nuclear power plants located in marine, estuarine, and coastal areas have the potential to affect EFH. EFH assessments have been completed as part of the license renewal process for a number of nuclear power plants (e.g., Brunswick, Pilgrim, Vermont Yankee, and Oyster Creek) and as part of the extended power uprate evaluation for the Hope Creek plant.

Overall, there are 17 nuclear power plants where potential impacts on EFH may be a consideration (Table 3.6-3), primarily because cooling water is withdrawn from or discharged to

Table 3.6-3. Operating Nuclear Power Plants for Which Essential Fish Habitat May Be a Consideration

Plant	State	Cooling Water Source
Brunswick[(a)]	North Carolina	Cape Fear River
Calvert Cliffs	Maryland	Chesapeake Bay
Columbia	Washington	Columbia River
Crystal River	Florida	Gulf of Mexico
Diablo Canyon	California	Pacific Ocean
Hope Creek[(b)]	New Jersey	Delaware River
Indian Point	New York	Hudson River
Millstone	Connecticut	Long Island Sound
Oyster Creek[(c)]	New Jersey	Barnegat Bay
Pilgrim[(d)]	Massachusetts	Cape Cod Bay
St. Lucie	Florida	Atlantic Ocean
Salem	New Jersey	Delaware River
San Onofre	California	Pacific Ocean
Seabrook	New Hampshire	Atlantic Ocean
Surry	Virginia	James River
Turkey Point	Florida	Biscayne Bay
Vermont Yankee[(e)]	Vermont	Connecticut River

(a) EFH assessment completed as part of SEIS for Brunswick license renewal (NRC 2006e).
(b) EFH assessment completed as part of the evaluation for the Hope Creek extended power uprate.
(c) EFH assessment completed as part of SEIS for Oyster Creek license renewal (NRC 2007c).
(d) EFH assessment completed as part of SEIS for Pilgrim license renewal (NRC 2007e).
(e) EFH assessment completed as part of SEIS for Vermont Yankee license renewal (NRC 2007f).

estuarine or marine habitats. However, cooling water withdrawn from or discharged to freshwater sources that provide habitat for some Federally managed anadromous species (e.g., salmon) could also affect EFH.

3.7 Historic and Cultural Resources

Historic and cultural resources include prehistoric era and historic era archaeological sites, historic districts, and buildings, as well as any site, structure, or object that may be considered eligible for listing on the *National Register of Historic Places* (NRHP). Historic and cultural resources also include traditional cultural properties (TCPs) that are important to a living community of people for maintaining their culture. "Historic property" is the legal term for a historic and/or cultural resource that is eligible for listing on the NRHP.

> ***Historic and Cultural Resources***
>
> ***Historic and cultural resources*** are areas, places, structures, natural features, and objects with an associated historical, cultural, archaeological, architectural, community, or aesthetic value. Examples include prehistoric and historic era archaeological sites, historic structures, and traditional cultural properties.
>
> ***Prehistoric era resources*** are the remains of human activities from the time period prior to the arrival of Europeans in North America in the 1490s.
>
> ***Historic era resources*** are those resources created after Europeans arrived in North America and are most often associated with Europeans or their descendants.
>
> ***Traditional cultural properties*** are historic and cultural resources that are associated with cultural practices or beliefs of a living community that are rooted in that community's history, and are important in maintaining the cultural identity of the community. Examples include traditionally used plants, gathering areas, and landscape features.

3.7.1 National Historic Preservation Act and NEPA

The National Historic Preservation Act (NHPA) of 1966, as amended (*United States Code*, Title 16, Section 470 [16 USC 470 et seq.]), Section 106, requires Federal agencies to take into account the effects of their "undertakings" on historic properties. Regulations define an undertaking as "a project, activity, or program funded in whole or in part under the direct or indirect jurisdiction of a Federal agency, including those carried out by or on behalf of a Federal agency; those carried out with Federal financial assistance; and those requiring a Federal permit, license or approval." (see 36 CFR 800.16(y)). License renewal is a Federal undertaking that requires compliance with the NHPA.

The NEPA process can be used to fulfill the requirements of NHPA Section 106 when preparing EISs (see 36 CFR 800.8). This allows the NRC to make the Section 106 review processes more efficient. The key to using the NEPA process to comply with Section 106 is early coordination and consultation. The Section 106 process also affords the Advisory Council on Historic Preservation a reasonable opportunity to comment.

The NRC will comply with the consultation requirements in the NHPA regulations in 36 CFR Part 800. The NRC will consult with State Historic Preservation Offices (SHPOs), Tribal representatives, and other interested parties to determine the Area of Potential Effect (APE) and if license renewal would affect any historic properties. Tribal Historic Preservation Officers (THPOs) can serve the function of a SHPO on Tribal lands. Other consulting parties, as identified in 36 CFR 800.2, can include representatives of the local government, the license renewal applicant, the Advisory Council on Historic Preservation, the public, and organizations with a demonstrated interest in the undertaking. The NRC will consider information provided by these consulting parties when making determinations.

While the NRC cannot impose mitigation measures that are not related to public health and safety from radiological hazards or common defense and security, mitigation measures can be implemented to avoid, minimize or mitigate any adverse effects to historic properties. Other consulting parties as identified in 36 CFR 800.2, can provide information to assist in these determinations.

The license renewal APE is the area that may be impacted by land-disturbing or other operational activities associated with continued plant operations and maintenance during the license renewal term and/or refurbishment. The APE typically encompasses the nuclear power plant site, its immediate environs including viewshed, and in-scope transmission lines. The APE may extend beyond the nuclear plant site and transmission lines when these activities may affect historic properties. This determination is made irrespective of land ownership or control.

If historic and cultural resources are present, the eligibility of any historic properties for listing on the NRHP is determined through the application of the NRHP criteria in 36 CFR 60.4 in consultation with SHPOs, tribal representatives, and other interested parties. SHPOs maintain a record of all historic and cultural resources in the State and ensure the protection of historic and cultural resources in the State. The NHPA requires that information on the locations of historic and cultural resources, as well as sensitive sacred and religious information, be withheld from the public to protect the resources (36 CFR 800.11(c)(1)). Other legal authorities regarding protection of information from public release may also apply.

Historic Property (36 CFR 800.16(l)(1))

Any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the *National Register of Historic Places* maintained by the Secretary of the Interior. Historic properties also include artifacts, records, and remains that are related to and located within such properties. The term includes properties of traditional religious and cultural importance to an Indian Tribe or Native Hawaiian organization and that meet the *National Register* criteria.

Extensive ground-disturbing activities occurred during nuclear power plant construction, and much of the land immediately surrounding the power block was disturbed down to bedrock. This activity would have eliminated any potential for historic or cultural resources to be present in this portion of the power plant site. Since many nuclear power plant sites were not investigated for the presence of historic and cultural resources prior to construction, a survey of any area which may be disturbed by ongoing operations and maintenance activities, including previously disturbed areas of the nuclear power plant site (other than the land immediately surrounding the power block), should be conducted by qualified professionals. The NRC will use this survey information in consultation with the SHPO and other consulting parties to effectively determine areas that could potentially contain historic and cultural resources.

3.7.2 Historic and Cultural Resources

Historic and cultural resources are the remains of past human activity and include prehistoric era and historic era archaeological sites, historic districts, buildings, or objects with an associated historical, cultural, archaeological, architectural, community, or aesthetic value. Historic and cultural resources also include traditional cultural properties (TCPs) that are important to a living community of people for maintaining their culture. A historic property is a historic or cultural resource that is eligible for listing on the NRHP.

Prehistoric era resources are those associated with the period before Europeans arrived in North America in the 1490s. Evidence of prehistoric peoples in North and South America suggests that humans have been in the Americas for at least 12,000 years. Some of the most heavily used areas on the landscape for prehistoric era people were along rivers, lakes, and the seashore. These locations provided freshwater and the most abundant food sources, as well as the most efficient ways to travel. Waterways formed the primary transportation routes in North America for thousands of years. As a result, prehistoric era archaeological sites tend to be found along these waterways. The types of prehistoric archaeological resources found include small temporary camps, larger seasonal camps that were returned to year after year, large village sites that were occupied continuously over several years or potentially centuries, or specialized-use areas associated with fishing or hunting or with tool and pottery manufacture.

Historic era resources are those associated with Europeans or their descendants. Similar to the prehistoric era, historic era sites tend to cluster near waterways as water was the most efficient form of transportation at the time. Historic era resources include farmsteads, mills, forts, residences, industrial sites (such as mines or canals), and shipwrecks.

TCPs are historic and cultural resources that are important for a group to maintain its cultural heritage. TCPs are closely associated with Native American cultures; however, a TCP can be associated with any living community. Examples of traditional cultural properties include traditional gathering areas where particular plants or materials were harvested, a sacred mountain or landscape that was crucial to a Tribe's identity, or burial locations that connect individuals or groups with their ancestors. As the location of traditional cultural properties is often kept private, SHPOs can often be unaware of these locations. Identification of TCPs is an important part of consultation with SHPOs, tribal representatives, or other interested parties.

The fact that past human activities were focused along waterways is important to note as most nuclear power plants are located along major rivers, lakes, or the ocean. Consequently, the potential for the presence of historic and cultural resources near most nuclear power plants is high. A review of historic and cultural resources at 40 nuclear plants that have already undergone license renewal indicates that generally very few archaeological sites have been identified at the power plant locations. In the cases where field investigations were undertaken, the average number of historic and cultural resources present was 35 per plant. At plants where field investigations did not take place, no sites were known. Some of the historic and cultural resources identified include village sites, town sites, and cemeteries.

Activities that take place as part of continued operations and refurbishment activities that could affect archaeological sites include grading for parking lots, construction of security barriers, any new construction or ground clearing, vegetation removal, and landscaping activities. Even a small amount of ground clearing could critically alter a small but very significant historic and cultural resource. For instance, a small short-term-occupation site can be a time capsule for understanding past lifeways, even if the site is only half an acre.

3.8 Socioeconomics

This section describes socioeconomic factors that have the potential to be directly or indirectly affected by changes in nuclear power plant operations. The nuclear plant and the communities that support it can be described as a dynamic socioeconomic system. The communities provide the people, goods, and services needed to operate the nuclear power plant. Power plant operations, in turn, provide wages and benefits for people and dollar expenditures for goods and services. The measure of a communities' ability to support power plant operations depends on the ability of the community to respond to changing environmental, social, economic, and demographic conditions.

The socioeconomics region of influence around a nuclear power plant is defined by the counties where plant employees and their families reside, spend their income, and use their benefits, thereby affecting the economic conditions of the region. Changes in nuclear power plant operations affect socioeconomic conditions in the regions surrounding them, including employment and income; population and housing; community services; and transportation.

3.8.1 Power Plant Employment and Expenditures

Nuclear power plant operations generate employment and expenditures at each plant site. Wage and salary and nonlabor expenditures create demand for a range of durable and nondurable goods provided by wholesalers and retailers, while wage and salary spending also create demand for health and professional services and for housing. Power plants also provide tax revenues for education, public safety, government services, and transportation.

Employment at nuclear power plants varies according to a number of factors, including the number of reactor units, power production, and the type and age of the plant. At 11 nuclear plants for which detailed economic annual data have been collected, employment averaged 1,337 workers, ranging from 528 workers at Three Mile Island to 2,385 workers at Palo Verde (Table 3.8-1). Annual wage and salary expenditures at the State level reflected the size of the labor force at each plant, ranging from $59.2 million at Grand Gulf to $194.2 million at Palo Verde. Annual labor expenditures averaged $122.6 million, or $95,029 per permanent full-time worker. In addition to labor expenditures, each plant also had expenditures for materials,

Table 3.8-1. State Employment, Expenditures, and Tax Revenues at 11 Nuclear Plants from 2003 through 2006[(a)]

Plant	Employment	Labor Expenditures ($ million)	Nonlabor Expenditures ($ million)	Total Expenditures ($ million)	Tax Revenues ($ million)
Diablo Canyon	1,638	123.1	48.8	171.9	27.0
Grand Gulf	621	59.2	1.8	61.0	26.2
Indian Point	1,559	145.9	54.9	200.8	35.3
Limerick	705[(b)]	NA[(c)]	NA	NA	NA
Millstone	1,406	96.4	63.0	159.4	25.0
Oconee	1,328[(b)]	NA	NA	NA	NA
Palo Verde	2,385	194.2	21.1	215.3	90.6
Peach Bottom	666[(b)]	NA	NA	NA	NA
Susquehanna	1,528	196.7	56.1	252.8	35.3
Three Mile Island	528	61.6	26.2	87.8	0.9
Wolf Creek	1,028	103.6	5.6	109.2	24.8

(a) Data for Millstone are for 2003; data for Diablo Canyon, Indian Point, Oconee, and Palo Verde are for 2004; data for Three Mile Island and Wolf Creek are for 2005; data for Grand Gulf, Limerick, Peach Bottom, and Susquehanna are for 2006.
(b) National employment data.
(c) NA = not available.
Sources: Nuclear Energy Institute, 2003, 2004a,b,c,d, 2005a,b, 2006a,b,c

equipment, and services to support power plant operations. Some plants, such as Millstone ($63.0 million), Susquehanna ($56.1 million), and Indian Point ($54.9 million), had significant nonlabor expenditures, while others spent less than $10 million. Annual nonlabor expenditures at the 11 plants averaged $34.7 million.

Nuclear power plants provide annual tax revenues to State and local governments. State and local taxes paid by power plants ranged from $0.9 million at Three Mile Island to $90.6 million at Palo Verde, averaging $27.6 million. Differences in tax revenues among plants are related to variations in State and local taxation laws, electricity output, plant size, and plant employment.

Additional employment and expenditures occur during refueling activities at each plant, when additional workers are employed over a 1 to 2-month period. Refueling outages generally occur on approximately 18-month to 24-month cycle.

3.8.2 Regional Economic Characteristics

Nuclear power plant operations affect socioeconomic conditions in the county in which the plant is located and in the counties in which the majority of the plant's employees reside. Regional economic conditions can vary depending on the location of the nuclear plant. In general, nuclear power plants in the United States are located in one of two broad regional economic settings: rural or semi-urban. Recent employment, expenditures and tax revenue information for a representative sample of 11 nuclear power plants is presented in Table 3.8-1.

3.8.2.1 Rural Economies

Many nuclear power plants are located in rural areas, where agriculture is the primary economic activity. Rural areas often have relatively simple economies, without many of the industries that provide equipment and services important to plant operations, and with smaller, less diversified labor markets that are often composed of lower-paying occupations requiring less skill. In addition to agriculture and related activities, a range of other activities, including those associated with the resource extraction, manufacturing, and transportation industries, may provide employment and income.

Among the 11 plants listed in Table 3.8-1, the seven shown in Table 3.8-2 are located in rural economies. Only two of these seven plants, Diablo Canyon and Oconee, provided 1 percent or more of regional employment, and average plant earnings at these plants (particularly Oconee, Wolf Creek, and Diablo Canyon) were higher than the regional average.

Employment, wages, salaries, and nonlabor expenditures are directly associated with plant operations. As direct expenditures circulate through the economy, producing additional economic activity, spending in the local and regional economy also produces indirect

Table 3.8-2. Plant and Regional Employment and Earnings in Rural Locations

Plant	Plant Regional Employment	Total Regional Employment	Percent of Total Regional Employment	Annual Avg. Plant Earnings per Worker ($)	Annual Avg. Regional Earnings per Worker ($)	Percent of Regional Avg. Earnings
Diablo Canyon	1,260	118,500	1.1	85,200	52,400	163
Grand Gulf	593	162,100	0.4	70,400	50,000	141
Oconee	1,312	161,108	0.8	83,100	45,700	182
Peach Bottom	523	652,903	0.1	75,700	63,500	119
Susquehanna	305	151,869	0.2	69,500	52,000	134
Three Mile Island	512	742,700	0.1	71,300	53,500	133
Wolf Creek	838	82,243	1.0	72,400	43,100	168

Source: Nuclear Energy Institute 2004a,c, 2005a,b, 2006a,c

employment and income. The size of the indirect local impact depends closely on both the extent to which plant employees live in the local area (and consequently the size of the wage and salary bill paid to local residents) and the presence of local vendors of material and supplies. These determine the ability of the local economy to absorb nonlabor spending.

Indirect impacts occur annually in the local area at a number of power plants as a result of direct plant expenditures. For example, 882 indirect jobs were created at Diablo Canyon and 952 jobs were created at Oconee; these are the two plants with the largest direct employment (Table 3.8-3). Almost 2,300 total jobs are created in the local area at these two plants annually. On average, an additional 0.4 job is created locally for every direct job at each plant. Expenditures at the Oconee plant produced $25.3 million in indirect income in the local area, $135.6 million in total. At Diablo Canyon, $19.1 million in income was produced in the host county, and $128.1 million was produced in total. On average, an additional 11 cents in income was produced in the local area for every dollar of direct income paid at each plant site.

Plant expenditures associated with wages, salaries, procurement, and tax revenues create additional direct and indirect impacts beyond the local area. At Diablo Canyon, 1,616 indirect jobs in the State were created by expenditures at the plant, in addition to 1,638 direct jobs (Table 3.8-4). At Susquehanna, the plant created 2,639 indirect jobs in the State, in addition to 1528 direct jobs; at Wolf Creek, 1,028 direct and 986 indirect jobs were created in the host State. On average, 1.3 additional jobs are created in the State for every direct job at each plant. Although the largest impacts occurred at the three plants that had the largest direct employment, the sizes of the indirect impact and total impact of each plant are related to variations in the extent of wage, salary, and procurement expenditures within each State.

Table 3.8-3. Local Economic Impacts of Plant Operations in Rural Locations[(a)]

Plant	Employment			Income ($ million)		
	Direct	Indirect	Total	Direct	Indirect	Total
Diablo Canyon	1,405	882	2,287	109.0	19.1	128.1
Grand Gulf	411	152	563	38.8	3.8	42.6
Oconee	1,328	952	2,280	110.3	25.3	135.6
Peach Bottom	248	71	319	28.4	2.0	30.4
Susquehanna	305	76	381	37.3	2.2	39.5
Three Mile Island	208	67	275	22.8	2.0	24.8
Wolf Creek	561	121	682	55.4	2.3	57.7

(a) Impacts from Diablo Canyon occur in San Luis Obispo County; from Grand Gulf occur in Warren and Claiborne Counties; from Oconee occur in Anderson, Oconee, and Pickens Counties; from Peach Bottom occur in York County; from Susquehanna occur in Luzerne County; from Three Mile Island occur in Dauphin County; and from Wolf Creek occur in Coffey County.

Source: Nuclear Energy Institute 2004a,c; 2005a,b; 2006a,c

Table 3.8-4. State Economic Impacts of Plant Operations in Rural Locations

Plant	Employment			Income ($ million)			State and Local Taxes ($ million)		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
Diablo Canyon	1,638	1,616	3,254	123.1	50.8	173.9	27.0	11.6	38.6
Grand Gulf	625	695	1,316	59.2	19.5	78.7	26.2	3.3	29.5
Susquehanna	1,528	2,639	4,167	196.7	96.6	293.3	35.3	14.8	50.2
Three Mile Island	528	848	1,376	69.6	29.6	91.2	0.9	4.8	5.7
Wolf Creek	1,028	986	2,014	103.6	25.6	129.3	24.8	5.0	29.9

Source: Nuclear Energy Institute 2004a,c; 2005a,b; 2006a,c

Annual expenditures at each plant also produced indirect income and tax revenues at the State level. The Susquehanna plant produced $96.6 million of indirect income in the State, $293.3 million in total. The Diablo Canyon plant produced $50.8 million of income in the State, and $173.9 million in total (Table 3.8-4). Expenditures at Susquehanna also produced $14.8 million of indirect tax revenues at the State and local level, with $11.6 million of indirect tax revenues generated by the Diablo Canyon plant. An additional 40 cents in income is produced in the State on average for every dollar of direct income paid at each plant site, and an additional $1.25 in tax revenues is produced on average for each dollar of direct State and local taxes paid at each plant.

3.8.2.2 Semi-Urban Economies

Many nuclear power plants are located in semi-urban areas. These areas have more complex economic structures than rural areas, containing a wider range of industries, with larger and more diverse labor markets. Semi-urban areas may also serve specialized economic functions, including maritime shipping, fishing, and boatbuilding; recreation; and tourism. Numerous locations serve residential areas containing second homes and hosting retirement communities.

The economies of many of the semi-urban areas in which nuclear plants are located have changed since these plants were constructed. Gradual residential and commercial development and the associated diversification of economic activity in these areas have changed the local and regional economic profile, with a decline in the importance of agriculture and other related activities and their replacement by manufacturing, retailing, and professional services. At other sites, especially those in coastal locations, participation in outdoor recreational activities by both the local and nonresidential population has also changed the focus of local and regional economic activity; this, together with the often-associated growth of retirement communities, rivals the importance of traditional economic activities in the vicinity of a power plant site in providing employment and income.

Among the 11 plants shown in Table 3.8-1, the four shown in Table 3.8-5 are located in semi-urban economies. None of the plants provided 1 percent or more of regional employment, and average plant earnings at these plants (particularly Millstone and Indian Point) were higher than the regional average.

Employment, wages, salaries, and nonlabor expenditures are directly associated with plant operations. As direct expenditures circulate through the economy, producing additional economic activity, spending in the local and regional economy also produces indirect employment and income. Local impacts shown in Table 3.8-6 are those impacts that occur in the county hosting the power plant and in the adjacent counties. The size of the indirect local impact depends closely on both the extent to which plant employees live in the host county or counties (and consequently the size of the wage and salary bill paid to local residents) and the presence of local vendors of material and supplies. These determine the ability of the local economy to absorb nonlabor spending.

Indirect impacts occur annually in the local area at a number of power plants as a result of direct plant expenditures. For example, 1,570 indirect jobs were created at Palo Verde, 1,272 were created at Millstone, and 1,198 were created at Indian Point. These are the three plants with the largest direct employment (Table 3.8-6). More than 3,900 total jobs are created annually in

Table 3.8-5. Plant and Regional Employment and Earnings in Semi-Urban Locations

Plant	Plant Regional Employment	Total Regional Employment	Percent of Total Regional Employment	Annual Avg. Plant Earnings per Worker ($)	Annual Avg. Regional Earnings per Worker ($)	Percent of Regional Avg. Earnings
Indian Point	1,053	899,331	0.2	121,700	85,800	142
Limerick	590	786,824	0.1	75,900	74,300	102
Millstone	1,066	130,721	0.8	80,200	52,100	154
Palo Verde	2,385	1,427,292	0.1	66,000	58,600	113

Source: Nuclear Energy Institute 2003; 2004b,d; 2006b

Table 3.8-6. Local Economic Impacts of Plant Operations in Semi-Urban Locations(a)

	Employment			Income ($ million)		
Plant	Direct	Indirect	Total	Direct	Indirect	Total
Indian Point	1,355	1,198	2,553	126.6	44.8	171.4
Limerick	253	132	385	31.3	5.7	36.9
Millstone	1,066	1,272	2,338	73.1	45.1	118.2
Palo Verde	2,373	1,570	3,943	193.2	51.9	245.2

(a) Impacts from Indian Point occur in Westchester, Duchess, Orange, Putnam, and Rockland Counties; from Limerick occur in Montgomery County; from Millstone occur in New London County; from Palo Verde occur in Maricopa County.
Source: Nuclear Energy Institute 2003; 2004b,d; 2006b

the local area at the Palo Verde plant. On average, an additional 0.8 job is created for every direct job at each plant. Expenditures at the Palo Verde plant produced $51.7 million in indirect income in the local area, $244.9 in total. At Millstone, $45.1 million in income was produced in the local area, and $44.8 million was produced at Indian Point. At Indian Point, a total of $171.4 million in income was produced annually, compared with $118.2 million at Millstone, because employment and direct wage and salary expenditures were higher at Indian Point. On average, an additional 40 cents in income is produced in the local area for every dollar of direct income paid at each plant site.

In addition to impacts in the local area, nuclear power plants also generate employment and income in the economies as a whole of the States in which plants are located, since plant expenditures associated with wages, salaries, procurement, and tax revenues create additional direct and indirect impacts beyond the local area. In 2006, expenditures at Millstone created 1,841 indirect jobs in the State, in addition to 1,406 direct jobs (Table 3.8-7). At Palo Verde, the

Table 3.8-7. State Economic Impacts of Plant Operations in Semi-Urban Locations

	Employment			Income ($ million)			State and Local Taxes ($ million)		
Plant[(a)]	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
Indian Point	1,559	1,620	3,179	145.9	65.2	211.1	35.3	14.4	49.7
Millstone	1,406	1,841	3,247	96.4	78.4	174.8	17.1	39.7	56.8
Palo Verde	2,385	1,800	4,185	194.2	55.1	249.3	54.1	7.8	62.0

(a) Data for Limerick are not included because impact estimates are not available at the State level.
Source: Nuclear Energy Institute 2003; 2004b,d; 2006b

plant created 1,800 indirect jobs in the State, in addition to 2,385 direct jobs. At Indian Point, 1,559 direct and 1,620 indirect jobs were created in the host State. On average, one additional job is created in the State for every direct job at each plant. Although the largest impacts occurred at the three plants with the largest direct employment, the sizes of the indirect impact and total impact of each plant are related to variations in the extent of wage, salary, and procurement expenditures within each State.

Annual expenditures at each plant also produced indirect income and tax revenues at the State level. The Millstone plant produced $78.4 million in indirect income in the host county, $174.8 in total (Table 3.8-7). At Indian Point, $65.2 million in income was produced in the local area, and $211.1 million in total. Expenditures at Millstone also produced $39.7 million in indirect tax revenues at the State and local level, with $14.4 million in indirect tax revenues generated by the Indian Point plant, and $7.8 million by Palo Verde. On average, an additional 51 cents in income is produced in the State for every dollar of direct income paid at each plant site, and an additional 96 cents in tax revenues is produced for each dollar of direct State and local taxes paid at each plant.

3.8.3 Demographic Characteristics

Although the majority of U.S. nuclear power plants are situated in smaller, rural communities, population densities within 20 mi (50 km) of most nuclear plant sites are generally high, and most are within 50 mi (80 km) of a community with a population of 100,000 (see Section D.7 in Appendix D). Demographic characteristics vary in the region around each nuclear power plant and may be affected by the remoteness of the nuclear plant to regional population centers.

Two measures of remoteness were developed for the 1996 GEIS, “sparseness” and “proximity,” which combine demographic data on population density and the distance to larger cities to place nuclear plants into three population classes. Population classifications of 11 representative nuclear power plant sites are presented in Table 3.8-8.

Table 3.8-8. Population Classification of Regions around Selected Nuclear Power Plants

Population	Plant	Population Density Within 20 mi	Sparseness Measure	Population Density Within 50 mi	Proximity Measure
Low	Palo Verde	13.3	1	227.5	4
	Wolf Creek	11.0	1	22.0	1
	Oconee	154.1	4	156.7	3
Medium	Diablo Canyon	286.7	4	106.8	3
High	Susquehanna	250.4	4	215.7	4
	Peach Bottom	299.3	4	698.6	4
	Millstone	440.4	4	699.9	4
	Three Mile Island	639.5	4	315.1	4
	Limerick	869.9	4	977.5	4
	Indian Point	839.7	4	2,265.5	4

Source: Argonne National Laboratory calculations.

Many communities have transient populations associated with regional tourist and recreational activities, weekend and summer homes, or populations of students who attend regional colleges and other educational institutions. Nuclear power plants located in coastal regions, notably Cook and Palisades on Lake Michigan and Oyster Creek on the New Jersey shore north of Atlantic City, have summer, weekend, and retirement populations and a range of recreational and environmental amenities that attract visitors from nearby metropolitan population centers.

Some areas, such as the region around Vermont Yankee, attract visitors seeking outdoor recreational activities, such as skiing.

In addition to transient populations, farms and factories in rural communities often employ migrant workers on a seasonal basis. For example, berry production near the Cook and Palisades Nuclear Plants is a local agricultural activity that employs a sizable migrant labor force in the summer.

3.8.4 Housing and Community Services

Housing in the vicinity of nuclear power plants ranges in number of housing units and the type and quality of available housing. Much of the difference is due to the nature of the local economy, particularly regional population and income levels; proximity to metropolitan areas; and the importance of recreation, tourism, second homes, and retirement communities.

Although long-term housing demand can be affected by changes in the number of permanent onsite employees, demand for rental housing increases during periodic outages, when refueling and maintenance workers require rental accommodations. This demand affects the availability and cost this type of housing. Some workers may occupy motels and other temporary accommodations, including housing provided onsite at some power plants.

Rural communities generally have small housing markets, stable prices for most types of housing, lower median house values, and stable vacancy rates. Housing markets in semi-urban regions are less stable with more housing turnover, higher prices for most types of housing, and lower vacancy rates. Controls on housing development are more likely in semi-urban communities, particularly where there is a transient seasonal population.

3.8.5 Tax Revenues

Nuclear power plants provide tax revenues to local and State governments. Although the most important source of revenue for local communities is property taxes, other sources of revenue include levies of electricity output and direct funding for local educational facilities and programs. In 2006, State and local taxes paid by power plants ranged from \$0.9 million at Three Mile Island to \$90.6 million at Palo Verde, averaging \$24.1 million (Table 3.8-9). Differences in tax revenues among plants are related to variations in local and State taxation laws, electricity output, power plant size, and plant employment. Tax revenues may be used by local, regional, and State governmental entities to fund education, public safety, local government services, and transportation. In smaller rural communities, power plant tax revenues can affect the level and quality of public services available to local residents, with property tax revenues paid by power plants contributing more than 50 percent of total property taxes in some communities (e.g., at the Cook

Sparseness Indices

Most Sparse	1	There are fewer than 40 people/mi^2 (15 people/km^2) and there is no community with 25,000 or more people within 20 mi (32 km) of the plant.
	2	There are 40 to 60 people/mi^2 (15 to 23 people/km^2) and there is no community with 25,000 or more people within 20 mi (32 km) of the plant.
	3	There are 60 to 120 people/mi^2 (23 to 46 people/km^2) and there is at least one community with more than 25,000 people/mi^2 (10,000 people/km^2) within 20 mi (32 km) of the plant.
Least Sparse	4	There are more than 120 people/mi^2 (46 people/km^2) within 20 mi (32 km) of the plant.

Proximity Indices

Not in Close Proximity	1	There are fewer than 50 people/mi^2 (19 people/km^2) and there is no city with more than 100,000 people within 50 mi (80 km) of the plant.
	2	There are 50 to 190 people/mi^2 (19 to 73 people/km^2) and there is no city with 100,000 people within 50 mi (80 km) of the plant.
	3	There are fewer than 190 people/mi^2 (73 people/km^2) and there are one or more cities with more than 100,000 people within 50 mi (80 km) of the plant.
In Close Proximity	4	There are more than 190 people/mi^2 (73 people/km^2) within 50 mi (80 km) of the plant.

Table 3.8-9. State and Local Tax Revenues Generated at Eight Nuclear Power Plants

Plant[(a)]	Tax Revenues ($ million)
Diablo Canyon	27.0
Grand Gulf	26.2
Indian Point	35.3
Millstone	25.0
Palo Verde	90.6
Susquehanna	35.3
Three Mile Island	0.9
Wolf Creek	24.8

(a) Data for Limerick, Oconee, and Peach Bottom are not included because impact estimates are not available at the State level.

Source: Nuclear Energy Institute 2003; 2004a,b,c; 2005a,b; 2006a,b,c

and Palisades plants in Michigan and the Nine Mile Point plant in New York). Even in semi-urban regions, revenues from power plants provide support for public services at the local level (e.g., at the Oyster Creek plant in New Jersey).

The restructuring of utilities has occurred in some States with the deregulation of electricity markets, and this has led to changes in the methods used to estimate property values at some nuclear power plants. At some plants, these changes have had an impact on the property taxes that utilities pay to State and local taxing jurisdictions. Any changes in tax revenues following utility deregulation would not occur as a direct result of license renewal.

3.8.6 Local Transportation

Local and regional transportation networks in the vicinity of nuclear power plant sites may vary considerably depending on the regional population density, location, and size of local communities, nature of economic development patterns, location of the region relative to interregional transportation corridors, and land surface features, such as mountains, rivers, and lakes. The impacts of employee commuting patterns on the transportation network in the vicinity of nuclear power plants depend on the extent to which these factors limit or facilitate traffic movements and on the size of the plant workforce that uses the network at any given time. Impacts at the local level in the immediate vicinity of power plant sites vary depending on the capacity of the local road network, local traffic patterns, and particularly the availability of alternate routes for power plant workers. Given the rural locations of most power plant sites, site traffic has a small impact on the local road system, since often there is not much other traffic on local roads in the immediate vicinity of the plant. Because most sites have only one access road, there may be congestion on this road at certain times, such as during shift changes.

3.9 Human Health

3.9.1 Radiological Exposure and Risk

Radiological exposures from nuclear power plants include offsite doses to members of the public and onsite doses to the workforce. Each of these impacts is common to all commercial U.S. reactors. The Atomic Energy Act requires the NRC to promulgate, inspect, and enforce standards that provide an adequate level of protection for public health and safety and the environment. The NRC continuously evaluates the latest radiation protection recommendations from international and national scientific bodies to establish the requirements for nuclear power plant licensees. The NRC has established multiple layers of radiation protection limits to protect the public against potential health risks from exposure to effluent discharges from nuclear power plant operations. If the licensees exceed a certain fraction of these dose levels in a calendar quarter, they are required to notify the NRC, investigate the cause, and initiate corrective actions within the specified time frame. Section 3.9.1.1 discusses regulatory requirements at nuclear power plants. Sections 3.9.1.2 and 3.9.1.3 discuss occupational and public exposure, respectively. These sections evaluate the performance of licensees in implementing these requirements, and they compare the doses and releases with permissible levels. Risk estimates are provided in Section 3.9.1.4.

3.9.1.1 Regulatory Requirements

Nuclear power reactors in the United States must be licensed by the NRC and must comply with NRC regulations and conditions specified in the license in order to operate. The licensees are required to comply with 10 CFR Part 20, Subpart C, “Occupational Dose Limits for Adults,” and 10 CFR Part 20, Subpart D, “Radiation Dose Limits for Individual Members of the Public.”

Regulatory Requirements for Occupational Exposure

10 CFR 20.1201 establishes occupational dose limits (see Table 3.9-1).

Table 3.9-1. Occupational Dose Limits for Adults Established by 10 CFR Part 20

Tissue	Dose Limit[(a)]
Whole body or any individual organ or tissue other than the lens of the eye	More limiting of 5 rem/yr TEDE to whole body or 50 rem/yr sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue other than the lens of the eye
Lens of the eye	15 rem/yr dose equivalent
Extremities, including skin	50 rem/yr shallow dose equivalent

(a) See text box for definitions. Note: To convert rem to sievert, multiply by 0.01.

Definitions

- ***Total effective dose equivalent (TEDE):*** Sum of the dose equivalent (for external exposure) and the committed effective dose equivalent (for internal exposure).
- ***Committed effective dose equivalent (CEDE):*** Sum of the products of the weighting factors for body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues.
- ***Deep dose equivalent:*** Applies to external whole-body exposure and is the dose equivalent at a tissue depth of 1 cm.
- ***Committed dose equivalent:*** Dose equivalent to organs or tissues from an intake of radioactive material for the 50-year period following the intake.
- ***Dose equivalent:*** Product of the absorbed dose in the tissue, quality factor, and all other necessary modifying factors at the location of interest.
- ***Shallow dose equivalent:*** Applies to the external exposure of the skin, as the dose equivalent at a tissue depth of 0.007 cm averaged over an area of 1 cm^2.
- ***Organ dose:*** Dose received as a result of radiation energy absorbed in a specific organ.
- ***Total body dose or whole body dose:*** Sum of the dose received from external exposure to the total body, gonads, active blood-forming organs, head and trunk, or lens of the eye and the dose due to the intake of radionuclides by inhalation and ingestion, where a radioisotope is uniformly distributed throughout the body tissues rather than being concentrated in certain parts.

Under 10 CFR 20.2206, the NRC requires licensees to submit an annual report of the results of individual monitoring carried out by the licensee for each individual for whom monitoring was required by 10 CFR 20.1502 during that year.

Under 10 CFR 20.2202 and 10 CFR 20.2203, the NRC requires all licensees to submit reports of all occurrences involving personnel radiation exposures that exceed certain control levels. The control levels are used to investigate occurrences and to take corrective actions as necessary. Depending on the magnitude of the exposure, the occurrence reporting is required immediately, within 24 hours, or within 30 days. On the basis of the reporting requirement, the control levels can be placed in one of three categories (A, B, or C), as follows (Burrows and Hagemeyer 2006):

- Category A, immediate notification. A total effective dose equivalent (TEDE) of 25 rem or more to any individual, an eye dose equivalent of 75 rem or more, or a shallow dose equivalent to the skin or extremities of 250 rad or more (10 CFR 20.2202(a)(1)).

- Category B, notification within 24 hours. A TEDE of 5 rem or more to any individual, an eye dose equivalent of 15 rem or more, or a shallow dose equivalent to the skin or extremities of 50 rem or more (10 CFR 20.2202(b)(1)).

- Category C, written report within 30 days. Any incident for which notification was required and doses or releases that exceed the limits in the license set by the NRC or EPA (10 CFR 20.2203).

Regulatory Requirements for Public Exposure

NRC regulations in 10 CFR Part 20 identify maximum allowable concentrations of radionuclides that can be released from a licensed facility into the air and water above background at the boundary of unrestricted areas to control radiation exposures of the public and releases of radioactivity. These concentrations are derived on the basis of an annual TEDE of 0.1 rem to individual members of the public. In addition, pursuant to 10 CFR 50.36a, nuclear power reactors have special license conditions called technical specifications for radioactive gaseous and liquid releases from the plant that are required to minimize the radiological impacts associated with plant operations to levels that are as low as is reasonably achievable (ALARA).

Appendix I to 10 CFR Part 50 provides numerical values on dose-design objectives for operation of LWRs to meet the ALARA requirement. The design objective doses for Appendix I are summarized here in Table 3.9-2.

In addition to keeping within NRC requirements, nuclear power plant releases to the environment must comply with EPA standards in 40 CFR Part 190, “Environmental Radiation Protection Standards for Nuclear Power Operations.” These standards specify limits on the annual dose equivalent from normal operations of uranium fuel-cycle facilities (except mining, waste disposal operations, transportation, and reuse of recovered non-uranium special nuclear and by-product materials). The standards are given in Table 3.9-2. Radon and its daughters are covered by Subpart D of 40 CFR Part 192 (the conforming NRC regulations are in Appendix A of 10 CFR Part 40).

Table 3.9-2. Design Objectives and Annual Standards on Doses to the General Public from Nuclear Power Plants[a]

Tissue	Gaseous Effluents	Liquid Effluents
Design objectives, Appendix I to 10 CFR 50		
Total body, mrem	5[b]	3
Any organ (all pathways), mrem		10
Ground-level air dose,[b] mrad	10 (gamma) and 20 (beta)	
Any organ[c] (all pathways), mrem	15	
Skin, mrem	15	
Dose standards, 40 CFR Part 190, Subpart B		
Whole body,[d] mrem	25	
Thyroid,[d] mrem	75	
Any other organ,[d] mrem	25	

(a) Calculated doses.
(b) The ground-level air dose has always been limiting because an occupancy factor cannot be used. The 5-mrem total body objective could be limiting only in the case of high occupancy near the restricted area boundary.
(c) Particulates, radioiodines.
(d) All effluents and direct radiation except radon and its daughters.

EPA standards in 40 CFR Part 61, “National Emission Standards for Hazardous Air Pollutants,” apply only to airborne releases. The EPA specified an annual effective dose equivalent limit of 10 mrem for airborne releases from nuclear power plants; however, no more than 3 mrem can be caused by any isotope of iodine. However, the EPA has stayed the rule for NRC-licensed commercial nuclear power reactors on the basis of its finding that NRC’s ALARA program for power reactor air effluents protects and is likely to continue to protect public health and safety with an ample margin of safety.

Experience with the design, construction, and operation of nuclear power reactors indicates that compliance with the design objectives of Appendix I to 10 CFR Part 50 will keep average annual releases of radioactive material in effluents at small percentages of the limits specified in 10 CFR Part 20 and 40 CFR Part 190. At the same time, the licensee is given the flexibility in operations, compatible with considerations of health and safety, to ensure that the public is provided with a dependable source of power, even under unusual operating conditions that might temporarily result in releases that were higher than such small percentages but still well within the regulatory limits.

Another 10 CFR Part 20 requirement is that the sum of the external and internal doses (TEDE) for a member of the public shall not exceed 100 mrem/yr. This value is an annual limit and is not intended to be applied as a long-term average goal. The dose limits in 10 CFR Part 20 are based on the methodology described in International Commission on Radiological Protection (ICRP) Publication 26 (ICRP 1977). The radiation levels at any unrestricted area should not exceed 2 mrem in any one hour. Licensees may comply with the 100-mrem limit by demonstrating (1) by measurement or calculation that the dose to the individual likely to receive the highest dose from sources under the licensee's control does not exceed the limit or (2) that the concentrations of radioactive material released in gaseous and liquid effluents averaged over a single year do not exceed the levels specified in 10 CFR Part 20, Appendix B, Table 2; and at the unrestricted area boundary, the dose from external sources would not exceed 2 mrem in any given hour and 50 mrem in a single year. The concentration values given in Table 2 of Appendix B to 10 CFR Part 20 are equivalent to the radionuclide concentrations that, if inhaled or ingested continuously in a year, would produce a TEDE of 50 mrem. Nuclear power reactors, as discussed earlier in this section, are subject to additional regulatory controls which maintain doses to members of the public to the ALARA dose-design objectives in Appendix I to 10 CFR Part 50.

3.9.1.2 Occupational Radiological Exposures

This section provides an evaluation of the radiological impacts on nuclear power plant workers. This evaluation extends to all nuclear power reactors. Currently there are 104 operating reactors in the United States, and all are LWRs. Among them, 35 are BWRs and 69 are PWRs.

Plant workers conducting activities involving radioactively contaminated systems or working in radiation areas can be exposed to radiation. Individual occupational doses are measured by NRC licensees as required by the basic NRC radiation protection standard, 10 CFR Part 20 (see Section 3.9.1.1). Most of the occupational radiation dose to nuclear plant workers results from external radiation exposure rather than from internal exposure from inhaled or ingested radioactive materials. Workers also receive radiation exposure during the storage and handling of radioactive waste and during the inspection of stored radioactive waste. However, this source of exposure is small compared with other sources of exposure at operating nuclear plants.

Table 3.9-3 shows the radiation exposure data from all commercial U.S. nuclear power plants for the years 1993 through 2005. The year 1993 was chosen as a starting date because the dose data for years before 1993 were presented in the original GEIS. For each year, the number of reactors, the number of workers receiving measurable exposures, the collective dose[g] for all reactors combined, and the number of individuals receiving a dose in the range of 4 to 5 rem are given. Data indicate that no worker received a dose in the range of 4 to 5 rem from 2003 to 2005. The collective dose has been about 12,000 person-rem or less since 2001.

(g) The collective dose is the sum of all personal doses and is expressed as person-rem.

Table 3.9-3. Occupational Whole-Body Dose Data at U.S. Commercial Nuclear Power Plants

Year	Number of Workers with Measurable Doses	Collective Dose (person-rem)	Number of Reactors	Number of Workers with Dose in the Range of 4 to 5 rem
1993	93,749	26,364	106	5
1994	83,454	21,704	107	0
1995	85.671	21,688	107	2
1996	84,644	18,883	109	0
1997	84,711	17,149	109	0
1998	71,485	13,187	105	1
1999	75,420	13,599	104	0
2000	74,108	12,652	104	0
2001	67,570	11,109	104	0
2002	73,242	12,126	104	1
2003	74,813	11,956	104	0
2004	69,849	10,368	104	0
2005	78,127	11,456	104	0

Source: Burrows and Hagemeyer 2006
Note: To convert rem to sievert (Sv), multiply by 0.01.

Table 3.9-4 shows the occupational dose history (since 1993) for all commercial U.S. reactors. Average collective occupational dose information and average annual individual worker doses are presented for plants that operated between 1993 and 2005. For the period from 1993 to 2005, the annual average dose per plant worker decreased from 0.31 to 0.18 rem for BWRs and from 0.25 to 0.12 rem for PWRs. During 2005, at all operating nuclear power plants, the annual average individual dose was 0.15 rem compared with an exposure limit of 5 rem. The average collective occupational exposure for the year 2005 was roughly 1.71 person-Sv (171 person-rem) per plant at BWRs and about 0.79 person-Sv (79 person-rem) per plant at PWRs.

Tables 3.9-5 and 3.9-6 show the 3-year collective dose per reactor, number of workers with measurable doses, and average dose per worker for BWRs and PWRs, respectively, for the years 2003 to 2005. For the years 2003 to 2005, the average collective occupational exposure for the BWRs was 1.63 person-Sv (163 person-rem) per plant, and for the PWRs, it was 0.81 person-Sv (81 person-rem).

Table 3.9-4. Annual Average Occupational Dose for U.S. Commercial Nuclear Power Plants

	Average Collective Occupational Dose Per Plant (person-rem)			Average Individual Whole-Body Dose Per Plant (rem)		
Year	**LWR**	**BWR**	**PWR**	**LWR**	**BWR**	**PWR**
1993	241	330	194	0.27	0.31	0.25
1994	203	327	137	0.26	0.31	0.22
1995	198	256	168	0.25	0.27	0.24
1996	173	256	131	0.22	0.25	0.20
1997	157	205	133	0.20	0.22	0.19
1998	126	190	92	0.18	0.21	0.17
1999	131	184	105	0.18	0.20	0.17
2000	122	174	95	0.17	0.20	0.15
2001	107	138	91	0.16	0.17	0.16
2002	117	175	87	0.17	0.20	0.14
2003	115	162	91	0.16	0.18	0.14
2004	100	156	71	0.15	0.16	0.14
2005	110	171	79	0.15	0.18	0.12

Source: Burrows and Hagemeyer 2006
Note: To convert rem to Sv, multiply by 0.01.

Deviations higher than these averages in the table are routinely experienced, depending largely on whether a plant had an outage during a given year and the nature and extent of refurbishment or repair activities undertaken during outages.

To identify trends, Figure 3.9-1 provides the average and median values of the annual collective dose per reactor for BWRs and PWRs for the years 1992 through 2005. The reported ranges of the values are shown by the vertical lines that extend to the minimum and maximum observed values. The rectangles indicate the range of values of the collective dose exhibited by those plants ranked in the 25th through the 75th percentiles. The median values do not normally fluctuate as much as the average values from year to year because they are not affected as much by the extreme values of the collective doses. The median collective dose was 64 person-rem for PWRs and 153 person-rem for BWRs in 2005. Figure 3.9-1 also shows that, in 2005, 50 percent of the PWRs reported collective doses between 44 and 107 person-rem, while 50 percent of the BWRs reported collective doses between 94 and 198 person-rem.

Table 3.9-5. Collective and Individual Worker Doses at BWRs from 2003 through 2005

Plant	Number of Reactor-Years	Collective TEDE per Reactor per Year (person-rem)	Number of Workers with Measurable TEDE	Average Annual TEDE per Worker (rem)
Limerick 1, 2	6	81	4,023	0.12
Hatch 1, 2	6	93	3,792	0.15
Duane Arnold	3	94	1,928	0.15
Oyster Creek	3	99	2,078	0.14
FitzPatrick	3	100	1,771	0.17
Susquehanna 1, 2	6	117	5,976	0.12
Grand Gulf	3	119	2,859	0.13
Fermi 2	3	125	3,047	0.12
Clinton	3	125	2,292	0.16
Monticello	3	126	2,056	0.18
Brunswick 1, 2	6	133	5,878	0.14
Hope Creek 1	3	149	4,918	0.09
Cooper	3	153	2,629	0.17
Peach Bottom 2, 3	6	154	4,864	0.19
Vermont Yankee	3	155	2,843	0.16
Pilgrim	3	166	3,076	0.16
Dresden 2, 3	6	166	6,148	0.16
River Bend 1	3	170	3,172	0.16
LaSalle 1, 2	6	193	6,716	0.17
Columbia	3	199	4,052	0.15
Nine Mile Point 1, 2	6	204	4,229	0.29
Browns Ferry 1, 2, 3	9	212	9,593	0.20
Quad Cities 1, 2	6	318	6,201	0.31
Perry	3	366	4,110	0.27
Totals and averages	105	–	98,251	0.17
Average per reactor-yr	–	163	–	–

Source: Burrows and Hagemeyer 2006
Note: To convert rem to Sv, multiply by 0.01.

Table 3.9-6. Collective and Individual Worker Doses at PWRs from 2003 through 2005

Plant	Number of Reactor-Years	Collective TEDE per Reactor per Year (person-rem)	Number of Workers with Measurable TEDE	Average Annual TEDE per Worker (rem)
Seabrook	3	43	2,306	0.06
Harris	3	45	1,697	0.08
Farley 1, 2	6	48	2,739	0.10
Prairie Island 1, 2	6	48	2,562	0.11
Summer 1	3	51	1,679	0.09
Ginna	3	52	1,185	0.13
Vogtle 1, 2	6	53	2,670	0.12
Point Beach 1, 2	6	54	2,105	0.15
Kewaunee	3	56	1,101	0.15
Indian Point 3	3	58	2,029	0.09
Robinson 2	3	63	1,852	0.10
North Anna 1, 2	6	63	2,692	0.14
Byron 1, 2	6	63	3,272	0.12
Wolf Creek 1	3	66	1,769	0.11
Palo Verde 1, 2, 3	9	68	5,281	0.12
Catawba 1, 2	6	70	3,551	0.12
Braidwood 1, 2	6	71	3,484	0.12
Indian Point 2	3	73	1,847	0.12
McGuire 1, 2	6	74	3,358	0.13
Comanche Peak 1, 2	6	74	2,868	0.16
Three Mile Island 1	3	75	2,290	0.10
Cook 1, 2	6	76	3,275	0.14
Waterford 3	3	78	1,672	0.14
Turkey Point 3, 4	6	79	3,667	0.13
Crystal River 3	3	84	2,031	0.13
Oconee 1, 2, 3	9	85	5,991	0.13
South Texas 1, 2	6	85	3,019	0.17
Beaver Valley 1, 2	6	85	3,871	0.13

Table 3.9-6. (cont.)

Plant	Number of Reactor-Years	Collective TEDE per Reactor per Year (person-rem)	Number of Workers with Measurable TEDE	Average Annual TEDE per Worker (rem)
Salem 1,2	6	86	5,959	0.09
Diablo Canyon 1,2	6	86	3,189	0.16
Surry 1,2	6	89	3,533	0.15
Davis-Besse	3	93	1,785	0.16
Calvert Cliffs 1,2	6	96	3,818	0.15
San Onofre 2,3	6	97	3,341	0.17
Sequoyah 1,2	6	102	4,770	0.13
Watts Bar	3	105	2,856	0.11
Millstone 2,3	6	110	3,407	0.19
Arkansas 1,2	6	113	4,535	0.15
Callaway 1	3	117	2,976	0.12
St. Lucie 1,2	6	118	4,356	0.16
Fort Calhoun	3	169	2,198	0.23
Palisades	3	195	1,952	0.30
Totals and averages	207	–	–	0.13
Average per reactor-yr	–	81	602	–

Source: Burrows and Hagemeyer 2006
Note: To convert rem to Sv, multiply by 0.01.

Table 3.9-7 presents the average, maximum, and minimum collective and individual occupational doses for all commercial nuclear power plants operating between 1993 and 2005. For PWRs, the maximum variation in collective dose and annual average occupational dose was observed for Indian Point Unit 2. From 1993 to 2005, the collective dose varied from 11 to 675 person-rem, and the annual average occupational dose varied from 0.02 to 0.45 rem.

For BWRs, the maximum variation in collective dose was observed for the Quad Cities plant. From 1993 to 2005, the collective dose varied from 72 to 893 person-rem. The maximum variation in the annual average occupational dose was observed for the Brunswick plant; from 1993 to 2005, it varied from 0.11 to 0.70 rem.

Table 3.9-8 shows the yearly annual collective occupational dose for all commercial nuclear power plants operating between 1993 and 2005 and Table 3.9-9 shows the yearly annual individual average occupational dose for all commercial nuclear power plants operating between

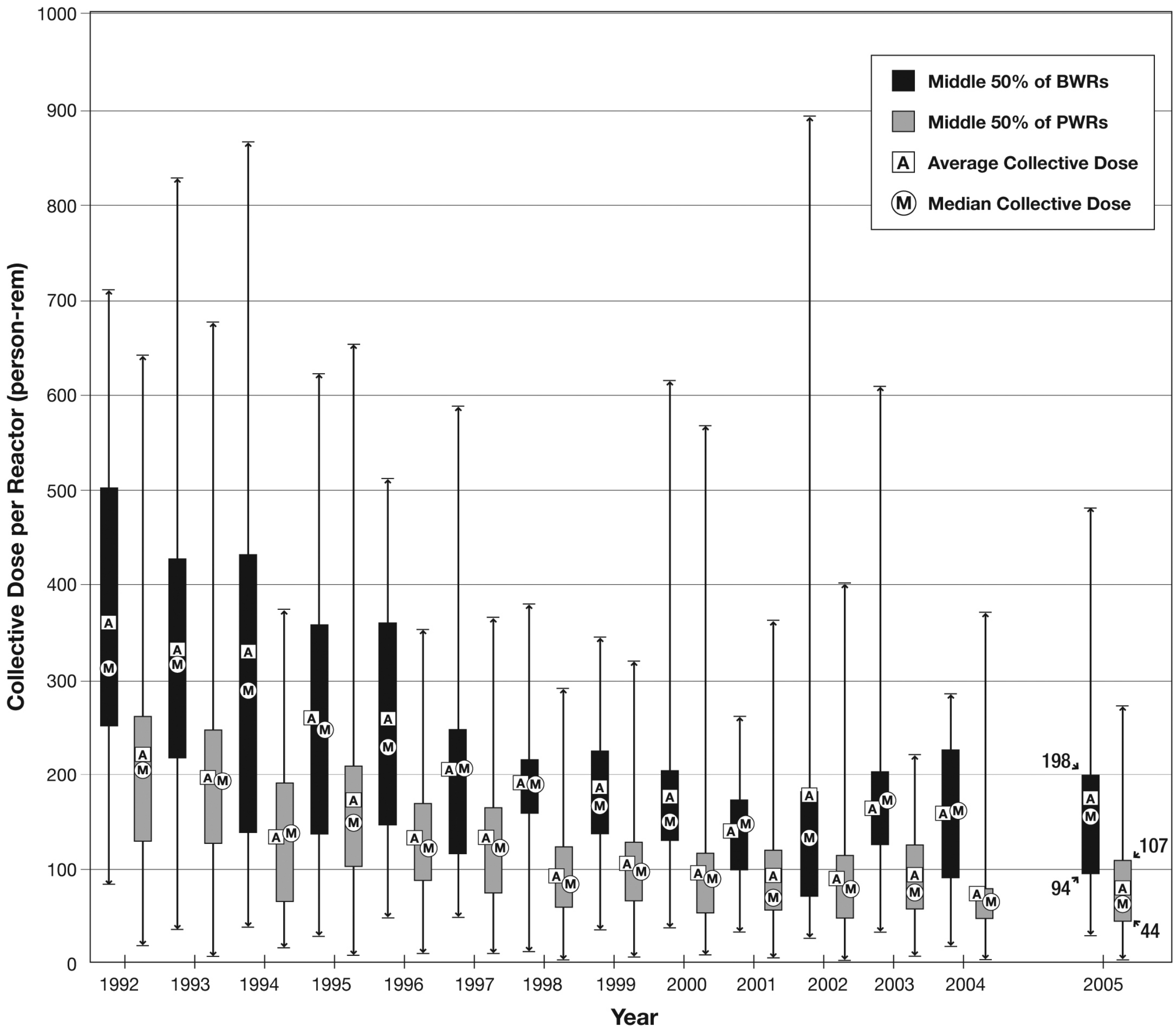

Figure 3.9-1. Average, Median, and Extreme Values of the Annual Collective Dose per Reactor from 1992 to 2005 (Burrows and Hagemeyer 2006)

1993 and 2005. The year 1993 was chosen as a starting date because the dose data for years before 1993 were presented in the 1996 GEIS. From 1993 through 2005, operating nuclear power plants would have gone through many refueling outages, 5-year ISI, 10-year ISI, and also some refurbishment activities. To check for trends, data were divided into two time frames: from 1993 to 1999 and from 2000 to 2005. The averages for these two time frames were calculated and compared. The yearly average collective dose from 2000 to 2005 was mostly lower than the dose from 1993 to 1999. For a few nuclear power plants, the average annual collective dose from 2000 to 2005 was higher, but in all cases, the yearly average occupational

Table 3.9-7. Annual Collective Dose and Annual Occupational Dose for Different Commercial Nuclear Power Plants from 1993 through 2005

	Collective Dose (person-rem/reactor)			Annual Occupational Dose (rem)		
Plant	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**
PWRs						
Arkansas 1, 2	107	238	50	0.13	0.20	0.09
Beaver Valley 1, 2	121	311	22	0.17	0.30	0.08
Braidwood 1, 2	103	167	44	0.16	0.26	0.09
Byron 1, 2	117	228	30	0.19	0.32	0.08
Callaway 1	137	321	8	0.14	0.29	0.03
Calvert Cliffs 1, 2	118	227	68	0.19	0.31	0.12
Catawba 1,2	104	231	41	0.15	0.25	0.08
Comanche Peak 1, 2	83	144	33	0.16	0.24	0.09
Cook 1, 2	110	275	14	0.15	0.30	0.06
Crystal River 3	117	353	4	0.12	0.30	0.03
Davis-Besse 1	132	403	6	0.13	0.28	0.03
Diablo Canyon 1, 2	121	295	59	0.17	0.29	0.11
Farley 1, 2	125	230	34	0.20	0.31	0.08
Fort Calhoun	146	273	22	0.21	0.31	0.10
Ginna	94	193	7	0.16	0.27	0.07
Harris 1	95	252	7	0.10	0.20	0.04
Indian Point 2	237	675	11	0.19	0.45	0.02
Indian Point 3	68	234	4	0.09	0.15	0.02
Kewaunee	80	200	4	0.18	0.27	0.04
McGuire 1, 2	116	246	36	0.17	0.27	0.08
Millstone Unit 2, 3	122	279	57	0.17	0.27	0.10
North Anna 1, 2	120	454	30	0.18	0.33	0.09
Oconee 1, 2, 3	102	193	50	0.17	0.29	0.10
Palisades	201	462	10	0.23	0.38	0.07
Palo Verde 1, 2, 3	90	197	47	0.16	0.28	0.10
Point Beach 1, 2	79	138	43	0.22	0.35	0.14
Prairie Island 1, 2	56	87	31	0.16	0.23	0.10

Table 3.9-7. (cont.)

Plant	Collective Dose (person-rem/reactor)			Annual Occupational Dose (rem)		
	Average	Maximum	Minimum	Average	Maximum	Minimum
PWRs (cont.)						
Robinson 2	117	337	5	0.13	0.28	0.04
Salem 1, 2	108	204	21	0.15	0.27	0.08
San Onofre 2, 3	125	384	6	0.16	0.35	0.04
Seabrook	63	186	6	0.07	0.13	0.02
Sequoyah 1, 2	130	216	43	0.15	0.23	0.07
South Texas 1, 2	106	165	24	0.17	0.22	0.07
St. Lucie 1, 2	152	323	50	0.20	0.34	0.10
Summer 1	117	374	10	0.13	0.26	0.05
Surry 1, 2	122	203	44	0.19	0.27	0.10
Three Mile Island 1	99	213	0	0.10	0.19	0.00
Turkey Point 3, 4	105	238	37	0.17	0.32	0.09
Vogtle 1, 2	100	226	41	0.18	0.32	0.10
Waterford	89	191	3	0.12	0.16	0.04
Wolf Creek 1	113	265	3	0.13	0.27	0.04
Watts Bar 1	84	166	3	0.08	0.12	0.03
BWRs						
Duane Arnold	166	407	19	0.20	0.39	0.09
Browns Ferry 1, 2, 3	174	290	98	0.21	0.26	0.16
Brunswick 1, 2	238	500	123	0.24	0.70	0.11
Clinton 1	195	498	34	0.20	0.40	0.10
Columbia	291	866	47	0.20	0.46	0.07
Cooper	155	391	39	0.18	0.35	0.10
Dresden 2, 3	282	828	130	0.23	0.60	0.11
Fermi 2	112	213	28	0.11	0.19	0.07
FitzPatrick	204	358	51	0.18	0.26	0.10
Grand Gulf	190	357	31	0.17	0.23	0.11
Hatch 1, 2	201	432	84	0.24	0.39	0.13
Hope Creek 1	175	350	26	0.14	0.25	0.08
LaSalle 1, 2	238	427	42	0.24	0.50	0.15

Table 3.9-7. (cont.)

Plant	Collective Dose (person-rem/reactor)			Annual Occupational Dose (rem)		
	Average	Maximum	Minimum	Average	Maximum	Minimum
BWRs (cont.)						
Limerick 1, 2	114	179	74	0.16	0.20	0.11
Monticello	186	494	35	0.27	0.52	0.10
Nine Mile Point 1, 2	210	380	75	0.25	0.33	0.16
Oyster Creek	263	844	28	0.17	0.35	0.09
Peach Bottom 2, 3	189	290	133	0.21	0.31	0.17
Perry	266	691	42	0.19	0.33	0.11
Pilgrim 1	231	588	38	0.21	0.37	0.08
Quad Cities 1, 2	388	893	72	0.35	0.52	0.20
River Bend	229	519	35	0.18	0.26	0.09
Susquehanna 1, 2	167	238	91	0.20	0.28	0.10
Vermont Yankee	146	231	38	0.20	0.26	0.15

Source: Burrows and Hagemeyer 2006
Note: To convert rem to Sv, multiply by 0.01.

dose was less than 0.4 rem. The yearly average occupational dose was mostly lower from 2000 to 2005 than from 1993 to 1999.

The data in Tables 3.9-8 and 3.9-9 show that although there are variations from year to year, there is no consistent trend that shows that occupational doses are increasing over time.

The average, maximum, and minimum collective occupational doses are presented in Table 3.9-10 for plants operated between 1993 and 2005. The average collective doses, however, are based on widely varying yearly doses. For example, between 1993 and 2005, annual collective doses for operating PWRs ranged from 0 to 675 person-rem; for operating BWRs, they ranged from 19 to 893 person-rem. From 1993 to 1998, the average collective dose decreased more than 50 percent for PWRs and 40 percent for BWRs. From 1999 through 2005, the average collective dose for PWRs was in a range 71 to 105 person-rem, and for BWRs, it was in a range of 138 to 184 person-rem.

Average, maximum, and minimum individual occupational doses per reactor are presented in Table 3.9-11 for plants that operated between 1993 and 2005. From 1993 through 1998, the average annual dose per plant worker decreased more than 30 percent for both PWRs and

Table 3.9-8. Annual Collective Dose for Commercial Nuclear Power Plants from 1993 through 2005

	Annual Collective Dose (person-rem/reactor)												
Plant	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
PWRs													
Arkansas 1, 2	134	86	193	102	60	84	92	121	53	133	50	53	238
Beaver Valley 1, 2	311	22	227	225	153	30	50	169	92	45	139	79	40
Braidwood 1, 2	137	149	118	167	161	130	73	97	51	46	123	48	44
Byron 1, 2	216	140	153	228	121	138	120	97	30	98	44	45	100
Callaway 1	225	14	187	248	12	201	321	16	107	96	8	121	223
Calvert Cliffs 1, 2	203	227	118	120	115	94	96	68	84	123	133	72	84
Catawba 1,2	198	104	231	151	133	81	60	94	58	41	106	62	42
Comanche Peak 1, 2	55	45	90	144	73	116	126	39	58	113	33	68	121
Cook 1, 2	22	240	102	107	275	53	86	169	14	139	105	78	46
Crystal River 3	60	228	8	353	179	19	251	15	148	5	127	4	123
Davis-Besse 1	348	144	7	167	10	155	28	168	6	403	220	7	51
Diablo Canyon 1, 2	141	295	143	88	110	87	225	91	59	75	68	127	62
Farley 1, 2	167	125	230	116	139	216	95	180	161	48	56	54	34
Fort Calhoun	157	23	139	226	41	224	159	35	226	164	212	22	273
Ginna	193	138	136	168	81	15	175	76	10	80	75	7	73
Harris 1	31	222	174	17	149	133	16	101	252	7	68	57	8
Indian Point 2	675	48	548	54	367	290	41	567	22	248	12	196	11
Indian Point 3	60	58	67	22	234	15	117	9	118	7	96	4	74
Kewaunee	106	72	109	126	56	88	5	100	200	4	73	91	4
McGuire 1, 2	232	199	69	119	246	71	129	67	69	91	36	98	87
Millstone Unit 2, 3	279	94	208	63	127	57	126	72	87	146	162	68	101
North Anna 1, 2	454	97	184	146	52	133	47	33	155	72	94	65	30
Oconee 1, 2, 3	79	179	101	86	74	122	67	91	193	75	82	123	50

Table 3.9-8. (cont.)

Plant	Annual Collective Dose (person-rem/reactor)												
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
PWRs (cont.)													
Palisades	289	60	462	318	48	217	218	26	363	24	203	371	10
Palo Verde 1, 2, 3	197	154	161	101	82	64	49	53	61	47	70	66	67
Point Beach 1, 2	93	85	95	138	46	85	97	70	66	91	43	55	65
Prairie Island 1, 2	53	55	54	56	87	59	36	53	63	64	31	72	42
Robinson 2	337	63	215	167	13	170	124	8	125	111	5	118	65
Salem 1, 2	204	94	109	150	88	21	159	99	77	147	62	75	121
San Onofre 2, 3	384	16	228	65	171	98	177	58	66	68	82	204	6
Seabrook	6	113	102	10	186	19	106	70	9	67	71	6	52
Sequoyah 1, 2	187	148	184	135	210	133	83	179	73	54	216	43	48
South Texas 1, 2	126	24	146	69	137	92	130	116	119	165	72	60	124
St. Lucie 1, 2	246	253	207	193	323	67	89	50	114	78	71	80	203
Summer 1	297	374	13	97	163	14	120	167	69	60	71	10	72
Surry 1, 2	192	189	203	105	160	95	69	97	165	44	163	60	44
Three Mile Island 1	206	40	213	16	204	17	155	9	197	7	155	3	66
Turkey Point 3, 4	138	238	108	94	207	78	64	110	51	37	124	59	55
Vogtle 1, 2	184	109	100	226	79	81	115	61	65	122	42	41	76
Waterford	15	191	153	27	148	24	123	132	5	109	95	3	136
Wolf Creek 1	183	235	14	171	265	10	148	143	5	100	89	3	107
Watts Bar 1[(a)]					113	3	99	122	6	94	166	6	144
BWRs													
Duane Arnold	407	120	357	270	63	237	201	44	138	35	124	19	140
Browns Ferry 1, 2, 3	290	287	138	130	174	123	149	111	98	119	201	224	212
Brunswick 1, 2	436	500	342	358	206	198	209	161	152	138	125	123	153

Table 3.9-8. (cont.)

Plant	Annual Collective Dose (person-rem/reactor)												
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
BWRs (cont.)													
Clinton	498	63	316	350	172	177	87	253	34	208	57	283	36
Columbia	469	866	456	373	251	286	155	53	227	47	205	66	325
Cooper	391	79	228	48	174	182	48	200	169	39	135	47	276
Dresden 2, 3	828	417	438	228	234	214	296	131	201	178	179	191	130
Fermi 2	35	213	28	157	49	208	36	146	169	38	168	145	62
FitzPatrick	232	322	327	357	91	358	68	301	63	231	51	186	63
Grand Gulf	332	56	342	357	105	304	226	35	185	176	31	158	168
Hatch 1, 2	335	432	244	221	361	160	165	201	115	107	84	90	104
Hope Creek 1	98	326	196	158	350	55	279	188	156	26	139	240	67
LaSalle 1, 2	427	363	256	410	158	211	288	130	42	225	232	180	168
Limerick 1, 2	109	138	130	117	117	179	136	131	105	80	74	75	94
Monticello	494	395	44	240	106	209	70	216	221	40	169	35	175
Nine Mile Point 1, 2	317	75	380	145	215	189	224	142	172	259	188	225	201
Oyster Creek	416	844	90	449	50	308	42	625	46	266	43	227	28
Peach Bottom 2, 3	276	290	199	141	245	183	160	166	172	167	178	133	153
Perry	278	691	64	307	272	42	326	56	258	70	607	73	417
Pilgrim 1	435	200	482	116	588	71	344	51	180	38	250	41	206
Quad Cities 1, 2	425	564	368	513	327	381	101	447	72	893	219	256	481
River Bend	180	519	85	473	347	58	344	216	208	35	217	236	56
Susquehanna 1, 2	168	221	238	145	217	181	216	166	144	130	125	136	91
Vermont Yankee	217	38	182	231	57	199	176	38	143	150	54	212	198

(a) 1st commercial operation in May 1996.
Source: Burrows and Hagemeyer 2006
Note: To convert rem to Sv, multiply by 0.01.

Table 3.9-9. Annual Average Measurable Occupational Doses at Commercial Nuclear Power Plant Sites from 1993 through 2005

	Average Measurable Occupational Doses (rem)												
Plant	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
PWRs													
Arkansas 1, 2	0.14	0.13	0.17	0.14	0.10	0.13	0.13	0.12	0.10	0.17	0.10	0.09	0.20
Beaver Valley 1, 2	0.30	0.09	0.29	0.27	0.22	0.08	0.12	0.20	0.15	0.09	0.17	0.12	0.08
Braidwood 1, 2	0.26	0.24	0.21	0.25	0.19	0.14	0.13	0.12	0.11	0.09	0.16	0.10	0.10
Byron 1, 2	0.32	0.29	0.28	0.28	0.16	0.15	0.16	0.20	0.08	0.15	0.11	0.10	0.13
Callaway 1	0.20	0.07	0.18	0.25	0.05	0.22	0.29	0.07	0.12	0.10	0.03	0.11	0.14
Calvert Cliffs 1, 2	0.28	0.31	0.20	0.20	0.21	0.18	0.17	0.15	0.19	0.16	0.16	0.12	0.18
Catawba 1, 2	0.25	0.16	0.24	0.19	0.17	0.14	0.12	0.16	0.12	0.09	0.15	0.11	0.08
Comanche Peak 1, 2	0.12	0.09	0.19	0.20	0.17	0.24	0.19	0.10	0.13	0.20	0.10	0.16	0.18
Cook 1, 2	0.07	0.27	0.15	0.19	0.30	0.09	0.10	0.14	0.06	0.17	0.15	0.15	0.11
Crystal River 3	0.09	0.21	0.04	0.30	0.18	0.06	0.19	0.06	0.16	0.04	0.13	0.03	0.13
Davis-Besse 1	0.28	0.17	0.03	0.18	0.05	0.16	0.07	0.15	0.05	0.20	0.21	0.04	0.09
Diablo Canyon 1, 2	0.19	0.26	0.18	0.12	0.17	0.13	0.29	0.17	0.11	0.15	0.13	0.21	0.13
Farley 1, 2	0.26	0.24	0.29	0.20	0.25	0.31	0.17	0.21	0.18	0.13	0.14	0.09	0.08
Fort Calhoun	0.22	0.11	0.22	0.31	0.16	0.28	0.24	0.14	0.29	0.22	0.23	0.10	0.26
Ginna	0.23	0.20	0.18	0.17	0.15	0.09	0.27	0.18	0.07	0.15	0.15	0.07	0.13
Harris 1	0.09	0.20	0.16	0.04	0.13	0.14	0.06	0.11	0.16	0.05	0.09	0.08	0.05
Indian Point 2	0.45	0.13	0.32	0.14	0.27	0.25	0.12	0.28	0.06	0.18	0.05	0.17	0.02
Indian Point 3	0.13	0.11	0.11	0.08	0.15	0.07	0.13	0.06	0.12	0.04	0.11	0.02	0.08
Kewaunee	0.24	0.20	0.26	0.27	0.20	0.23	0.05	0.25	0.18	0.04	0.17	0.16	0.04
McGuire 1, 2	0.27	0.24	0.11	0.15	0.22	0.14	0.20	0.14	0.14	0.16	0.08	0.18	0.12
Millstone Unit 2, 3	0.27	0.15	0.25	0.13	0.18	0.10	0.15	0.10	0.13	0.19	0.25	0.17	0.15
North Anna 1, 2	0.33	0.19	0.24	0.24	0.12	0.22	0.13	0.09	0.25	0.16	0.18	0.13	0.09

Table 3.9-9. (cont.)

Plant	Average Measurable Occupational Doses (rem)												
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
PWRs (cont.)													
Oconee 1, 2, 3	0.16	0.28	0.19	0.17	0.16	0.22	0.13	0.16	0.29	0.13	0.11	0.16	0.10
Palisades	0.32	0.15	0.38	0.29	0.14	0.24	0.23	0.10	0.35	0.11	0.25	0.38	0.07
Palo Verde 1, 2, 3	0.28	0.23	0.26	0.18	0.16	0.14	0.11	0.12	0.13	0.10	0.11	0.15	0.10
Point Beach 1, 2	0.33	0.31	0.35	0.27	0.14	0.19	0.20	0.18	0.18	0.19	0.14	0.17	0.15
Prairie Island 1, 2	0.20	0.10	0.21	0.20	0.23	0.20	0.13	0.17	0.18	0.13	0.10	0.12	0.11
Robinson 2	0.28	0.15	0.20	0.16	0.04	0.17	0.15	0.06	0.15	0.13	0.04	0.12	0.08
Salem 1, 2	0.11	0.20	0.18	0.18	0.20	0.10	0.27	0.17	0.12	0.12	0.10	0.10	0.08
San Onofre 2, 3	0.35	0.06	0.24	0.10	0.21	0.18	0.24	0.11	0.12	0.12	0.13	0.23	0.04
Seabrook	0.05	0.13	0.13	0.05	0.12	0.03	0.08	0.06	0.02	0.06	0.07	0.02	0.05
Sequoyah 1, 2	0.23	0.17	0.22	0.19	0.21	0.17	0.12	0.18	0.11	0.09	0.17	0.07	0.08
South Texas 1, 2	0.22	0.07	0.20	0.12	0.17	0.16	0.20	0.17	0.18	0.22	0.16	0.14	0.20
St. Lucie 1, 2	0.34	0.27	0.28	0.27	0.28	0.11	0.16	0.10	0.17	0.16	0.15	0.14	0.18
Summer 1	0.26	0.24	0.05	0.14	0.20	0.05	0.15	0.18	0.14	0.09	0.10	0.05	0.10
Surry 1, 2	0.27	0.25	0.22	0.21	0.24	0.16	0.14	0.16	0.26	0.11	0.20	0.12	0.10
Three Mile Island 1	0.11	0.09	0.17	0.06	0.19	0.06	0.13	0.05	0.16	0.04	0.13	0.03	0.07
Turkey Point 3, 4	0.22	0.32	0.19	0.16	0.26	0.15	0.14	0.17	0.12	0.09	0.17	0.11	0.10
Vogtle 1, 2	0.27	0.21	0.21	0.32	0.16	0.16	0.17	0.14	0.15	0.21	0.10	0.11	0.14
Waterford	0.08	0.16	0.14	0.08	0.13	0.09	0.15	0.16	0.05	0.14	0.13	0.04	0.15
Wolf Creek 1	0.19	0.22	0.06	0.17	0.27	0.05	0.18	0.17	0.05	0.12	0.11	0.04	0.12
Watts Bar 1[(a)]					0.10	0.03	0.10	0.12	0.03	0.10	0.12	0.03	0.12
BWRs													
Duane Arnold	0.39	0.24	0.32	0.25	0.18	0.23	0.24	0.14	0.15	0.11	0.15	0.09	0.16
Browns Ferry 1, 2, 3	0.24	0.26	0.16	0.20	0.23	0.23	0.26	0.20	0.19	0.18	0.23	0.21	0.17
Brunswick 1, 2	0.30	0.70	0.26	0.26	0.19	0.20	0.23	0.20	0.19	0.16	0.14	0.11	0.16

Table 3.9-9. (cont.)

Plant	Average Measurable Occupational Doses (rem)												
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
BWRs (cont.)													
Clinton 1	0.40	0.15	0.27	0.30	0.23	0.17	0.14	0.20	0.10	0.15	0.15	0.17	0.12
Columbia	0.34	0.46	0.27	0.26	0.21	0.23	0.15	0.08	0.15	0.07	0.13	0.09	0.19
Cooper Station	0.35	0.24	0.21	0.10	0.16	0.19	0.15	0.21	0.13	0.11	0.15	0.10	0.22
Dresden 2, 3	0.60	0.36	0.35	0.26	0.17	0.18	0.18	0.11	0.14	0.13	0.17	0.19	0.13
Fermi 2	0.10	0.19	0.07	0.11	0.08	0.15	0.08	0.12	0.14	0.08	0.14	0.11	0.11
FitzPatrick	0.16	0.20	0.26	0.26	0.14	0.20	0.12	0.24	0.10	0.19	0.17	0.17	0.16
Grand Gulf	0.18	0.12	0.22	0.23	0.20	0.22	0.19	0.12	0.17	0.17	0.11	0.13	0.13
Hatch 1, 2	0.39	0.39	0.33	0.29	0.37	0.20	0.18	0.21	0.16	0.17	0.13	0.15	0.16
Hope Creek 1	0.14	0.18	0.12	0.15	0.20	0.09	0.25	0.15	0.10	0.12	0.09	0.10	0.08
LaSalle 1, 2	0.50	0.40	0.32	0.31	0.19	0.20	0.21	0.14	0.15	0.22	0.21	0.15	0.16
Limerick 1, 2	0.17	0.18	0.16	0.14	0.16	0.19	0.15	0.20	0.19	0.13	0.11	0.12	0.13
Monticello	0.52	0.50	0.22	0.32	0.27	0.31	0.16	0.27	0.26	0.10	0.20	0.13	0.19
Nine Mile Point 1, 2	0.27	0.19	0.33	0.18	0.30	0.22	0.26	0.16	0.25	0.21	0.25	0.33	0.29
Oyster Creek	0.16	0.35	0.12	0.24	0.10	0.22	0.09	0.30	0.10	0.18	0.10	0.17	0.09
Peach Bottom 2, 3	0.31	0.27	0.21	0.17	0.26	0.19	0.20	0.19	0.24	0.17	0.22	0.19	0.17
Perry	0.23	0.33	0.11	0.19	0.18	0.11	0.19	0.11	0.19	0.16	0.32	0.15	0.24
Pilgrim 1	0.33	0.26	0.37	0.22	0.36	0.13	0.28	0.12	0.16	0.08	0.17	0.10	0.17
Quad Cities 1, 2	0.39	0.52	0.36	0.46	0.26	0.35	0.20	0.32	0.20	0.47	0.44	0.22	0.33
River Bend	0.21	0.24	0.13	0.23	0.21	0.12	0.26	0.20	0.17	0.09	0.17	0.17	0.11
Susquehanna 1, 2	0.23	0.28	0.27	0.20	0.26	0.23	0.24	0.18	0.16	0.14	0.13	0.13	0.10
Vermont Yankee	0.26	0.17	0.25	0.24	0.22	0.21	0.21	0.19	0.17	0.16	0.15	0.15	0.18

(a) 1st commercial operation in May 1996.
Source: Burrows and Hagemeyer 2006
Note: To convert rem to Sv, multiply by 0.01.

Table 3.9-10. Annual Collective Occupational Dose per Plant for Commercial Nuclear Power Plants

	Collective Occupational Dose (person-rem) per Plant for PWRs			Collective Occupational Dose (person-rem) per Plant for BWRs		
Year	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**
1993	194	675	6	330	828	35
1994	137	374	14	327	866	38
1995	168	548	7	256	482	28
1996	131	353	10	256	513	48
1997	133	367	10	205	588	49
1998	92	290	3	190	381	42
1999	105	321	5	184	344	36
2000	95	567	8	174	614	35
2001	91	363	5	138	258	34
2002	87	403	4	175	893	26
2003	91	220	5	162	607	31
2004	71	371	0	156	283	19
2005	79	273	4	171	481	28

Source: Burrows and Hagemeyer 2006
Note: To convert rem to Sv, multiply by 0.01.

BWRs. From 1999 through 2005, the average annual dose per plant worker for PWRs ranged from 0.12 to 0.17 rem, and for BWRs, ranged from 0.16 to 0.20 rem. The annual dose per plant worker for operating PWRs ranged from 0.0 to 0.45 rem; for operating BWRs, it ranged from 0.07 to 0.70 rem.

Table 3.9-12 provides the distribution of individual doses for 2005. The dose distribution indicates that no worker received doses greater than 3 rem in 2005. Only 17 workers (0.01 percent) received whole-body doses exceeding 2 rem during 2005. At BWRs, less than 0.03 percent of the workers received doses greater than 2 rem. At PWRs, no worker received a dose greater than 2 rem, and less than 0.3 percent of the workers received a dose greater than 1 rem. No worker exposure exceeded 5 rem during that calendar year. Figure 3.9-2 shows the collective dose distribution by dose range for all commercial U.S. reactors from 2001 to 2005. The distribution of collective dose has been fairly constant over the past 5 years, with a slight decrease noted from 2002 to 2005 in each dose range.

Table 3.9-11. Annual Individual Occupational Dose for Commercial Nuclear Power Plants

	Whole-Body Dose (rem) per Plant for PWRs			Whole-Body Dose (rem) per Plant for BWRs		
Year	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**
1993	0.25	0.45	0.05	0.31	0.60	0.10
1994	0.22	0.32	0.06	0.31	0.70	0.12
1995	0.24	0.38	0.03	0.27	0.37	0.07
1996	0.20	0.32	0.04	0.25	0.46	0.10
1997	0.19	0.30	0.04	0.22	0.37	0.08
1998	0.17	0.31	0.03	0.21	0.35	0.09
1999	0.17	0.29	0.05	0.20	0.28	0.08
2000	0.15	0.28	0.05	0.20	0.32	0.08
2001	0.16	0.35	0.02	0.17	0.26	0.10
2002	0.14	0.22	0.04	0.20	0.47	0.07
2003	0.14	0.25	0.03	0.18	0.44	0.09
2004	0.14	0.38	0.00	0.16	0.33	0.09
2005	0.12	0.26	0.02	0.18	0.33	0.08

Source: Burrows and Hagemeyer 2006
Note: To convert rem to Sv, multiply by 0.01.

As mentioned in Section 3.9.1.1, under 10 CFR 20.2206, the NRC requires licensees to submit an annual report of the results of individual monitoring. In addition to reporting data on external exposures, licensees are required to report information about internal exposures. Licensees are required to list for each intake, the radionuclide, pulmonary clearance class, intake mode, and amount of the intake in microcuries. Twenty-five intakes by ingestion and other modes were reported by licensees during 2005 (5 for cobalt-58, 14 for cobalt-60, 1 for cesium-134, 1 for iron-59, and 1 for manganese-54). Many more intakes were reported for the inhalation mode. The inhalation intakes were mainly from cobalt-60, cobalt-58, manganese-54, americium-241, curium-242, curium-243, plutonium-238, and plutonium-239 (Burrows and Hagemeyer 2006). Table 3.9-13 lists the number of individuals with measurable committed effective dose equivalent (CEDE), collective CEDE, and average measurable CEDE per individual as reported by different nuclear power reactor stations.

A portion of the total workforce can be defined as “transient.” These individuals are usually employed for special functions and may be employed at multiple reactor sites during a given year. Data for individual reactors described earlier include these people, but only for each

Table 3.9-12. Number of Workers at BWRs and PWRs Who Received Whole-Body Doses within Specified Ranges during 2005

Dose Range (rem)	BWRs	PWRs	Total
<0.1 (measurable)	18,235	28,209	46,444
0.1 to 0.25	7,443	10,311	17,754
0.25 to 0.50	4,848	4,343	9,191
0.50 to 0.75	174	1,160	2,904
0.75 to 1.00	706	398	1,104
1.00 to 2.00	521	162	683
2.00 to 3.00	17	0	17
3.00 to 4.00	0	0	0
4.00 to 5.00	0	0	0
5.00 to 6.00	0	0	0
6.00 to 12.00	0	0	0
>12	0	0	0
Total	25,449	57,125	82,574

Source: Burrows and Hagemeyer 2006
Note: To convert rem to Sv, multiply by 0.01.

power plant. Thus, some people are counted more than once, and some people receive greater annual doses than are reported by individual plants. In 1993, there were about 27,000 of these people (Burrows and Hagemeyer 2006). Over the years, doses to transient workers at nuclear power plants have been decreasing in the same way as doses to more permanent workers, going from an average of 0.49 rem in 1993 to 0.32 rem in 2005 (Burrows and Hagemeyer 2006). In 2005, three transient workers received whole body doses between 3 and 4 rem, and none received more than 4 rem (Burrows and Hagemeyer 2006).

A decreasing trend in the highest annual collective dose is somewhat apparent, as is a decreasing trend for the average collective dose. In addition to decreases in collective dose, the average annual dose per nuclear plant worker decreased during this period (1993 through 2005) from 0.31 to 0.18 rem for BWRs and from 0.25 to 0.12 rem for PWRs (Table 3.9-11). A breakdown of the number of individual workers receiving doses in different ranges for 2005 is provided in Table 3.9-12. These data demonstrate that 94 percent of plant radiation workers received less than 1 rem, and no worker received more than 4 rem. Overall data presented in Tables 3.9-1 through 3.9-6 provide evidence that doses to nearly all radiation workers are far

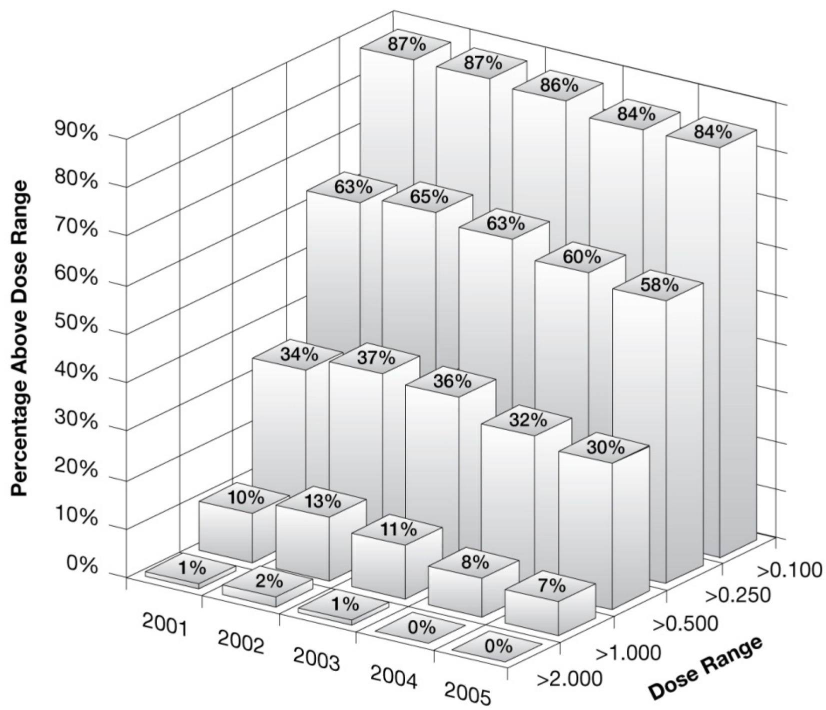

Figure 3.9-2. Collective Dose Distribution for All Commercial U.S. Reactors by Dose Range (rem) for 2001 through 2005 (Burrows and Hagemeyer 2006)

below the worker dose limit established by 10 CFR Part 20, and that the continuing efforts to maintain doses at ALARA levels have been successful.

As mentioned in Section 3.9.1.1, under 10 CFR 20.2202 and 10 CFR 20.2203, the NRC requires that all licensees submit reports of all occurrences involving personnel radiation exposures and releases of radioactive material that exceed certain control levels. For 2003 through 2005, there was no occurrence reported for nuclear power reactors (Burrows and Hagemeyer 2006).

3.9.1.3 Public Radiological Exposures

Commercial nuclear power plants, under controlled conditions, release small amounts of radioactive materials to the environment during normal operation. Radioactive waste management systems are incorporated into each plant. They are designed to remove most of the fission-product radioactivity that leaks from the fuel, as well as most of the activation- and corrosion-product radioactivity produced by neutrons in the vicinity of the reactor core. The amounts of radioactivity released through vents and discharge points to areas outside the plant

Table 3.9-13. Collective and Average CEDE for Commercial U.S. Nuclear Power Plant Sites in 2005

Plant	Number of Individuals with Measurable CEDE	Collective CEDE (person-rem)	Average Measurable CEDE (rem)
Duane Arnold	1	0.010	0.010
Arkansas	6	0.226	0.038
Browns Ferry	117	0.396	0.003
Brunswick	1	0.029	0.029
Columbia	2	0.019	0.010
Comanche Peak	3	0.072	0.024
Cooper	12	0.189	0.016
Davis-Besse	1	0.002	0.002
Hatch	1	0.022	0.022
Limerick	11	0.074	0.007
Millstone 1	2	0.025	0.013
Monticello	1	0.011	0.011
North Anna	1	0.017	0.017
Oconee	11	0.224	0.020
Palo Verde	9	0.264	0.029
Point Beach	2	0.018	0.009
Quad Cities	5	0.070	0.014
San Onofre	1	0.001	0.001
Sequoyah	23	0.063	0.003
St. Lucie	6	0.039	0.007
Summer	3	0.030	0.010
Susquehanna	4	0.021	0.005
Three Mile Island 1	1	0.018	0.018
Vermont Yankee	10	0.072	0.007
Vogtle	1	0.015	0.015
Watts Bar	170	2.869	0.017
Wolf Creek	3	0.007	0.002

Source: Burrows and Hagemeyer 2006
Note: To convert rem to Sv, multiply by 0.01.

boundaries are recorded and published annually in the radioactive effluent release reports for each facility. These reports are publicly available on the NRC's Agencywide Documents Access and Management System (ADAMS). The effluent releases result in radiation doses to humans. Nuclear power plant licensees must comply with Federal regulations (e.g., 10 CFR Part 20, Appendix I to 10 CFR Part 50, 10 CFR 50.36a, and 40 CFR Part 190) and technical specifications in the operating license.

Potential environmental pathways through which persons may be exposed to radiation originating in a nuclear power plant include the atmospheric and water pathways. Radioactive materials released under controlled conditions include fission products and activation products. Fission product releases consist primarily of the noble gases and some of the more volatile materials like tritium, isotopes of iodine, and cesium. These materials are monitored before release to determine whether the limits on releases can be met. Releases to the aquatic pathways are similarly monitored. Radioactive materials in the liquid effluents are processed in radioactive waste treatment systems. The major radionuclides released to aquatic systems have been tritium, isotopes of cobalt, and cesium.

When an individual is exposed to radioactive materials released by the plant into air or water pathways, the dose is determined in part by the amount of time spent in the vicinity of the source or the amount of time the radionuclides inhaled or ingested are retained in the individual's body (exposure). The consequences associated with this exposure are evaluated by calculating the dose. The major exposure pathways include the following:

- Inhalation of contaminated air;
- Drinking milk or eating meat from animals that graze on open pasture on which radioactive contamination may be deposited;
- Eating vegetables grown near the site; and
- Drinking (untreated) water or eating fish caught near the point of discharge of liquid effluents.

Radiation doses are calculated for the maximally exposed individual (MEI) (that is, a hypothetical individual potentially subject to maximum exposure). Doses are calculated by using site-specific data where available. For those cases in which site-specific data are not readily available, conservative (overestimating) assumptions are used to estimate dose. Members of the general public are also exposed when the LLW is shipped offsite. The public radiation exposures from radioactive material transportation have been addressed in Table S-4 of 10 CFR Part 51. Table S-4 indicates that the cumulative dose to the exposed public from the transport of both LLW and spent fuel is estimated to be about 0.03 person-Sv (3 person-rem) per reactor year (see Section 4.12.1.1).

Effluent Pathways for Calculations of Dose to the Public

Radioactive effluents can be divided into several groups on the basis of their physical characteristics. Among the airborne effluents, the radioisotopes of the noble gases krypton, xenon, and argon neither deposit on the ground nor are absorbed and accumulated within living organisms; therefore, the noble gas effluents act primarily as a source of direct external radiation emanating from the effluent plume. For these effluents, dose calculations are performed for the site boundary where the highest external-radiation doses to a member of the general public are estimated to occur.

A second group of airborne radioactive effluents—the fission-product radioiodines and tritium—are also gaseous, but some of them can be deposited on the ground or inhaled during respiration. For this class of effluents, estimates are made of direct external radiation doses from ground deposits (as well as exposure to the plume). Estimates are also made of internal radiation doses to total body, thyroid, bone, and other organs from inhalation and from vegetable, milk, and meat consumption.

A third group of airborne effluents consists of particulates and includes fission products, such as cesium and strontium, and activated corrosion products, such as cobalt and chromium. These effluents contribute to direct external radiation doses and to internal radiation doses through the same pathways as those described above for the radioiodine. Doses from the particulates are combined with those from the radioiodines and tritium for comparison with one of the design objectives of Appendix I to 10 CFR Part 50.

Liquid effluent constituents could include fission products such as strontium and iodine; activation and corrosion products, such as sodium, iron, and cobalt; and tritiated water. These radionuclides contribute to the internal doses through the pathways described above from fish consumption, water ingestion (as drinking water), and consumption of meat or vegetables raised near a nuclear plant and using irrigation water, as well as from any direct external radiation from recreational use of the water near the point of a plant’s discharge.

The release of each radioisotope and the site-specific meteorological and hydrological data serve as input to radiation-dose models that estimate the maximum radiation dose that would be received outside the facility by way of a number of pathways for individual members of the public and for the general public as a whole. These models and the radiation-dose calculations are discussed in Revision 1 of Regulatory Guide 1.109 (NRC 1977).

Doses from gaseous radioactive iodine and radioactive material in particulate form in gaseous effluents are calculated for individuals at the location or source point (e.g., site boundary, garden, residence, milk cow or goat, meat animal) where the highest radiation dose to a member of the public has been established from each applicable pathway (e.g., ground deposition, inhalation, vegetable consumption, milk consumption, meat consumption). Only those pathways associated with airborne effluents that are known to exist at a single location are combined to calculate the total maximum exposure to an exposed individual. Pathway doses associated with liquid effluents are conservatively combined without regard to any single location but are assumed to be associated with the maximum exposure of an individual.

A number of possible exposure pathways to humans are evaluated to determine the impact of routine releases from each nuclear facility on members of the general public living and working outside the site boundaries. A listing of these exposure pathways include external radiation exposure from gaseous effluents, inhalation of iodines and particulate contaminants in the air, drinking milk from a cow or goat or eating meat from an animal that grazes on open pasture near the site on which iodines or particulates may be deposited, eating vegetables from a garden near the site (that may be contaminated by similar deposits), and drinking water or eating fish or invertebrates caught near the point of liquid effluent discharge. Other exposure pathways may include external irradiation from surface deposition; eating of animals and crops grown near the site and irrigated with water contaminated by liquid effluents; shoreline, boating, and swimming activities; drinking potentially contaminated water; and direct radiation being emitted from the plant itself. Calculations for most pathways are limited to a radius of 50 mi (80 km). For this study, effluent and MEI dose information was collected from a series of publicly available annual radioactive effluent release reports that licensees submit to NRC every year.

Radiological Monitoring

Background radiation measurements at all reactor sites were obtained prior to operation of the nuclear reactor. Thus, each facility has characterized the natural background levels of radioactivity and radiation and their variations among the anticipated important exposure pathways in the areas surrounding the facilities. The operational, radiological environmental monitoring program (REMP) is conducted at each site to provide data on measurable levels of radiation and radioactive materials in the site environs in accordance with 10 CFR Parts 20 and 50. The REMP quantifies the environmental impacts associated with radioactive effluent releases from the plant. The REMP monitors the environment throughout the plant’s operating lifetime to monitor radioactivity in the local environment. The REMP provides a mechanism for determining the levels of radioactivity in the environment to ensure that any accumulation of radionuclides released into the environment will not become significant as a result of plant operations. The REMP also measures radioactivity from other nuclear facilities that may be in the area (i.e., other nuclear power plants, hospitals using radioactive material, research facilities or any other facility licensed to use radioactive material). Thus, the REMP monitors the cumulative impacts from all sources of radioactivity in the vicinity of the power plant. To obtain information on radioactivity around the plant, samples of environmental media (e.g., surface water, groundwater, drinking water, air, milk, locally grown crops, locally produced food products, river, ocean, or lake sediment, and fish and other aquatic biota) are collected from areas surrounding the plant for analysis to measure the amount of radioactivity, if any, in the samples. The media samples reflect the radiation exposure pathways (i.e., inhalation, ingestion, and physical location near the plant) to the public from radioactive effluents released by the nuclear power plant and from background radiation (i.e., cosmic sources, naturally occurring radioactive material, including radon and global fallout). The NRC has standards for the amount of radioactivity in the sample media, which if exceeded, must be reported to the NRC and the licensee must conduct an investigation. The REMP supplements the radioactive effluent monitoring program by verifying that measurable concentrations of radioactive materials and levels of radiation in the environment are not higher than expected when compared against data on the amount of radioactive effluent discharged.

The REMP can also identify the existence of effluents from unmonitored release points. A periodic land use survey identifies changes in the use of unrestricted areas to provide a basis for modifying the monitoring programs to reflect a new exposure pathway or a different site-specific dose calculation parameter. The results of the REMP are documented by each licensee in the annual radiological environmental monitoring reports and submitted to NRC every year and are publically available in NRC's ADAMS document system.

Public Radiation Doses

Table 3.9-14 shows the total body dose to the public, ground-level air dose, and dose to a critical organ for three years (2004 through 2006) from gaseous effluent releases for several PWRs and BWRs. The dose varies from year to year and also from reactor to reactor. The maximum total body dose is 0.14 mrem, maximum dose to a critical organ is 0.17 mrem, maximum ground-level air dose from gamma radiation is 0.04 mrad, and maximum ground-level dose from beta radiation is 0.06 mrad. All doses are much less than the design objectives shown in Table 3.9-2.

Table 3.9-15 shows the total body dose to the public and dose to a critical organ for 3 years (2004 through 2006) from liquid effluent releases for the same PWRs and BWRs. The total body dose and dose to critical organ of the MEI from liquid effluent releases varies from year to year and also from reactor to reactor. The maximum total body dose is 0.06 mrem, and the maximum dose to a critical organ is 0.06 mrem. The doses are much less than the design objectives shown in Table 3.9-2.

Table 3.9-14. Doses from Gaseous Effluent Releases for 2004 through 2006

Reactor Name	No. of Reactors	2004 Total Body (mrem)	2004 Gamma[a] (mrad)	2004 Beta[a] (mrad)	2004 Critical Organ (mrem)
PWRs					
Comanche Peak[b]	2	1.95×10^{-2}	2.05×10^{-3}	8.00×10^{-4}	1.95×10^{-2}
Cook[b]	2	8.00×10^{-2}	9.50×10^{-4}	2.65×10^{-3}	NR[c]
Indian Point 2	1	NR	4.35×10^{-3}	1.75×10^{-2}	6.00×10^{-3}
Indian Point 3	1	NR	1.20×10^{-4}	7.70×10^{-4}	8.00×10^{-4}
Robinson	1	NR	4.00×10^{-3}	1.70×10^{-3}	8.20×10^{-2}
San Onofre[b]	2	NR	4.05×10^{-2}	5.00×10^{-2}	6.50×10^{-3}
Surry[b]	2	NR	3.40×10^{-4}	4.55×10^{-4}	3.75×10^{-2}
BWRs					
Hatch 1	1	7.20×10^{-3}	5.20×10^{-5}	6.80×10^{-5}	7.20×10^{-3}
Hatch 2	1	1.00×10^{-2}	4.30×10^{-5}	5.80×10^{-5}	1.10×10^{-2}
Vermont Yankee	1	NR	0	0	8.00×10^{-3}
Limerick[b]	2	1.05×10^{-3}	1.65×10^{-3}	1.00×10^{-3}	3.55×10^{-3}
Columbia	1	3.70×10^{-2}	1.90×10^{-3}	6.80×10^{-4}	3.80×10^{-2}

Reactor Name	No. of Reactors	2005 Total Body (mrem)	2005 Gamma[a] (mrad)	2005 Beta[a] (mrad)	2005 Critical Organ (mrem)
PWRs					
Comanche Peak[b]	2	1.85×10^{-2}	2.05×10^{-2}	5.00×10^{-2}	1.65×10^{-1}
Cook[b]	2	7.00×10^{-2}	1.30×10^{-3}	2.00×10^{-3}	NR
Indian Point 2	1	NR	9.00×10^{-5}	6.00×10^{-4}	6.50×10^{-4}
Indian Point 3	1	NR	1.10×10^{-3}	6.00×10^{-3}	3.60×10^{-3}
Robinson	1	NR	9.70×10^{-3}	3.60×10^{-3}	7.40×10^{-2}
San Onofre[b]	2	NR	3.50×10^{-2}	4.90×10^{-2}	1.95×10^{-3}
Surry[b]	2	NR	8.00×10^{-4}	1.45×10^{-3}	7.50×10^{-2}
BWRs					
Hatch 1	1	8.60×10^{-3}	0	0	8.70×10^{-3}
Hatch 2	1	1.20×10^{-2}	0	0	1.20×10^{-2}
Vermont Yankee	1	NR	3.30×10^{-2}	3.20×10^{-3}	1.10×10^{-2}
Limerick[b]	2	1.20×10^{-3}	1.80×10^{-3}	1.25×10^{-3}	4.35×10^{-2}
Columbia	1	2.80×10^{-2}	2.70×10^{-3}	9.50×10^{-4}	3.00×10^{-2}

Table 3.9-14. (cont.)

Reactor Name	No. of Reactors	2006 Total Body (mrem)	Gamma(a) (mrad)	Beta(a) (mrad)	Critical Organ (mrem)
PWRs					
Comanche Peak(b)	2	2.30×10^{-2}	3.60×10^{-3}	9.00×10^{-4}	8.50×10^{-2}
Cook(b)	2	1.35×10^{-1}	2.60×10^{-3}	2.80×10^{-2}	NR
Indian Point 2	1	NR	2.55×10^{-3}	9.00×10^{-3}	6.00×10^{-3}
Indian Point 3	1	NR	5.40×10^{-5}	1.60×10^{-4}	1.10×10^{-3}
Robinson	1	NR	2.50×10^{-3}	8.80×10^{-4}	1.40×10^{-1}
San Onofre(b)	2	NR	3.70×10^{-2}	6.00×10^{-2}	6.30×10^{-3}
Surry(b)	2	NR	5.50×10^{-4}	8.50×10^{-4}	7.00×10^{-2}
BWRs					
Hatch 1	1	7.20×10^{-3}	4.40×10^{-6}	1.30×10^{-5}	7.20×10^{-3}
Hatch 2	1	2.30×10^{-2}	0	0	2.30×10^{-2}
Vermont Yankee	1	NR	8.80×10^{-5}	1.40×10^{-2}	9.60×10^{-3}
Limerick(b)	2	7.50×10^{-4}	1.10×10^{-3}	7.00×10^{-4}	2.35×10^{-3}
Columbia	1	2.00×10^{-2}	6.10×10^{-3}	2.10×10^{-3}	2.00×10^{-2}

(a) Values represent ground-level air doses.
(b) There is more than one plant operating at these reactor sites, and the combined doses were reported in the annual effluent release report. The reported doses were divided by the number of reactors to get the dose per reactor.
(c) NR = not reported in the site's effluent release report.
Sources: Each site's annual effluent release reports
Note: To convert mrem to mSv, multiply by 0.01.

Table 3.9-16 presents the dose to the MEI for the years 2004 to 2006 for a few PWRs and BWRs. Under most circumstances, the dose calculations, which were made by the sites, overestimate the dose because of conservative assumptions. The table shows that the MEI doses varied from about 0.02 mrem at the Columbia Generating Station in 2006 to about 15 mrem at Vermont Yankee in 2006. For most reactors, the annual MEI doses are a few millirem or less. At Vermont Yankee, the dose is relatively high because of the close proximity of the MEI to the plant. Over 99.9 percent of the individual's dose is attributed to direct radiation from the plant (NRC 2007f).

Radiological Exposure from Naturally Occurring and Artificial Sources

Table 3.9-17 identifies background doses to a typical member of the U.S. population as summarized in NCRP (2009). In the table, the annual values are rounded to the nearest 1 percent. A total average annual effective dose equivalent of 620 mrem/yr to members of the

Table 3.9-15. Dose from Liquid Effluent Releases for 2004 through 2006

Reactor Name	No. of Reactors	2004 Total Body (mrem)	2004 Critical Organ (mrem)	2005 Total Body (mrem)	2005 Critical Organ (mrem)	2006 Total Body (mrem)	2006 Critical Organ (mrem)
PWRs							
Comanche Peak[a]	2	5.50×10^{-2}	5.50×10^{-2}	6.00×10^{-2}	6.00×10^{-2}	5.00×10^{-2}	5.00×10^{-2}
Cook[a]	2	1.30×10^{-2}	1.40×10^{-2}	8.50×10^{-3}	1.00×10^{-2}	1.30×10^{-2}	1.30×10^{-2}
Robinson	1	6.60×10^{-4}	7.20×10^{-4}	9.20×10^{-5}	9.60×10^{-5}	3.50×10^{-4}	3.60×10^{-4}
Indian Point 2	1	3.20×10^{-3}	1.10×10^{-2}	8.10×10^{-4}	1.30×10^{-3}	8.80×10^{-4}	1.30×10^{-3}
Indian Point 3	1	2.00×10^{-4}	5.50×10^{-4}	4.50×10^{-4}	5.40×10^{-4}	1.30×10^{-4}	1.60×10^{-4}
San Onofre[a]	2	2.55×10^{-3}	1.00×10^{-2}	1.35×10^{-3}	4.00×10^{-3}	1.10×10^{-3}	3.90×10^{-3}
Surry[a]	2	1.30×10^{-4}	3.60×10^{-4}	1.20×10^{-4}	4.55×10^{-4}	1.55×10^{-4}	5.50×10^{-4}
BWRs							
Hatch 1	1	4.20×10^{-3}	6.30×10^{-3}	3.20×10^{-3}	4.80×10^{-3}	2.60×10^{-3}	3.80×10^{-3}
Hatch 2	1	9.50×10^{-4}	1.40×10^{-3}	1.20×10^{-3}	1.90×10^{-3}	3.50×10^{-4}	4.50×10^{-4}
Vermont Yankee	1	0	0	0	0	0	0
Limerick[a]	2	7.50×10^{-4}	1.05×10^{-3}	5.50×10^{-4}	5.50×10^{-4}	1.10×10^{-3}	1.15×10^{-3}
Columbia	1	0	0	0	0	0	0

(a) There are two or more plants operating at these reactor sites. The reported doses in the annual effluent release reports were divided by 2 to get the dose per reactor.
Source: Each site's annual effluent release reports
Note: To convert mrem to mSv, multiply by 0.01.

U.S. population is contributed by two primary sources: naturally occurring background radiation and medical exposure to patients.

Natural radiation sources other than radon result in 13 percent of the typical radiation dose received. The larger source of radiation dose in ubiquitous background (37 percent) is from radon, particularly because of homes and other buildings that trap radon and significantly enhance its dose contribution over open-air living. The remaining 50 percent of the average annual effective dose equivalent consists of radiation mostly from medical procedures (computed tomography, 24 percent; nuclear medicine, 12 percent; interventional fluoroscopy, 7 percent; and conventional radiography and fluoroscopy, 5 percent) and a small fraction from consumer products (2 percent). The consumer product exposure category includes exposure to members of the public from building materials, commercial air travel, cigarette smoking, mining and agriculture products, combustion of fossil fuels, highway and road construction materials, and glass and ceramic. The industrial, security, medical, education, and research exposure category includes exposure to the members of the public from nuclear power generation; DOE

Table 3.9-16. Total Effective Dose Equivalent (mrem) to the Maximally Exposed Individual (MEI) for 2004 through 2006

Site[(a)]	No. of Reactors	2004	2005	2006
PWRs				
Cook	2	0.108	0.095	0.182
Indian Point	2	<4.0	<4.1	<7.1
San Onofre	2	0.29	0.4	0.6
BWRs				
Vermont Yankee	1	13.3	13.5	15.3
Columbia	1	0.037	0.028	0.019

(a) Some of the reactors in Tables 3.9-9 and 3.9-10 are not included because the dose to the MEI was not reported in the site's effluent release reports for these reactors.
Source: Each site's annual effluent release reports

installation; decommissioning and radioactive waste; industrial, medical, education, and research activities; contact with nuclear medicine patients; and security inspection systems. The occupational exposure category includes exposure to workers from medical, aviation, commercial nuclear power, industry and commerce, education and research, government, the DOE, and military installations. Radiation exposures from occupational activities, industrial, security, medical, educational and research contribute insignificantly to the total average effective dose equivalent.

Inadvertent Liquid Radioactive Releases

As mentioned before, all commercial nuclear power plants routinely release radioactive material to the environment in the form of liquids and gases in accordance with regulations (Table 3.9-2). Each year, plant operators submit an effluent release report that documents the amount of radioactive material released to the environment during the year. This report also includes the public dose impact from the releases. Plant operators also conduct environmental monitoring in the vicinity and submit an environmental monitoring report every year to the NRC. However, some sites have had inadvertent radioactive liquid releases that were not initially monitored.

After the discovery of a leak, each licensee performed appropriate monitoring and assessed the radiation exposure to a member of the public. In all cases, the calculated dose to a member of the public was below the ALARA design objectives in Appendix I to 10 CFR Part 50.

Table 3.9-17. Average Annual Effective Dose Equivalent of Ionizing Radiation to a Member of the U.S. Population for 2006

Source	Effective Dose Equivalent	
	mrem	Percent of Total
Ubiquitous background		
Radon and thoron	228	37
Natural		
Cosmic	33	5
Terrestrial	21	3
Internal	29	5
Total ubiquitous background	**311**	**50**
Medical		
Computed tomography	147	24
Nuclear medicine	77	12
Interventional fluoroscopy	43	7
Conventional radiography and fluoroscopy	33	5
Total medical	**300**	**48**
Consumer products	**13**	**2**
Industrial, security, medical, educational and research	**0.3**	**0.05**
Occupational	**0.5**	**0.08**
Total	**624.8**	**100**

Source: Adapted from NCRP 2009

Table 3.9-18 provides a list of the known inadvertent releases to the environment primarily from 1996 through 2006.

After inadvertent releases of tritium that resulted in groundwater contamination at the Braidwood, Indian Point, Byron, and Dresden nuclear sites were recently detected, the NRC chartered a taskforce to conduct a lessons-learned review of these incidents. The taskforce also reviewed and evaluated public health and environmental impacts, along with many other aspects, such as regulatory framework and NRC inspection.

The impacts from inadvertent releases would be in addition to the impacts from routine effluent releases and would depend on many factors, such as the amount and type of radionuclide,

Table 3.9-18. Inadvertent Releases of Radioactive Liquids at Nuclear Power Plants

Site	Date of Release Discovery	Source of Release	Radionuclides Detected
Braidwood	March 2005	Vacuum breaker valves on the circulating water blowdown line	Tritium
Byron	February 2006	Vacuum breaker valves on the circulating water blowdown line	Tritium
Callaway	June 2006	Air release valves on the circulating water blowdown line	Tritium, cobalt-58, cobalt-60, cesium-134, and cesium-137
Dresden	August 2004, January 2006	Non-safety-related high-pressure coolant injection suction and return line	Tritium
Hatch	December 1986	Fuel transfer canal, because of operator action	Tritium
Indian Point	August 2005—Unit 1 leakage predates August 2005	Unit 1 and Unit 2 spent fuel pools	Tritium, nickel-63, cesium-137, strontium-90, and cobalt-60
Oyster Creek	September 1996	Condensate transfer system, because of operator action	Tritium
Palo Verde	March 2006	Rain condensing onto property after a gaseous release	Tritium
Perry	March 2006	Feedwater system venturi	Tritium
Point Beach	1999	Retention pond	Tritium, cesium-137
Seabrook	June 1999	Spent fuel pool	Tritium
Salem	September 2002	Spent fuel pool	Tritium
Three Mile Island	May 2006	Condensate storage tank	Tritium
Watts Bar	August 2002	Effluent release pipe and spent fuel pool transfer tube sleeve	Tritium and mixed fission products

Source: NRC 2006c

environmental transport, and how the receptor would come in contact with the contaminated media. For example, tritium enters the body when people eat or drink food or water that contains tritium or when they absorb it through their skin. People can also inhale tritium as a gas in the air. Once tritium enters the body, it quickly distributes uniformly throughout the soft tissue. At the Braidwood site between March 2005 and 2006, the plant operator sampled water in the drinking water wells of several nearby residents and found tritium contamination levels in a range of 1,400 to 1,600 pCi/L above background levels. These tritium contamination levels are much lower than the EPA's drinking water standard of 20,000 pCi/L for tritium.

The task force focused on the inadvertent releases that had the potential to have a measurable dose impact on a member of the public and/or the offsite environment on the basis of the source's strength and its potential for movement offsite. Table 3.9-19 lists the maximum tritium contamination detected onsite and at offsite locations from the inadvertent release events. The table shows that currently, for most locations, contamination has not migrated offsite.

The most significant conclusion of the task force regarded the lack of public health impacts. Although there have been number of industry events in which radioactive liquid was released to the environment in an unplanned and unmonitored fashion, based on the data available, the task force did not identify any instances where the health of the public was impacted (NRC 2006c).

Radiation Health Effects Studies

Studies published by the Radiation Public Health Project assert that strontium-90 levels in the environment are rising and are responsible for cancers in children and infant mortality. This group of studies also claims that radioactive effluents from nuclear power plants are directly responsible for the increases in strontium-90 concentrations in baby teeth (Gould et al. 2000; Mangano et al. 2003).

Strontium-90 does not occur naturally. It comes from three sources: (1) fallout from aboveground explosions from testing of nuclear weapons worldwide from 1963 to 1980, (2) radioactive releases from the 1986 Chernobyl nuclear power plant accident in the Ukraine, and (3) radioactive releases from nuclear power plants into the environment.

Approximately 16.8 million Ci of strontium-90 were produced and globally dispersed in atmospheric nuclear weapons testing until 1980. Also, as a result of the Chernobyl accident, approximately 216,000 Ci of strontium-90 were released into the atmosphere (UNSCEAR 2000). The total annual release of strontium-90 into the atmosphere from all 104 commercial nuclear power plants operating in the United States is typically 1/1,000th of a curie (NRC 1993). At an individual nuclear power plant, the amount of strontium-90 released in gaseous effluent is so low that it is usually at or below the minimum detectable activity of sensitive detection equipment. For this reason, any strontium-90 detected in the environment near a nuclear power plant would probably not have come from the plant but would instead be attributed to fallout from nuclear weapons testing or from the Chernobyl accident.

The NRC has established strict limits on the amount of radioactive emissions allowed to be released from nuclear plants to the environment and the resulting exposure for members of the public and plant workers (see Table 3.9-2). All power plant operators are required to monitor radioactive airborne and liquid discharges from the plant and to file a report of these discharges annually with the NRC. These reports, which are publicly available, list the radioactive isotopes

Table 3.9-19. Dose from Inadvertent Releases of Radioactive Liquids at Nuclear Power Plants

Site	Maximum Tritium Contamination (pCi/L) Detected within the Site Boundary	Maximum Water Contamination (pCi/L) at Offsite Locations	Receptor and Pathways	Yearly Dose (mrem)
Braidwood	225,000 to 250,000	1,400 to 1,600	Child: water ingestion; Adult: fish and water ingestion	Child: 0.16 Adult: 0.07
Byron	3,800	None detected	NA[(a)]	NA
Callaway	20,000 to 200,000	None detected	NA	NA
Dresden	486,000 to 680,000	None detected	NA	NA
Hatch[(b)]	See footnote (a)	None detected at offsite water sources—long-term monitoring in place	Negligible	Negligible
Indian Point[(c)]	200,000 for tritium 100 for nickel-63 50 for strontium-90	Dose calculated conservatively	MEI[(d)]	0.0021
Oyster Creek	16,000	None detected	NA	NA
Palo Verde	71,400	None detected	NA	NA
Perry	60,000	None detected	NA	NA
Point Beach	14,250	None detected	NA	NA
Seabrook	750,000	Groundwater plume has not migrated offsite	Negligible	Negligible
Salem[(e)]	15,000,000	None detected	NA	NA
Three Mile Island	45,000	None detected	NA	NA
Watts Bar	30,000	Groundwater plume has not migrated offsite	Negligible	Negligible

(a) NA = Not applicable because water contamination was not detected at offsite locations.
(b) Approximately 124,000 gal of liquid containing 0.2 Ci of tritium and 0.373 Ci of mixed fission products were released to a swamp onsite.
(c) Source for data is Indian Point (2005).
(d) MEI = Maximally Exposed Individual.
(e) Extensive groundwater remediation program in place.
Source: NRC 2006c
Note: To convert mrem to mSv, multiply by 0.01.

released, the quantity released, and the radiation dose to the public. The concentrations of radionuclides released into the environment from a nuclear facility are generally too low to be measurable outside the plant's boundary. In addition to limits on effluent releases, plant operators maintain an environmental monitoring program that is reviewed and inspected regularly by the NRC to ensure that the program complies with its requirements. To demonstrate that the plant is within the regulatory limits, operators regularly sample and analyze the surrounding soil, vegetation, cow's milk, air, aquatic biota, and water. In a given year, a plant operator samples and analyzes hundreds of environmental samples. The results of environmental monitoring and assessment efforts are provided to the NRC in an annual report, which is available to the public. It is reasonable to conclude that strontium-90 would be seen in the environment well before it is seen in baby teeth. In order for it to be in the environment from nuclear power plants, it would have to be seen in significant quantities in the effluent stream from these facilities. However, strontium-90 is not present in the effluents at such levels (NRC 2007g).

Several studies have been conducted to examine health effects around nuclear power plants (National Cancer Institute 1990; ACS 2001; FDOH 2001; IDPH 2000, 2006). The National Cancer Institute looked at cancer mortality rates around 52 nuclear power plants and 10 other nuclear facilities. The study concluded there was no evidence that nuclear facilities may be linked causally with excess deaths from leukemia or from other cancers in populations living nearby. In light of the information that has become available since 1990 and due to the demographic changes in the last 20 years, the NRC has asked the National Academy of Sciences (NAS) to perform a state-of-the-art study on cancer risk for populations surrounding nuclear power facilities (NRC 2012). The NAS study will update the 1990 National Cancer Institute report. The study began in the summer of 2010 and is expected to be completed within four years. The ACS in 2001 concluded that cancer clusters do not occur more often near nuclear plants than they do by chance elsewhere. In 2001, the Florida Bureau of Environmental Epidemiology reviewed claims that there are striking increases in cancer rates in southeastern Florida counties caused by increased radiation exposures from nuclear power plants. However, when they used the same data to reconstruct the calculations on which the claims were based, Florida officials were not able to identify unusually high rates of cancers in these counties when rates were compared with rates in the rest of the State of Florida and the nation (FDOH 2001). In 2000, the Illinois Department of Public Health (IDPH) compared childhood cancer statistics for counties with nuclear power plants to similar counties without nuclear plants and found no statistically significant difference (IDPH 2000). In 2006, the IDPH studied pediatric cancer incidence and mortality rates for children near nuclear reactor sites. No evidence of an increased trend in the cancer incidence rate after startup of nuclear power plants was found (IDPH 2006). Boice et al. (2005) evaluated the rates of total cancer, leukemia, and cancer of brain tissue and other nervous tissue in children and across all ages in St Lucie County with respect to the years before and after the nuclear power station began operation and compared the results with rates in two similar counties in Florida (Polk and Volusia). Over the prolonged period 1950 through 2000, no unusual patterns of childhood cancer mortality were found for St Lucie County as a whole. In particular, no unusual patterns of childhood cancer mortality were seen in relation to the startup of the St Lucie nuclear power station in 1976. Further, there were no significant differences in mortality between the study and comparison counties for any cancer in the time period after the power station was in operation (Boice et al. 2005).

On the basis of all the preceding discussion, several studies appear to refute the claims made in the studies published by the Radiation Public Health Project.

3.9.1.4 Risk Estimates from Radiation Exposure

In estimating the health effects resulting from both occupational and offsite radiation exposures as a result of operating nuclear power facilities, the normal probability coefficients for stochastic effects recommended by the ICRP (ICRP 1991) were used. The coefficients consider the most recent radiobiological and epidemiological information available and are consistent with the United Nations Scientific Committee on the Effects of Atomic Radiation. The coefficients used (Table 3.9-20) are the same as those published by ICRP in connection with a revision of its recommendations (ICRP 1991). Excess hereditary effects are listed separately because radiation-induced effects of this type have not been observed in any human population, as opposed to excess malignancies that have been identified among populations receiving instantaneous and near-uniform exposures in excess of 10 rem. Details regarding the risk of radiation-induced health effects are provided in Section D.8 in Appendix D.

In 2006, the National Research Council's Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR) published BEIR-VII, entitled *Health Risks from Exposure to Low Levels of Ionizing Radiation* (BEIR 2006).

BEIR-VII provides estimates of the risk of incidence and mortality for males and females (see Table D.8-4 in Appendix D). If the total fatal cancer risk is the sum of cancer deaths from all solid cancers and leukemia, then the fatal cancer risk coefficient for the general public would be 6×10^{-4}/person-rem (see Table D.8-5 in Appendix D). The fatal cancer risk for the general public based on ICRP is 5×10^{-4}/person-rem (Table 3.9-20). There is a difference of approximately 20 percent in the fatal cancer risk coefficient based on ICRP recommendation and the BEIR-VII report. The difference of 20 percent is within the margin of uncertainty associated with these estimates. See Section D.8.1.4 in Appendix D for a detailed discussion of the BEIR VII report.

Table 3.9-20. Nominal Probability Coefficients Used in ICRP (1991)[(a)]

Health Effect	Occupational	Public
Fatal cancer	4	5
Hereditary	0.6	1

(a) Estimated number of excess effects among 10,000 people receiving 10,000 person-rem. Coefficients are based on "central" or "best" estimates.
Source: ICRP 1991

The NRC completed a review of the BEIR VII report and documented its findings in the Commission paper SECY-05-0202, *Staff Review of the National Academies Study of the Health Risks from Exposure to Low Levels of Ionizing Radiation (BEIR VII)*, dated October 29, 2005 (NRC 2005b) (ADAMS Accession No. ML052640532). In this paper, the NRC concluded that the findings presented in the BEIR VII report agree with the NRC's current understanding of the health risks from exposure to ionizing radiation. The NRC agreed with the BEIR VII report's major conclusion that current scientific evidence is consistent with the hypothesis that there is a linear, no-threshold dose response relationship between exposure to ionizing radiation and the development of cancer in humans. This conclusion is consistent with the process the NRC uses to develop its standards of radiological protection. Therefore, the NRC's regulations continue to be adequately protective of public health and safety and the environment.

If the occupational worker is exposed at 10 CFR Part 20 dose limits for 1 year, the probability of developing fatal cancer (on the basis of ICRP recommendations) from exposure due to an operating nuclear reactor is equal to 2×10^{-3} on the basis of ICRP recommendations. However, the average individual worker doses are much less than the dose limits (see Table 3.9-4), and, at the doses observed, the probability of developing fatal cancer would be in the range of 1.2×10^{-4} to 4.8×10^{-5}.

If the member of the public is exposed at 40 CFR Part 190 dose limits, the probability of developing fatal cancer (on the basis of ICRP recommendations) from exposure resulting from operating a nuclear reactor is equal to 1.25×10^{-5}. However, the MEI doses are much less than the dose limits (see Table 3.9-16), and, at the doses observed, the probability of developing fatal cancer would be in the range of 7.7×10^{-6} to 1.0×10^{-8}.

3.9.1.5 Conclusion

Radiation doses to nuclear power plant workers and members of the public from the current operation of nuclear power plants have been examined, and the radiation doses were found to be well within design objectives and regulations in each instance. Therefore, the health impacts from radiation to the workers and the public are considered to be SMALL.

3.9.2 Chemical Hazards

Chemicals enter the body through the skin, by inhalation, or by ingestion. Chemical exposure produces different effects on the body depending on the chemical and the amount of exposure. Chemicals can cause cancer, affect reproductive capability, disrupt the endocrine system, or have other health effects. Acute effects from chemical exposure occur immediately (e.g., when somebody inhales or ingests a poisonous substance such as cyanide). Chronic or delayed effects result in symptoms such as skin rashes, headaches, breathing difficulties, and nausea.

In nuclear power plants, chemical effects could result from discharges of chlorine or other biocides, small-volume discharges of sanitary and other liquid wastes, chemical spills, and heavy metals leached from cooling system piping and condenser tubing. Impacts of chemical discharges to human health are considered to be SMALL if the discharges of chemicals to water bodies are within effluent limitations designed to ensure protection of water quality and if ongoing discharges have not resulted in adverse effects on aquatic biota.

The discharged chemicals, including chlorine and other biocides, are regulated by the NPDES permitting system of each nuclear power plant. Regulatory concerns about the toxic effects of chlorine and its combination products, as well as operating experience with controlling biofouling, have led many plants to eliminate the use of chlorine or reduce the amount used below the levels that were originally anticipated in the environmental statements associated with issuing the construction permit and operating license. Some power plants use mechanical cleaning methods or, because of the abrasive properties of particulates in the intake water, do not have to clean the condenser cooling system at all. Other plants chlorinate the condenser cooling or service water systems but can isolate certain portions for treatment (e.g., a single unit of a multi-unit plant), thereby allowing dilution to reduce the concentration of chlorine in the discharge. Because of these refinements and the process for modifying NPDES permit conditions as needed, water quality degradation from existing biocide usage at once-through nuclear power plants is controlled (see Section 3.5).

Minor chemical spills or temporary off-specification discharges from sanitary waste treatment systems and other low-volume effluents (e.g., excessive coliform counts or total suspended solids levels, pH outside of permitted range) were cited as common NPDES permit violations in the 1996 GEIS (NRC 1996). Such NPDES noncompliances have been variable, random in occurrence, and readily amenable to correction. These minor discharges or spills do not constitute widespread, consistent water quality degradation. Effects on water quality from minor chemical discharges and spills have been of small significance and have been mitigated as needed (NRC 1996). Significant cumulative impacts to water quality would not be expected because the small amounts of chemicals released by these minor discharges or spills are readily dissipated in the receiving water body. Spills and off-specification discharges occur seldom enough that regulatory agencies have expressed no concern about them with regard to operating nuclear power plants (NRC 1996).

Heavy metals (e.g., copper, zinc, and chromium) may be leached from condenser tubing and other heat exchangers and discharged by power plants as small-volume waste streams or corrosion products. Although all are found in small quantities in natural waters (and many are essential micronutrients), concentrations in the power plant discharge are controlled in the NPDES permit because excessive concentrations of heavy metals can be toxic to aquatic organisms (see Section 3.6). The ability of aquatic organisms to bioaccumulate heavy metals, even at low concentrations, has led to concerns about toxicity to both the humans and the biota that consume contaminated fish and shellfish. For example, the bioconcentration of copper discharged from the Chalk Point plant (a fossil-fuel power plant on Chesapeake Bay) resulted in oyster "greening" (Roosenburg 1969). The bioaccumulation of copper released from the Robinson plant resulted in malformations and decreased reproductive capacity among bluegill in the cooling reservoir (Harrison 1985). At the Diablo Canyon nuclear plant, it was observed that the concentration of soluble copper in effluent water was high during the startup of water circulation through the condenser system after a shutdown (Harrison 1985). In all three examples of excessive accumulation of copper (Diablo Canyon, Chalk Point, and Robinson), replacement of the copper alloy condenser tubes with another material (e.g., titanium) eliminated the problem.

The EPA is responsible for the regulation of most chemicals that can enter the environment. The EPA administers the following Federal acts related to chemical contamination: the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA); Toxic Substances Control Act (TSCA); Resource Conservation and Recovery Act (RCRA); Clean Water Act (CWA); Safe Drinking Water Act (SDWA); Clean Air Act (CAA); and Comprehensive Environmental Response Compensation and Liability Act (CERCLA).

Nuclear power plants may be required in some instances to submit annual reports of the environmental releases of listed toxic chemicals manufactured, processed, or otherwise used that are above threshold quantities, depending on State regulations or other specific circumstances. In addition, management, including treatment, storage, disposal, and release to the environment, of essentially all of the hazardous chemicals used at nuclear power plants is regulated by RCRA, FIFRA, TSCA, or the CWA. In the case of releases to State and Federal waters, the CWA requires that nuclear power plants obtain NPDES permits, which establish protective release limits and controls as well as monitoring and reporting requirements. RCRA, FIFRA, and TSCA also establish reporting requirements that frequently apply to management of nonradioactive hazardous chemicals at nuclear power plants, and some nuclear power plants may undertake activities that require a RCRA permit. Nuclear power plants are required by the NRC to operate in compliance with all applicable environmental laws, regulations, and permits, therefore minimizing the impact on the environment, workers, and the public. Therefore, the health impacts from chemicals on workers and the public are considered SMALL.

3.9.3 Microbiological Hazards

Some microorganisms associated with nuclear power plant cooling towers and thermal discharges can have deleterious impacts on the health of plant workers and the public. Microorganisms of concern include the enteric pathogens *Salmonella* spp. and *Shigella* spp., as well as *Pseudomonas aeruginosa* and thermophilic fungi. Tests for these pathogens are well established, and factors germane to their presence in aquatic environments are known and, in some cases, controllable. Other aquatic microorganisms normally present in surface waters have only recently been recognized as pathogenic for humans. Among these are Legionnaires' disease bacteria (*Legionella* spp.) and free-living amoebae of the genera *Naegleria* and *Acanthamoeba*, the causative agents of various, although rare, human infections. Factors affecting the distribution of *Legionella* spp. and pathogenic free-living amoebae are not well understood. Simple, rapid tests for their detection and procedures for their control are not yet available.

Potential adverse health effects of microorganisms on nuclear power plant workers are an issue for plants that use cooling towers. The potential for adverse health effects on the public from microorganisms in thermal effluents is an issue for nuclear plants that use cooling ponds, lakes, or canals and that discharge to small rivers (defined in NRC 1996 as having an average flow of less than 2,830 m^3/s [100,000 ft^3/s]). These issues are evaluated here by reviewing what is known about the organisms that are potentially enhanced by plant operation. Potential effects are described below.

3.9.3.1 Background Information on Microorganisms of Concern

Salmonella typhimurium and *S. enteritidis* are two of the more common species of the Enterobacteriaceae that cause fever, abdominal cramps, and diarrhea. *Salmonella* spp. can occasionally establish localized infection (e.g., septic arthritis) or progress to sepsis. The affected groups include all ages, but groups at greatest risk for severe or complicated disease include infants, the elderly, and persons with compromised immune systems. *Salmonella* spp. can thrive at temperatures from 50 to 120°F (CDC 2007; Kendall 2007).

Shigella spp. is similar to *Salmonella* spp. in its mode of transmission but has a much shorter incubation period (1 to 7 days). It produces severe dysentery with production of a potent exotoxin. The optimum growth temperature for the organism is 99°F, but it can grow at much higher temperatures (NRC 1996).

Pseudomonas aeruginosa can be found in soil, humidifiers, hospital respirators, water, and sewage, and on the skin of healthy individuals. Certain strains can produce a potent endotoxin, and the organism can cause symptoms that include fever, bacteriuria, bacteremia, pneumonia, otitis, and opportunistic wound and ophthalmic infections. *Pseudomonas aeruginosa* is an opportunistic pathogen that causes serious and sometimes fatal infections in immunocompromised individuals. The organism produces toxins that are harmful to humans and animals. It has an optimal growth temperature of 98.6°F and can tolerate a temperature as high as 107.6°F (Todar 2004).

Thermophilic microorganisms can have optimum growth at temperatures of 122°F or more, a maximum temperature tolerance of up to 158°F, and a minimum tolerance of about 68°F (Deacon 2003).

Legionella spp. consists of at least 46 species and 70 serogroups. It is responsible for Legionnaires' disease, with the onset of pneumonia in the first two weeks of exposure. Risk groups for *Legionella* spp. include the elderly, cigarette smokers, persons with chronic lung or an immunocompromising disease, and persons receiving immunosuppressive drugs. A temperature range of 90 to 105°F is best for *Legionella* spp. growth (CDC 2005).

Populations of the pathogenic amoeba flagellate *Naegleria fowleri* is the causative agent of human primary amoebic meningoencephalitis. The affected groups include all ages, but groups at greatest risk for severe or complicated disease include infants, the elderly, and persons with compromised immune systems. *Naegleria* spp. is ubiquitous in nature and can be enhanced in heated water bodies at temperatures ranging from 95 to 106°F or higher. This organism is rarely found in water cooler than 95°F, and infection rarely occurs in water temperatures of 95°F or less (Tyndall et al. 1989).

During the scoping meeting for the Calvert Cliffs license renewal SEIS, one member of the public raised an issue about the microorganisms that live in high radiation and extreme heat conditions (such as within the spent fuel pool) based on the article "Something's Bugging Nuclear Fuel" published in *Science News* (1998). The commenter asked that consideration be given to these types of organisms, the possibility of their mutation, and consequences if they escaped from the plant into the natural aquatic environment. The NRC consulted specialists in the field; the following is a summary of their conclusions as presented in the SEIS (NRC 1999):

- Many types of organisms can live in the temperature range of the spent fuel pools (100 to 150°F).

- There is a potential for mutation in all living organisms, but microbes that have high levels of radiation resistance have also developed extremely efficient repair systems.

- Organisms that are associated with thermal waters of the spent fuel pool are likely to die if they are transferred into the relatively much lower water temperatures typical of surface waters. If the organisms are truly adapted to the high temperatures typical of the spent fuel pool, they probably would not be able to survive and compete with the indigenous microorganisms of the relatively cold waters of the natural water sources.

In summary, the NRC concluded that microorganisms that live in high radiation and extreme heat conditions typical of the spent fuel pool do not pose a risk to humans or the environment.

3.9.3.2 Studies of Microorganisms in Cooling Towers

In 1981, cooling water systems at 11 nuclear power plants and associated control source waters were studied for the presence of thermophilic free-living amoebae, including *N. fowleri*. The presence of pathogenic *N. fowleri* in these waters was tested, and while all but one test site was positive for thermophilic free-living amoebae, only two test sites were positive for pathogenic *N. fowleri*. Pathogenic *N. fowleri* were not found in any control source waters (Tyndall 1981). In addition to testing for pathogenic amoebae in cooling water, testing for the presence of *Legionella* spp. was also done (Tyndall 1981). The concentrations of *Legionella* spp. in these waters were determined. In general, the artificially heated waters showed only a slight increase (i.e., no more than tenfold) in concentrations of *Legionella* spp. relative to source water. In a few cases, source waters had higher levels than did heated waters. Infectious *Legionella* spp. were found in 7 of 11 test waters and 5 of 11 control source waters.

Subsequently, a more detailed study of *Legionella* spp. in the environs of coal-fired power plants was undertaken to determine the distribution, abundance, infectivity, and aerosolization of *Legionella* spp. in power plant cooling systems (Tyndall 1983; Christensen et al. 1983; Tyndall et al. 1985). This study found that positive air samples did not occur often at locations that were not next to cleaning operations, which suggests that aerosolized *Legionella* spp. associated with downtime procedures have minimal impact beyond these locations. Even within plant boundaries, detectable airborne *Legionella* spp. appear to be confined to very limited areas. In these areas, however, the more contact individuals have with the most concentrated *Legionella* spp. populations, particularly if they become aerosolized (as they do in some downtime operations), the more likely it is that workers are exposed.

There is new evidence that suggests that *Legionella*-like amoebal pathogens (LLAPs) may be an unrecognized significant cause of respiratory disease (Berk et al. 2006). In this study, the occurrence of infected amoebae in water, biofilm, and sediment samples from 40 cooling towers (non-nuclear sites) and 40 natural aquatic environments were compared. The natural samples were collected from rivers, creeks, lakes, and ponds from Tennessee, Kentucky, New Jersey, Florida, and Texas. The cooling tower samples were collected from industries, hospitals, municipal buildings, universities, and other public sites from Tennessee, Kentucky, and Texas. The infected amoebae were found in 22 cooling tower samples and 3 natural samples. According to this study, the probability of infected amoebae occurring in cooling towers is 16 times higher than in natural environments.

3.9.3.3 Microbiological Hazards to Plant Workers

Exposure to *Legionella* spp. from power plant operations is a potential problem for a subset of the workforce. Plant personnel most likely to come in contact with *Legionella* aerosols would be workers who dislodge biofilms, where *Legionella* are often concentrated, such as during the cleaning of condenser tubes and cooling towers. Since Legionellosis is a respiratory disease, workers engaged in such activities should be protected by wearing appropriate respiratory protection.

Because the route of infection for *N. fowleri* is nasal, workers exposed to aerosols of this pathogen also should be protected with respiratory protection. If workers are involved in underwater maintenance or other activities associated with thermally altered discharge waters known to harbor *N. fowleri*, they should wear appropriate gear to prevent entry of the amoebae into the nasal cavity.

In response to these various studies, workers at nuclear power plants are typically required to use respiratory protection when cleaning cooling towers and condensers. Also, for worker protection, one nuclear plant with high concentrations of *N. fowleri* in the circulating water successfully controlled the pathogen through chlorination before its yearly downtime operation (Tyndall 1983). It is anticipated that plant operators would continue to use proven industrial hygiene principles to minimize worker exposures to these organisms in mists of cooling towers (NRC 1996).

3.9.3.4 Microbiological Hazards to the Public

From the above studies, it is clear that heavily used bodies of freshwater merit special attention and possibly routine monitoring for pathogenic *Naegleria*. Since *Naegleria* concentrations in freshwater can be enhanced by thermal additions, nuclear power plants that utilize cooling lakes, canals, ponds, or small rivers may enhance the naturally occurring thermophilic organisms. The observed risk to swimmers from waters infected with *N. fowleri* is low but not zero (Hallenbeck and Brenniman 1989). Exposure to *Legionella* spp. from power plant operations would not generally impact the public because concentrated aerosols of the bacteria would not traverse plant boundaries. On the basis of the information available on microorganisms that may inhabit high-radiation, high-temperature environments (such as the spent fuel pool), the NRC concludes they have little potential for significantly increasing in number in the environment, and they would not have a deleterious effect on public health.

It is possible that the operations of the plants that use cooling ponds, lakes, canals, or small rivers may enhance the presence of thermophilic organisms (NRC 1996). There are currently 23 reactor sites that fit this category. Data for 14 sites from this category (Arkansas, Browns Ferry, Dresden, Farley, Fort Calhoun, Hatch, McGuire, Monticello, North Anna, Oconee, Peach Bottom, Quad Cities, Robinson, and Vermont Yankee) that have gone through or are going through license renewal were reviewed to predict the level of thermophilic microbiological organism enhancement at any given site. Health departments were contacted by many sites (Arkansas, Browns Ferry, Dresden, Farley, McGuire, Quad Cities, Oconee, and Robinson), and none of them had any concerns regarding the threat to the public from the thermophilic pathogens attributable to the plant operations. For some plants, such as Hatch, Quad Cities, and Monticello, NPDES permits had set limits on the maximum daily temperature for the discharge. At most of the sites where the public has access to the freshwater sources, temperatures could support survival of the thermophilic microorganisms in the summer but are generally below the range that is known to be conducive to their growth. For all 14 sites, the actual hazard to public health from enhancement of thermophilic microbiological organisms was not identified, documented, or substantiated.

3.9.4 Electromagnetic Fields

All nuclear power plants have power transmission systems associated with them. They consist of switching stations (or substations) located on the plant site and the transmission lines needed to connect the plant to the regional electrical distribution grid. Transmission lines operate at a frequency of 60 Hz (60 cycles per second), which is low compared with the frequencies of 55 to 890 MHz for television transmitters and 1,000 MHz and greater for microwaves.

Electric fields are produced by voltage, and their strength increases with increases in voltage. An electric field is present as long as equipment is connected to the source of electric power. The unit of electric field strength is V/m or kV/m (1 kV/m = 1,000 V/m). A magnetic field is produced from the flow of current through wires or electrical devices, and its strength increases as the current increases. The unit of magnetic field strength is gauss (G), milligauss (mG), or tesla (T). One tesla equals 10,000 G and 1 G equals 1,000 mG. Electric and magnetic fields, collectively referred to as the electromagnetic field (EMF), are produced by operating transmission lines. Members of the public near transmission lines may be exposed to the EMFs produced by the transmission lines. The EMF varies in time as the current and voltage change, so that the frequency of the EMF is the same (e.g., 60 Hz for standard alternating current, or AC). Electrical fields can be shielded by objects such as trees, buildings, and vehicles. Magnetic fields, however, penetrate most materials, but their strength decreases with increasing distance from the source.

Power lines associated with nuclear plants usually have voltages of 230 kV, 345 kV, 500 kV, or 765 kV (a voltage occurring primarily in the eastern United States). EMF strength at ground level varies greatly under these lines, generally being stronger for higher-voltage lines, a flat configuration of conductors, relatively flat terrain, terrain with no shielding obstructions (e.g., trees or shrubs), and a closer approach of the lines to the ground. At locations where the field strength is at a maximum, the measured values under 500-kV lines often average about 4 kV/m but sometimes exceed 6 kV/m. Maximum electric field strengths at ground level are 9 kV/m for 500-kV lines and 12 kV/m for 765-kV lines (NRC 1996).

Measured magnetic field strengths at the location of maximum values beneath 500-kV lines often average about 70 mG. During peak electricity use, when line current is high, the field strength may peak at 140 mG (about 1 percent or less of the time) (NRC 1996).

The EMFs resulting from 60-Hz power transmission lines fall under the category of nonionizing radiation. Much of the general population has been exposed to power line fields since near the turn of the 20th century. There was little concern about health effects from such exposures until the 1960s. A series of events during the 1960s and 1970s heightened public interest in the possibility of health effects from nonionizing radiation exposures and resulted in increased scientific investigation in this area (NRC 1996). Then, in 1979, results of an epidemiological study suggested a correlation between proximity to high-current wiring configurations and incidence of childhood leukemia (Wertheimer and Leeper 1979). This report resulted in additional interest and scientific research; however, no consistent evidence linking harmful effects with 60-Hz exposures has been presented. Many studies have been conducted on the safety of the electric field, but no health effects have been associated with the magnitude of the electric fields that are associated with electrical power usage (Patty and Hill 2006). Most research on health effects has focused on magnetic fields.

3.9.5 Other Hazards

Nuclear power plants are industrial facilities having many of the typical occupational hazards found at any other electric power generation utility. Workplace hazards can be grouped into physical hazards (e.g., slips and trips, falls from height, and those related to transportation, temperature, humidity, and electricity), physical agents (noise, vibration, and ionizing radiation), chemical agents, biological agents, and psychosocial issues (work-related stress due to excessive working time and overnight shifts). The hazards from ionizing radiation, chemical agents, and biological hazards are discussed in Sections 3.9.1, 3.9.2, and 3.9.3, respectively. Power plant and maintenance workers could be working under potentially hazardous physical conditions (e.g., excessive heat, cold, and pressure), including electrical work, power line maintenance, and repair work.

Transmission lines are necessary to transfer energy from all types of electrical generating facilities, including nuclear power plants, to consumers. The potential exposure to workers and the public from the EMFs is discussed in Section 3.9.4. The workers and general public at or around the nuclear power plants and along the transmission lines are exposed to the potential for acute electrical shock from transmission lines. This hazard is discussed in the following section.

3.9.5.1 Occupational Hazards

The Occupational Safety and Health Administration (OSHA) is responsible for developing and enforcing workplace safety regulations. OSHA was created by the Occupational Safety and Health Act of 1970 (29 USC 651 et seq.), which was enacted to safeguard the health of workers. With specific regard to nuclear power plants, plant conditions which result in an occupational risk, but do not affect the safety of licensed radioactive materials, are under the statutory authority of OSHA rather than the NRC as set forth in a Memorandum of Understanding (53 FR 47279, November 22, 1988) between the NRC and the Occupational

Safety and Health Administration (OSHA). Regardless, occupational hazards can be minimized when workers adhere to safety standards and use appropriate protective equipment; however, fatalities and injuries from accidents can still occur.

Table 3.9-21 lists the total number of fatal occupational injuries that occurred in 2005 in different industry sectors. For the utility sector, of which the nuclear industry is a part, 30 workers suffered fatal occupational injuries, 22 of which were from electric power generation, transmission, and distribution. The rate of fatal injuries in the utility sector was less than the rate in the construction; transportation and warehousing; agriculture, forestry, fishing, and hunting; wholesale trade; and mining sectors. Table 3.9-22 lists the incidence rates of nonfatal occupational injuries and illnesses in different utilities for 2005. The incidence rate of nonfatal occupational injuries and illnesses is least for electric power generation, followed by electric power transmission control and distribution.

Table 3.9-23 lists the number and rate of fatal occupational injuries that occurred in 2005 for selected occupations. The fatality rate for installers and repairers of electrical power lines can be estimated at 0.032 percent (BLS 2005b). The occupational safety and health hazards issue is generic to all types of electrical generating stations, including nuclear power plants, and is of small significance if the workers adhere to safety standards and use protective equipment.

3.9.5.2 Shock Hazard

As described in Section 3.1.6.5, in-scope transmission lines include only those lines that would not continue to operate if a plant's license was not renewed. Using this criterion, in-scope transmission lines are those lines that connect the plant to the first substation of the regional electric grid. This substation is frequently, but not always, located on the plant property. The greatest hazard from a transmission line is direct electrical contact with the conductors. The electrical contact can occur without physical contact between a grounded object and the conductor (e.g., when arcing occurs across an air gap) (BPA 1998). The electric field created by a high-voltage line extends from the energized conductors to other conducting objects, such as the ground, vegetation, buildings, vehicles, and persons. Potential field effects can include induced currents, steady-state current shocks, spark-discharge shocks, and, in some cases, field perception and neurobehavioral responses.

The shock hazard issue is evaluated by referring to the National Electric Safety Code (NESC). The purpose of the NESC is the practical safeguarding of persons during the installation, operation, or maintenance of electric supply and communication lines and associated equipment. The NESC contains the basic provisions that are considered necessary for the safety of employees and the public under the specified conditions (IEEE 2007).

Table 3.9-21. Number and Rate of Fatal Occupational Injuries by Industry Sector in 2005

Industry Sector	Number	Rate (per 100,000 employees)
Construction	1,192	11.0
Transportation and warehousing	885	17.6
Agriculture, forestry, fishing, and hunting	715	32.6
Government	520	2.4
Professional and business services	482	3.5
Manufacturing	393	2.4
Retail trade	400	2.4
Leisure and hospitality	213	1.8
Wholesale trade	204	4.4
Mining	159	25.6
Other services	210	3.0
Educational and health services	150	0.8
Financial activities	99	1.0
Information	65	2.1
Utilities[a]	30	3.6
Electric utilities[b]	22	NA[c]
Power generation[d]	11	NA
Hydroelectric power generation	4	NA
Fossil fuel electric power generation	4	NA
Power transmission control and distribution[e]	9	NA
Natural gas distribution	4	NA
Water sewage and other system	3	NA
All sectors	5,734	4.0

(a) The numbers of fatalities from transportation, falls, and exposure to harmful substances or the environment were 10, 7, and 11, respectively.
(b) The numbers of fatalities from transportation, falls, and exposure to harmful substances or the environment were 7, 5, and 9, respectively.
(c) NA = not available.
(d) The numbers of fatalities from transportation, falls, and exposure to harmful substances or the environment were 3, 3, and 5, respectively.
(e) The numbers of fatalities from transportation and exposure to harmful substances or the environment were 3 and 4, respectively.
Source: BLS 2005a,b

Table 3.9-22. Employment and Incidence Rate of Nonfatal Occupational Injuries and Illnesses in Different Utilities in 2005

Utility	Rate (per 100 Employees)	Employment (in 1000s)
Electric utilities	4.0	400.6
Power generation	3.3	240.1
Power transmission control and distribution	5.1	160.5
Natural gas distribution	5.9	107.0
Water sewage and other system	7.6	45.7
Overall	4.6	553.3

Source: BLS 2005c

Table 3.9-23. Number and Rate of Fatal Occupational Injuries for Selected Occupations in 2005

Occupation	Number	Rate per 100,000 Employed
Fishers and related fishing work	48	118.4
Aircraft pilots and flight engineers	81	66.9
Logging workers	80	92.9
Structural iron and steel workers	35	55.6
Refuse and recyclable material collectors	32	43.8
Farmers and ranchers	341	41.1
Electrical power-line installers and repairers	36	32.7
Drivers/sales workers and truck drivers	993	29.1
Miscellaneous agricultural workers	176	23.2
Construction laborers	339	22.7

Source: BLS 2005b

Primary shock currents are produced mainly through direct contact with conductors and have effects ranging from a mild tingling sensation to death by electrocution. Tower designs preclude direct public access to the conductors. Secondary shock currents are produced when humans make contact with (1) capacitively charged bodies, such as a vehicle parked near a transmission line, or (2) magnetically linked metallic structures, such as fences near transmission lines. A person who contacts such an object could receive a shock and experience a painful sensation at the point of contact. The intensity of the shock depends on the EMF strength, the size of the object, and how well the object and the person are insulated from ground.

Design criteria that limit hazards from steady-state currents are based on the NESC, which requires that utility companies design transmission lines so that the short-circuit current to ground, produced from the largest anticipated vehicle or object, is limited to less than 5 milliamperes (mA) (IEEE 2007). No similar code exists for the limitation of the magnetic fields of transmission lines; however, because of concerns about the safety of magnetic fields, several States have created their own regulations (NRC 1996).

With respect to shock safety issues and license renewal, three points must be made. First, in the licensing process for the earlier licensed nuclear plants, the issue of electrical shock safety was not addressed. Second, some plants that received operating licenses with a stated transmission line voltage may have chosen to upgrade the line voltage for reasons of efficiency, possibly without reanalysis of induction effects. Third, since the initial NEPA review for those utilities that evaluated potential shock situations under the provision of the NESC, land use may have changed, resulting in the need for a reevaluation of this issue. Electrical shock potential is minimized for transmission lines that are operated in adherence with the NESC.

3.10 Environmental Justice

Under Executive Order (E.O.) 12898, Federal agencies are responsible for identifying and addressing potential disproportionately high and adverse human health and environmental impacts on minority and low-income populations. In 2004, the Commission issued its *Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions* (69 FR 52040), which states, "The Commission is committed to the general goals set forth in E.O. 12898, and strives to meet those goals as part of its NEPA review process."

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations"

"Each Federal agency, whenever practicable and appropriate, shall collect, maintain, and analyze information assessing and comparing environmental and human health risks borne by populations identified by race, national origin, or income. To the extent practical and appropriate, Federal agencies shall use this information to determine whether their programs, policies, and activities have disproportionately high and adverse human health or environmental effects on minority populations and low-income populations."

The Council of Environmental Quality (CEQ) provides the following information in *Environmental Justice: Guidance Under the National Environmental Policy Act* (CEQ 1997):

- **Disproportionately High and Adverse Human Health Effects.** Adverse health effects are measured in risks and rates that could result in latent cancer fatalities, as well as other fatal or nonfatal adverse impacts on human health. Adverse health effects may include bodily impairment, infirmity, illness, or death. Disproportionately high and adverse human health effects occur when the risk or rate of exposure to an environmental hazard for a minority or low-income population is significant (as defined by CEQ) and appreciably exceeds the risk or exposure rate for the general population or for another appropriate comparison group.

- **Disproportionately High and Adverse Environmental Effects.** A disproportionately high environmental impact that is significant (as defined by CEQ) refers to an impact or risk of an impact on the natural or physical environment in a low-income or minority community that appreciably exceeds the environmental impact on the larger community. Such effects may include ecological, cultural, human health, economic, or social impacts. An adverse environmental impact is an impact that is determined to be both harmful and significant (as defined by CEQ). In assessing cultural and aesthetic environmental impacts, impacts that uniquely affect geographically dislocated or dispersed minority or low-income populations or American Indian tribes are considered.

The environmental justice analysis assesses the potential for disproportionately high and adverse human health or environmental effects on minority and low-income populations that could result from the continued operation of a nuclear power plant during the renewal term. In assessing the impacts, the following CEQ definitions of minority individuals and populations and low-income population were used:

- **Minority individuals.** Individuals who identify themselves as members of the following population groups: Hispanic or Latino, American Indian or Alaska Native, Asian, Black or African American, Native Hawaiian or Other Pacific Islander, or two or more races meaning individuals who identified themselves on a Census form as being a member of two or more races, for example, Hispanic and Asian.

- **Minority populations.** Minority populations are identified when (1) the minority population of an affected area exceeds 50 percent or (2) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis. Minority populations may be communities of individuals living in close geographic proximity to one another, or they may be a geographically dispersed or transient set of individuals, such as migrant workers or American Indians, who, as a group, experience common conditions with regard to environmental exposure or environmental effects. The appropriate geographic unit of analysis may be a political jurisdiction, county, region, or State, or some other similar unit that is chosen so as not to artificially dilute or inflate the affected minority population.

- **Low-income population.** Low-income population is defined as individuals or families living below the poverty level as defined by the U.S. Census Bureau's Current Population Reports, Series P-60 on Income and Poverty (USCB 2007). Low-income populations may be communities of individuals living in close geographic proximity to one another, or they may be a set of individuals, such as migrant workers, who, as a group, experience common conditions.

Consistent with the definition used in the impact analysis for public and occupational health and safety, affected populations are defined as minority and low-income populations who reside within a 50-mi (80-km) radius of a nuclear plant. Data on low-income and minority individuals are usually collected and analyzed at the census tract level or census block group level.[h]

The presence of minority and low-income individuals located within 50 mi (80 km) of each nuclear power plant site vary considerably depending on the proximity of larger communities to power plant sites, the location of Native American Tribal lands, historical population trends in the region around each site, and the nature of regional economic activity. Typically, plant sites in rural areas in the southern and southwestern United States are more likely to have larger minority populations. Examples are the Browns Ferry, Brunswick, Catawba, Farley, North Anna, Robinson, Summer, and Surry plants. Sites closer to metropolitan areas may have both larger minority populations and larger low-income populations. These include the Dresden, Ginna, Indian Point, and Pilgrim plants.

Section 4-4 of Executive Order 12898 directs Federal agencies, whenever practical and appropriate, to (a) collect and analyze information on the consumption patterns of populations who rely principally on fish and/or wildlife for subsistence and (b) communicate the risks of these consumption patterns to the public. Consideration is given to whether there are any ways in which minority or low-income populations could be disproportionately affected by means of examining impacts on American Indian, Hispanic, and other traditional-lifestyle, special-pathway receptors. Special pathways take into account the levels of contamination in native vegetation, crops, soils and sediments, surface water, fish, and game animals on or near power plant sites in order to assess the risk of radiological exposure through subsistence consumption of fish, native vegetation, surface water, sediment, and local produce; the absorption of contaminants in sediments through the skin; and the inhalation of airborne particulate matter. The identification of special-pathway receptors can be important in an environmental justice analysis because

(h) A census block group is a combination of census blocks, which are statistical subdivisions of a census tract. A census block is the smallest geographic entity for which the U.S. Census Bureau (USCB) collects and tabulates decennial census information. A census tract is a small, relatively permanent statistical subdivision of counties delineated by local committees of census data users in accordance with USCB guidelines for the purpose of collecting and presenting decennial census data. Census block groups are subsets of census tracts (USCB 2005).

consumption patterns may reflect the traditional or cultural practices of minority and low-income populations in the area.

Many nuclear plants have a comprehensive radiological environmental monitoring program to assess the impact of site operations on the environment (see Section 3.9.1). Samples are collected from the aquatic and terrestrial pathways applicable to the site. Aquatic pathways generally include fish, surface water, and sediment, while terrestrial pathways include airborne particulates, radioiodine, milk, food products, crops, and direct radiation. The concentrations of contaminants that are found in native vegetation, crops, soils, sediment, surface water, fish, and game animals in areas surrounding nuclear power plants are usually quite low (at or near the threshold of detection) and seldom above background levels. Consequently, no disproportionately high and adverse human health impacts have been implicated in special-pathway receptor populations in the regions around most nuclear power plants as a result of subsistence consumption of fish and wildlife.

3.11 Waste Management and Pollution Prevention

As part of their normal operations and as a result of equipment repairs and replacements due to normal maintenance activities, nuclear power plants routinely generate both radioactive and nonradioactive wastes. Nonradioactive wastes include hazardous and nonhazardous wastes. There is also a class of waste, called mixed waste, that is both radioactive and hazardous. The systems used to manage (i.e., treat, store, and dispose of) these wastes are described in Sections 3.1.4 and 3.1.5. The basic characteristics and current disposition paths for these waste streams are discussed in Section 3.11.1 for radioactive waste, 3.11.2 for hazardous waste, 3.11.3 for mixed waste, and 3.11.4 for nonradioactive nonhazardous waste. Waste minimization and pollution prevention measures commonly employed at nuclear power plants are reviewed in Section 3.11.5.

3.11.1 Radioactive Waste

There are basically two types of radioactive waste generated at nuclear power plants: (1) LLW and (2) spent nuclear fuel. These two waste types are discussed in Sections 3.11.1.1 and 3.11.1.2, respectively.

3.11.1.1 Low-Level Radioactive Waste

The NRC's definition of LLW is included in 10 CFR 61.55. Depending on the types and concentrations of radionuclides in the waste, the NRC classifies LLW as belonging to Class A, Class B, Class C, or greater-than-Class C. Class A wastes generally contain short-lived radionuclides at relatively low concentrations, whereas the half-lives and concentrations of radionuclides in the Class B and C wastes are progressively higher. In addition, Class B wastes must meet more rigorous requirements with regard to their form to ensure stability after disposal (e.g., by adding chemical stabilizing agents such as cement to the waste or placing the waste in a disposal container or structure that provides stability after disposal). Class C wastes must not only meet the more rigorous requirements above but also require the implementation of additional measures at the disposal facility to protect against inadvertent intrusion (e.g., by increasing the thickness and hardness of the cover over the waste disposal cell). Wastes containing radionuclides at concentrations that are higher than what is allowed for Class C wastes are classified as greater-than-Class C. Disposal of greater-than-Class C waste is the responsibility of the U.S. Department of Energy (DOE). DOE is currently preparing an environmental impact statement (EIS) to evaluate the various alternatives for disposing of these wastes (DOE 2007).

> ***Radioactive Wastes Associated with Commercial Nuclear Power Plants***
>
> ***Low-Level Waste:*** Radioactive material that (a) is not high-level radioactive waste, spent nuclear fuel, or by-product material (as defined in Section 11e(2) of the Atomic Energy Act of 1954 [42 USC 2014(e)(2)]) and (b) is classified by the NRC, consistent with existing law, as low-level radioactive waste (as defined in the Low-Level Radioactive Waste Policy Act, as amended, Public Law 99-240).
>
> ***Spent Nuclear Fuel:*** Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing (as included in the Nuclear Waste Policy Act of 1982, as amended, Public Law 97-425).

LLW generated at nuclear power plants generally consists of air filters, cleaning rags, protective tape, paper and plastic coverings, discarded contaminated clothing, tools, equipment parts, and solid laboratory wastes (all these are collectively known as dry active waste) and wet wastes that result during the processing and recycling of contaminated liquids at the plants. Wet wastes generally consist of evaporator bottoms, spent demineralizer or ion exchange resins, and spent filter material from the equipment drain, floor drain, and water cleanup systems. The wet wastes are generally solidified, dried, or dewatered to make them acceptable at a disposal site. Some plants perform these operations onsite, while others ship their waste to a third-party vendor offsite for processing before it is sent to a disposal facility. The transportation and disposal of solid radioactive wastes are performed in accordance with the applicable requirements of 10 CFR Part 71 and 10 CFR Part 61, respectively.

LLW shipments from nuclear power plants to disposal facilities or waste processing centers and from waste processing centers to disposal facilities are generally made by trucks. Wastes are segregated and packaged by class. For load leveling purposes, the wastes may be stored onsite at the plant temporarily before shipment offsite. Construction and operation of any LLW storage areas and any activities related to storage and processing of LLW onsite, including the preparation of waste for shipment and loading on vehicles before shipment, are carried out in accordance with the licensing requirements imposed by the NRC. All such operations are accounted for when the applicants prepare their annual radioactive effluent release reports to demonstrate compliance with the applicable Federal standards and requirements. The primary standards applicable to all the power plants are contained in 10 CFR Part 20, 40 CFR Part 190, and Appendix I to 10 CFR Part 50.

There are currently three operating disposal facilities in the United States that are licensed to accept commercial-origin LLW. They are located in Barnwell, South Carolina; Richland, Washington; and Clive, Utah. The facility in Utah, operated by EnergySolutions, is licensed to accept only Class A LLW, whereas the other two facilities can accept Class A, B, and C wastes (GAO 2004). In 2001, the South Carolina legislature imposed restrictions on the Barnwell facility that state that after June 2008, the facility can accept waste from generators in only three States: South Carolina, New Jersey, and Connecticut. The Richland facility accepts LLW from only 11 States: Washington, Alaska, Hawaii, Idaho, Montana, Oregon, Utah, Wyoming, Colorado, Nevada, and New Mexico. It is expected to close in 2056. The EnergySolutions facility in Utah accepts only Class A waste, but it can come from any State. This facility currently does not have a projected closing date.

The Low Level Radioactive Waste Policy Act (Public Law 96-573) was enacted in 1980. This act made each State responsible for providing for the disposal of the LLW generated within the State, either by itself or in cooperation with other States, with the exception of waste produced by DOE and the nuclear propulsion component of the Department of the Navy. The aims of the Low Level Radioactive Waste Policy Act were to provide more LLW disposal capacity on a regional basis and to more equitably distribute responsibility for the management of LLW among the States. As an incentive for States to manage waste on a regional basis, Congress consented to the formation of interstate agreements known as compacts, and it granted compact member States the authority to exclude LLW from States that are members of other compacts or unaffiliated with a compact.

In January 1986, Congress passed the Low-Level Radioactive Waste Policy Amendments Act (Public Law 99-240). This act extended the original January 1, 1986, deadline for developing new disposal facilities by 7 years to January 1, 1993. It also made the Federal Government responsible for disposing of commercial-origin greater-than-Class C waste.

As of the writing of this EIS, only one compact, consisting of the States of Texas and Vermont, has developed a LLW disposal facility and has received a license to construct and operate the facility (WCS 2009). The facility, known as the Waste Control Specialists LLC site (WCS), is located in Andrews County, Texas. The facility is authorized by the Texas Commission on Environmental Quality (TCEQ) to dispose of Class A, B, and C LLW in a near-surface disposal facility. In addition to LLW, the WCS facility is also licensed for processing, storage, and disposal of hazardous waste and mixed LLW. The owners of the facility are in the process of developing rules governing the disposal of commercial LLW and other types of waste the facility is authorized to receive from waste generators in States other than Texas and Vermont. The operation of the facility will be overseen by TCEQ and the Texas Low-Level Radioactive Waste Compact Commission with membership from Texas and Vermont.

Annual quantities of LLW generated at the nuclear power plants vary from year to year depending on the number of maintenance activities undertaken and the number of unusual occurrences taking place in that year. However, on average, the volume and radioactivity of LLW generated at a PWR are approximately 10,600 ft^3 (300 m^3) and 1,000 Ci (3.7×10^{13} Bq) per year, respectively (Table 6.6 in NRC 1996). The annual volume and activity of LLW generated at a BWR are approximately twice the values indicated for a PWR. The total volume and activity of LLW generated at all the LWRs in the United States are approximately 706,000 ft^3 (20,000 m^3) and 60,000 Ci (2.2×10^{15} Bq), respectively (Table 6.6 in NRC 1996). Approximately 95 percent of this waste is Class A (NEI 2007b). Table 3.11-1 shows the volume and activity of LLW shipped offsite per operating reactor unit from 10 power plant sites in 2006. For example, there are two operating units at the Comanche Peak site, and the volume and activity of LLW shipped from the Comanche Peak site in 2006 were 5,720 ft^3 (162 m^3) and 178 Ci (6.59×10^{12} Bq) per unit, with the total volume and activity shipped from the site being twice these values, namely 11,400 ft^3 (324 m^3) and 374 Ci (1.38×10^{13} Bq), respectively. The numbers in Table 3.11-1 were obtained from the annual radioactive effluent release reports issued by each plant for 2006.

Almost all of the LLW generated at the reactor sites is shipped offsite, either directly to a disposal facility or to a processing center for volume reduction or another type of treatment before being sent to a disposal site. The number of shipments leaving each reactor site varies but generally ranges from a few to about 100 per year. 10 CFR Part 20, Subpart K, discusses the various means by which the licensees may dispose of their radioactive waste.

3.11.1.2 Spent Nuclear Fuel

Spent nuclear fuel is fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated. When spent fuel is removed from a reactor, it is stored in racks placed in a pool (called the spent fuel pool) to isolate it from the environment and to allow the fuel rods to cool. Licensing plans contemplate disposal of spent fuel in a deep geological repository. Siting and developing a permanent repository is required by the Nuclear Waste Policy Act of 1982. Delays in siting a permanent repository, coupled with rapidly filling spent fuel pools at some plants, have led utilities to seek means of continued onsite storage. These include (1) expanded pool storage, (2) aboveground dry storage, (3) longer fuel burnup to reduce the amount of spent fuel requiring interim storage, and (4) shipment of spent fuel to other plants. Any modification to the spent fuel storage configuration at a nuclear power plant is subject to NRC review and approval. Each review consists of a safety review and the preparation of an environmental review. As part of the

Table 3.11-1. Solid Low-Level Radioactive Waste Shipped Offsite per Reactor from 10 Power Plant Sites in 2006[a]

Plant	Volume (m^3)	Activity (Ci)	Number of Shipments	Number of Reactors
PWRs				
Comanche Peak	162	187	6.5	2 (Units 1 and 2)
Cook	97.2	60	32	2 (Units 1 and 2)
Indian Point	501	316	16.3	3 (Units 1, 2, and 3)[b]
Robinson 2	145	173	6	1 (Unit 2)
San Onofre	3,210	150	116.3	3 (Units 1, 2, and 3)[b]
Surry	391	223	11	2 (Units 1 and 2)
BWRs				
Hatch	148	445	55	2 (Units 1 and 2)
Vermont Yankee	61	18,800[c]	104	1
Limerick	55	291	27	2 (Units 1 and 2)
Columbia	368	1,570	28	1

(a) The numbers in the table were obtained from each plant's 2006 Annual Radioactive Effluent Release Report.
(b) Unit 1 is shut down at both Indian Point and San Onofre. In 2006, Unit 1 at Indian Point was in the safe storage condition and would have generated very little LLW; however, at San Onofre, Unit 1 was actively being decommissioned and would have generated a considerable amount of LLW.
(c) Includes shipment of irradiated components.

environmental review for such a modification, the NRC generally prepares an environmental assessment (EA).

Expanded pool storage options include (1) enlarging the capacity of spent fuel racks, (2) adding racks to existing pool arrays ("dense-racking"), (3) reconfiguring spent fuel with neutron-absorbing racks, and (4) employing double-tiered storage (installing a second tier of racks above those on the pool floor).

Aboveground dry storage involves moving the spent fuel assemblies, which have been stored in the spent fuel pool for a certain period of time, to aboveground, shielded enclosures that are air cooled (also known as dry storage). The fuel is stored in the spent fuel pool to cool, typically for several years, before it may be moved to a dry cask storage facility. In the late 1970s and early 1980s, the need for alternative storage began to grow when pools at many nuclear reactors began to fill up with stored spent fuel. Utilities began looking at options such as dry cask storage for increasing their storage capacity for spent fuel.

Dry cask storage allows spent fuel to be surrounded by inert gas inside a container called a cask. The casks are typically steel cylinders that are either welded or bolted closed. The steel cylinder provides a leak-proof containment for the spent fuel. Each cylinder is surrounded by additional steel, concrete, or other material to provide radiation shielding to workers and members of the public. Some of the cask designs can be used for both storage and transportation.

There are various dry storage cask system designs. With some designs, the steel cylinders containing the fuel are placed vertically in a concrete vault; other designs orient the cylinders horizontally. The concrete vaults provide the radiation shielding. Other cask designs orient the steel cylinder vertically on a concrete pad at a dry cask storage site and use both metal and concrete outer cylinders for radiation shielding. Figure 3.11-1 shows two of the typical dry cask storage designs. The location of the dry casks is in a facility known as an Independent Spent Fuel Storage Installation or ISFSI. This is a complex designed and constructed for the interim storage of spent nuclear fuel, solid reactor-related greater than class C waste, and other radioactive materials associated with spent nuclear fuel and reactor-related greater than class C waste storage. The ISFSI is generally located within the same site where the nuclear fuel is used. They are licensed by the NRC under either a general license or a site-specific license (see 10 CFR Part 72). Figure 3.11-2 shows the locations of currently licensed ISFSIs.

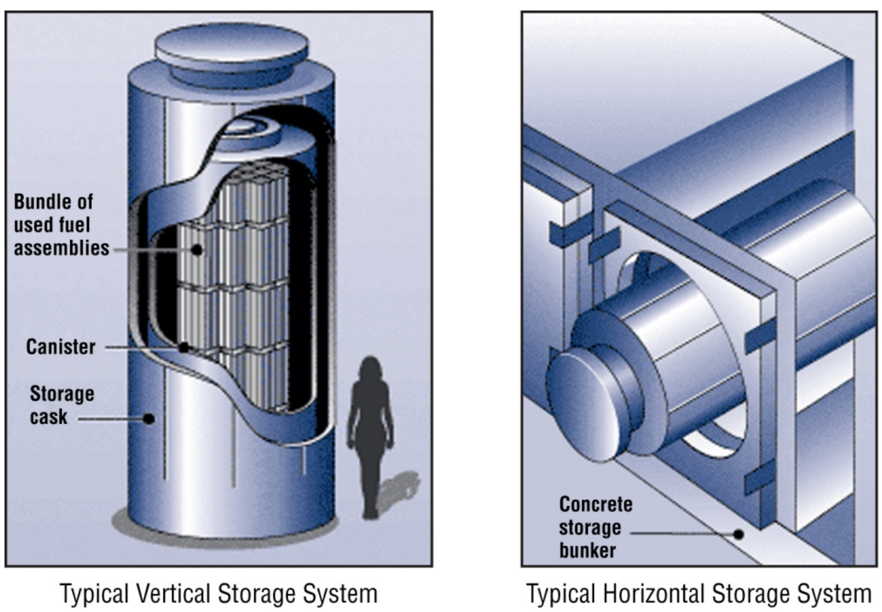

Figure 3.11-1. Typical Dry Cask Storage Systems (NRC 2007h)

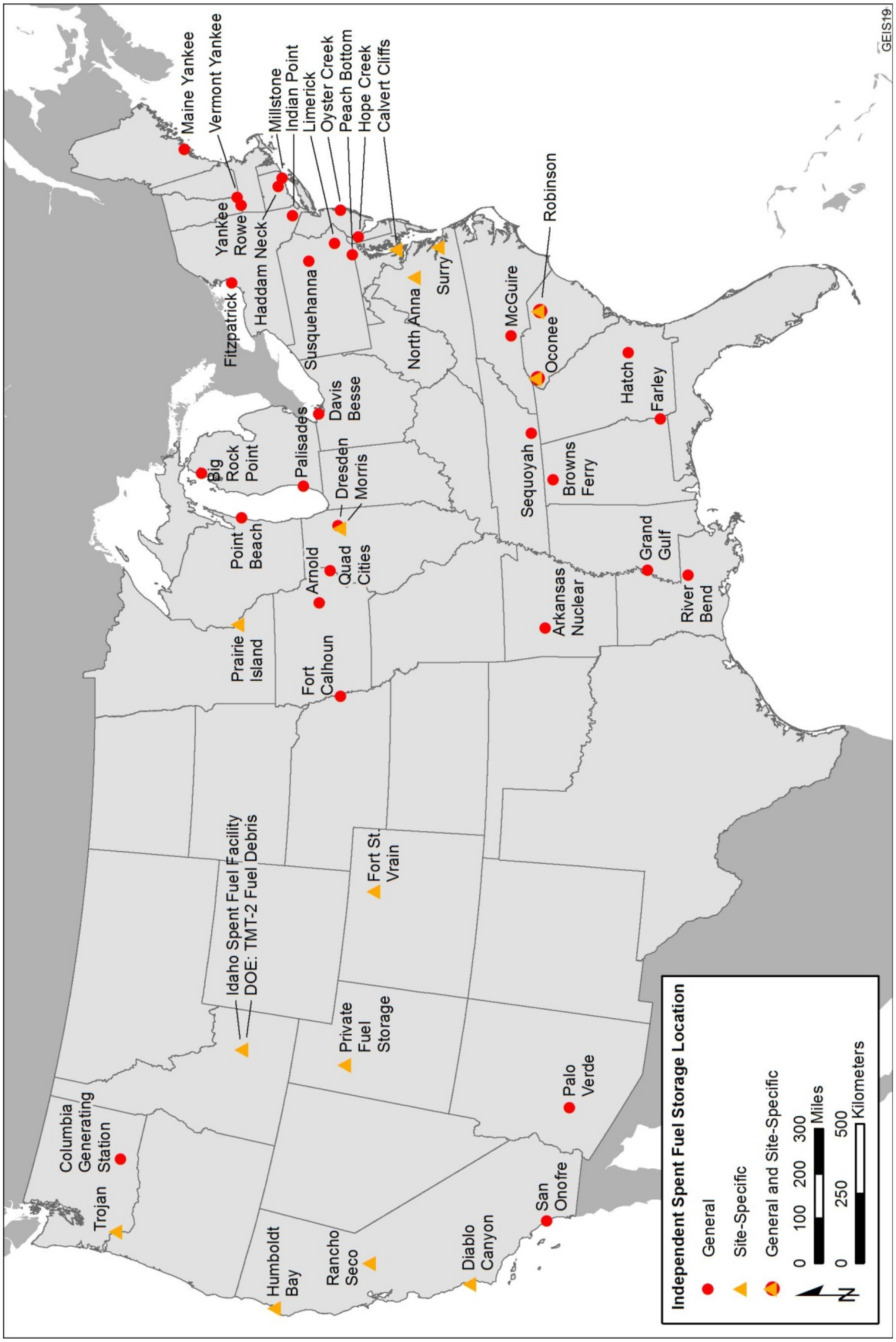

Figure 3.11-2. Locations of Independent Spent Fuel Storage Installations Licensed by the NRC (NRC 2007i)

Longer-burnup fuel is fuel from which more energy can be obtained before it is taken out of the reactor and declared spent. As a result of using this fuel, less spent fuel is generated for the same amount of energy produced in a reactor.

Although plants running out of storage space may enter into agreements with others that have space for sale or lease, this approach is widely viewed as an interim measure, practical only for utilities that own more than one nuclear plant (NRC 1996).

3.11.2 Hazardous Waste

Hazardous waste is defined by the EPA in 40 CFR Part 261, "Identification and Listing of Hazardous Waste," as solid waste that (1) is listed by the EPA as being hazardous; (2) exhibits one of the characteristics of ignitability, corrosivity, reactivity, or toxicity; or (3) is not excluded by the EPA from regulation as being hazardous. All aspects of hazardous waste generation, treatment, transportation, and disposal are strictly regulated by the EPA or by the States under agreement with the EPA per the regulations promulgated under RCRA (PL 94-580).

Other Wastes Associated with Commercial Nuclear Power Plants

Hazardous Waste: A solid waste or combination of solid wastes that, because of its quantity, concentration, or physical, chemical, or infectious characteristics, may (1) cause or significantly contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness or (2) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed (as defined in the Resource Conservation and Recovery Act, as amended, Public Law 94-580).

Mixed Waste: Waste that is both hazardous and radioactive.

Nonradioactive Nonhazardous Waste: Waste that is neither radioactive nor hazardous.

The types of hazardous waste that nuclear power plants typically generate include waste paints, lab packs, and solvents. The quantities of these wastes generated at individual plants are highly variable but, generally, relatively small when compared with the quantities at most other industrial facilities that generate hazardous waste. Most nuclear power plants accumulate their hazardous waste onsite as authorized under RCRA and transport it to a treatment facility where it undergoes treatment. The remaining residues are sent to a permanent disposal facility. There are quite a few RCRA-permitted treatment and disposal facilities throughout the United States that are used by the owners of nuclear power plants.

There is a class of hazardous waste, called universal waste, that the EPA has authorized to be handled differently from the other kinds of hazardous waste. The EPA's universal waste regulations streamline hazardous waste management standards for Federally designated universal wastes, which include batteries, pesticides, mercury-containing equipment, and lamps.

The regulations govern the collection and management of these widely generated wastes, thus facilitating environmentally sound collection and proper recycling or treatment.

The Federal universal waste regulations are set forth in 40 CFR Part 273. States can modify the universal waste rule and add additional universal waste(s) in individual State regulations. Nuclear power plants follow the regulations set forth by the EPA or by their State agencies, as applicable, to manage their universal waste.

3.11.3 Mixed Waste

Wastes that are both radioactive and hazardous are called mixed waste. They are subject to dual regulation: by the EPA or an authorized State for their hazardous component, and by the NRC or an agreement State for their radioactivity. The types of mixed wastes generated at nuclear power plants include organics (e.g., liquid scintillation fluids, waste oils, halogenated organics), metals (e.g., lead, mercury, chromium, and cadmium), solvents, paints, and cutting fluids. The quantity of mixed waste generated varies considerably from plant to plant (NRC 1996). Overall, the quantities generated during operations are generally relatively small, but because of the added complexity of dual regulation, it is more problematic for plant owners to manage and dispose of mixed wastes than the other types of wastes. Similar to hazardous waste, mixed waste is generally accumulated onsite in designated areas as authorized under RCRA, then shipped offsite for treatment as appropriate and for disposal. The only disposal facilities that are authorized to receive mixed LLW for disposal at present are the EnergySolutions and the WCS facilities discussed under Section 3.11.1.1 on LLW.

Occupational exposures and any releases from onsite treatment of these and any other types of wastes are considered in evaluating compliance with the applicable Federal standards and regulations, for example, 10 CFR Part 20, 40 CFR Part 190, and Appendix I to 10 CFR Part 50.

3.11.4 Nonradioactive, Nonhazardous Waste

Like any other industrial facility, nuclear power plants generate wastes that are not contaminated with either radionuclides or hazardous chemicals. These wastes include trash, paper, wood, and sewage. Solid wastes, defined as nonhazardous by 40 CFR Part 261, are collected and disposed of in a local landfill. Sanitary wastes defined as nonhazardous by 40 CFR Part 261 are generally treated at an onsite sewage treatment plant, and the residues are sent to local landfills. Some power plants discharge directly to a municipal sewage treatment facility, while others collect their sanitary waste in onsite septic tanks and empty the tanks periodically, shipping the pumped sewage to a local sanitary waste treatment plant. The uncontaminated wastes and sewage are tested for radionuclides before being sent offsite to make sure that there is no inadvertent contamination. Any offsite releases from the onsite sewage treatment plants are conducted under NPDES permits. Most plants also collect and test the stormwater runoff from their sites before discharging it offsite.

3.11.5 Pollution Prevention and Waste Minimization

Waste minimization and pollution prevention are important elements of operations at all nuclear power plants. The licensees are required to consider pollution prevention measures as dictated by the Pollution Prevention Act (Public Law 101-508) and RCRA (PL 94-580).

In addition, licensees have waste minimization programs in place that are aimed at minimizing the quantities of waste sent offsite for treatment or disposal. Waste minimization techniques employed by the licensees may include (1) source reduction, which includes (a) changes in input materials (e.g., using materials that are not hazardous or are less hazardous), (b) changes in technology, and (c) changes in operating practices; and (2) recycling of materials either onsite or offsite. For example, the licensees tend to reuse lead shielding components onsite until they have no further use for them. The establishment of a waste minimization program is also a requirement for managing hazardous wastes under RCRA.

3.12 References

7 CFR Part 657. *Code of Federal Regulations*, Title 7, *Agriculture*, Part 657, "Prime and Unique Farmlands."

7 CFR Part 658. *Code of Federal Regulations*, Title 7, *Agriculture*, Part 658, "Farmland Protection Policy Act. "

10 CFR Part 20. *Code of Federal Regulations*, Title 10, *Energy*, Part 20, "Standards for Protection Against Radiation."

10 CFR Part 40. *Code of Federal Regulations*, Title 10, *Energy*, Part 40, "Domestic Licensing of Source Material."

10 CFR Part 50. *Code of Federal Regulations*, Title 10, *Energy*, Part 50, "Domestic Licensing of Production and Utilization Facilities."

10 CFR Part 51. *Code of Federal Regulations*, Title 10, *Energy*, Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions."

10 CFR Part 61. *Code of Federal Regulations*, Title 10, *Energy*, Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste."

10 CFR Part 71. *Code of Federal Regulations*, Title 10, *Energy*, Part 71, “Packaging and Transportation of Radioactive Material.”

10 CFR Part 72. *Code of Federal Regulations*, Title 10, *Energy*, Part 72, “Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater than Class C Waste.”

10 CFR Part 100. *Code of Federal Regulations*, Title 10, *Energy*, Part 100, “Reactor Site Criteria.”

24 CFR Part 51. *Code of Federal Regulations*, Title 24, *Housing and Urban Development*, Part 51, “Environmental Criteria and Standards.”

36 CFR Part 60. *Code of Federal Regulations*, Title 36, *Parks, Forests, and Public Property*, Part 60, “National Register of Historic Places.”

36 CFR Part 800. *Code of Federal Regulations*, Title 36, *Parks, Forests, and Public Property*, Part 800, “Protection of Historic Properties.”

40 CFR Part 50. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 50, “National Primary and Secondary Ambient Air Quality Standards.”

40 CFR Part 61. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 61, “National Emission Standards for Hazardous Air Pollutants.”

40 CFR Part 125. *Code of Federal Regulations*, Title 40, *Protection of the Environment*, Part 125, “Criteria and Standards for the National Pollutant Discharge Elimination System.”

40 CFR Part 190. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 190, “Environmental Radiation Protection Standards for Nuclear Power Operations.”

40 CFR Part 192. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 192, “Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings.”

40 CFR Part 261. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 261, “Identification and Listing of Hazardous Waste.”

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4 Environmental Consequences and Mitigating Actions

4.1 Introduction

The U.S. Nuclear Regulatory Commission (NRC) evaluated the environmental consequences of the proposed action (i.e., license renewal) including the (1) impacts associated with continued operations and refurbishment activities similar to those that have occurred during the current license term; (2) impacts of various alternatives to the proposed action; (3) impacts from the termination of nuclear power plant operations and decommissioning after the license renewal term (with emphasis on the incremental effect caused by an additional 20 years of operation); (4) impacts associated with the uranium fuel cycle; (5) impacts of postulated accidents (design-basis accidents and severe accidents); (6) cumulative impacts of the proposed action; and (7) resource commitments associated with the proposed action, including unavoidable adverse impacts, the relationship between short-term use and long-term productivity, and irreversible and irretrievable commitment of resources.

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In evaluating impacts for this revision of the *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (NRC 1996, referred to in this document as the "1996 GEIS"), the NRC used a standard of significance based on the Council on Environmental Quality (CEQ) terminology for "significantly" (see Title 40, Section 1508.27 in the *Code of Federal Regulations* [40 CFR 1508.27]), which considers both "context" and "intensity." The NRC established three significance levels—SMALL, MODERATE, and LARGE—and has used these levels and associated definitions as standard practice in preparing its supplemental environmental impact statements (SEISs) to the GEIS. As indicated in Section 1.5, the definitions of the three significance levels are as follows:

- **SMALL:** Environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.

- **MODERATE:** Environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.

- **LARGE:** Environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

These levels are used for describing the impacts of most aspects of the proposed action as well as the impacts of alternatives to the proposed action. Resource-specific definitions are provided where applicable.

4.1.1 Environmental Consequences of the Proposed Action

As described in Section 2.1, a number of activities associated with the proposed action could have environmental consequences. The proposed action includes the activities associated with normal operations during the license renewal term, including (1) plant operation, (2) activities needed to support operations and meet infrastructure requirements (e.g., road improvements, new parking lots, waste storage facilities, and new ancillary buildings), and (3) refurbishment actions needed to replace and/or repair critical portions of reactor systems.

The assessment includes a determination of the magnitude of the impact (SMALL, MODERATE, or LARGE, as defined above) and whether or not the analysis of the environmental issue could be applied to all or a category of plants. Issues are assigned a Category 1 or a Category 2 designation as follows:

Category 1 issues are those that meet all of the following criteria:

- The environmental impacts associated with the issue were determined to apply either to all plants or, for some issues, to plants having a specific type of cooling system or other specified plant or site characteristics.

- A single significance level (i.e., SMALL, MODERATE, or LARGE) was assigned to the impacts (except for offsite radiological impacts—collective impacts from other than the disposal of spent fuel and high-level waste).

- The mitigation of adverse impacts associated with the issue was considered in the analysis, and it was determined that additional plant-specific mitigation measures are not likely to be sufficiently beneficial to warrant implementation.

For issues that meet the three Category 1 criteria, no additional plant-specific analysis is required in future supplemental EISs (SEISs) unless new and significant information is identified.

Category 2 issues are those that do not meet one or more of the criteria of Category 1 and for which, therefore, an additional plant-specific review is required.

A total of 78 impact issues that are related to the proposed action were identified (summarized in Table 2.1-1). For each potential environmental impact issue identified, the GEIS revision (1) describes the nuclear power plant activity that could affect the resource, (2) identifies the resource that is affected, (3) evaluates past license renewal reviews and other available information, (4) assesses the nature and magnitude of the environmental impact on the affected resource, (5) characterizes the significance of the effect, (6) determines whether the results of the analysis apply to all nuclear power plants (i.e., whether the impact issue is Category 1 or Category 2), and (7) considers additional mitigation measures for adverse impacts. In cases for which the issue differs from that presented in the 1996 GEIS, the rationale for the new treatment is presented.

4.1.2 Environmental Consequences of Continued Operations and Refurbishment Activities during the License Renewal Term

In most cases, the impacts of continued operations and refurbishment activities during the license renewal term are similar to the impacts that have resulted from the operation of licensed nuclear power plants during the current license term.

The activities that would occur during normal operations of the license renewal term and that are thus the subject of this evaluation are discussed in Section 2.1. It is important to note that the impacts of the original construction of the nuclear power plants and past operational impacts are not the focus of this evaluation of environmental consequences. Both the impacts of original construction and the impacts of past operations have affected and, in many cases, established the current conditions at each plant and vicinity. These conditions serve as the baseline for the impact analyses presented in this section. Past impacts are presented in the description of the affected environment in Chapter 3. In these cases, the impacts of continued operations and refurbishment activities during the license renewal term are similar to the impacts that have resulted from the operation of licensed nuclear power plants during the current license term. In most cases, impacts of the proposed action would not represent a change from current conditions and are considered SMALL. In other cases, the proposed action could result in a change from current conditions, and the impacts could be considered MODERATE or LARGE.

A total of 78 impact issues (including 5 issues related to waste management at both nuclear power plants and other nuclear fuel cycle facilities) that are related to continued operations and refurbishment activities during the license renewal term were identified and evaluated; they are summarized in Table 2.1-1. This revised GEIS provides the technical basis for the issues presented in Table B-1 in Appendix B, Subpart A, of 10 CFR Part 51. The identified impact issues are discussed by resource topic in the remainder of this section. The assessment approaches specific to each resource area are described in Appendix D.

4.1.3 Environmental Consequences of the No-Action Alternative

The no-action alternative represents a decision by the NRC not to issue a renewed operating license. If a license is not renewed, the licensee would have to shut the plant down. At some point in time, all plants eventually would be required to shut down and undergo decommissioning. Under the no-action alternative, these eventualities would occur sooner than if the NRC issued a renewed license.

Denying license renewal and ceasing operation under the no-action alternative may lead to a variety of potential outcomes, but these are essentially the same as the ones that would eventually occur once plant operations ceased after license renewal (see Section 4.12.2 for a discussion of these effects). Reactor shutdown would result in a net reduction in power production capacity. The power not generated by the nuclear plant during a license renewal term would likely be replaced by (1) generating alternatives other than the nuclear power plant, (2) demand-side management, (3) power purchased from other electricity providers, or (4) some combination of these options. Note that NRC's consideration of the no-action alternative does not involve the determination of whether any power is needed or should be generated. The decision to generate power and the determination of how much power is needed are at the discretion of State, Federal (non-NRC), and utility officials.

4.1.4 Environmental Consequences of Replacement Power Alternatives

Replacement power alternatives consider the potential environmental impacts from the construction and operation of alternative power generating technologies (including a new nuclear reactor) that could replace the power from an existing nuclear power plant. Each resource area in this chapter assesses the environmental effects of constructing and operating various replacement power alternatives. Alternatives were selected on the basis of reviews of energy technologies that are either currently commercially viable on a utility scale and operational prior to the expiration of a reactor's operating license or can be expected to become commercially viable on a utility scale and operational prior to the expiration of a reactor's operating license. Other energy technologies that hold promise for becoming part of a bulk electricity portfolio sometime in the future are identified but not evaluated in detail. Should the need arise to replace the electrical power generating capacity of a reactor, either because its operating license will not be renewed or because of changes in strategies to meet changing regional or local demand, the necessary replacement power is likely to be provided by a suite or portfolio of electrical energy producing technologies, including, perhaps, expansions of the capacities of one or more existing power-generating facilities within the region. The number of possible combinations of energy producing technologies to replace lost electrical power generating capacity is quite large. An evaluation of even a small fraction of these combinations would not significantly advance the knowledge base supporting the license renewal decision. Consequently, individual technologies rather than combinations are evaluated as replacement power alternatives in this GEIS. Data on commercial products or services are included for information purposes only. No endorsement is implied. The NRC does not engage in energy-planning decisions and makes no judgment as to which of the replacement power alternatives would be chosen in any given case.

In addition to the installation of electrical energy producing technologies, replacement power could also be provided by importing power over the bulk electricity grid. Power replaced through energy purchases would likely have similar characteristics to some of the replacement power alternatives being considered, and would be dependent on available energy sources at the time of the purchase. At the time of publication, coal, natural gas, and nuclear-fueled power plants are the most-prevalent sources of purchased replacement power, though an increasing number of renewable power sources are emerging. As such, the effects of purchased power are likely to be similar to the effects of operating a combination of electrical energy producing technologies or similar to the fossil or nuclear-fueled alternatives. Impacts overall are likely to be lower for purchased power (if existing power generation and transmission capacity is also available) since no construction is necessary. On the other hand, since existing plants are likely to have less-stringent emissions controls, operational impacts to air quality and human health may be slightly greater for purchased power than for new construction.

4.1.5 Environmental Consequences of Terminating Nuclear Power Plant Operations and Decommissioning

All operating nuclear power plants will terminate operations and be decommissioned at some point after the end of their operating licenses or after a decision is made to cease operations. License renewal could potentially delay this eventuality for an additional 20 years beyond the current license period. The impacts of decommissioning nuclear plants were evaluated in the *Generic Environmental Impact Statement for Decommissioning Nuclear Facilities: Supplement 1, Regarding the Decommissioning of Nuclear Power Reactors*, NUREG-0586 (NRC 2002a). The effects of license renewal on the impacts of terminating nuclear power plant operations and decommissioning are considered a single environmental issue. Because the impacts are expected to be SMALL at all plants and for all environmental resources, it is considered a Category 1 issue. The impacts of terminating nuclear power plant operations and decommissioning for each resource area are discussed in Section 4.12.2.

4.2 Land Use and Visual Resources

4.2.1 Environmental Consequences of the Proposed Action—Continued Operations and Refurbishment Activities

Since September 11, 2001, changes in onsite land use have occurred at nuclear power plants across the nation, with increased restrictions on site access and changes in barricades and landscaping to enhance security. Generally, land use conditions are expected to continue unchanged until plant decommissioning. Similarly, the use of transmission line ROWs is projected to continue with few, if any, changes in restrictions and easements.

In addition, the presence and visual profiles of operating nuclear power plants and transmission lines have been well established during the current licensing term. These conditions would remain unchanged during the 20-year license renewal term.

4.2.1.1 Land Use

In the 1996 GEIS, the impacts of nuclear power plant operations on onsite land use, power line right of way, and offsite land use (license renewal term and refurbishment) were evaluated separately. While it was concluded that impacts to onsite land use and power line right of ways would be small at all plants, anticipated changes in population and tax revenues attributed to license renewal and power plant refurbishment were predicted to have SMALL to MODERATE impacts on offsite land use. Subsequent license renewal reviews have shown, however, that license renewal and power plant refurbishment have had little or no effect on offsite land use.

Land use impact issues evaluated for this GEIS revision include the impacts of continued plant operations and refurbishment activities on (1) onsite land use (evaluated in the 1996 GEIS); (2) offsite land use (consolidation and reclassification of two 1996 GEIS issues: (1) offsite land use (refurbishment) and (2) offsite land use (license renewal term)); and (3) offsite land use in transmission line ROWs (issue was renamed from the 1996 GEIS issue, “Power line right-of-ways”).

Onsite Land Use

Operational activities at a nuclear power plant during the license renewal term would be similar to those occurring during the current license term. Generally, onsite land use conditions would remain unchanged. However, additional spent nuclear fuel and low-level radioactive waste generated during the license renewal term could require the construction of new or expansion of existing onsite storage facilities. Should additional storage facilities be required, this action would be addressed in separate license reviews conducted by the NRC. The NRC has not identified any information or situations during previous license renewal reviews that would alter the conclusion that impacts from continued plant operations and refurbishment would be SMALL for all commercial nuclear power plants. Refurbishment activities, such as steam generator and vessel head replacement, have not permanently changed onsite land use conditions.

On the basis of these considerations, the NRC concludes that the impact of continued plant operations during the license renewal term and refurbishment on onsite land use would be SMALL for all nuclear plants and remains a Category 1 issue.

Offsite Land Use

The impacts of continued plant operations during the license renewal term and refurbishment on offsite land use were evaluated separately in the 1996 GEIS. It was predicted that impacts associated with refurbishment and changes in population and tax revenue on offsite land use could range from SMALL to MODERATE. Subsequent license renewal reviews, however, have shown no power plant-related population changes or significant tax revenue changes due to license renewal. Non-outage employment levels at nuclear power plants have remained relatively unchanged or have decreased. With no increase in the number of workers, there has been no increase in housing, infrastructure, or demand for services beyond what has already occurred. Operational activities during the license renewal term would be similar to those occurring during the current license term and would not affect offsite land use beyond what has already been affected. The NRC has not identified any information or situations, including low population areas or population and tax revenue changes resulting from license renewal that would alter the conclusion that impacts on offsite land use would be SMALL for all nuclear power plants.

For plants that have the potential to impact a coastal zone or coastal watershed, as defined by each State participating in the National Coastal Zone Management Program, applicants for license renewal must submit to the affected State a certification that the proposed license renewal is consistent with the State Coastal Zone Management Program. Applicants must coordinate with the State agency that manages the State Coastal Zone Management Program to obtain a determination that the proposed nuclear plant license renewal would be consistent with the State program. Consistency with State Coastal Zone Management Programs assures that impacts in State coastal zones will be SMALL.

On the basis of these considerations, the NRC concludes that the impact of continued plant operations during the license renewal term and refurbishment on offsite land use would be SMALL at all plants and is considered a Category 1 issue.

Offsite Land Use in Transmission Line ROWs

As previously discussed in Section 3.1.6.5, in most cases, transmission lines originating at power plant substations are no longer owned or managed by nuclear power plant licensees. Accordingly, only those transmission lines that connect the plant to the switchyard where electricity is fed into the regional power distribution system (encompassing those lines that connect the plant to the first substation of the regional electric power grid) and power lines that feed the plant from the grid during outages are considered within the scope of license renewal environmental reviews. Operational activities in offsite transmission line ROWs, within this scope of review, during the license renewal term, would be similar to those occurring during the current license term and would not affect offsite land use in transmission line ROWs beyond what has already been affected.

Certain land use activity in the ROW is usually restricted. Land cover is generally managed through a variety of maintenance procedures so that vegetation growth and building construction do not interfere with power line operation and access. Land use within ROWs are limited to activities that do not endanger power line operation; these include recreation, off-road vehicle use, grazing, agricultural cultivation, irrigation, roads, environmental conservation, and wildlife areas.

Impacts on crop production that may have been caused by transmission line interference with aerial spraying have been reported by one field study of cotton, rice, and soybean fields crossed by a 500-kV line in eastern Arkansas (Parsch and Norman 1986). This study hypothesized that crop yields could be reduced either by electromagnetic fields (EMFs) or by inadequate aerial spraying directly under the power lines. Only cotton yields were found to be reduced; 15 percent less lint was produced under the lines than 150 ft (46 m) from the lines. The resulting loss of income from cotton was estimated as $85.25 per year for an 1,100-ft (335-m) span of the lines, based on a 15 percent yield reduction and an average lint yield of 480 lb/acre (538 kg/hectare). The field sampling and statistical analyses were extensive; the observed yield reduction appeared to be real rather than a sampling error. However, the study could not determine whether the EMF or line interference with aerial spraying caused the yield reduction.

Transmission lines do not preclude the use of the land for farming or environmental and recreational use. Transmission lines connecting nuclear power plants to the electrical grid are no different from transmission lines connecting any other power plant.

The impact of transmission lines on offsite land use during the license renewal term was considered to be SMALL for all plants and was designated as a Category 1 issue in the 1996 GEIS. No new information that would alter that conclusion has been identified in subsequent license renewal reviews.

On the basis of these considerations, the NRC concludes that the impact of transmission line ROWs on offsite land use during the license renewal term would be SMALL for all plants and remains a Category 1 issue.

4.2.1.2 Visual Resources

In the 1996 GEIS, the NRC considered the visual resource impacts of continued plant operations, refurbishment, and transmission lines separately as follows: (1) aesthetic impacts (refurbishment); (2) aesthetic impacts (license renewal term); and (3) aesthetic impacts of transmission lines (license renewal term). Subsequent license renewal environmental reviews conducted by the NRC have shown that nuclear power plants and transmission lines have not changed in appearance significantly over time, so aesthetic impacts are not anticipated. The three issues identified in the 1996 GEIS were combined and are evaluated as a single issue.

Aesthetic Impacts

As previously discussed, the NRC considered the impacts of continued plant operations during the license renewal term and refurbishment on visual resources separately in the 1996 GEIS. The NRC concluded that for both issues the impacts on visual resources would be SMALL for all plants and both were determined to be Category 1 issues, because the existing visual profiles of nuclear power plants were not expected to change during the license renewal term. A case study performed for the 1996 GEIS found a limited number of situations where nuclear power plants had a negative effect on visual resources. Negative perceptions were based on aesthetic considerations (for instance, the plant is out of character or scale with the community or the viewshed), physical environmental concerns, safety and perceived risk issues, an anti-plant attitude, or an anti-nuclear orientation. It is believed that these negative perceptions would persist regardless of mitigation measures. Subsequent license renewal reviews have not revealed any new information that would change this perception.

In addition, the visual appearance of transmission lines is not expected to change during the license renewal term. After the containment building and cooling towers, transmission line towers are probably the most frequently observed structure associated with nuclear power plants. Transmission lines from nuclear power plants are generally indistinguishable from those from other power plants. Since electrical transmission lines are common throughout the United States, they are generally perceived with less prejudice than the nuclear power plant itself. Also, the visual impact of transmission lines tends to wear off when viewed repeatedly. Replacing or moving towers or burying cables to reduce the visual impact would be impractical from both an efficiency and cost-benefit perspective. The impact of transmission lines during the license renewal term on visual resources was considered to be SMALL for all plants and designated as a Category 1 issue in the 1996 GEIS. No new information that would alter that conclusion has been identified in subsequent license renewal environmental reviews.

On the basis of these considerations, the NRC concludes that the aesthetic impacts of continued plant operations during the license renewal term, refurbishment, and transmission lines, within this scope of review, on visual resources would be SMALL for all plants and remains a Category 1 issue.

4.2.2 Environmental Consequences of Alternatives to the Proposed Action

Construction—Construction of a new power plant would involve the permanent commitment of land for the power plant, plant intake and discharge structures, water treatment facilities, and cooling towers. Other construction-related land use impacts would include land clearing, excavations, drilling of monitoring wells, and the installation of temporary support facilities. Material laydown areas and onsite concrete batch plants would also represent additional temporary land use and visual impacts. These would be removed after the power plant is completed. Depending on location, construction of electrical substation, switchyards, transmission lines, railroad spurs, access roads may also be required. Some of these facilities could affect offsite land use.

Construction at an existing nuclear power plant site or brownfield site would have less of an impact on land use and visual resources than a greenfield site. Construction at an existing nuclear power plant site would have the least impact on land use, because the plant could make use of existing intake and discharge structures, substations, transmission lines, office buildings, parking lots, and access roads. Constructing a power plant at a greenfield site would remove land from other productive uses such as agriculture. It could convert potential prime farmland to industrial use. In addition, construction at a greenfield site would have a more dramatic impact on visual resources, since the industrial power plant would likely be significantly different from the surrounding landscape. Constructing at a brownfield site would have less of an impact on the land use than a greenfield site.

The increase in traffic to and from the construction site could require changes to existing transportation infrastructure and traffic patterns resulting in offsite land use impacts and visual impacts. These impacts would cease at the end of construction.

Operations—Land would be in use throughout the period of power plant operation. Visual resources would also be affected. Visual impacts would be similar to other industrial activities at an existing nuclear power plant site or brownfield site. However, the height of new buildings structures as well as transmission line, meteorological, and cooling towers could add to the visual impact. Condensate plumes during plant operations may be visible for some distance during certain weather conditions.

4.2.2.1 Fossil Energy Alternatives

Construction and Operations—Impacts on land use from constructing coal- or natural gas-fired power plants would be similar. However, a coal-fired power plant would need more land than a natural gas-fired plant due to the need for coal fuel delivery and waste storage facilities. As a result, the coal-fired power plant would also have a higher visual impact.

4.2.2.2 New Nuclear Alternatives

Construction and Operations—Land would be required for the construction of spent nuclear fuel and low-level radioactive waste storage facilities. The appearance of the reactor containment and turbine buildings would add to the visual impact.

4.2.2.3 Renewable Alternatives

Construction—Land requirements for renewable energy facilities vary greatly. Biomass fueled energy facilities with utility-scale capacities could require at least 300 ac (122 ha). Flat plate solar photovoltaic systems would require approximately 6.2 ac (2.5 ha)/MW; however, improvements in photovoltaic cell efficiency could reduce the amount of land required to 0.68 ac (0.28 ha)/MW by 2030. Solar thermal facilities with concentrators would require substantial land area. Projected land requirements for advanced power tower facilities generating 200 MWe in the year 2030 would be 612 ac (247 ha). Given the expected capacity factor of advanced power tower facilities, the land requirements equate to 1.1×10^{-3} ha/MWh/yr (EERE 1997). Land area required for an advanced solar power trough facility operating in 2030 with a rated capacity of 320 MW would be 792 ac (320 ha) (EERE 1997).

Wind energy facilities would require approximately 0.3 ac (0.12 ha)/MW. Utility-scale wind farms would require relatively large areas. However, unlike solar technologies, once construction is completed, land areas between the turbines can be put to other beneficial (nonintrusive) use. Substantially lesser amounts of land area would be required for geothermal facilities (estimated at 173 ac [70 ha] for a 49 MW facility) (BLM 1999), and very small amounts of land (for cable landings and substations, estimated at 100 ac [40.4 ha] for utility-scale offshore energy facilities) would be required for offshore wind and current facilities.

For renewable energy technologies that utilize combustion and/or steam cycles, the appearance of buildings, height and prominence of smokestacks, and condensate plumes, would have a visual impact.

Operations—The operational impacts of alternative energy technologies on land use and visual resources are presented in the following subsections.

Hydroelectric Energy Sources

Hydroelectric dams and reservoirs capable of generating utility-scale power would be substantial in scale and prominence and have a visual impact. Large dams that also serve as flood control could significantly affect land use patterns upstream and downstream beyond the decommissioning of the facility.

Geothermal

Geothermal facilities would be less prominent, typically located in remote areas and may generate a steam plume that is visible from long distances. Visual resources would be affected by wellheads, exposed transfer piping, and power plant structures, and could have a dramatic impact on a remote area. The intermittent creation of steam condensate plumes would be visible from great distances.

Wind

A relatively large area of land would be required for wind energy; however, only about 5 to 10 percent of the land area would be utilized by turbines, power collection and conditioning systems, and other support facilities. Land affected by the installation of buried power and communication cables interconnecting each turbine with a power substation would be minimally intrusive. Wind farms, although less complex than combustion-based facilities in their visual appearance, would have a visual impact due to the height of the turbines. Offshore wind farms could be sufficiently distant from the shore to attenuate most, if not all, of the visual impacts on onshore observers.

Biomass

The physical appearance of a biomass fuel-fired energy facility would be similar to that of a fossil fuel fired facility. The industrial footprint would be less. Additional land would be required, however, for growing biomass crops.

Municipal Solid Waste, Refuse-Derived Fuel, and Landfill Gas

The physical appearance of a municipal solid waste, refuse-derived and landfill gas-fired energy facility would be similar to that of a fossil fuel fired facility, but the amount of land needed for the energy production facilities would be less. Some additional land would be required, however, for fuel handling facilities (e.g., storage piles, hammermills, grinders, bucket conveyors, blowers, and pneumatic conveyance systems). Buildings, smokestacks, cooling towers, and condensate plumes would have a visual impact, but would be comparable to a fossil fuel-fired facility.

Solar Thermal

Land would be required for the powerblock (steam cycle, turbine/generator building, substation, cooling towers, condensate plume, and support equipment). Visual impacts would occur if a power tower technology is employed as well as the array of solar collectors.

Solar Photovoltaic

Utility-scale facility would require a very large area of land. Visual resources would be affected by the size of the facility.

Ocean Wave and Current

Land use would be only slightly affected by land-based support systems (cable landing, substation, and warehouse and repair facility); existing piers and docks are expected to be sufficient to support the offshore facility during operation. Above-water components are expected to be relatively inconspicuous, even when equipped with marker lights; their relatively small height above the water, their distance from shore, and the curvature of the earth may serve to partially or completely conceal them from onshore observers.

4.3 Air Quality and Noise

4.3.1 Environmental Consequences of the Proposed Action—Continued Operations and Refurbishment Activities

Ambient air quality and noise conditions at all nuclear power plants and associated transmission lines have been well established during the current licensing term. Notwithstanding significant changes to the nature and type of industrial activities in the area, these conditions are expected to remain unchanged during the 20-year license renewal term.

The focus of this section is the impacts of continued operations and refurbishment activities during the license renewal term on air quality and noise. Refurbishment and associated construction activities can affect air quality (e.g., fugitive dust, vehicle and equipment exhaust emissions, and automobile exhaust from commuter traffic). Baseline meteorological, climatological, and ambient air quality and noise conditions at operating plants are discussed in Sections 3.3.1 and 3.3.2, respectively. License renewal is expected to result in a continuation of similar conditions for an extended period commensurate with the license renewal term, typically 20 years. As a result, the criteria air pollutants emitted and the noise generated during normal continued plant operations over the license renewal term are not expected to change substantially and thus should remain SMALL.

4.3.1.1 Air Quality

Two issues related to impacts on air quality during the license renewal term are considered in this section:

- Air quality impacts (all plants); issue encompasses impacts of continued operations (not considered in the 1996 GEIS) and refurbishment activities on air quality, including nonattainment or maintenance area conformity (issue was modified, reclassified, and renamed from the 1996 GEIS); and
- Air quality effects of transmission lines. This issue was evaluated in the 1996 GEIS.

Air Quality Impacts (All Plants)

Continued Operations—The impact of continued plant operations during the license renewal term on air quality was not identified as an issue in the 1996 GEIS. It is evaluated here because of the potential for air quality to be affected by the operations of fossil-fuel-fired equipment needed for normal operations and by the operations of cooling towers in plants that use a closed-cycle cooling system. These potential impacts are discussed below.

Impacts on air quality during normal plant operations can result from operations of fossil-fuel-fired equipment needed for various plant functions (see Section 3.3.2). Each licensed plant typically employs emergency diesel generators for use as a backup power source. Emergency diesel generators and fire pumps typically require State or local operating permits. These generators provide a standby source of electric power for essential equipment required during plant upset or an emergency event. They also provide for safe reactor shutdown and for the maintenance of safe conditions at the power station during such an event. These diesel generators are typically tested once a month with several test burns of various durations (e.g., 1 to several hours). In addition to these maintenance tests, longer-running endurance tests are also typically conducted at each plant. Each generator is typically tested for 24 hours on a staggered test schedule (e.g., once every refueling outage). Plants with nonelectric fire pumps, typically also diesel-fired, usually employ test protocols identical or similar to those used for emergency generators. Maintenance procedures during these tests would include, for example, checks for leaks of lubricating oil or fuel from equipment, and pumps would be replaced as required. Most State air pollution regulations provide exemptions for air pollution sources that are not routinely operated, which can be defined as sources with insignificant activity meeting specified operating criteria (e.g., so many hours of continuous operation over specified periods or so many hours of operation per year).

In addition to the emergency diesel generators, fossil fuel (i.e., diesel-, oil-, or natural-gas-fired) boilers are used primarily for evaporator heating, plant space heating, and/or feed water purification. These units typically operate at a variable load on a continuous basis throughout the year unless end use is restricted to one application, such as space heating. Air emissions include carbon monoxide (CO), nitrogen oxides (NO_x), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), particulate matter (PM), and volatile organic compounds (VOCs) for diesel-, natural-gas-, and oil-fired units. Natural-gas-fired units emit only trace amounts of VOCs and PM that has an aerodynamic diameter of 10 μm or less (PM_{10}). The utility boilers at commercial plants are relatively small when compared with most industrial boilers and are typically regulated through State-level operating permits.

The potential impact from emergency generators and boilers on air quality would be expected to be SMALL for all plants, and, given the infrequency and short duration of maintenance testing, it would not be an air quality concern even at those plants located in or adjacent to nonattainment areas. The locations of the currently designated nonattainment areas near nuclear plants are shown in Section 3.3.2.

As discussed in Section 3.3, cooling tower drift can increase downwind PM concentrations, impair visibility, ice roadways, cause drift deposition, and damage vegetation and painted surfaces. There are currently 24 licensed nuclear power plants that use wet cooling towers in closed-cycle cooling systems. Most of the plants use two or more towers for reactor heat removal. Of the 47 operating towers, 24 are natural draft cooling towers and 23 are mechanical draft cooling towers. There are currently no dry or hybrid (combinations incorporating elements of both dry and wet design) systems being used at operating nuclear plants. Only 1 of the 47 towers (a natural draft cooling tower at the Hope Creek plant in New Jersey) is operating at a plant that uses high-salinity water for cooling system makeup. An air quality impact analysis performed in support of an extended power uprate request for Hope Creek assessed emissions related to cooling tower drift droplets and PM for this worst-case situation and found that the impacts of cooling tower operations on air quality were small, as summarized in Section 3.3.2.

Thus, although there is the potential for some air quality impacts to occur as a result of equipment and cooling tower operations, even in the worst-case situation (Hope Creek), the impacts have been small, and licensees would be required to operate within State permit requirements.

Refurbishment Activities—Potential sources of impacts on air quality during refurbishment activities associated with continued operations during the license renewal term include (1) fugitive dust from site excavation and grading and (2) emissions from motorized equipment, construction vehicles, and workers' vehicles. Some refurbishment activities would be performed on equipment inside existing buildings and would not generate air emissions.

With application of adequate controls or mitigation measures and best practices, the air quality impacts from these air pollution sources would be small and of relatively short duration. The disturbed area for refurbishment actions, if required, is expected to be 10 ac (4 ha) or less, based on assumptions from the 1996 GEIS. During site excavation and grading, some PM in the form of fugitive dust would be released into the atmosphere. Because of the (1) small size of the disturbed area, (2) relatively short construction period, (3) availability of paved roadways at existing facilities, and (4) use of best management practices (BMPs) (such as watering, chemical stabilization, and seeding), fugitive dust resulting from these construction activities would likely be minimal.

Construction vehicles and other motorized equipment would generate exhaust emissions that include small amounts of CO, NO_x, VOCs, and PM. These emissions would be temporary (restricted to the construction period) and localized (occurring only in the immediate vicinity of construction areas). Emissions impacts from construction equipment and vehicles (e.g., CO, hydrocarbons, and PM from use of diesel fuels) and from fugitive dust emissions from ground-clearing and grading activities could be SMALL or MODERATE. For refurbishment occurring in geographical areas with poor or marginal air quality, the emissions generated from these activities could be cause for concern in a few cases (e.g., building demolition, debris removal, and new construction). However, the 1990 Clean Air Act Amendments include a provision that no Federal agency shall support any activity that does not conform to a State Implementation Plan designed to achieve the National Ambient Air Quality Standards (NAAQS) for criteria pollutants (sulfur dioxide [SO_2], nitrogen dioxide [NO_2], CO, ozone [O_3,], lead [Pb], PM_{10}, and PM with a mean aerodynamic diameter of 2.5 μm or less [$PM_{2.5}$]).

On April 5, 2010, the U.S. Environmental Protection Agency (EPA) issued its 40 CFR Part 51 and 93 revisions to the General Conformity Regulations in the *Federal Register* (75 FR 17254) These regulations revised and updated the general conformity regulations published on November 30, 1993, in 58 FR 63214. General conformity requires Federal agencies to ensure that a proposed Federal action in air quality nonattainment or maintenance areas conforms to the applicable State Implementation Plan. A conformity analysis must be completed before the action is taken. A conformity analysis begins with an applicability analysis to determine whether the action is exempt or has total net direct and indirect emissions below the *de minimis* levels. The *de minimis* emission levels (40 CFR 93.153(b)) serve as screening values to determine whether a conformity determination must be undertaken for a proposed Federal action. The applicability analysis must be documented. If conformity applies, the agency must prepare a written conformity analysis and determination for each pollutant for which the emissions caused by a proposed Federal action would exceed the *de minimis* levels. An area is designated as nonattainment for a criteria pollutant if it does not meet NAAQS for the pollutant. A maintenance area is one that a State has redesignated from nonattainment to attainment. The current nationwide designations of nonattainment and maintenance areas are identified in Section 3.3.2.

The *de minimis* levels for air emissions vary depending on air quality conditions in the area where the plant is located. In most cases, the *de minimis* levels are established at 100 tons per year. Exceptions include:

- NO_x or VOC emissions of 10, 25, and 50 tons per year in extreme, severe, and serious ozone nonattainment areas, respectively;
- VOC emissions of 50 tons per year in ozone nonattainment areas inside an ozone transport region stretching from Virginia to Maine;
- PM_{10} emissions of 70 tons per year in serious PM_{10} nonattainment areas; and
- Lead emissions of 25 tons per year in lead nonattainment areas.

None of the operating nuclear plants are located in extreme, severe, or serious ozone nonattainment areas; in serious PM_{10} nonattainment areas; or in lead nonattainment areas. Therefore, the *de minimis* levels applied to plants in the nonattainment areas are 100 tons per year for all criteria pollutants except VOC emissions of 50 tons per year for plants within the ozone transport region.

In maintenance areas, the *de minimis* levels are 100 tons per year for all pollutants, except for 50 tons per year for VOCs inside the ozone transport region. The *de minimis* levels of 25 tons per year apply in maintenance areas, but no plants are located in these areas.

In addition to the above, *de minimis* levels of 100 tons per year applies to SO_2 and NO_x emissions in $PM_{2.5}$ nonattainment and maintenance areas unless NO_x is determined not to be a significant $PM_{2.5}$ precursor. Levels of 100 tons per year may apply to emissions of VOCs and ammonia if either is determined to be a significant precursor. The regulations require that direct construction emissions including construction vehicle and equipment exhaust and fugitive dust and indirect emissions such as those from worker and delivery vehicles be included in the conformity analysis.

Emissions from construction equipment and vehicles are expected to be small for anticipated refurbishment projects on the basis of activities that have occurred to date; however, larger projects may require a sizeable workforce that could contribute vehicle exhaust emissions that could exceed the *de minimis* thresholds for CO, NO_x, and VOCs (the latter two contribute to the formation of O_3) in nonattainment and maintenance areas. In addition, the amount of fugitive dust generated by dust resuspension from larger projects involving construction vehicle use onsite or vehicle use in the vicinity of construction activities may approach or exceed the threshold for PM_{10} and $PM_{2.5}$ in nonattainment and maintenance areas. Dust suppression measures could be implemented in areas of concern. In summary, emissions from equipment and vehicle exhaust and fugitive dust could result in impacts, but could be mitigated through appropriate fugitive dust control measures.

In the 1996 GEIS, the NRC concluded that the impacts from plant refurbishment associated with license renewal on air quality could range from SMALL to LARGE, although these impacts were expected to be SMALL for most plants. However, findings from license renewal SEISs published since the 1996 GEIS have shown that refurbishment activities, such as steam generator and vessel head replacement, have not required the large numbers of workers and months of time, as well as the degree of land disturbance, that was conservatively estimated in the 1996 GEIS. Presumed air pollutant emissions, including levels of fugitive dust, have therefore not been realized. The NRC concludes that the impact of refurbishment activities on air quality during the license renewal term would be SMALL for most plants, but could be cause for concern at plants located in or near air quality nonattainment or maintenance areas, depending on the nature of the planned activity. Still, the impacts would be temporary and cease once projects were completed and implementation of BMPs including fugitive dust controls and the imposition of new and/or revised conditions in State and local air emissions permits would ensure conformance with applicable State or Tribal Implementation Plans.

On the basis of these considerations, the NRC concludes that the air quality impact of continued nuclear plant operations during the license renewal term and refurbishment would be SMALL for all plants, and that the impacts of license renewal on air quality should be considered a Category 1 issue.

Air Quality Effects of Transmission Lines

Small amounts of ozone and substantially smaller amounts of oxides of nitrogen are produced by transmission lines during corona, a phenomenon that occurs when air ionizes near isolated irregularities on the conductor surface such as abrasions, dust particles, raindrops, and insects. Several studies have quantified the amount of ozone generated and concluded that the amount produced by even the largest lines in operation (765 kilovolt [kV]) is insignificant (SNYPSC 1978; Scott-Walton et al. 1979; Janes 1980; Varfalvy et al. 1985). Monitoring of ozone levels for two years near a Bonneville Power Administration 1,200-kV prototype line revealed no increase in ambient ozone levels caused by the line (Bracken and Gabriel 1981; Lee et al. 1989). Ozone concentrations generated by transmission lines are therefore too low to cause any significant effects. The minute amounts of oxides of nitrogen produced are similarly insignificant. A finding of SMALL significance for transmission lines, within this scope of review (see Sections 3.1.1 and 3.1.6.5 in this GEIS), is supported by the evidence that production of ozone and oxides of nitrogen are insignificant and does not measurably contribute to ambient levels of those gases. Potential mitigation measures (e.g., burying transmission lines) would be very costly and would not be warranted. This is a Category 1 issue.

4.3.1.2 Noise

One issue related to noise impacts during the license renewal term and refurbishment is considered in this section:

- Noise impacts of continued operations and refurbishment activities. This issue was evaluated in the 1996 GEIS.

Noise Impacts

Noise from nuclear plant operations can often be detected offsite relatively close to the plant site boundary. Sources of noise and the relative magnitude of impacts during normal nuclear power plant operations are discussed in Section 3.3.3. Major sources of noise at operating nuclear power plants are cooling towers, turbines, transformers, large pumps, and cooling water system motors. Nuclear plant operations have not changed appreciably with time, and no change in noise levels or noise-related impacts are expected during the license renewal term. Since no change is expected in the amount of noise generated during the license renewal term, the only issue of concern is the number of people now living close to the nuclear power plant who are exposed to operational noise.

Given the industrial nature of the power plant and the number of years of plant operation, noise from a nuclear plant is generally nothing more than a continuous minor nuisance. However, noise levels may sometimes exceed the 55 dBA level that the EPA uses as a threshold level to protect against excess noise during outdoor activities (EPA 1974). However, according to the EPA this threshold does “not constitute a standard, specification, or regulation,” but was intended to provide a basis for State and local governments establishing noise standards. Nevertheless, noise levels at the site boundary are expected to remain well below regulatory standards for offsite residents.

Noise would also be generated by construction-related activities and equipment used during refurbishment. However this noise would occur for relatively short periods of time (several weeks) and is not expected to be distinguishable from other operational noises at the site boundary nor create an adverse impact on nearby residents.

In the 1996 GEIS, the NRC concluded that noise was not a problem at operating plants and was not expected to be a problem at any nuclear plant during the license renewal term. The magnitude of noise impacts was therefore determined to be SMALL for all plants, and the issue was designated as Category 1. No new information altering this conclusion has been identified in subsequent license renewal reviews.

On the basis of these considerations, the NRC concludes that the noise impact of continued nuclear plant operations during the license renewal term and refurbishment would be SMALL for all plants, and remains a Category 1 issue.

4.3.2 Environmental Consequences of Alternatives to the Proposed Action

Construction—Air quality impacts would include criteria pollutants from construction vehicles and equipment and dust from land clearing and grading. VOCs could be released from organic solvents used in cleaning, during the application of protective coatings, and the onsite storage and use of petroleum-based fuels. Construction vehicles and equipment would also generate noise. Impacts, however, would be temporary, and both air quality and noise impacts would return to pre-construction levels after construction was completed.

Air quality and noise impacts from construction activities would be similar whether occurring at a greenfield site, brownfield site, or at an existing nuclear power plant. The impacts would be greatest, however, at a greenfield site because of cleaner ambient air quality and noise conditions, even though greenfield sites may also be found in NAAQS nonattainment areas. Onsite concrete batch plants, if required, would also contribute to construction-related dust and noise.

Operations—Air quality would be affected during operations by cooling tower drift; auxiliary power equipment, building heating, ventilation, and air conditioning (HVAC) systems; and vehicle emissions. Auxiliary power equipment could include standby diesel generators and power systems for emergency power and auxiliary steam.

Ambient noise levels would be affected by cooling towers (water pumps, cascading water, or fans), transformers, turbines, pumps, compressors, loudspeakers, other auxiliary equipment such as standby generators, and vehicles. Air quality and noise impacts would be the greatest at greenfield sites.

4.3.2.1 Fossil Energy Alternatives

Construction—Air quality and noise impacts would be the same as described in Section 4.3.2. The impact analysis for fossil energy alternatives is based on projected impacts of facilities studied by the U.S. Department of Energy’s (DOE’s) National Energy Technology Laboratory (NETL). Baseline performance and cost data for 12 technologies are presented in a report issued by NETL (NETL 2007).

An independent study conducted by the EPA on some of the technologies in the NETL report provides additional environmental impact data (EPA 2006). However, due to different power plant designs and fuel used in the NETL and EPA studies the data are not directly comparable.

Nevertheless, data from both studies are presented to provide a range of environmental impacts. Most of the data presented in the following sections are extracted from those two reports.

Operations—Fossil fuel power plants can have a significant impact on air quality. The burning of fossil fuels is a major source of criteria pollutants and greenhouse gases, primarily CO_2, as well as other hazardous air pollutants. The exact nature of these pollutants depends on the chemical constituency of the fuel, combustion technology, air pollution control devices, and onsite management of fuel (e.g., coal) and waste material. Sources of noise include coal delivery, coal crushing, and fuel and waste handling activities.

The EPA has identified 13 trace elements likely to be emitted from an integrated gasification combined cycle (IGCC) facility, including arsenic, cadmium, lead, mercury, and selenium. The average concentrations of trace elements emitted in pounds emitted per million Btu input ($lb/10^6$ Btu) are as follows: antimony (4), arsenic (2.1), beryllium (0.09), cadmium (2.9), chloride (740), chromium (2.7), cobalt (0.57), fluoride (38), lead (2.9), manganese (3.1), mercury (1.7), nickel (3.9), and selenium (2.9) (EPA 2006).

Table 4.3-1 displays some of the anticipated air quality impacts of coal-burning technologies (EPA 2006). Table 4.3-2 shows projected emissions of criteria and hazardous air pollutants from fossil fuel plants (NETL 2007). The values presented in the two tables represent the possible range of operational emissions that could result from fossil-fuel-fired power plants.

Fossil fueled power plants not equipped with carbon capture and storage devices will emit large amounts of CO_2 and lesser amounts of other greenhouse gases. EPA projections of CO_2 emissions from a 500-MW integrated gasification combined cycle facility burning bituminous, sub-bituminous, and lignite coals are 1,441 lb/MWh (or 199 lb/MBtu), 1,541 lb/MWh (208 lb/MBtu), and 1,584 lb/MWh (211 lb/MBtu), respectively (EPA 2006). However, as can be seen from the data presented in Table 4.3-2, CO_2 emissions can be reduced by as much as 90 percent with the installation of carbon capture and storage devices.

4.3.2.2 New Nuclear Alternatives

Construction—Air quality and noise impacts for the construction of a new nuclear power plant would be the same as described in Section 4.3.2.

Operations—An operating nuclear plant would have minor air emissions associated with diesel generators and other small-scale intermittent sources. Air quality and noise impacts would be the same as described in Section 4.3.2.

Table 4.3-1. Projected Air Quality Impacts for Selected Power Production Technologies Burning Various Ranks of Coal[(a)]

Fuel	Technology[(b)]	Projected Air Quality Impacts (lb/MWh)							SO_2 Removal Percent	NO_x Removal Basis[(f)]
		NO_x (NO_2)	SO_2	CO	Particulate[(c)]	VOCs	Lead[(d)]	Mercury[(e)]		
Bituminous coal	IGCC	0.355	0.311	0.217	0.051	–	1.0×10^{-6} to 2.4×10^{-6}	5.50×10^{-6}	99	15 ppmvd @ 15 percent O_2
	Subcritical PC	0.528	0.757	0.880	0.106	0.021	3.40×10^{-5} to 18×10^{-5}	6.69×10^{-6}	98	0.06 lb/MBtu
	Supercritical PC	0.494	0.709	0.824	0.099	0.020	3.18×10^{-5} to 17×10^{-5}	6.26×10^{-6}	98	0.06 lb/MBtu
	Ultra-Supercritical PC	0.442	0.634	0.737	0.088	0.018	2.84×10^{-5} to 15×10^{-5}	5.6×10^{-6}	98	0.06 lb/MBtu
Sub-bituminous coal	IGCC	0.326	0.089	0.222	0.052	–	1.0×10^{-6} to 2.4×10^{-6}	3.11×10^{-6}	97.5	15 ppmvd @ 15 percent O_2
	Subcritical PC	0.543	0.589	0.906	0.109	0.025	18×10^{-5} to 23×10^{-5}	3.80×10^{-6}	87[(g)]	0.06 lb/MBtu
	Supercritical PC	0.500	0.541	0.832	0.100	0.023	16.6×10^{-5} to 21×10^{-5}	3.49×10^{-6}	87[(g)]	0.06 lb/MBtu
	Ultra-supercritical PC	0.450	0.488	0.750	0.090	0.020	15×10^{-5} to 19×10^{-5}	3.15×10^{-6}	87[(g)]	0.06 lb/MBtu
Lignite coal	IGCC	0.375	0.150	0.225	0.053	–	1.0×10^{-6} to 2.4×10^{-6}	5.48×10^{-6}	99	15 ppmvd @ 15 percent O_2
	Subcritical PC	0.568	0.814	0.947	0.114	0.026	18.9×10^{-5} to 24×10^{-5}	6.9×10^{-6}	95.8	0.06 lb/MBtu
	Supercritical PC	0.524	0.751	0.873	0.105	0.024	17.5×10^{-5} to 22×10^{-5}	6.37×10^{-6}	95.8	0.06 lb/MBtu
	Ultra-supercritical PC	0.498	0.714	0.830	0.100	0.022	16.6×10^{-5} to 21×10^{-5}	6.06×10^{-6}	95.8	0.06 lb/MBtu

Footnotes on next page.

Table 4.3–1. (cont.)

(a) Proximate analyses values (weight percent) for bituminous/sub-bituminous/lignite study coals include: weight percent ash: 9.70/4.50/17.92; moisture: 11.12/27.40/31.24; fixed carbon: 44.19/36.70/22.96; volatiles: 34.99/31.40/28.08. Higher heating values (Btu/lb) for study coals are: 11,667/8,800/6,312.

(b) None of the technologies represented in this table is equipped with carbon capture and storage (CCS) capability. The EPA study (EPA 2006) on which data in this table are based included only coal combustion technologies. IGCC = integrated gasification combined cycle. PC = pulverized coal.

(c) Particulate removal is 99.9 percent or greater for IGCC cases and 99.8 percent for bituminous coal, 99.7 percent for sub-bituminous coal, and 99.9 percent for lignite coal in the PC cases. Particulate matter emission rates shown include the overall filterable particulate matter only.

(d) Little empirical evidence exists on the behavior of lead in IGCC facilities. The EPA anticipates that approximately 5 percent of the lead in the input coal will be emitted to the air, while the remaining lead will remain with gasifier slag and other solid wastes generated in other gas cleaning units.

(e) As with lead, the behavior of mercury in IGCC systems is not well understood. It is anticipated that as much as 60 percent of coal-derived mercury will be potentially emitted to the atmosphere; however, fabric filters and scrubbers installed for particulate and SO_2 controls may effectively capture as much as 98 percent of the mercury present in exhaust gases. With the advent of mercury emission regulations and the installation of other devices specifically designed to capture mercury, the EPA expects that a larger fraction of mercury contained in the coal will ultimately be found in solid wastes generated in those mercury capture devices.

(f) A percent removal for NO_x cannot be calculated with a basis (i.e., an uncontrolled unit), for comparison. Also, the PC and IGCC technologies use multiple technologies (e.g., combustion controls, selective catalytic reduction [SCR]) to control NO_x. NO_x emission comparisons are based on emission levels expressed in parts per million volume (dry basis) (ppmvd) at 15 percent oxygen for IGCC and lb/MBtu for PC cases.

(g) A relatively low SO_2 removal efficiency of 87 percent results from a relatively low sulfur content in sub-bituminous coal of only 0.22 percent. Higher removal efficiencies occur with higher sulfur-content coals.

Source: EPA 2006

Table 4.3-2. Performance and Cost Data for Fossil-Fuel-Fired Power Plants That Are Likely Alternatives to Retired Nuclear Reactors

Parameter	Integrated Gasification Combined Cycle					
	General Electric Energy		ConocoPhillips		Shell	
CO_2 capture	No	Yes	No	Yes	No	Yes
Gross power output (kWe)	770,350	744,960	742,510	693,840	748,020	693,555
Auxiliary power requirement (kWe)	130,100	189,285	119,140	175,600	112,170	176,420
Net power output (kWe)	640,250	555,675	623,370	518,240	635,850	517,135
Coal flow rate (lb/hr)	489,634	500,379	463,889	477,855	452,620	473,176
Natural gas flow rate (lb/hr)	NA[(a)]	NA	NA	NA	NA	NA
Higher heating value (HHV) thermal input (kWe)	1,674,044	1,710,780	1,685,023	1,633,771	1,547,493	1,617,772
Net plant HHV efficiency (percent)	38.2	32.5	39.3	31.7	41.1	32.0
Net plant HHV heat rate (Btu/kWh)	8,922	10,505	8,681	10,757	8,304	10,674
CO_2 emissions (lb/hr)	1,123,781	114,476	1,078,144	131,328	1,054,221	103,041
CO_2 emissions (tons/yr) @ CF[(b)]	3,937,728	401,124	3,777,815	460,175	3,693,990	361,056
CO_2 emissions (lb/MBtu)	197	19.6	199	23.6	200	18.7
CO_2 emissions (kg/MWh)[(b)]	662	69.7	659	85.9	639	67.4
CO_2 emissions (lb/MWh)[(b)]	1,469	154	1,452	189	1,409	149
CO_2 emissions (lb/MWh)[(c)]	1,755	206	1,730	253	1,658	199
SO_2 emissions (lb/hr)	73	56	68	48	66	58
SO_2 emissions (tons/yr) @ CF[(b)]	254	196	237	167	230	204
SO_2 emissions (lb/MBtu)	0.012	0.0096	0.0125	0.0085	0.0124	0.0105
SO_2 emissions (kg/MWh)[(c)]	0.0427	0.0341	0.0413	0.0311	0.0398	0.0380
SO_2 emissions (lb/MWh)[(c)]	0.0942	0.0751	0.0909	0.0686	0.0878	0.0837
NO_x emissions (lb/hr)	313	273	321	277	309	269
NO_x emissions (tons/yr) @ CF[(b)]	1,096	955	1,126	972	1,082	944
NO_x emissions (lb/MBtu)	0.055	0.047	0.059	0.050	0.058	0.049
NO_x emissions (kg/MWh)[(c)]	0.184	0.166	0.196	0.181	0.187	0.176
NO_x emissions (lb/MWh)[(c)]	0.406	0.366	0.433	0.400	0.413	0.388
PM emissions (lb/hr)	41	41	38	40	37	39
PM emissions (tons/yr) @ CF[(b)]	142	145	135	139	131	137
PM emissions (lb/MBtu)	0.0071	0.0071	0.0071	0.0071	0.0071	0.0071
PM emissions (kg/MWh)[(c)]	0.024	0.025	0.023	0.026	0.023	0.026
PM emissions (lb/MWh)[(c)]	0.053	0.056	0.052	0.057	0.050	0.057
Hg emissions (lb/hr)	0.0033	0.0033	0.0031	0.0032	0.0030	0.0032
Hg emissions (tons/yr) @ CF[(b)]	0.011	0.012	0.011	0.011	0.011	0.011
Hg emissions (lb/MBtu)	0.571	0.571	0.571	0.571	0.571	0.571
Hg emissions (kg/MWh)[(b)]	1.92×10^{-6}	2.03×10^{-6}	1.89×10^{-6}	2.08×10^{-6}	1.83×10^{-6}	2.08×10^{-6}
Hg emissions (lb/MWh)[(b)]	4.24×10^{-6}	4.48×10^{-6}	4.16×10^{-6}	4.59×10^{-6}	4.03×10^{-6}	4.55×10^{-6}

Table 4.3-2. (cont.)

Parameter	Pulverized Coal Boiler				NGCC	
	PC Subcritical		PC Supercritical		Advanced F Class	
CO_2 capture	No	Yes	No	Yes	No	Yes
Gross power output (kWe)	583,315	679,923	580,260	663,445	570,200	520,090
Auxiliary power requirement (kWe)	32,870	130,310	30,110	117,450	9,840	38,200
Net power output (kWe)	550,445	549,613	550,150	545,995	560,360	481,890
Coal flow rate (lb/hr)	437,699	646,589	411,282	586,627	NA	NA
Natural gas flow rate (lb/hr)	NA	NA	NA	NA	165,182	165,182
HHV thermal input (kWe)	1,496,479	2,210,668	1,406,161	2,005,660	1,103,363	1,103,363
Net plant HHV efficiency (%)	36.8	24.9	39.1	27.2	50.8	43.7
Net plant HHV heat rate (Btu/kWh)	9,276	13,724	8,721	12,534	6,719	7,813
CO_2 emissions (lb/hr)	1,038,110	152,975	975,370	138,681	446,339	44,634
CO_2 emissions (tons/yr) @ CF[(b)]	3,864,884	569,524	3,631,301	516,310	1,661,720	166,172
CO_2 emissions (lb/MBtu)	203	20.3	203	20.3	119	11.9
CO_2 emissions (kg/MWh)[(c)]	807	102	762	94.8	355	38.9
CO_2 emissions (lb/MWh)[(c)]	1,780	225	1,681	209	783	85.8
CO_2 emissions (lb/MWh)[(d)]	1,886	278	1,773	254	797	93
SO_2 emissions (lb/hr)	433	Negligible	407	Negligible	Negligible	Negligible
SO_2 emissions (tons/yr) @ CF[(b)]	1,613	Negligible	1,514	Negligible	Negligible	Negligible
SO_2 emissions (lb/MBtu)	0.0848	Negligible	0.0847	Negligible	Negligible	Negligible
SO_2 emissions (kg/MWh)[(c)]	0.3369	Negligible	0.3179	Negligible	Negligible	Negligible
SO_2 emissions (lb/MWh)[(c)]	0.7426	Negligible	0.7007	Negligible	Negligible	Negligible
NO_x emissions (lb/hr)	357	528	336	479	34	34
NO_x emissions (tons/yr) @ CF[(b)]	1,331	1,966	1,250	1,784	127	127
NO_x emissions (lb/MBtu)	0.070	0.070	0.070	0.070	0.009	0.009
NO_x emissions (kg/MWh)[(c)]	0.278	0.352	0.263	0.328	0.027	0.030
NO_x emissions (lb/MWh)[(c)]	0.613	0.777	0.579	0.722	0.060	0.066
PM emissions (lb/hr)	66	98	62	89	Negligible	Negligible
PM emissions (tons/yr) @ CF[(b)]	247	365	232	331	Negligible	Negligible
PM emissions (lb/MBtu)	0.0130	0.0130	0.0130	0.0130	Negligible	Negligible
PM emissions (kg/MWh)[(c)]	0.052	0.065	0.049	0.061	Negligible	Negligible
PM emissions (lb/MWh)[(c)]	0.114	0.144	0.107	0.134	Negligible	Negligible
Hg emissions (lb/hr)	0.0058	0.0086	0.0055	0.0078	Negligible	Negligible
Hg emissions (tons/yr) @ CF[(b)]	0.022	0.032	0.020	0.029	Negligible	Negligible
Hg emissions (lb/MBtu)	1.14	1.14	1.14	1.14	Negligible	Negligible
Hg emissions (kg/MWh)[(c)]	4.54×10^{-6}	5.75×10^{-6}	4.29×10^{-6}	5.35×10^{-6}	Negligible	Negligible
Hg emissions (lb/MWh)[(c)]	1.00×10^{-5}	1.27×10^{-5}	9.45×10^{-6}	1.18×10^{-5}	Negligible	Negligible

(a) NA = not applicable.
(b) Capacity factor (CF) is 80 percent for IGCC cases and 85 percent PC and NGCC cases.
(c) Value is based on gross output.
(d) Value is based on net output.
Source: NETL 2007

4.3.2.3 Renewable Alternatives

Construction—Air quality and noise impacts for the construction of land-based alternative energy technologies would be the same as described in Section 4.3.2. Air quality impacts associated with the construction of offshore power generating facilities and support structures include the emission of criteria pollutants from construction barges and equipment (e.g., cranes, compressors) and vehicles delivering materials and crews to embarkation locations on the shore, and dust from the construction of onshore facilities (e.g., cable landings, substations).

Construction-related noise impacts would be substantially different offshore than those associated with onshore construction since these activities would be distant from most human receptors and because noise propagates much greater distances in water. Marine animals that use noise for navigation (e.g., echolocation) would be affected by construction-related noise. Sources of noise would include crew vessels and construction and equipment barges; seismic technologies used to characterize the site; explosives or pile driving to construct foundations for offshore wind turbines or anchoring devices for wave, tidal, and current energy capturing equipment; and excavation of sea bottoms for installation of buried power and communication cables. Construction-related impacts on air quality and noise would generally be temporary.

Operations—The operational impacts of alternative energy technologies on air quality and noise are presented in the following subsections.

Hydroelectric Energy Sources

Air quality would be affected by minor emissions of criteria pollutants during plant operations, primarily from workforce vehicles and internal combustion engines on pumps, air compressors, emergency power generators, and other support equipment.

Geothermal

Air quality would be affected by the release of criteria pollutants from vehicles and equipment utilizing internal combustion engines. Air quality would be affected by the release of dissolved hydrogen sulfide from geothermal fluids during well operation; installation of hydrogen sulfide control/capture devices on wellheads would be required to regulate release to acceptable levels. Air quality would be affected by the release of greenhouse gases, estimated to be 1,570 lb/hr of greenhouse gases (carbon dioxide 92.3 percent, methane 0.1 percent) during operation. Greenhouse gas emission rate is approximately 26 times less than the rate of release from a fossil fuel-fired power plant. Air quality could also be affected by the release of small amounts of acid rain precursors (NO_x, SO_2).

During winter months, air quality and visibility would be affected by ground-level fogging/icing that could occur from cooling towers. Ambient noise levels would be affected by cooling towers, compressors, and internal combustion engines and manipulation of fluids under high pressure. Noise could be as much as 45 dB above background at offsite locations.

Wind

Wind farms would have no discernible impacts on air quality. Noise impacts would include aerodynamic noise from the turbine rotor and mechanical noise from turbine drivetrain components.

Noise from offshore wind farms consisting of aerodynamic and mechanical noise from the wind turbine transmitted underwater via the tower could affect marine species, especially those that use echolocation to navigate. Onshore components of offshore wind facilities would affect land animals when located at or near important habitats. Because of water density, noise travels proportionally greater distances under water; thus, the area over which noise impacts may occur would be much greater for offshore wind farms.

Biomass

Air impacts would result from feedstock handling activities (storage, crushing/grinding, loading conveyors, etc.) and combustion. Combustion of biomass generally results in smaller amounts of greenhouse gas (primarily CO_2) than combustion of fossil fuel. For some biomass sources such as energy crops, the amount of CO_2 released during their combustion is roughly equivalent to the amount absorbed by the plants during their growing cycle. Except for greenhouse gas emissions of vehicles and equipment used to plant, cultivate, and harvest, energy crops are considered to be greenhouse gas-neutral with respect to their application in electrical energy production. Conversion to energy of biomass that would otherwise be managed as a solid waste represents a net greenhouse gas “sink” since combustion for energy production avoids the greenhouse gas emissions (primarily methane) that would have resulted from the landfilling and decomposition of such materials. Example criteria pollutant impacts (in lb/MWh; NREL 2003) include:

SO_x	Wood waste burned in stoker boiler	0.08
	Fluidized bed combustion	0.08
	Energy crops combusted in IGCC system	0.05
NO_x	Wood waste burned in stoker boiler	2.1
	Fluidized bed combustion	0.9
	Energy crops combusted in IGCC system	2.2

CO	Wood waste burned in stoker boiler	12.2
	Fluidized bed combustion	0.17
	Energy crops combusted in IGCC system	0.23
PM_{10}	Wood waste burned in stoker boiler	0.50
	Fluidized bed combustion	0.3
	Energy crops combusted in IGCC system	0.01

A 200-MW co-firing wood biomass coal facility (where biomass is 15 percent of the total heat input) operating in 2030 with an 80 percent capacity factor providing 771 GWh/yr electricity would have the following air emissions (EERE 1997):

SO_2 40,544 T/yr (36,200 MT/yr)

CO_2 3,248,224 T/yr (2,900,200 MT/yr)

Noise impacts from biomass combustion facilities would be similar in nature and magnitude to coal-fired plants of equivalent size and capacity.

Municipal Solid Waste, Refuse-Derived Fuel, and Landfill Gas

Air impacts from combustion of refuse-derived fuel would depend on the quality of the fuel. Criteria and hazardous air pollutants could be released if not removed during refuse-derived fuel production. Air pollutants of concern include hydrochloric acid, nitric oxide (NO), sulfuric acid, arsenic, cadmium, chromium (VI), dioxins/furans, various polycyclic aromatic hydrocarbons (PAHs), chlorinated benzenes, dienes, phenols, and polychlorinated biphenyls (PCBs). Air quality could be affected by the release of dioxins and other PAHs from the incomplete combustion of fuel. Noise impacts from municipal solid waste, refuse-derived fuel, and landfill gas combustion facilities would be similar in nature and intensity to coal-fired and natural gas-fired power plants. Noise sources would include municipal solid waste feedstock preparation activities (cutting grinding, etc., to produce a feedstock of uniform size) and pump and compressor noise from the collection and transfer of landfill gas.

Solar Thermal

Dust could be released due to the removal of vegetation. Noise during operations would include mechanical noise from operation of powerblock components (steam cycle and cooling system pumps, turbines, and generators), and pump noise from circulation of heat transfer fluids, cooling tower noise (fans, cascading water).

Solar Photovoltaic

Dust could be released from the plant site due to the removal of vegetation. Individual photovoltaic cells could release toxic heavy metals to the atmosphere (primarily cadmium, selenium, and arsenic) in the event of fire. Virtually no discernible noise or air quality impacts would result from the routine operation of the facility.

Ocean Wave and Current

Air quality would be only minimally affected by facility operation; air quality would be affected by the release of criteria pollutants during periodic inspection, maintenance, and repair; vessels are expected to burn low-sulfur diesel fuel. Onshore air quality would be affected by the release of criteria pollutants from workforce vehicles and the possible release of fugitive dust from onshore support facilities. Mechanical noise from moving parts and hydrodynamic noise from the interaction of turbine blades with water would minimally affect the ambient above-water noise environment; underwater noise sources (primarily turbine blades, mechanical noise from other moving parts, and vessel propellers) could travel great distances and could affect marine organisms, especially those utilizing echolocation.

4.4 Geologic Environment

4.4.1 Environmental Consequences of the Proposed Action—Continued Operations and Refurbishment Activities

Geology and Soils

The impacts on geology and soils during the license renewal term were not considered in the 1996 GEIS. Geologic and soils conditions at all nuclear power plants and associated transmission lines have been well established during the current licensing term. These conditions are expected to remain unchanged during the 20-year license renewal term.

The impact of continued operations and refurbishment associated with license renewal on geologic and soil resources would consist of soil disturbance, including sediment and/or any associated bedrock, for projects, such as replacing or adding buildings, roads, parking lots, and belowground and aboveground utility structures. Implementing BMPs would reduce soil erosion and subsequent impacts on surface water quality. These practices include, but are not limited to, minimizing the amount of disturbed land, stockpiling topsoil before ground disturbance, mulching and seeding in disturbed areas, covering loose materials with geotextiles, using silt fences to reduce sediment loading to surface water, using check dams to minimize the erosive power of drainages, and installing proper culvert outlets to direct flows in streams or drainages.

Detailed geotechnical analyses would be required to address the stability of excavations, foundation footings, and slope cuts for building construction, road creation, or other refurbishment-related construction projects. Depending on the plant location and design, riverbank or coastline protection might need to be upgraded, especially at water intake or discharge structures, if natural flows, such as storm surges, cause an increase in erosion. In addition, the Farmland Protection Policy Act (7 USC 4201 et seq.) requires Federal agencies to take into account agency actions affecting the preservation of farmland including prime and other important farmland soils, as described in Section 3.4. While the Farmland Protection Policy Act could apply in some circumstances at nuclear power plant sites (e.g., development of renewable energy resources as an alternative to license renewal, other projects completed with Federal assistance including funding), it does not apply to Federal permitting or licensing actions for activities on private or non-Federal lands (7 CFR 658.2).

Plant-specific environmental reviews conducted by the NRC to date have not identified any significant impact issues related to geology and soils.

As discussed in Section 3.4, nuclear power plants were originally sited, designed, and licensed in consideration of the geologic and seismic criteria set forth in 10 CFR 100.10(c)(1) and 10 CFR Part 100, Appendix A, and constructed in accordance with 10 CFR Part 50, Appendix A. In its license renewal environmental reviews, the NRC considers the risk to reactors from seismicity in the evaluation of severe accident mitigation alternatives. Where appropriate, seismic issues are also assessed in the site-specific safety review that is performed for license renewals.

Further, the NRC requires all licensees to take seismic activity into account in order to maintain safe operating conditions at all nuclear power plants. When new seismic hazard information becomes available, the NRC evaluates the new information to determine if any changes are needed at existing plants. This reactor oversight process, which includes seismic safety, is separate and distinct from license renewal.

Consequently, the impact of continued operations during the license renewal term and refurbishment activities relative to the geologic environment would be SMALL for all nuclear plants and a Category 1 issue.

4.4.2 Environmental Consequences of Alternatives to the Proposed Action

Construction—For all alternatives (including fossil energy, new nuclear, and renewable alternatives) discussed in this section, the impacts of construction on geology and soils would be similar. Land would be cleared of vegetation during construction. Soils would be stored onsite for redistribution at the end of construction. Land clearing during construction and the installation of power plant structures and impervious pavements would alter surface drainage.

Natural drainage patterns at brownfield sites have been previously altered. Sources of aggregate such as crushed stone and sand and gravel would be required for construction of buildings, foundations, roads, and parking lots.

4.4.2.1 Fossil Energy Alternatives

Operations—Impacts on soil and geologic resources during power plant operations would be limited to the extraction of fossil fuel, typically at existing mining and drilling locations far from the power plant. Surface mining or underground mining for coal would result in various degrees of overburden clearing, soil stockpiling, waste rock disposal, re-routing of drainages, and management of any co-located geologic resources. Eventual mine closure would require proper restoration efforts to reduce the impact of erosion of replaced topsoil. Drilling for petroleum resources would involve clearing and grading for drill pads and construction of underground pipelines with associated soil disturbance. Proper design of surface water crossings would be needed to manage the potential for erosion at these locations.

4.4.2.2 New Nuclear Alternatives

Operations—Impacts on soil and geologic resources during operation would be limited to the extraction of ore material used to make nuclear fuel, typically at existing mining locations far from the power plant. The extraction could involve mining techniques similar to those used for fossil fuels, along with management of ore tailings. An alternative method is solution mining, which would involve the construction of drilling pads, similar to those used for the extraction of petroleum.

4.4.2.3 Renewable Alternatives

Operations—The operational impacts of alternative energy technologies on geology and soils are presented in the following subsections.

Hydroelectric Energy Sources

Geology and soils in the immediate area of a dam and reservoir would be affected by sedimentation in the reservoir basin and changes in upstream and downstream erosion patterns. Dams would induce downstream impacts such as low and high flow conditions, changes in sediment transport and deposition patterns, and channel erosion or scouring.

Geothermal

The injection of cooled geothermal fluids might induce microseismic activity. The removal of large quantities of groundwater could result in land subsidence. The alternative of engineered geothermal systems applied to hot, dry rock resources would avoid the possibility of subsidence.

Biomass

Soils would be affected by contaminants potentially present in runoff from unprotected piles of feedstock materials, fly ash and bottom ash, and scrubber sludge. Farming could result in soil erosion and the release of pesticides and fertilizers to nearby water bodies or to shallow groundwater aquifers.

Solar Thermal and Photovoltaic

This alternative requires a large amount of land. To avoid a fire hazard, solar collection devices would need to be kept free of vegetation. This practice could result in soil erosion in cleared areas by wind and precipitation runoff.

4.5 Water Resources

Hydrologic and water quality conditions at all nuclear power plants and associated transmission lines have been well established during the current licensing term. However, continued operations and refurbishment activities could have an impact on water resources during the license renewal term. This section describes the potential impact of these proposed activities and alternatives to these proposed activities on surface water and groundwater resources.

4.5.1 Environmental Consequences of the Proposed Action—Continued Operations and Refurbishment Activities

Continued operations and refurbishment activities during the license renewal term could affect surface water and groundwater resources in a manner similar to what has occurred during the current license term (see Sections 3.5.1 and 3.5.2, respectively).

4.5.1.1 Surface Water Resources

For the most part, no significant surface water impacts are anticipated during the license renewal term that would be different from those occurring during the current license term. Certain operational changes (such as a power uprate) affecting surface water would be evaluated by the NRC in a separate environmental assessment. For potential impacts to water resources, the use of surface water is of greatest concern because of the high volumetric flow rates required for condenser cooling at power plants. Withdrawals from surface water bodies are high for both once-through and closed-cycle cooling systems. Consumptive water use occurs through evaporation and drift, especially from cooling towers, and may affect water availability downstream from plants along rivers. Associated impacts on surface water quality may result from the discharge of thermal effluent containing chemical additives. Other potential impacts on surface water are the result of normal industrial plant activities during the license renewal term.

The following issues concern impacts on surface water that may occur during the license renewal term:

- Surface water use and quality (non-cooling system impacts) (consolidation and expansion of two issues evaluated in the 1996 GEIS: (1) impacts of refurbishment on surface water quality and (2) impacts of refurbishment on surface water use);
- Altered current patterns at intake and discharge structures (evaluated in the 1996 GEIS);
- Altered salinity gradients (evaluated in the 1996 GEIS);
- Altered thermal stratification of lakes (evaluated in the 1996 GEIS);
- Scouring caused by discharged cooling water (evaluated in the 1996 GEIS);
- Discharge of metals in cooling system effluent (evaluated in the 1996 GEIS);
- Discharge of biocides, sanitary wastes, and minor chemical spills (consolidation of two issues evaluated in the 1996 GEIS: (1) discharge of chlorine or other biocides and (2) discharge of sanitary wastes and minor chemical spills);
- Surface water use conflicts (plants with once-through cooling systems) (evaluated in the 1996 GEIS);
- Surface water use conflicts (plants with cooling ponds or cooling towers using makeup water from a river) (issue was modified from the 1996 GEIS to include all rivers);
- Effects of dredging on surface water quality (new issue not considered in the 1996 GEIS); and
- Temperature effects on sediment transport capacity (evaluated in the 1996 GEIS).

Surface Water Use and Quality (Non-Cooling System Impacts)

This issue is a consolidation and expansion of two 1996 GEIS issues (impacts of refurbishment on surface water quality and impacts of refurbishment on surface water use). Continued operations and refurbishment activities could result in the degradation of water quality within the receiving watershed. Power plant sites and land-disturbing activities can increase the variety and quantity of pollutants entering receiving water bodies such as streams, rivers, and lakes. Pollutants within stormwater runoff from plant sites can include suspended sediment; pesticides and nutrients from landscaped areas; oil, grease, and toxic chemicals from motor vehicles; spills of hydrocarbon fuels; paints; road salts; heavy metals from roof shingles and motor vehicles; and thermal pollution from impervious surfaces. These pollutants could potentially harm aquatic and terrestrial species, contaminate recreational areas, and degrade drinking water supplies.

In an effort to minimize or eliminate impacts to the water quality of receiving water bodies, BMPs are typically included as conditions within NPDES permits. BMPs are measures used to control the adverse stormwater-related effects of land disturbance and development. They include structural devices designed to remove pollutants, reduce runoff rates and volumes, and protect aquatic habitats. BMPs also include nonstructural or administrative approaches, such as training to educate staff on the proper handling and disposal of potential pollutants.

Permanent BMPs are designed to control pollutants to the maximum extent practicable during continued operations of the power plant. Extended detention and infiltration basins are examples of pollutant removal features designed to remove pollutants based on volume. Hydrodynamic separator systems (hydrodynamic devices, baffle boxes, swirl concentrators, or cyclone separators) and other devices are examples of pollutant removal devices that are typically designed based on flow rate.

Refurbishment activities involving construction-related land disturbance are expected to be managed by an approved Stormwater Pollution Prevention Plan (SWPPP). The SWPPP would indicate the structural and non-structural BMPs that must be implemented for the duration of the refurbishment activity. Examples of construction BMPs include use of sediment (silt) fences, check dams, staked hay bales, sediment ponds, and mulching and geotextile matting of disturbed areas.

BMPs and conformance to plant site NPDES permits, encompassing those covering stormwater discharges associated with construction and industrial activity, are expected to be followed during continued operations and refurbishment activities. Implementation of spill prevention and control plans would further reduce the likelihood of any liquid chemical spills.

Continued operations and refurbishment activities will require water for non-cooling-related purposes, including some consumptive use (i.e., water that is used but not returned to the source and effectively lost). The water source is dependent on the nuclear power plant site, water availability, and the nature of any refurbishment activities. Typical water sources at nuclear plants are surface water, groundwater, and public domestic (potable) water.

Water may be used during refurbishment activities for concrete production, dust control, washing stations, facility and equipment cleaning, and soil compaction and excavation backfilling. However, the impacts due to the volume of water consumed from a surface water source would be insignificant when compared with that used and consumed by a plant's cooling system.

The use of groundwater for non-cooling system uses would have a similar, minimal impact on the surface water source as a direct surface water withdrawal, assuming an interconnection between the groundwater source and surface water body. Groundwater withdrawal near a water body with a disconnected groundwater table would have no effect on the surface water resource.

The use of public domestic water would reduce the direct consumptive use impacts on surface water resources. Still, domestic water runoff and water main breaks have the potential to introduce an additional pollutant (residual chlorine), which could impact water quality. It is expected that such occurrences would be rare and would be identified and corrected as piped domestic water is metered at the point of interconnection with a plant's water distribution system. Any such occurrences are not expected to present a significant water quality concern over the license renewal term.

Surface water consumption for non-cooling water-related operational activities is anticipated to be negligible and limited to such uses as facility and equipment cleaning. As a result, no surface use conflicts would be expected.

The impacts of refurbishment on surface water use and quality during the license renewal term were considered to be SMALL for all plants and were designated as Category 1 issues in the 1996 GEIS, and non-cooling system operational impacts on water use and quality are expected to be SMALL, as described above. In addition, if refurbishment took place during a reactor shutdown, the overall water use by the facility would be greatly reduced. No new information in plant-specific SEISs or associated literature has been identified that would change this conclusion. On the basis of these considerations, the non-cooling system impacts of continued operations and refurbishment activities on surface water resources would be SMALL for all nuclear plants. This is a Category 1 issue.

Altered Current Patterns at Intake and Discharge Structures

The large flow rates associated with cooling system water use have the potential to alter current patterns. The degree of influence depends on the design and location of the intake and discharge structures and the characteristics of the surface water body. The effect on currents near the intake and discharge locations is expected to be localized, and any problems would have been mitigated during the early operational period of a plant (NRC 1996). Most nuclear power plants are sited on large bodies of water to make use of the water for cooling purposes. The size of large rivers, lakes, or reservoirs precludes significant current alterations except in the vicinity of the structures. For ocean shore or bay settings, the effect is further reduced when compared with the strong natural water movement patterns. For example, current patterns have been modified at the Oyster Creek plant, which is located inland from Barnegat Bay in New Jersey. The once-through cooling system for this plant was created by modifying two small rivers originally flowing parallel into the bay. On the north side of the plant, the South Branch of the Forked River was enlarged between the plant and the bay to serve as an intake canal. On the south side of the plant, Oyster Creek was enlarged between the plant and the bay for use as a discharge canal. Near the plant, the two waterways were joined. Bay water is pulled from the bay through the intake canal to the plant, against the original flow direction of the lowest reach of the South Branch of the Forked River. Flow at the mouth of this river is therefore both reversed and significantly increased, while flow at the mouth of the Oyster Creek discharge canal is significantly increased. While current patterns in Barnegat Bay in the immediate vicinity of the intake and discharge canals are affected by operations, the effect is minor on the overall Barnegat Bay system (NRC 1996, 2007b).

This issue has no relevance to plants relying on cooling ponds because they are man-made features without natural currents.

Impacts from altered current patterns at intake and discharge structures during the license renewal term were considered to be SMALL for all plants and were designated as a Category 1 issue in the 1996 GEIS. No new information has been identified in plant-specific SEISs or associated literature that would change this conclusion. On the basis of these considerations, the impact of altered current patterns at intake and discharge structures would be SMALL for all nuclear plants and remains a Category 1 issue.

Altered Salinity Gradients

This issue relates to plants located on estuaries and addresses changes in salinity caused by cooling system water withdrawals and discharges. Using the same example site as for the current patterns issue, the Oyster Creek plant's construction included modification of the lower reaches of two creeks. These portions of the creeks were originally brackish, with a mix of freshwater from their upper reaches and tidally influenced bay water. Because of the cooling system operations, the water quality of these lower reaches now essentially matches that of Barnegat Bay, with contributions of freshwater from their upper reaches being relatively minor. These lower reaches are also affected by occasional dredging activities, and the discharge canal receives water to which heat and chemicals have been added. The salinity changes do not affect the upper portions of these streams. In the 1996 GEIS, only minor effects had been noted in Barnegat Bay.

As documented in the 1996 GEIS and Calvert Cliffs SEIS (NRC 1999b), the NRC found that the Calvert Cliffs plant on the Chesapeake Bay has not had significant effects on bay salinity. Altered salinity gradients are expected to be noticeable only in the immediate vicinity of intake and discharge structures.

Impacts from altered salinity gradients at intake and discharge structures during the license renewal term were considered to be SMALL for all plants and were designated as Category 1 issues in the 1996 GEIS. No new information has been identified in plant-specific SEISs or associated literature that would alter this conclusion. On the basis of these considerations, the impact of altered salinity gradients would be SMALL for all nuclear plants and remains a Category 1 issue.

Altered Thermal Stratification of Lakes

Because cooling systems typically withdraw from the deeper, cooler portion of the water column of lakes or reservoirs and discharge to the surface, they have the ability to alter the thermal stratification of the surface water. This is not considered an issue for rivers or oceans because of mixing caused by natural turbulence.

A thermal plume of discharge water loses heat to the atmosphere and to the receiving surface water body. It also undergoes mixing with the surface water. In the 1996 GEIS, examples included the Oconee plant in South Carolina, where the withdrawal of cool, deep water for cooling purposes favors warmwater fish species at the expense of coolwater fish. Mitigation of this effect is possible by modifying the allowable discharge water temperature. In an example from the McGuire power plant in North Carolina, a modeling study indicated that increasing the permitted discharge temperature would reduce the withdrawal of cool, deep water and conserve coolwater species habitat.

Thermal plumes may be studied through field measurements and modeling studies. For plants on lakes or reservoirs, the thermal effect on stratification is examined periodically through the National Pollutant Discharge Elimination System (NPDES) permit renewal process. Problems with thermal stratification due to nuclear power plant operations have not been encountered.

Impacts from altered thermal stratification of lakes and reservoirs during the license renewal term were considered to be SMALL for all plants and were designated as Category 1 issues in the 1996 GEIS. No new information has been identified in plant-specific SEISs or associated literature that would alter this conclusion. On the basis of these considerations, the impact of altered thermal stratification of lakes would be SMALL for all nuclear plants and remains a Category 1 issue.

Scouring Caused by Discharged Cooling Water

The high flow rate of water from a cooling system discharge structure has the potential to scour sediments and redeposit them elsewhere. The scouring will remove fine-grained sediments, resulting in turbidity, and leave behind coarse-grained sediments.

The degree of scouring depends on the design of the discharge structure and the character of the sediments. Scouring is expected to occur only in the vicinity of the discharge structure where flow rates are high. While scouring is possible during reactor startup, operational periods would typically have negligible scouring. Natural sediment transport processes could bring fresh sediment into the discharge flow area. These processes include transport due to ocean currents, tides, river meandering, and storm events.

In the 1996 GEIS, scouring had not been noted as a problem at most plants and had been observed at only three nuclear power plants (Calvert Cliffs, Connecticut Yankee [no longer operating], and San Onofre). The effects at these plants were localized and minor.

Impacts from scouring caused by discharged cooling water during the license renewal term were considered to be SMALL for all plants and were designated as a Category 1 issue in the 1996 GEIS. No new information has been identified in plant-specific SEISs or associated literature that would alter this conclusion. On the basis of these considerations, the impact of scouring caused by discharged cooling water is SMALL for all nuclear plants and remains a Category 1 issue.

Discharge of Metals in Cooling System Effluent

Heavy metals such as copper, zinc, and chromium can be leached from condenser tubing and other components of the heat exchange system by circulating cooling water. These metals are normally addressed in NPDES permits because high concentrations of them can be toxic to aquatic organisms. During normal operations, concentrations are normally below laboratory detection levels. However, plants occasionally undergo planned outages for refueling, with stagnant water remaining in the heat exchange system. During an outage at the Diablo Canyon plant in California, the longer residence time of water in the cooling system resulted in elevated copper levels in the discharge when operations resumed; abalone (*Haliotis* spp.) deaths were attributed to the increased copper (NRC 1996). At the Robinson plant in South Carolina, the gradual accumulation of copper in its reservoir resulted in impacts on the bluegill (*Lepomis macrochirus*) population. In both cases, copper condenser tubes were replaced with titanium ones, and the problem was eliminated (NRC 1996). Impacts from the discharge of metals in cooling system effluent during the license renewal term were considered to be SMALL for all plants and were designated as a Category 1 issue in the 1996 GEIS. No new information has been identified in plant-specific SEISs or associated literature that would alter this conclusion. On the basis of these considerations, the impact of the discharge of metals in cooling system effluent would be SMALL for all nuclear plants and remains a Category 1 issue.

Discharge of Biocides, Sanitary Wastes, and Minor Chemical Spills

The use of biocides is common and is required to control biofouling and nuisance organisms in plant cooling systems. However, the types of chemicals, their amounts or concentrations, and the frequency of their use may vary. The use of biocides at nuclear power plants was discussed generally in Section 3.5.1. Ultimately, any biocides used in the cooling system are discharged to surface water bodies. The discharge of treated sanitary waste also occurs at plants. Discharge may occur via onsite wastewater treatment facilities, via an onsite septic field, or through a connection to a municipal sewage system. Minor chemical spills collected in floor drains are associated with industry in general and are a possibility at all plants. Each of these factors represents a potential impact on surface water quality. In the 1996 GEIS, the impacts of these releases were evaluated as two issues: (1) discharge of chlorine or other biocides and (2) discharge of sanitary wastes and minor chemical spills. Here they are treated as a single issue.

Discharges of cooling water and other plant wastewaters are monitored through the NPDES program administered by the EPA, or, where delegated, individual States. The NPDES permit contains requirements that limit the flow rates and pollutant concentrations that may be discharged at permitted outfalls. The permit may also include biological monitoring parameters that are primarily associated with the discharge of cooling water. Wastewater discharge is also covered through NPDES permitting, and it includes biochemical monitoring parameters. Discharge from building drains is also addressed in the NPDES permit. Because of Federal or State regulatory involvement, and because regulatory and resource agencies have not found significant problems with outfall monitoring, the impacts from the discharge of chlorine and other biocides and minor spills of sanitary wastes and chemicals during license renewal and refurbishment were considered to be SMALL for all plants and designated as Category 1 issues in the 1996 GEIS. No new information has been identified in plant-specific SEISs or associated literature that would alter this conclusion. On the basis of these considerations, the discharge of biocides, sanitary wastes, and minor chemical spills would be SMALL for all nuclear plants and remains a Category 1 issue.

Surface Water Use Conflicts (Plants with Once-Through Cooling Systems)

Nuclear power plant cooling systems may compete with other users relying on surface water resources, including downstream municipal, agricultural, or industrial users. Once-through and closed-cycle cooling systems have different water consumption rates. Once-through cooling systems return most of their withdrawn water to the same surface water body, with evaporative losses of less than 3 percent (Solley et al. 1998). Consumptive use by plants with once-through cooling systems during the license renewal term is not expected to change unless power uprates, with associated increases in water use, are proposed. Such uprates would require an environmental assessment by the NRC.

Future scenarios for water availability focus on climate change and associated changes in precipitation and temperature patterns. Increased temperatures and/or decreased rainfall would result in lower river flows, increased cooling pond evaporation, and lowered water levels in the Great Lakes or reservoirs. While weather will vary from year to year, the results of climate change models and the projected changes to surface water runoff in the 21st century (NETL 2006) predicted increases in runoff in the eastern United States and decreases in runoff in the western United States, where water is currently less available. Regardless of overall climate change, droughts could result in problems with water supplies and allocations. Because future agricultural, municipal, and industrial users would continue to share their demands for surface water with power plants, conflicts might arise if the availability of this resource decreased. This situation would then necessitate decisions by local, State, and regional water planning officials.

Population growth around nuclear power plants has caused increased demand on municipal water systems, including systems that rely on surface water. Municipal intakes located downstream of a nuclear power plant could experience water shortages, especially in times of drought. Water demands upstream of a plant could impact the water availability at the plant's intake.

In the 1996 GEIS, impacts of continued operations and refurbishment on water use conflicts associated with once-through cooling systems were considered to be SMALL and were designated as a Category 1 issue. No new information has been identified in plant-specific SEISs or associated literature that would alter this conclusion. On the basis of these considerations, the NRC concludes that the impact on water use conflicts from the continued operation and refurbishment activities would be SMALL for plants that utilize once-through cooling and remains a Category 1 issue.

Surface Water Use Conflicts (Plants with Cooling Ponds or Cooling Towers Using Makeup Water from a River)

Nuclear power plant cooling systems may compete with other users relying on surface water resources, including downstream municipal, agricultural, or industrial users. Closed-cycle cooling is not completely closed, because the system discharges blowdown water to a surface water body and withdraws water for makeup of both the consumptive water loss due to evaporation and drift (for cooling towers) and blowdown discharge. For plants using cooling towers, the makeup water needed to replenish the consumptive loss of water to evaporation can be significant and is reported at 60 percent or more of the condenser flow rate by Solley et al. (1998). Cooling ponds will also require makeup water as a result of naturally occurring evaporation, evaporation of the warm effluent, and possible seepage to groundwater.

Consumptive use by plants with cooling ponds or cooling towers using makeup water from a river during the license renewal term is not expected to change unless power uprates, with associated increases in water use, are proposed. Such uprates would require an environmental assessment by the NRC. In the 1996 GEIS, application of this issue applied only to rivers with low flow[a] so as to define the difference between plants located on "small" versus "large" rivers. However, any river, regardless of size, can experience low flow conditions of varying severity during periods of drought and changing conditions in the affected watershed such as upstream diversions and use of river water. NRC has subsequently determined that use of the term "low flow" in categorizing river flow is of little value considering that all rivers can experience low flow conditions.

Further and as stated earlier, increased temperatures and/or decreased rainfall would result in lower river flows, increased cooling pond evaporation, and lowered water levels in the Great Lakes or reservoirs. Regardless of overall climate change, droughts could result in problems with water supplies and allocations. Conflicts might arise due to competing agricultural, municipal, and industrial user demands for surface water with power plants. Closed cooling systems are more susceptible to these issues than once-through cooling systems because they consume more water. For this reason, climate change is more of a potential concern for water use conflicts among closed systems.

Population growth around nuclear power plants has caused increased demand on municipal water systems, including systems that rely on surface water. Municipal intakes located downstream from a nuclear power plant could experience water shortages, especially in times of drought. Similarly, water demands upstream from a plant could impact the water availability at the plant's intake.

(a) A river with low flow was previously defined in 10 CFR 51.53(c)(3)(ii)(A) and in the 1996 GEIS as one with an annual flow rate that is less than 3.15×10^{12} ft^3/yr (9×10^{10} m^3/yr).

As discussed in the 1996 GEIS, water use conflicts have also been observed for plants with closed-cycle cooling systems. The Limerick plant on the Schuylkill River in Pennsylvania is cited as an example of a plant on which limits were imposed on the rate of withdrawal from a river for the purpose of avoiding water use conflicts, including downstream water availability and water quality. Availability problems for downstream habitat and users may be anticipated at other plants.

Water use conflicts associated with plants with cooling ponds or cooling towers using makeup water from a river with low flow were considered to vary among sites because of differing site-specific factors, such as makeup water requirements, water availability (especially in terms of varying river flow rates), changing or anticipated changes in population distributions, or changes in agricultural or industrial demands. No new information has been identified in plant-specific SEISs or associated literature has been identified that would alter this conclusion.

On the basis of these considerations, the impact of water use conflicts from the continued operation of nuclear power plants with cooling ponds or cooling towers using makeup water from a river could be SMALL or MODERATE, depending on factors such as plant-specific design characteristics affecting consumptive water use, the characteristics of the water body serving as the source for makeup water, and the amount of competing use for that water. Because the impact could vary among nuclear plants, the issue continues to be Category 2.

Effects of Dredging on Surface Water Quality

Dredging in the vicinity of surface water intakes, canals, and discharge structures takes place in order to remove deposited sediment and maintain the function of plant cooling systems. Dredging may also be needed to maintain barge shipping lanes. Whether accomplished by mechanical, suction, or other methods, dredging disturbs sediments in the surface water body and affects surface water quality by temporarily increasing the turbidity of the water column. In areas affected by industries, dredging can also mobilize heavy metals, PCBs, or other contaminants in the sediments.

The frequency of dredging depends on the rate of sedimentation. At the Oyster Creek plant in New Jersey, dredging took place during site construction to create canals for the once-through cooling system (NRC 2007b). Depth measurements are performed there every two years, and dredging has taken place on portions of the canal system since construction. At the Susquehanna plant in Pennsylvania, the plant’s river intake and diffuser pipe are dredged annually (NRC 2008b).

In general, maintenance dredging affects localized areas for a brief period of time. Dredging operations are performed under permits issued by the U.S. Army Corps of Engineers (USACE), and possibly from State or local agencies. The physical alteration of water bodies is regulated by Federal and State statutes under Section 401 (Certification) and Section 404 (Permits) of the Clean Water Act. The USACE regulates the discharge of dredged and/or fill material under Section 404, while Section 401 requires the applicant for a Section 404 permit to also obtain a Water Quality Certification from the State in order to confirm that the discharge of fill materials will be in compliance with applicable State water quality standards. If dredging could affect threatened or endangered species or critical habitat, as established under the Endangered Species Act, the USACE must consult with the U.S. Fish and Wildlife Service or the National Marine Fisheries Service (NMFS) before it makes a permit decision. In issuing a Section 404 permit, the USACE also considers other potential impacts on aquatic resources, archaeological resources, Tribal concerns, and the permitting requirements of State and local agencies. The permitting process may include planning for the sampling and disposal of the dredged sediments.

The impact of dredging has not been found to be a problem at operating nuclear power plants. Dredging has localized effects on water quality that tend to be short-lived. The impact of dredging on water quality would be SMALL for all nuclear plants and is considered a Category 1 issue.

Temperature Effects on Sediment Transport Capacity

Increased temperature and the resulting decreased viscosity have been hypothesized to change the sediment transport capacity of water, leading to potential sedimentation problems, altered turbidity of rivers, and changes in riverbed configuration. Coutant (1981) discussed the theoretical basis for such possible changes, as well as relevant field investigations, and concluded that there is no indication that this is a significant problem at operating power stations. Examples of altered sediment characteristics are more likely the result of power plant structures (e.g., jetties or canals) or current patterns near intakes and discharges; such alterations are readily mitigated.

Based on review of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and public comments on previous license renewal reviews, there is no evidence that temperature effects on sediment transport capacity have caused adverse environmental effects at any existing nuclear power plant. Regulatory agencies have expressed no concerns regarding the impacts of temperature on sediment transport capacity. Furthermore, because of the small area near a nuclear power plant affected by increased water temperature, it is not expected that plant operations would have a significant impact. Effects are considered to be of SMALL significance for all plants. No change in the operation of the cooling system is expected during the license renewal term so no change in effects on sediment transport capacity is anticipated. This issue remains Category 1.

4.5.1.2 Groundwater Resources

Operational activities during the license renewal term would be similar to those occurring during the current license term. The impact issues of concern are availability of groundwater and the effect of nuclear plant operations on groundwater quality.

The following eight issues concern impacts on groundwater that may occur during the license renewal term:

- Groundwater contamination and use (non-cooling system impacts) (issue was modified and expanded from the 1996 GEIS issue, “Impacts of refurbishment on groundwater use and quality,” to include the impacts of continued operations including potential groundwater contamination);

- Groundwater use conflicts (plants that withdraw less than 100 gallons per minute [gpm]) (evaluated in the 1996 GEIS);

- Groundwater use conflicts (plants that withdraw more than 100 gallons per minute [gpm]) (consolidation of two issues from the 1996 GEIS: (1) groundwater use conflicts (potable and service water and dewatering; plants that use >100 gpm) and (2) groundwater use conflicts (Ranney wells));

- Groundwater use conflicts (plants with closed-cycle cooling systems that withdraw makeup water from a river) (issue was modified from the 1996 GEIS to include all rivers);

- Groundwater quality degradation resulting from water withdrawals (consolidation of two issues from the 1996 GEIS: (1) groundwater quality degradation (Ranney wells) and (2) groundwater quality degradation (saltwater intrusion));

- Groundwater quality degradation (plants with cooling ponds in salt marshes) (evaluated in the 1996 GEIS);

- Groundwater quality degradation (plants with cooling ponds at inland sites) (evaluated in the 1996 GEIS); and

- Radionuclides released to groundwater (new issue not considered in the 1996 GEIS).

Groundwater Contamination and Use (Non-Cooling System Impacts)

This renamed issue is an expansion of the issue "Impacts of refurbishment on groundwater use and quality" from the 1996 GEIS with the addition of the impacts of industrial activities associated with continued operations on groundwater use and quality.

As mentioned in Section 3.5.2, the original construction of some plants required dewatering of a shallow aquifer, and operational dewatering takes place at some plants including for groundwater contaminant plume control. This is accomplished by systems of pumping wells or drain tiles. Continued operations and refurbishment activities during the license renewal term are not expected to require any significant dewatering that would have an incremental effect on groundwater availability over that which has already taken place. Such dewatering impacts are expected to remain SMALL and confined to the boundaries of operating plants.

In the 1996 GEIS, the groundwater impacts associated with refurbishment activities were considered to be SMALL for all nuclear plants. No new information has been identified in plant-specific SEISs or associated literature that would alter this conclusion.

The contamination of groundwater and soil can result from general industrial practices at any site and is not limited to those occurring at nuclear power plants. Such industrial practices can be evaluated generically, as they are common to industrial facilities and nuclear power plants. Activities that result in contamination may include the use of solvents, hydrocarbon fuels (diesel and gasoline), heavy metals, or other chemicals. These materials all have the potential to affect groundwater and soil if released. Furthermore, contaminants present in the soil can act as long-term sources of contamination to underlying groundwater depending on the severity of the spill.

Based on previous plant-specific reviews, these types of groundwater and soil contamination problems have occurred at some operating plants. Release of contaminants into groundwater and soil degrades the quality of these resources, even if applicable groundwater quality standards are not exceeded. This includes *de minimis* quantities of contaminants that do not typically require reporting to regulatory agencies because they are below applicable threshold quantities and/or have been promptly remediated and would not otherwise pose a long-term threat to human health and the environment.

Examples of the types of contamination that may be present at a plant include hydrocarbon leaks or spills at a storage tank, leaked or spilled solvents from barrels, and a hydraulic oil line break (NRC 2006d), thallium in soil at a seepage pit, heavy metals in soil at a sand blasting site, a diesel fuel line leak, methyl tertiary butyl ether (MTBE) from spills of a gasoline storage tank, PCBs in soil as a result of former dielectric fluid use (NRC 2007b), and hydrocarbon spills and sulphuric acid leaks (NRC 2008b). These situations have required regulatory involvement by State agencies during both monitoring and remediation phases. Remediation has taken place in the form of excavation and recovery wells. In these instances, all contamination was either remediated with no further action required by regulatory agencies or has been confined to the plant site with remediation continuing, as with the ongoing recovery of diesel fuel at the Oyster Creek plant. Nevertheless, the number of occurrences of such problems can be minimized by means of proper chemical storage, secondary containment, and leak detection equipment. In addition, nuclear plants have their own programs for handling chemicals, waste, and other hazardous and toxic materials in accordance with Federal and State regulations and permits generally require the use of BMPs to prevent releases to the environment. Continued implementation of such programs and procedures such as pollution and spill prevention and control plans including BMPs (e.g., good housekeeping of the plant site, preventive maintenance, routine inspections, etc.) would reduce the likelihood of any inadvertent releases to soils and/or groundwater.

An additional source of groundwater contamination can be the use of wastewater ponds or lagoons. At the Cook plant in Michigan, permitted wastewater ponds are used for receiving treated sanitary wastewater and for process wastes from the turbine room sump. Groundwater monitoring has shown that concentrations of water quality parameters have increased to levels above background but below drinking water standards (NRC 2005a). As a result, in an arrangement with the county, the use of groundwater by other users in a designated area has been restricted with the affected groundwater limited to the southwestern portion of the plant property.

Contaminants in wastewater disposal ponds and lagoons, whether lined or unlined, at a plant have the potential to enter groundwater and soils. However, the use of wastewater disposal ponds and lagoons is subject to discharge authorizations under National Pollutant Discharge Elimination System (NPDES) and State wastewater discharge permit programs and monitoring.

Remediation of groundwater contamination can involve long-duration cleanup processes that depend on the types, properties, and concentrations of the contaminants; aquifer properties; groundwater flow field characteristics; and remedial objectives. Contaminants may be able to migrate to onsite potable wells or to the wells of offsite groundwater users. Groundwater monitoring programs, including monitoring of onsite drinking water quality in accordance with safe drinking water regulations, would be expected to identify problems before contaminated groundwater reached receptors; however, monitoring wells need to be present and in proper locations in order to detect contaminants.

On the basis of these considerations, the impact of continued operations during the renewal period and refurbishment activities on groundwater use would be SMALL for all nuclear plants. Further, the impact of plant industrial practices and their impact on groundwater quality associated with continued operations and refurbishment activities would continue to be SMALL. This issue is considered Category 1.

Groundwater Use Conflicts (Plants That Withdraw Less Than 100 Gallons per Minute [gpm])

Water wells are commonly used at sites to provide water for the potable water system, although municipal water is available at some nuclear plants. Groundwater may also be used for landscaping (see Section 3.5.2). At some sites, groundwater is the source for the makeup and service water systems. In this case, the water undergoes treatment to prepare it for the intended use.

The pumping of groundwater creates a cone of depression in the potentiometric surface around the pumping well. The amount the water table or potentiometric surface declines and the overall extent of the cone depend on the pumping rate, characteristics of the aquifer (e.g., its permeability), whether the aquifer is confined or unconfined, and certain boundary conditions (including the nearby presence of a hydrologically connected surface water body). Generally, plants with a peak withdrawal rate of less than 100 gpm (378 L/min) do not have a significant cone of depression. Their potential for causing conflict with other groundwater users would depend largely on the proximity of the other wells. As stated in the 1996 GEIS, cones of depression usually do not extend past the property boundary, reducing the possibility of a groundwater use conflict.

In the 1996 GEIS, the groundwater impacts associated with continued operations during the license renewal term were considered to be SMALL for all nuclear plants and designated as Category 1. No new information has been identified in plant-specific SEISs or associated literature that would alter this conclusion. On the basis of these considerations, the impact on groundwater use conflicts from continued operations during the license renewal term for all nuclear plants that withdraw less than 100 gpm (378 L/min) would be SMALL and remains a Category 1 issue.

Groundwater Use Conflicts (Plants That Withdraw More Than 100 Gallons per Minute [gpm])

This issue is a consolidation of two issues in the 1996 GEIS: (1) groundwater use conflicts (potable and service water and dewatering; plants that use >100 gpm) and (2) groundwater use conflicts (Ranney wells).

Nuclear power plants withdraw groundwater for various purposes. Most plants use groundwater to supply their potable water and service water needs. In some cases, groundwater is pumped to intentionally lower high water tables. At the Grand Gulf plant in Mississippi, Ranney wells in the Mississippi River alluvium are used to provide cooling system makeup water (see Section 3.5.2).

As described in the section above, the pumping of groundwater is expected to create a cone of depression around the well, with the degree of aquifer dewatering dependent on various factors. A nuclear plant may have several wells, with combined pumping in excess of 100 gpm (378 L/min). Overall site pumping rates of this magnitude have the potential to create conflicts with other local groundwater users if the cone of depression extends to the offsite well(s). Large offsite pumping rates for municipal, industrial, or agricultural purposes may, in turn, lower the water level at power plant wells. For any user, allocation is normally determined though a State-issued permit.

Groundwater use conflicts have not been observed at any nuclear power plants, and no significant change in water well systems is expected over the license renewal term. If a conflict did occur, it might be possible to resolve it if the power plant relocated its well or wellfield to a different part of the property. The siting of new wells would be determined through a hydrogeologic assessment.

In the 1996 GEIS, groundwater use conflicts were considered for plants that withdraw more than 100 gpm (378 L/min) or plants that use Ranney wells. The NRC concluded that the impacts of continued operations and refurbishment would not necessarily be the same at all nuclear plant sites (i.e., a Category 2 issue) because of site-specific factors (e.g., well pump rates, well locations, and hydrogeologic factors) and that the impacts could be SMALL, MODERATE, or LARGE. No new information has been identified in plant-specific SEISs or associated literature that would alter this conclusion. On the basis of these considerations, groundwater use conflicts for plants that withdraw more than 100 gpm (378 L/min) could be SMALL, MODERATE, or LARGE, depending on the plant-specific characteristics described above and remains a Category 2 issue.

Groundwater Use Conflicts (Plants with Closed-Cycle Cooling Systems That Withdraw Makeup Water from a River)

In the case of plants with cooling towers or cooling ponds that rely on a river for makeup of consumed (evaporated) cooling water, it is possible water withdrawals from the river could lead to groundwater use conflicts with other users. This situation could occur because of the interaction between groundwater and surface water, especially in the setting of an alluvial aquifer in a river valley. Consumptive use of the river water, if significant enough to lower the river’s water level, would also influence water levels in the alluvial aquifer. Shallow wells of nearby groundwater users could therefore have reduced water availability or go dry. During times of drought, the effect would be occurring naturally, although withdrawals for makeup water would increase the effect. In the 1996 GEIS, a situation at the Duane Arnold plant in Iowa was described in which a reservoir on a small tributary is used as a secondary supply of makeup water for the plant’s cooling towers. During low-flow conditions in the plant’s usual source of water, the Cedar River, the plant is not allowed to withdraw river water. Instead, it uses the reservoir temporarily. Because the high rate of water usage can lower the water level in the reservoir significantly, local users of shallow groundwater may be affected. As described for other issues above, this situation is highly dependent on the area's hydrogeologic framework and the locations, depths, and pump rates of wells, in addition to the amount that the surface water level declines.

In the 1996 GEIS, groundwater use conflicts were evaluated for plants that use cooling towers withdrawing makeup water from a river during continued operations and refurbishment. NRC found that conflicts would not necessarily be the same at all nuclear plant sites because of site-specific factors (e.g., the amount of surface water decline, well pump rates, well locations, and hydrogeologic factors). The resulting impact could be SMALL, MODERATE, or LARGE. Therefore, this issue was considered Category 2. No new information has been identified in plant-specific SEISs or associated literature that would alter this conclusion. On the basis of these considerations, groundwater use conflicts for nuclear plants that use closed-cycle cooling systems that withdraw makeup water from a river could have SMALL, MODERATE, or LARGE impacts depending on the plant-specific characteristics of surrounding areas described above and remains a Category 2 issue.

Groundwater Quality Degradation Resulting from Water Withdrawals

This issue is a consolidation of two related issues in the 1996 GEIS: (1) groundwater quality degradation (Ranney wells) and (2) groundwater quality degradation (saltwater intrusion). These two issues both consider the possibility of groundwater quality becoming degraded as a result of drawing water of potentially lower quality into an aquifer. For this reason, they are discussed here as a single issue.

A well near a river may draw lower-quality river water into the aquifer as a function of the interaction between groundwater and surface water. An example of Ranney wells (see Section 3.5.2) at the Grand Gulf plant in Mississippi causing induced infiltration of Mississippi River water into the alluvial aquifer was discussed in the 1996 GEIS. While site-specific hydrogeologic factors and well design may provide some control on the flow of surface water to the well, the bulk of the groundwater pumped by a well in an alluvial aquifer near a river is expected to be induced surface water, with a smaller component of groundwater from the direction opposite the river. If well pumping is continuous, the only portion of the shallow aquifer significantly affected by induced infiltration remains in the capture zone of the well(s). Therefore, the portion of the aquifer with water quality parameters approaching those of the river water would usually be located on the power plant's property.

Wells in a coastal setting (e.g., ocean shore or estuary) have the potential to cause saltwater intrusion into the aquifer. This water quality problem is a common concern for large pumping centers associated with municipal or industrial users. The degree of saltwater intrusion depends on the cumulative pumping rates of wells, their screen depths, and hydrogeologic conditions. Deep, confined aquifers, for example, may be separated from saline aquifers closer to the surface. However, as evaluated in the 1996 GEIS, the potential for inducing saltwater intrusion was considered to be of SMALL significance at all sites because groundwater consumption from confined aquifers for potable and service water uses by nuclear power plants is a small fraction of groundwater use in all cases. Where saltwater intrusion has been a problem, the large users have been for agricultural (irrigation) and municipal water supply uses.

Impacts related to groundwater quality degradation for nuclear plants that use Ranney wells and groundwater quality degradation (saltwater intrusion) were designated as Category 1 issues in the 1996 GEIS. No new information has been identified in plant-specific SEISs or associated literature that would alter this conclusion. On the basis of these considerations, groundwater quality degradation resulting from water withdrawals would be SMALL for all nuclear plants and remains a Category 1 issue.

Groundwater Quality Degradation (Plants with Cooling Ponds in Salt Marshes)

Nuclear plants that use cooling ponds as part of their cooling water system discharge effluent to the pond. The effluent's concentration of contaminants and other solids increases relative to that of the makeup water as it passes through the cooling system. These changes include increased total dissolved solids (or TDS), since they concentrate as a result of evaporation, increased heavy metals (because cooling water contacts the cooling system components), and increased chemical additives to prevent biofouling. Because all the ponds are unlined (NRC 1996), the water discharged to them can interact with the shallow groundwater system and may create a groundwater mound. In this case, groundwater below the pond can flow radially outward, and this groundwater would have some of the characteristics of the cooling system effluent.

In salt marsh locations, the groundwater is naturally brackish (i.e., with a TDS concentration of about 1,000 to more than 10,000 milligrams per liter [mg/L]) and, thus, is already limited in its uses. As such, this issue concerns only the potential for changing the groundwater use category of the underlying shallow and brackish groundwater due to the introduction of cooling water contaminants. Two nuclear plants, South Texas in Texas and Turkey Point in Florida, have cooling systems (man-made cooling pond and cooling canal system, respectively) located relatively near or constructed in salt marshes. Plants relying on brackish water cooling systems would not further degrade the quality of the shallow aquifer relative to its use classification. This is because groundwater quality beneath salt marshes is already too poor for human use (i.e., it is non-potable water) and is only suitable for industrial use. Plants relying on cooling ponds in salt marsh settings are expected to have a SMALL impact on groundwater quality. This is the same conclusion reached in the 1996 GEIS. No new information has been identified in plant-specific SEISs or associated literature that would alter this conclusion. On the basis of these considerations, the impact of groundwater quality degradation for nuclear plants using cooling ponds in salt marshes would be SMALL and it remains a Category 1 issue.

Groundwater Quality Degradation (Plants with Cooling Ponds at Inland Sites)

The above discussion on cooling ponds relates to this issue. Some nuclear power plants that rely on unlined cooling ponds are located at inland sites surrounded by farmland or forest or undeveloped open land. Degraded groundwater has the potential to flow radially from the ponds and reach offsite groundwater wells. The degree to which this occurs depends on the water quality of the cooling pond; site hydrogeologic conditions (including the interaction of surface water and groundwater); and the location, depth, and pump rate of water wells. Mitigation of significant problems stemming from this issue could include lining existing ponds, constructing new lined ponds, or installing subsurface flow barrier walls. Groundwater monitoring networks would be necessary to detect and evaluate groundwater quality degradation. The degradation of groundwater quality associated with cooling ponds has not been reported for any inland nuclear plant sites.

The 1996 GEIS considered the impacts of this issue during continued operations and concluded that the impact would not necessarily be the same at all sites (i.e., a Category 2 issue) and could be SMALL, MODERATE, or LARGE. No new information has been identified in plant-specific SEISs or associated literature that would alter this conclusion.

On the basis of these considerations, the impacts of groundwater quality degradation for plants using cooling ponds at inland sites could be SMALL, MODERATE, or LARGE, depending on site-specific differences in the cooling pond's water quality; site hydrogeologic conditions (including the interaction of surface water and groundwater); and the location, depth, and pump rate of water wells. This issue remains Category 2.

Radionuclides Released to Groundwater

This is a new Category 2 issue. It has been added to the GEIS in order to evaluate the potential contamination of groundwater from the release of radioactive liquids from plant systems into the environment.

This issue was added because there were numerous instances of inadvertent releases of liquids containing radioactive material into the groundwater at nuclear power plants. The issue is relevant to license renewal because all commercial nuclear power plants routinely release radioactive gaseous and liquid materials into the environment. These radioactive releases are designed to be planned, monitored, documented, and released into the environment at designated discharge points. However, within the past several years, there have been numerous events at power reactor sites which involved unknown, uncontrolled, and unmonitored release of liquids containing radioactive material into the groundwater. NRC regulations in 10 CFR Part 20 and in 10 CFR Part 50 limit the amount of radioactive material, from all sources at a nuclear power plant, released into the environment to levels that are as low as is reasonably achievable (ALARA). The regulations are designed to protect the public and the environment.

The majority of the inadvertent liquid release events involved tritium, which is a radioactive isotope of hydrogen. However, other radioactive isotopes, such as cesium and strontium, have also been inadvertently released into the groundwater. The types of events include leakage from spent fuel pools, buried piping, and failed pressure relief valves on an effluent discharge line.

In 2006, the NRC's Executive Director for Operations chartered a task force to conduct a lessons-learned review of these incidents. On September 1, 2006, the task force issued its report: *Liquid Radioactive Release Lessons Learned Task Force Report* (NRC 2006a).

The most significant conclusion dealt with the potential health impacts on the public from the inadvertent releases. Although there were numerous events where radioactive liquid was released to the groundwater in an unplanned, uncontrolled, and unmonitored fashion, based on the data available, the task force did not identify any instances where public health and safety was adversely impacted.

Specific examples from NRC (2006a) focus on tritium releases at 15 plants. Concentrations of tritium in sampled onsite groundwater at many of these plants ranged well above the EPA drinking water standard of 20,000 pCi/L. Examples include onsite monitoring well samples of up to 250,000 pCi/L at the Braidwood plant in Illinois, up to 211,000 pCi/L at the Indian Point plant in New York (NRC 2008c), up to 486,000 pCi/L at the Dresden plant in Illinois, more than 30,000 pCi/L at the Watts Bar plant in Tennessee, and 71,400 pCi/L at the Palo Verde plant in Arizona. Examples of samples taken either directly from the source of the leak or from nearby onsite monitoring wells include samples with up to 200,000 pCi/L of tritium at the Callaway plant in Missouri, up to 15,000,000 pCi/L at the Salem plant in New Jersey, and up to 750,000 pCi/L at the Seabrook plant in New Hampshire. At the Byron plant in Illinois, tritium in monitoring wells was above the background level but below drinking water standards (up to 3,800 pCi/L). The location and construction of the monitoring wells relative to potential leak locations have not been evaluated. For each example, it is possible that a different well placement could detect higher or lower activity concentrations.

Other reported instances (NRC 2006a) of tritium above background levels have been a result of operator error, licensed discharge, or leaks or discharges to drain systems. At the Oyster Creek plant in New Jersey, a mistake involving a valve allowed tritium-contaminated water to flow to the discharge canal. Sampling of this water showed levels of 16,000 pCi/L. At the Wolf Creek plant in Kansas, an onsite lake receiving liquid effluent was found to have a tritium activity concentration of 13,000 pCi/L (NRC 2008a). The Perry plant in Ohio had water samples in its drainage system with an activity concentration of 60,000 pCi/L. In each of these cases, the tritium present at the surface could infiltrate or seep into the groundwater system.

The NRC does not consider the referenced tritium releases to be a health risk to the public or onsite workers (NRC 2006a) because the tritiated groundwater is expected to remain onsite. However, an exception is the event at Braidwood, which resulted in detectable concentrations of tritium at an offsite location. Sampling of an offsite residential well at Braidwood showed 1,600 pCi/L of tritium which is above the background level but well below EPA's drinking water standard. There would be no potential for risk to workers unless onsite wells were used for the potable water system and if the leak was in the capture zone of the well. However, the NRC requires that the onsite potable well water be monitored for radioactivity to protect plant workers.

The task force identified that under current NRC regulations the potential exists for unplanned, uncontrolled, and unmonitored releases of radioactive liquids to migrate offsite into the public domain. The following elements collectively contribute to this conclusion:

- Some of the power plant components that contain radioactive fluids that have leaked were constructed to commercial standards, in contrast to plant safety systems that are typically fabricated to more stringent requirements. The result is a lower level of assurance that these types of components will be leak proof over the life of the plant.

- Some of the components that have leaked were not required by NRC requirements to be subject to surveillance, maintenance, or inspection activities by the licensee. This increases the likelihood that leakage in such components can go undetected. Additionally, relatively low leakage rates may not be detected by plant operators, even over an extended period of time.

- Portions of some components or structures are physically not visible to operators, thereby reducing the likelihood that leakage will be identified. Examples of such components include buried pipes and spent fuel pools.

- Leakage that enters the ground below the plant may be undetected because there are generally no NRC requirements to monitor the groundwater onsite for radioactive contamination unless an onsite well is used for drinking water or irrigation.

- Contamination in groundwater onsite may migrate offsite undetected. Although the power plant operator is required by NRC regulations to perform offsite environmental monitoring, the sampling locations are typically in the vicinity of the routine effluent discharge point into the environment, not around plant systems, piping, and tanks containing radioactive liquids.

Another aspect encountered by the NRC due to the inadvertent releases was the high level of concern from the public, even at the very low radiation levels caused by the events. There has also been significant media coverage and demands by State and local government officials and members of Congress for the NRC to take action to stop these events.

On the basis of the information and experience with these leaks, the NRC concludes that the impact to groundwater quality from the release of radionuclides could be SMALL or MODERATE, depending on the magnitude of the leak, radionuclides involved, hydrogeologic factors, the distance to receptors, and the response time of plant personnel to identify and stop the leak in a timely fashion. Since the leaks are not planned and there are currently no NRC regulations that would require the timely identification and termination of a leak, there is no information available to make a generic assessment. Therefore, a site-specific evaluation in the Environmental Report is needed for each application for license renewal, and this issue is considered Category 2.

4.5.2 Environmental Consequences of Alternatives to the Proposed Action

Construction—For all alternatives discussed in this section, the impacts of construction on water resources would be similar. Construction-related impacts on hydrology (land clearing and impervious pavements) would alter surface drainage patterns and groundwater recharge zones. Surface water runoff over disturbed ground and material stockpiles could increase levels of dissolved and suspended solids and other contaminants. Groundwater withdrawn from onsite wells and dewatering systems could depress the water table and possibly change the direction of groundwater flow near the plant. Concrete production and wetting of ground surfaces and unpaved roadways for fugitive dust control could require substantial amounts of water. Appropriate permits, including a Clean Water Act Section 404 permit, Section 401 certification, and Section 402(p) NPDES general stormwater permit, would be required prior to construction. These impacts would apply generally to the construction phase of each of the alternatives discussed below. Differences among alternatives would depend not only on the selected technology but also on site-specific factors, which cannot be evaluated here. Discussion of such differences is outside the scope of this GEIS.

Operation—Most electrical power plants require water for cooling. As a result, fossil-fueled and nuclear power plants are generally located near large surface water bodies, including lakes, rivers, or oceans. Water cooling systems at power plants use either once-through or closed-cycle systems. Potable water can be purchased from municipalities or commercial water providers or obtained from onsite wells or a combination of the above.

Potential operational impacts to surface waters could occur from blowdown and evaporative losses in the steam cycle and cooling system and from drift of chemically treated cooling water from the cooling tower. Releases of industrial wastewaters would be controlled by an NPDES permit. The operational impacts of alternative energy technologies on land use and visual resources are presented in the following subsections.

4.5.2.1 Fossil Energy Alternatives

Operation—Fossil fuel power plants require a continuous supply of water to operate. Water demands vary greatly among technologies, ranging from a low of 3,760 gpm (14,222 L/min) for an IGCC technology without carbon capture and storage to more than 14,000 gpm (53,000 L/min) for a subcritical pulverized coal unit with carbon capture and storage. EPA estimates of raw water usage for various coal-burning technologies, normalized to a nominal generating capacity of 500 MWe, appear in Table 4.5-1. Water resources would be affected not only by water withdrawals but by reintroduction of water from steam cycle, cooling tower, and gasifier blowdown water. Hydrology would also be affected by wastewater generated by coal and exhaust-gas cleaning devices that may be operating and by other ancillary industrial activities.

Water usage is a function of the coal combustion technology, heating value of the coal being consumed, the design of the primary cooling systems (e.g., once-through versus closed-cycle, mechanical versus natural draft, dry cooling, and wet/dry hybrid cooling), and the operation of various other devices, such as gasifiers and gas-cleaning units (including flue gas desulfurization), all of which require water.

Table 4.5-1. Raw Water Usage Estimates for Fossil Fuel Electric Power Technologies

	Coal Rank[b]		
Technology[a]	Bituminous	Sub-bituminous	Lignite
IGCC	4,960 (685) [4,950][c]	5,010 (676) [5,000][c]	5,270 (700) [5,259][d]
Subcritical PC[e]	9,260 (1,050) [9,241]	9,520 (1,050) [9,501]	9,960 (1,050) [9,940]
Supercritical PC[e]	8,460 (1,050) [8,443]	8,830 (1,060) [8,812]	9,200 (1,055) [9,182]
Ultra-supercritical PC[e]	7,730 (1,050) [7,717]	7,870 (1,050) [7,857]	8,710 (1,050) [8,695]

(a) IGCC = integrated gasification combined cycle; PC = pulverized coal.
(b) Water usage expressed as lb/MWh (lb/MBtu input) [gal/min].
(c) 500-MWe (net) unit equipped with a slurry-feed gasifier.
(d) 500-MWe (net) unit equipped with a solid-feed gasifier.
(e) 500-MWe (net) unit.
Source: EPA 2006

4.5.2.2 New Nuclear Alternatives

Water resources would be affected by operation of the cooling system and by discharges of blowdown water from the cooling system and steam cycle, both of which can introduce chemical contaminants and heat to the receiving surface water body. Operation of these systems could also affect hydrology by reducing available surface water volume, altering current patterns at intake and discharge structures, altering salinity gradients, scouring and increases in sediment caused by discharges of treated cooling water, and increasing water temperature. Hydrologic impacts would vary, depending on the surface water source used for cooling as well as the cooling water system employed. Hydrology can also be affected by the plant’s service water system, which provides water for turbine and reactor auxiliary equipment cooling, reactor shutdown cooling, and other services. Surface water and groundwater can also be affected by discharges authorized under permits and by accidental spills and leaks of radionuclides, chemicals, and fuels to the ground surface. Overall, impacts on water resources at a greenfield site could be significant and depend highly on local circumstances and factors such as other dependencies on the hydrologic resources. Hydrologic impacts at a brownfield site or an existing nuclear facility could also be significant, depending on whether or not the new nuclear plant could use the existing cooling water system.

4.5.2.3 Renewable Alternatives

The operational impacts of alternative energy technologies on water resources are presented in the following subsections.

Hydroelectric Energy Sources

Reservoirs could be affected by changes in water temperature and amounts of dissolved oxygen. Surface water temperatures in the reservoir could be affected when water flow is reduced. Warm water released from the top of the dam and cooler water released from the lower portions of the dam could affect river water temperatures downstream. Additionally, both low- and high-flow conditions would alter sediment transport and deposition patterns.

Geothermal

Hydrology would be affected by water consumed by the facility; the project could consume up to 6.8 ac-ft/yr (i.e., about 2.2 million gal [8,390 m^3]) of water during operation. Degradation and loss of integrity of geothermal wells could affect shallow groundwater quality through the release of contaminants. Liners installed on any surface impoundments should be sufficient to protect surface water resources from contamination by industrial fluids (including geothermal fluids) during routine operation.

Wind

No impacts on water resources are expected to result from routine operation of either onshore or offshore wind farms.

Biomass

Water demands for cooling and steam would be similar to those of fossil fuel-fired power plants. Water demand could equal evaporative water loss from cooling tower and flue gas scrubbers, and blowdown waters discharged from steam cycle and cooling water systems. Water demand could range from 3,000 to 5,000 gpm (11,400 to 18,900 L/min). Water quality would be affected by contaminants released in runoff from piles of feedstock materials, fly and bottom ash, and scrubber sludge.

Solar Thermal

There is a potential for contamination from accidental release of working fluids (heat transfer fluids) or thermal storage media (molten salts) contained in binary systems. For an advanced power tower facility operating in 2030 and using a wet mechanical cooling tower, projected water demands (i.e., consumptive use as a result of water lost to evaporation) would be about 630 gal (2.4 m^3)/MWh (EERE 1997).

4.6 Ecological Resources

4.6.1 Environmental Consequences of the Proposed Action—Continued Operations and Refurbishment

Environmental conditions at all nuclear power plants and associated transmission lines have been well established during the current licensing term. These conditions are expected to remain unchanged during the 20-year license renewal term. The following section describes the effects of continued operations and refurbishment activities on terrestrial and aquatic resources over the license renewal term.

Continued operations and refurbishment are not expected to change substantially over the license renewal term. Therefore, license renewal generally represents a continuation of current environmental stresses that have existed over many years of operation. However, due to the ever-changing nature of biological communities, the impacts of continued operation may change. These conditions are described in Sections 3.6.1 (Terrestrial Resources), 3.6.2 (Aquatic Resources), and 3.6.3 (Special Status Species and Habitats). The factors associated with continued operations and refurbishment activities that could affect these resources over the 20-year license renewal term are presented in the following sections.

4.6.1.1 Terrestrial Resources

Continued operations of the nuclear power plants during the 20-year license renewal term are expected to include operation of cooling towers, operation of once-through cooling systems and cooling ponds, management of transmission line ROWs, maintenance of site facilities, releases of gaseous and liquid effluents, and potentially, and refurbishment-related construction activities. Terrestrial habitats and wildlife would continue to be exposed to cooling tower drift; maintenance activities associated with ROWs, cooling systems, and site facilities; and chemical and radiological releases. Cooling towers and transmission lines would continue to be potential collision hazards for birds, wildlife near the site would be exposed to elevated noise levels, and refurbishment-related construction activities could result in habitat loss and disturbance of wildlife. Details regarding these impacting factors are presented in Section 3.6.1.

This section considers the following issues related to terrestrial resources:

- Effects on terrestrial resources (non-cooling system impacts) (issue was modified from the 1996 GEIS to encompass the impacts of continued operations and refurbishment);

- Exposure of terrestrial organisms to radionuclides (new issue not considered in the 1996 GEIS);

- Cooling system impacts on terrestrial resources (plants with once-through cooling systems or cooling ponds) (issue was modified and renamed from the 1996 GEIS issue, “Cooling pond impacts on terrestrial resources”);

- Cooling tower impacts on vegetation (plants with cooling towers) (consolidation of two issues from the 1996 GEIS: (1) cooling tower impacts on crops and ornamental vegetation, and (2) cooling tower impacts on native plants);

- Bird collisions with plant structures and transmission lines (consolidation of two issues in the 1996 GEIS: (1) bird collisions with cooling towers and (2) bird collision with transmission lines);

- Water use conflicts with terrestrial resources (plants with cooling ponds or cooling towers using makeup water from a river) (new issue not specifically considered in the 1996 GEIS);

- Transmission line ROW management impacts on terrestrial resources (consolidation of two issues from the 1996 GEIS: (1) power line ROW management (cutting and herbicide application) and (2) floodplains and wetland on power line ROW)). This issue includes impacts on upland plant communities; and

- Electromagnetic fields on flora and fauna (plants, agricultural crops, honeybees, wildlife, livestock) (issue from the 1996 GEIS).

Effects on Terrestrial Resources (Non-Cooling System Impacts)

Continued operations and refurbishment activities could continue to affect onsite terrestrial resources during the license renewal term at all operating nuclear power plants. Factors that could potentially result in impacts include landscape maintenance activities, stormwater management, and elevated noise levels. These impacts would, for the most part, be similar to past and ongoing impacts. The 1996 GEIS did not evaluate the impact of continued operations and maintenance on onsite biota, but this issue has been identified by the NRC for consideration in this GEIS revision on the basis of environmental reviews performed for plant-specific SEISs.

Nuclear power plant sites are typically maintained as modified habitats with lawns and other landscaped areas; however, they may also include disturbed early successional habitats or even small areas of relatively undisturbed habitat. Onsite developed areas are generally maintained by mowing and the application of herbicides or pesticides. The diversity of plant species in these areas is generally kept at a reduced level. Plant species often consist of cultivated varieties or weedy species tolerant of disturbance. Areas of the nuclear plant site outside the security fence may include natural areas, such as forests or shrublands, in various degrees of disturbance. Onsite wetlands may be affected by stormwater management. Effects may include changes in plant community characteristics, altered hydrology, decreased water quality, and sedimentation (EPA 1993, 1996; Wright et al. 2006). Impervious surfaces within the watershed generally result in increased runoff and reduced infiltration, causing changes in the frequency or duration of inundation or soil saturation and greater fluctuations in wetland water levels. Runoff may contain sediments, contaminants from road and parking surfaces, or herbicides. Erosion of wetland substrates and plants can result from increased flow velocities from impervious surfaces. Onsite wildlife near transformers or cooling towers are exposed to elevated noise levels that could disrupt behavioral patterns. Maintenance of landscaped areas generally keeps wildlife diversity lower than in surrounding habitats. Wildlife species occurring on sites within the security areas are typically limited by low habitat quality and generally include common species adapted to industrial sites.

The characteristics of terrestrial habitats and wildlife communities currently on nuclear power plant sites have generally developed in response to many years of typical operations and maintenance programs. While some may have reached a relatively stable condition, some habitats and populations of some species may have continued to change gradually over time. Operations and maintenance activities during the license renewal term are expected to be similar to current activities (see Section 2.1). Because the species and habitats present on the sites (i.e., weedy species and habitats they make up) are generally tolerant of disturbance, it is expected that continued operations during the license renewal term would maintain these habitats and wildlife communities in their current State, or maintain current trends of change.

Terrestrial habitats and wildlife could be affected by ground disturbance from refurbishment-related construction activities. Land disturbed during the construction of new independent spent fuel storage installations (ISFSIs) would range from about 2.5 to 10 ac (1 to 4 ha). Other activities may include new parking areas for plant employees, access roads, buildings, and facilities. Temporary project support areas for equipment storage, worker parking, and material laydown areas could also result in the disturbance of habitat and wildlife. In the 1996 GEIS, the NRC considered only the impacts of refurbishment on terrestrial habitats and concluded that the impacts would not necessarily be the same at all sites (i.e., a Category 2 issue) and could range from SMALL to LARGE.

Operational activities occurring in undeveloped portions of the site would affect terrestrial habitats and wildlife. Some wildlife would be displaced to nearby available habitats. However, competition would increase for many species, reducing the likelihood of survival of displaced individuals. Indirect effects could include fugitive dust, alteration of hydrology from changes in surface water flow patterns and infiltration to shallow groundwater, water quality degradation, or establishment of invasive species. Species that are more sensitive to disturbance may be displaced by more tolerant species. Affected habitats may include uplands or wetlands on or near the activity as well as wetlands within the watershed. Alterations in vegetative cover, the compaction of upland soils, or the development of impervious surfaces within the watershed generally result in more runoff and less infiltration to shallow groundwater, causing an increase or decrease in the hydrologic input to nearby wetlands (EPA 1993, 1996; Wright et al. 2006). Effects include changes in the frequency or duration of inundation or soil saturation and greater fluctuations in wetland water levels. Runoff often contains sediments, contaminants from road and parking surfaces, or herbicides used in managing ROW or site vegetation (EPA 1993, 1996; Wright et al. 2006). The erosion of wetland substrates and plants can result from increased flow velocities. Actions that result in the discharge of dredge or fill material into wetlands that are under the jurisdiction of the Clean Water Act (CWA) require a Section 404 permit from the USACE. Actions that could potentially affect threatened or endangered species would require consultation with the U.S. Fish and Wildlife Service (USFWS) under Section 7 of the Endangered Species Act (ESA), or with State resource agencies. Rare or unique plant communities, sensitive habitats such as wetlands or rookeries, or high-quality undisturbed habitats may occur in or near potentially affected areas. Impacts on such habitats could be considered LARGE if they caused the destabilization of a resource. Impacts would be considered SMALL if only previously disturbed or other lower-quality habitats were affected.

Successful application of environmental review procedures, employed by the licensees at many of the operating nuclear plant sites, would result in the identification and avoidance of important terrestrial habitats. In addition, the application of BMPs to minimize the area affected; to control fugitive dust, runoff, and erosion from project sites; to reduce the spread of invasive nonnative plant species; and to reduce disturbance of wildlife in adjacent habitats could greatly reduce the impacts of continued operations and refurbishment activities.

Site-specific factors related to refurbishment activities may vary considerably among nuclear power plant sites. The habitats present on or in the vicinity of nuclear power plants also vary greatly. Therefore, a generic determination of potential impacts on terrestrial resources from refurbishment or other activities is not possible. Impacts on terrestrial habitats and wildlife would depend on site-specific factors, and impact assessments would need to be conducted on a site-specific basis prior to license renewal. Consistent with this finding, the NRC concluded in the 1996 GEIS that the impacts of refurbishment actions could be significant if important resources are affected, depending on site-specific conditions.

On the basis of these considerations, the NRC concludes that the impact of continued operations and refurbishment activities similar to those occurring during the current license term on terrestrial resources could be SMALL, MODERATE, or LARGE, depending on site-specific differences in the terrestrial resources present, project-specific activities, and the effectiveness of mitigation measures. The issue is therefore considered Category 2.

Exposure of Terrestrial Organisms to Radionuclides

This section addresses the issue of potential impacts of radionuclides on terrestrial organisms resulting from normal operations of a nuclear power plant during the license renewal term. This issue was not evaluated in the 1996 GEIS. However, public concerns about the impacts of radionuclides on terrestrial organisms at some nuclear power plants have led to an evaluation of the issue in this GEIS revision.

Radionuclides may be released from nuclear power plants into the environment via a number of pathways. Releases into terrestrial environments often result from deposition of small amounts of radioactive particulates released from power plant vents during normal operations. typically include krypton, xenon, and argon (which do not contain radioactive particles), tritium, isotopes of iodine, and cesium, and they may also include strontium, cobalt, and chromium. Radionuclides may also be released into the aquatic environment from the liquid effluent discharge line. Radionuclides that enter shallow groundwater from cooling ponds can be taken up by terrestrial plant species, including both upland species and wetland species, where wetlands receive groundwater discharge. Terrestrial biota may be exposed to ionizing radiation from radionuclides through direct contact with water or other media, inhalation, or ingestion of food, water, or soil.

The uptake of radionuclides from soil and water by many plant species and their incorporation into plant tissues have been well demonstrated (Bell et al. 1988; Hinton et al. 1996; Hinton et al. 1999; Hitchcock et al. 2005; Kaplan et al. 2005; Sahr et al. 2005; NCRP 2006; Pinder et al. 2006). The degree of uptake varies according to the degree to which the radionuclide binds to the sediment particles (the partition coefficient [Kd] of the nuclide and sediment constituents, such as clay particles) as well as other environmental factors, such as pH or the concentrations of other elements such as potassium (NCRP 2006). The effects on plants of chronic exposure to radionuclides range from reduced trunk growth, canopy cover, stem growth, photosynthetic capacity, seed production and germination in trees, and reduced reproductive potential in herbaceous plants, to chromosome damage as well as mortality in both groups (IAEA 1992; Real et al. 2004; Sahr et al. 2005). Growth effects have been observed at dose rates above 0.01 rad/hr (100 μGy/hr), while chromosome effects have occurred at 2.0×10^{-6} rad/hr (0.02 μGy/hr) (Real et al. 2004). Radionuclides are transferred to herbivores and subsequently to higher trophic levels, such as predators (Meyers-Schone and Walton 1990; Kelsey-Wall et al. 2005; Beresford et al. 2005; NCRP 2006).

The DOE guideline for radiation dose rates from environmental media recommends limiting the radiation dose to riparian and terrestrial mammals to less than 0.1 rad/d (0.001 Gy/d) and limiting the dose to terrestrial plants to less than 1.0 rad/d (0.01 Gy/d) (DOE 2002). These guidelines were developed on the basis of experimental evidence that negative effects would not occur at these doses. The effects of ionizing radiation on populations of terrestrial organisms have been given considerable attention in the literature. A report by the International Atomic Energy Agency (IAEA 1992) described invertebrate organisms as being less sensitive to ionizing radiation than are vertebrates. There is additional evidence indicating that some terrestrial wildlife species may be more resistant to ionizing radiation than are humans. For instance, Ulsh et al. (2000) examined the effects of cesium-137 radiation on cellular processes of wild turtles and humans. They discovered that human fibroblasts were 1.7 times more sensitive to ionizing radiation than the fibroblasts of wild turtles.

Eisler (1994) summarized studies examining the effects of ionizing radiation on aquatic and terrestrial organisms and reported that chronic doses at the minimum treatment dose of 90 rad/d (0.9 Gy/d) reduced the growth of some bird species. Few studies examine the effects of ionizing radiation on birds at doses lower than 90 rad/d (0.9 Gy/d), and none of them observed any adverse effects. For example, Zach et al. (1993) found no negative effects on the breeding performance of adults or the growth of nestling tree swallows (*Tachycineta bicolor*) at doses as low as 0.014 rad/d (1.4×10^{-4} Gy/d). Eisler (1994) also reported that an acute exposure of 1.1 rad (0.011 Gy) was demonstrably harmful to small mammals. In a summary by Real et al.

(2004), radiological dose rates as low as 1 rad/d (0.01 Gy/d) could be potentially harmful to some terrestrial plant species, although most effects were observed at doses greater than 100 rad/d (1 Gy/d). Furthermore, IAEA (1992) concluded that irradiation at chronic dose rates of 1 rad/d (0.01 Gy/d) or less are not likely to negatively affect plant populations.

Genetic effects of ionizing radiation on terrestrial biota have not been demonstrated at doses below the DOE guidelines. Turner et al. (1971) found that doses as low as 4 rad/d (0.04 Gy/d) adversely affect the reproductive capabilities of the leopard lizard (*Crotaphytus wislizenii*), and Nagasawa et al. (1990) observed chromosomal aberrations in the cells of hamsters at acute radiation doses as low as 2 rad (0.02 Gy). The European Committee on Radiation Risk (ECRR) reviewed studies concerning the effects of low-level radiation exposures on a variety of animal species. Although study details were not provided, the ECRR noted that a wide range of animal studies show juvenile mortality effects from internal irradiation, which have not been addressed by the International Commission on Radiological Protection (ICRP) or other risk agencies (ECRR 2003).

The NRC conducted a review of all operating nuclear power plants to evaluate the potential impacts of radionuclides on terrestrial biota from continued operations. Site-specific radionuclide concentrations in water, sediment, and soils were obtained from Radiological Environmental Monitoring Program (REMP) reports for 15 nuclear plants. These 15 plants were selected to represent sites with a range of radionuclide concentrations in the media, including plants with high annual worker total effective dose equivalent (TEDE) values (Tables 3.9-5 and 3.9-6) or public exposures (Tables 3.9-9, 3.9-10, and 3.9-11) for both boiling water reactors (BWRs) and pressurized water reactors (PWRs). The RESRAD-BIOTA dose evaluation model (DOE 2004e) was used to calculate estimated dose rates for terrestrial biota by using the media concentrations presented in the REMP reports (see Section D.5 in Appendix D for further details on the approach used).

Results of the RESRAD-BIOTA dose modeling are presented in Table 4.6-1, showing the total dose estimates for three different terrestrial ecological receptors: riparian animal (an animal that was assumed to spend approximately 50 percent of its time in aquatic environments and 50 percent of its time in terrestrial environments), terrestrial animal, and terrestrial plant. The maximum estimated dose rate calculated for any of the nuclear power plants is 0.0354 rad/d (3.54×10^{-4} Gy/d) (riparian animal at the Browns Ferry plant), which is below the guideline value of 0.1 rad/d (0.001 Gy/d) for a riparian animal receptor. It is unlikely that the normal operations of these power plants would have adverse effects on terrestrial biota resulting from radionuclide releases because the calculated doses are below protective guidelines and thus would not significantly affect populations.

On the basis of these calculations and a review of the available literature, the NRC concludes that the impact of routine radionuclide releases from past and current operations and

Table 4.6-1. Estimated Radiation Dose Rates to Terrestrial Ecological Receptors from Radionuclides Measured in Water, Sediment, and Soils at U.S. Nuclear Power Plants

Power Plant	Sum of Total Dose (rad/d) for Receptor [(a)] Riparian Animal	Terrestrial Animal	Terrestrial Plant	Source
Arkansas Nuclear	4.62×10^{-4}	3.37×10^{-7}	1.04×10^{-7}	Entergy 2006a
Browns Ferry	3.54×10^{-2}	1.10×10^{-2}	1.03×10^{-2}	TVA 2003
Calvert Cliffs	2.90×10^{-7}	2.65×10^{-3}	2.49×10^{-4}	CEG 2003
Columbia	2.62×10^{-3}	4.45×10^{-4}	2.82×10^{-5}	Energy Northwest 2005
Comanche Peak	1.50×10^{-2}	2.89×10^{-6}	9.37×10^{-7}	TXU 2004
Cook	2.48×10^{-3}	2.22×10^{-3}	2.44×10^{-4}	IMP 2006
Hatch	2.39×10^{-3}	1.82×10^{-6}	5.19×10^{-7}	Southern Company 2003
Fort Calhoun	5.26×10^{-4}	3.41×10^{-7}	1.06×10^{-7}	OPPD 2004
Indian Point	2.30×10^{-3}	2.22×10^{-3}	2.44×10^{-4}	Entergy 2006b
Millstone	3.31×10^{-3}	2.20×10^{-3}	2.20×10^{-4}	DNC 2004
Nine Mile Point	2.40×10^{-3}	1.83×10^{-6}	5.24×10^{-7}	CEG 2004
Palisades	6.00×10^{-6}	2.89×10^{-7}	9.48×10^{-8}	NMC 2004
Point Beach	7.79×10^{-3}	2.48×10^{-2}	2.12×10^{-2}	EIML 2005
San Onofre	7.79×10^{-3}	2.48×10^{-2}	2.12×10^{-2}	SCE 2005
Vermont Yankee	7.56×10^{-3}	1.85×10^{-6}	5.30×10^{-7}	Entergy 2003

(a) Dose rates were estimated with RESRAD-BIOTA (DOE 2004e) by using site-specific radionuclide concentrations in water, sediment, and soils obtained from the REMP reports.

refurbishment activities on terrestrial biota would be SMALL for all nuclear plants and would not be expected to appreciably change during the renewal period. It is considered a Category 1 issue.

Cooling System Impacts on Terrestrial Resources (Plants with Once-Through Cooling Systems or Cooling Ponds)

Terrestrial vegetation and wildlife could be affected by the continued operation of cooling systems at nuclear power plants during the 20-year license renewal term. This issue applies to nuclear power plants with once-through cooling systems and cooling ponds typically with low levels of consumptive use. In the 1996 GEIS, the NRC evaluated the impacts to terrestrial ecology from cooling ponds but not the impacts from once-through cooling systems. Impacts of cooling ponds on terrestrial resources were considered to be SMALL for all plants that used cooling ponds and were designated as Category 1 issues in the 1996 GEIS. The impact on terrestrial resources from the operations of other cooling systems has been identified by the NRC for consideration in this GEIS revision. The impacts of cooling tower operations are considered as a separate issue elsewhere in this section.

Primary impacts of continued operation of the cooling systems at nuclear power plants include alterations of the physical environment that terrestrial organisms inhabit. Such changes to the physical environment may include increased water temperatures; humidity and fogging; contaminants in surface water or groundwater; and disturbance of wetlands from maintenance dredging of onsite cooling ponds, disposal of dredged material from such dredging, and erosion of shoreline wetlands. Unlike dredging of navigable waterways discussed in other GEIS issues, maintenance dredging of onsite cooling ponds and onsite disposal of dredged material (e.g., mud) typically do not require permits. Water temperatures in cooling ponds, canals, and reservoirs may increase as warm water effluent is discharged from the power plants. The elevated water temperatures associated with the cooling system may affect the distributions of some terrestrial plant and animal species associated with riparian or wetland communities. For example, the growth of plants along the cooling pond shoreline is restricted by the thermal effluent at the H.B. Robinson plant in South Carolina (NRC 2003b). Increased humidity and fogging around the cooling system discharge resulting from elevated water temperatures may alter the distributions of some vegetation communities. The cooling system may also transport contaminants generated during normal power plant operations to animal and plant receptors. Terrestrial biota may be exposed to contaminants released from the power plant's cooling system, either by direct contact with the cooling system effluent or through uptake from aquatic food sources near the cooling system. Terrestrial plants and wildlife associated with wetland or riparian communities along the receiving water body may be exposed, as well as wildlife that forage in these waters, such as waterfowl. In these cases, contaminants associated with the cooling system may have adverse impacts on terrestrial organisms. Maintenance dredging near cooling system intakes or outfalls may disturb wetland habitats along with accumulated sediments, and sedimentation from dredging disposal may indirectly affect wetlands. Shoreline wetlands or riparian habitats may be affected by erosion resulting from high-velocity effluent discharges or altered current patterns. The impacts of the cooling system are of concern if water temperature, humidity and fogging levels, contaminants associated within the discharged effluent, maintenance activities, or discharge flows have adverse effects on local plant and animal populations.

The NRC examined the potential impacts of the operation of nuclear power plant cooling systems on terrestrial resources during the 20-year license renewal term by reviewing published site-specific radiological effluent release (RER) reports, site environmental reports (ERs), and SEISs. For this analysis, a total of eight nuclear power plants with different types of cooling systems were investigated to determine the effects of cooling system operation on terrestrial resources. The type of cooling system that operated at each of the eight power plants reviewed, and a summary of the contaminants evaluated in the aquatic effluent, is shown in Table 4.6-2.

Contaminants investigated to be of potential concern in the liquid effluent associated with cooling systems at nuclear power plants include chlorine and other biocides, tritium, heavy metals, VOCs, oil products, and strontium. The concentrations of these contaminants have been found to be low within the liquid effluent discharged from the nuclear power plants.

Although water screening guidelines have not been established for terrestrial biota, compliance with NPDES permits should ensure that nonradioactive contaminant concentrations discharged from the cooling system are low enough to have only SMALL impacts on water quality and aquatic communities.

From a review of the 2006 RER reports for the power plants, quarterly tritium releases in liquid effluent may be as high as 1.69×10^{-5} µCi/mL. These concentrations do not exceed the public health-regulated tritium concentrations specified in 10 CFR Part 20, Appendix B, Table 2, which is set at 0.001 µCi/mL for water effluent concentrations. Tritium concentrations discharged in liquid effluent are much lower than those reported to have adverse effects on terrestrial wildlife. For example, Cahill et al. (1975) exposed rats to 1, 10, 50, or 100 µCi/mL of tritium in drinking water per day. They found that rats exposed to the higher doses (50 and 100 µCi/mL) experienced shorter life spans, whereas no adverse chronic effects were observed in rats at the two lower doses (1 and 10 µCi/mL). Therefore, the discharge of contaminants on terrestrial resources during the license renewal term is considered to be of SMALL significance.

Table 4.6-2. Contaminants Evaluated in Cooling Systems at Selected Power Plants

Power Plant	Cooling System	Contaminants	References
Dresden	Cooling lake and spray canal	Chlorine, tritium, heavy metals	NRC 2004a; Exelon 2003
Oyster Creek	Once-through cooling	Chlorine, tritium, VOCs	NRC 2007b
Palisades	Mechanical draft cooling tower	Chlorine, tritium, bromine, oil	NRC 2006d
Peach Bottom	Once-through cooling with towers	Chlorine, tritium, strontium	NRC 2003a; Exelon 2001a
Pilgrim	Once-through cooling	Chlorine, tritium, heavy metals	NRC 2007c
Turkey Point	Closed-cycle canal	Chlorine, tritium	NRC 2002b; FPL 2000
Vermont Yankee	Once-through cooling and towers	Chlorine, copper, iron, zinc	NRC 2007a
Wolf Creek	Closed-cycle cooling pond	Chlorine, tritium	WCNOC 2002; WCGS 2003

In the operation of the cooling system, contaminants (e.g., heavy metals) may be leached from condenser tubing and discharged by the power plant's cooling system. Elevated concentrations of these contaminants are toxic to aquatic and terrestrial organisms. In the past, the use of copper alloy condenser tubes in the cooling systems at the H.B. Robinson plant in South Carolina and Diablo Canyon plant in California resulted in the discharge of copper in the liquid effluent, which was observed to have adverse effects on the morphology and reproduction of resident bluegill populations at the Robinson plant (Harrison 1985), and abalone (*Haliotis* spp.) deaths were attributed to the increased copper levels discharged after a resumption of operations at Diablo Canyon (NRC 1996). Terrestrial wildlife that feed on these fish in the receiving waters could have been exposed to elevated copper levels. Also, potential reductions in populations of prey species could affect predator species. However, the replacement of the copper alloy condenser tubes with tubes made of different materials (e.g., titanium) has rectified this problem.

Thermal impacts on terrestrial habitats or wildlife exposed to elevated temperatures have not been identified at the nuclear power plants; however, as noted above, the growth of plants along portions of cooling pond shorelines may be restricted by high-temperature effluents. Temperature increases in receiving water bodies due to effluent discharges are regulated through NPDES permits to limit the extent of temperature increases for the protection of biota. In addition, because the plant communities present have been influenced by many years of facility operation, the elevated temperatures are unlikely to result in mortality of wetland and riparian plants that may be exposed to the discharges because species that are intolerant of elevated temperatures are unlikely to be growing near the outfall. The heated effluents could lengthen the growing season for wetland or riparian plant communities present. A potentially beneficial effect of the heated discharges at the Turkey Point plant in Florida has been the development of suitable habitat for the American crocodile (*Crocodylus acutus*), an established population of which occupies the cooling canal system. In addition, ice-free open water areas that provide foraging opportunities for the bald eagle (*Haliaeetus leucocephalus*) and various waterfowl species are often maintained by heated discharges during winter months at a number of nuclear plants in northern States. These benefits would be expected to continue during the license renewal term.

The impingement of waterfowl at the cooling water intakes has been observed at some nuclear plants, such as the Cook plant in Michigan, the Nine Mile Point plant in New York, and the Point Beach plant in Wisconsin. About 400 ducks, primarily lesser scaup (*Aythya affinis*), were impinged at the D.C. Cook plant in December 1991 (Mitchell and Carlson 1993); about 100 ducks, both greater scaup (*Aythya marila*) and lesser scaup, were impinged in January 2000 at the Nine Mile Point plant (NRC 2006e). At Point Beach, a number of double-crested cormorants (*Phalacrocorax auritus*) were impinged in September 1990, and 33 birds (mostly gulls) were impinged from June 2001 through December 2003 (NRC 2005b). Changes in operational procedures, such as the periodic cleaning of zebra mussels off intake structures, and changes in intake structure design, have been implemented to minimize the impacts on waterfowl. It is likely that any impingement over the license renewal term would result in only minor effects on waterfowl populations.

Groundwater quality can be degraded by contaminants present in cooling ponds and cooling canals. Deep-rooted terrestrial plants could be exposed to these contaminants. In addition, biota could be exposed to contaminants at locations of groundwater discharge, such as wetlands or riparian areas. However, as noted above, contaminant concentrations are typically very low, and any effects on terrestrial plants would be expected to be SMALL. Mitigation may also be implemented where sensitive resources could be affected. At the Turkey Point plant in Florida, for example, the flow of hypersaline groundwater from the cooling canals toward the Everglades to the west is prevented by an interceptor ditch, located along the west side of the canal system, from which groundwater inflow is extracted (NRC 2002b).

Surface water or groundwater that is withdrawn by nuclear power plants may potentially reduce the availability of water to terrestrial biota, such as those associated with wetlands or riparian areas along surface water bodies used as sources of cooling water, or those supported by groundwater discharges to wetlands or riparian areas. For once-through cooling systems, flow reductions from consumptive use generally represent a small decrease in water availability and have not resulted in water use conflicts for terrestrial resources. For example, losses due to the operation of the cooling system at the Peach Bottom plant in Pennsylvania, which operates as a once-through system with helper cooling towers, represent less than 2 percent of the minimum monthly average river flow of the cooling water source (NRC 2003a). In contrast, however, for some closed-cycle systems, consumptive water use may result in conflicts with requirements for the protection of riparian, wetland, or other communities, primarily where the nuclear plants are located on small bodies of water or small streams. Although water withdrawal rates are much lower for closed-cycle systems (which require makeup water as a result of evaporative losses) than for once-through systems, consumptive losses may be relatively high. Because of restrictions imposed at some plants on water withdrawal and consumption rates, which are protective of biotic resources, reductions in plant operations may be required under certain conditions when there are low water levels, such as during droughts. During extensive droughts, temporary impacts on riparian and wetland communities could occur.

Impacts on terrestrial biota associated with the operation of the cooling system have not been reported as a problem at any of the nuclear power plants evaluated. No adverse effects on terrestrial plants or animals have been reported as a result of increased water temperatures, fogging, humidity, or reduced habitat quality. Because of the low concentrations of contaminants within the liquid effluents associated with the cooling systems, the uptake and accumulation of contaminants in the tissues of wildlife exposed to the contaminated water or aquatic food sources are not expected to be a significant issue, and the impacts are expected to be SMALL for all plants. Potential mitigation measures would include regular monitoring of the cooling systems for water quality and measures to exclude wildlife from contaminated ponds. On the basis of these considerations, the NRC concludes that the impact of continued operation of the cooling systems on terrestrial resources would be SMALL for all nuclear plants and is considered a Category 1 issue.

Cooling Tower Impacts on Vegetation (Plants with Cooling Towers)

Continued operation of cooling towers could affect vegetation during the license renewal term. This issue applies only to operating nuclear power plants with cooling towers. The issue is a consolidation of two issues evaluated in the 1996 GEIS: (1) cooling tower impacts on crops and ornamental vegetation and (2) cooling tower impacts on native plants. Impacts of cooling tower emissions on these resources were considered to be SMALL for all plants and were designated as Category 1 issues in the 1996 GEIS.

As discussed in Section 3.6.1, terrestrial habitats in the vicinity of nuclear power plant cooling towers have been exposed to deposition of cooling tower drift particulates (including salt), deposition of water droplets on vegetation from drift, structural damage from freezing vapor plumes, and increased humidity. Drift contains small amounts of particulates that are dispersed from cooling towers over a wide area, with particulates from natural draft towers dispersing over a larger area and at a lower deposition rate than from mechanical draft towers (NRC 1996). However, most of the deposition from cooling towers occurs in relatively close proximity to the towers. Generally, deposition rates from these cooling towers have been below those that are known to result in measurable adverse impacts on plants, and no deposition effects on agricultural crops or plant communities have been observed at most of the nuclear power plants (NRC 1996). Exceptions have been observed at some nuclear plants; however, the impacts have been addressed by changes to cooling tower operations. For example, high levels of sulfate deposition, along with temporary excessive icing conditions at the Palisades plant on the southeast shoreline of Lake Michigan, resulted in the loss of about 5 ac (2 ha) of dune forest near the cooling towers and its replacement with a dense scrub-shrub community within several years of the startup of operations (NRC 2006b). These conditions were subsequently resolved by changes made to the cooling system.

Salt deposition from cooling tower drift is a potential impacting factor that can affect coastal power plants that use high-salinity water for cooling. The only such nuclear plant is the Hope Creek plant in New Jersey, which has natural draft cooling towers and withdraws cooling water from the Delaware River estuary (see Section 3.3.2 for a discussion of Hope Creek cooling tower drift emissions). High rates of deposition on plants or soil can result in injury to plants from acute effects and may result in changes to plant communities from chronic effects (Talbot 1979). Salt-tolerant species may increase in abundance, while sensitive species may decrease. Some salt-tolerant species are invasive and may become dominant in affected areas. However, no measurable effects from cooling tower drift on plant communities in the vicinity of Hope Creek have been observed (NRC 1996). The Palo Verde plant in Arizona uses cooling water with somewhat elevated salt concentrations. Studies have detected elevated levels of salt in plant leaves near the plant; however, the studies showed that no changes to native plants or crop production occurred (see Section 3.3.2 for a discussion of cooling tower drift emissions from the Palo Verde plant).

Impacts from icing have been rare, minor, and localized near nuclear power plant cooling towers and have been corrected by changes in tower operation at the plants where they occurred. For example, icing damaged oak trees adjacent to the cooling towers at the Prairie Island plant in Minnesota, changing the tree canopy structure and reducing acorn viability. Changes in tower operations eliminated the impacts (NRC 1996). Impacts from increased humidity have not been observed at nuclear power plants.

The continued operation of nuclear power plants would not be expected to result in increases in deposition rates from cooling towers or the accumulation of deposition constituents in soils. Because of the solubility of these materials, they are generally removed through precipitation. Plant communities in the vicinity of cooling towers have been exposed to many years of cooling tower operations, and are unlikely to change during the license renewal term. Any effects of icing during the renewal period would continue to be rare, minor, and localized. On the basis of these considerations, the NRC concludes that the impact of continued operation of cooling towers on plant communities would be SMALL for all nuclear plants and is considered a Category 1 issue.

Bird Collisions with Plant Structures and Transmission Lines

This section addresses the issue of avian mortality resulting from collisions of birds with natural draft cooling towers and transmission lines, within this scope of review (see Sections 3.1.1 and 3.1.6.5 in this GEIS), and other plant structures at nuclear power plants. Natural draft towers, which are tall structures (usually taller than 330 ft [100 m]), cause some mortality, whereas mechanical draft towers, which are smaller (usually shorter than 100 ft [30 m]), cause negligible mortality (NRC 1996). Because of these facts, mechanical draft towers are not addressed here. The impacts from birds colliding with cooling towers and transmission lines were evaluated by reviewing the primary literature for avian collision mortality associated with all types of man-made objects, as well as the results of monitoring studies conducted at six nuclear plants. The magnitude of the impact of the mortality caused by cooling towers is determined by examining the actual numbers and species of birds killed and comparing this mortality with the total avian mortality resulting from other man-made objects relative to bird population size.

Throughout the United States, it has been estimated that millions of birds are killed each year when they collide with man-made objects, including cooling towers, radio and television towers, buildings, vehicles, wind generation facilities, transmission lines, and numerous other objects

(Erickson et al. 2001). Many of these deaths can be considered unlawful take under the Endangered Species Act or the Migratory Bird Treaty Act. Bird mortality resulting from collisions with man-made structures is of concern if the stability of the local or migratory population of any bird species is threatened or if the reduction in numbers within any bird population significantly impairs its function within the ecosystem.

The number of collision-related bird deaths varies, depending on the type of man-made object. For example, Table 4.6-3 shows the estimated annual bird collision mortality in the United States. Collisions with buildings and windows account for the greatest number of collision mortalities annually, whereas wind generation facilities account for the least number of collision- related deaths (Table 4.6-3; Erickson et al. 2001). These estimates differ largely as a result of the density of the man-made structures in the study areas. It is estimated that more than 98 million commercial and residential buildings exist across the United States (Klem 1990; Erickson et al. 2001); compare this number with the number of wind turbines, which is less than 20,000 in 29 States (Manville 2005).

There are nearly 100,000 communication towers registered with the Federal Communications Commission (68 FR 53696 k), some of which have been observed to cause a large number of avian collision mortalities (Able 1973; Kemper 1996; Crawford and Engstrom 2001). Most of these large mortality events at communication towers occur at night during spring and fall migration periods involving songbirds that appear to become confused by tower lights (Taylor and Kershner 1986; Larkin and Frase 1988; Manville 2005). For example, a single television tower in northern Florida, Crawford and Engstrom (2001) reported more than 44,000 bird

Table 4.6-3. Estimated Annual Bird Collision Mortality in the United States

Source	Annual Mortality[a]
Vehicles[b]	60 million to 80 million
Buildings and windows[c]	98 million to 980 million
Power lines[d]	10,000 to 174 million
Communication towers[e]	4 million to 50 million
Wind generation facilities[f]	10,000 to 40,000

(a) Estimated annual mortality was extrapolated from literature reviews.
(b) Includes automobiles, trains, and airplanes.
(c) Includes buildings and attached structures such as smokestacks and windows.
(d) Includes all electric communication lines and transmission lines.
(e) Includes radio, television, cellular, microwave, and public safety towers.
(f) Includes wind turbines and supporting structures.
Source: Erickson et al. 2001

collision mortalities over a 29-year period. Communication towers involved with the most bird collisions are tall (exceeding 1,000 ft [305 m]), illuminated at night with incandescent lights, guyed, and located near wetlands and bird migration pathways (Manville 2005). During nights of heavy cloud cover or fog, the incandescent lights illuminating the communication towers may attract migrating songbirds to the towers, increasing the likelihood of collisions. Compared to communication towers, cooling towers at nuclear power plants are shorter (less than 650 ft [200 m]) and are illuminated with low-intensity light sources (1.0 ft-candle or less), such that migrating birds may not be as attracted to them, thus decreasing the likelihood of collision.

Natural draft cooling towers and transmission lines create collision hazards for migratory and local bird species. Monitoring of bird collisions has been done at several nuclear plants with natural draft cooling towers, including the Susquehanna plant on the Susquehanna River near Berwick in eastern Pennsylvania, the Davis-Besse plant on the shore of Lake Erie in north central Ohio, the Beaver Valley plant on the Ohio River in extreme western Pennsylvania, the former Trojan plant on the Columbia River in extreme northwestern Oregon, the Three Mile Island plant near Harrisburg in southeastern Pennsylvania, and the Arkansas plant on Dardanelle Lake in northwestern Arkansas. The following information regarding those plants was obtained from nuclear plant annual monitoring reports and from Temme and Jackson (1979).

At the Susquehanna plant, surveys were conducted on weekdays during the spring and fall bird migrations from 1978 through 1986. (Unit 1 began operating in 1983 and Unit 2 came online in 1985.) The plant's natural draft towers are 165-m (540-ft) tall and illuminated at the top with 480-V aircraft warning strobe lights. About 1,500 dead birds (total for all survey years, an average of 166 per year) representing 63 species were found; they had apparently collided with the cooling towers. Other birds were probably lost in the tower basin water during plant operation. Most of the birds were songbirds. Fewer collisions seemed to occur during plant operation, when cooling tower plumes and noise may have frightened birds away from the towers.

At Davis-Besse, extensive surveys for dead birds were conducted from fall 1972 to fall 1979. Early morning surveys at the 152-m-tall (499-ft-tall) cooling tower were made almost daily from mid-April to mid-June and from the first of September to late October. After the tower began operating in the fall of 1976, some dead birds were lost through the water outlets of the tower basin. A total of 1,561 dead birds were found, an average of 195 per year. The dead birds included 1,229 at the cooling tower, 224 around Unit 1 structures, and 108 at the meteorological tower. Most were night-migrating songbirds, particularly wood-warblers (family Parulidae), vireos (*Vireo* spp.), and kinglets (*Regulus* spp.). Waterfowl that were abundant in nearby marshes and ponds suffered little collision mortality. Most collision mortalities at the cooling tower occurred during years when the cooling tower was not well illuminated (1974 to spring 1978). After the completion of Unit 1 structures and installation of many safety lights around the buildings in the fall of 1978, collision mortality was significantly reduced (average of 236 per year from 1974 through 1977, 135 in 1978, and 51 in 1979). This reduction was accomplished by installing low-intensity light sources (1.0 ft-candle or less) to illuminate the cooling tower, which allowed birds to see and avoid it. It appears that the lights at nuclear plants do not confuse birds to the extent that lights on radio or TV towers sometimes do.

At Beaver Valley, surveys were conducted at the natural draft tower in the spring and fall seasons from 1974 through 1978. A total of 27 dead birds were found. At the Trojan plant, surveys were conducted weekly in 1984 and 1988 at the 499-ft-tall (152-m-tall) cooling tower, meteorological tower, switchyard, and generation building. No dead birds were found. At the 371-ft-tall (113-m-tall) cooling towers at Three Mile Island, 66 dead birds were found from 1973 through 1975. No dead birds were found at the Arkansas plant, where monitoring at the natural draft tower was done twice weekly from October 15 through April 15 in 1978–79 and 1979–80.

The available data on cooling-tower collision mortality suggest that cooling towers at nuclear power plants cause only a very small fraction of the total annual bird collision mortality from all sources. A very high percentage of all collision mortalities occur during the spring and fall bird migration periods and involve primarily songbirds migrating at night. The relatively few nuclear power plants in the United States that have natural draft towers (24 towers at operating nuclear power plants), combined with the relatively low bird mortality at individual natural draft towers, indicates that (1) bird populations are not greatly affected by collisions with nuclear power plant cooling towers and (2) the contribution of cooling towers to the cumulative effects of bird collision mortalities is very small. Mechanical draft cooling towers, which are not nearly as tall as natural draft towers, pose little risk to migrating birds.

Because the frequency of avian mortality resulting from collisions with cooling towers is small for any species, it is unlikely that the losses would threaten the stability of local migratory bird populations or result in a noticeable impairment of the function of a species within local ecosystems. There is no reason to believe that the annual mortality rate resulting from collision of birds with any cooling tower would be different during the license renewal term. Mitigation measures may include illuminating the natural draft cooling towers at night with low-intensity lights so birds can see the towers and avoid collisions. Because cooling towers represent only a small part of total bird collision mortality, it is not expected that there will be any incremental impact on bird populations from cooling tower collision mortality as a result of license renewal. The impact from bird collisions with cooling towers during the license renewal term was considered to be SMALL for all nuclear plants and was designated as a Category 1 issue in the 1996 GEIS. No new information has been identified in the plant-specific SEISs prepared to date or the literature that would alter that conclusion.

The potential for birds to collide with transmission lines depends on a number of factors, such as bird species, migration behavior, and location and physical characteristics of the transmission line (Bevanger 1988; Janss 2000; Manville 2005). Larger-bodied bird species such as raptors are more likely to collide with transmission lines (Harness and Wilson 2001; Manville 2005), whereas smaller-bodied birds such as migrating songbirds are more likely to collide with towers (Temme and Jackson 1979). This difference is most likely the result of differences in the behavior of raptors and songbirds. Raptors are known to use utility structures as perch locations and nest sites more often than do songbirds (Blue 1996; Manville 2005), whereas nocturnal migrating songbirds may become confused by the lights on communication towers (Crawford and Engstrom 2001). Lights are not a contributing factor in bird collisions at transmission lines because lights are not generally used to mark transmission lines.

It is unknown to what extent bird populations are negatively affected by deaths caused by collisions with transmission lines. Generally, bird mortality resulting from collisions with transmission lines has appeared to be only a small fraction of total mortality; therefore, it has not been considered to have significant population impacts (Stout and Cornwell 1976; Banks 1979). However, rare, threatened, or endangered species may be affected by transmission lines, particularly if the lines pass through areas where such species are concentrated (Sergio et al. 2004; Sundar and Choudhury 2005). There are no reports of relatively high collision mortality occurring at the transmission lines associated with nuclear power plants in the United States. As described in Section 3.1.6.5 and further in 3.1.1, in-scope transmission lines include only those lines that connect the plant to the first substation that feeds into the regional power distribution system. This substation is frequently, but not always, located on the plant property. The length of transmission lines associated with nuclear plants is considerably less than the total 500,000 mi (800,000 km) of transmission lines estimated within the United States (Manville 2005). Therefore, transmission lines associated with nuclear power plants are likely responsible for only a small fraction of total bird collision mortality.

Because the literature does not indicate there is a significant impact from collision mortality on overall species populations and because there are no known instances in which nuclear plant transmission lines have affected local bird populations, it is not expected that the mortality resulting from bird collisions with transmission lines associated with nuclear plants and an additional 20 years of plant operation would cause long-term reductions in bird populations.

The impact of bird collisions with transmission lines during the license renewal term was considered to be SMALL for all plants and was designated as a Category 1 issue in the 1996 GEIS. No new information was identified in the site-specific SEISs prepared to date or the literature that would alter that conclusion. On the basis of these considerations, the NRC concludes that the impact of bird collisions with plant structures and transmission lines during the license renewal term would be SMALL for all nuclear plants and remains a Category 1 issue.

Water Use Conflicts with Terrestrial Resources (Plants with Cooling Ponds or Cooling Towers Using Makeup Water from a River)

In the 1996 GEIS, water use conflicts included ecological impacts on aquatic and riparian communities. The NRC separated out the ecological impacts in this revised GEIS to specifically address the effects of water use conflict on terrestrial resources in riparian communities. This new issue specifically applies to nuclear power plants with cooling ponds or cooling towers, typically with high levels of consumptive use and that use makeup water from a river. Water use conflicts with terrestrial resources in riparian communities could occur when water that supports these resources is diminished either because of decreased availability due to droughts; increased water demand for agricultural, municipal, or industrial usage; or a combination of such factors. For example, Wolf Creek uses Coffee County Lake for cooling (NRC 2008a). Makeup water for the lake is withdrawn from the Neosho River downstream of John Redmond Reservoir. The Neosho River is a small river with especially low water flow during drought conditions. The riparian communities downstream of this reservoir may be affected by the plant’s water use during periods when the lake level is low and makeup water is obtained from the Neosho River. For the Wolf Creek plant, the water use conflict impact is SMALL to MODERATE and a site-specific condition. For future license renewals, the potential range of impact levels at plants with cooling ponds or cooling towers using makeup water from a river cannot be determined at this time. The NRC concludes that the impact of water use conflicts with riparian communities is a plant-specific Category 2 issue.

Transmission Line ROW Management Impacts on Terrestrial Resources

This section evaluates the extent to which plant communities and wildlife populations could be affected by transmission line ROW management during the license renewal term at all nuclear power plants. This issue is a consolidation of two issues that were evaluated in the 1996 GEIS: (1) power line ROW management (cutting and herbicide application) and (2) floodplains and wetland on power line ROW. Impacts on these resources were considered to be SMALL for all plants and were designated as Category 1 issues in the 1996 GEIS. As described in Section 3.1.6.5 and further in 3.1.1, in-scope transmission lines include only those lines that connect the plant to the first substation that feeds into the regional power distribution system. This substation is frequently, but not always, located on the plant property.

Generally, ROW management involves clearcutting, selective cutting of tall woody vegetation, mowing, or herbicide application. These activities alter the physical features of vegetation communities by reducing vegetation height, density, and species diversity, which may impact wildlife populations inhabiting those areas. The cutting of woody vegetation is usually not needed in grassland, desert, or shrub habitats, so associated impacts are not an issue there. Habitat quality in the ROW and nearby areas may be affected, and ROW management may affect local wildlife populations. Data on the effects of maintenance of transmission line ROWs specifically associated with nuclear power plants are not available, but the literature applies to such transmission lines because the methods used to maintain transmission line ROWs are similar for any transmission line ROW at any facility.

Plant communities are affected by the presence of maintained ROWs as well as other ongoing maintenance activities. The principal impacts associated with transmission line ROWs occur as a result of the initial clearing activities during transmission line installation. During installation, forested upland and wetland habitats in ROWs are typically converted to scrub-shrub communities, herbaceous upland, or emergent wetland types when trees are removed. Effects are less extensive where ROWs are established in grassland, desert, or shrub habitats. ROW effects extend beyond the area of direct disturbance. Transmission line ROWs established in otherwise undeveloped areas contribute to habitat fragmentation and affect the distribution of species in undisturbed areas along the corridors. The effects of habitat fragmentation associated with clearings and the creation of edges may continue to develop over a considerable period of time, since some species are lost while others become established (Saunders et al. 1991). Clearings in wooded areas tend to contribute to an increase in deer populations and increased access to forest interior areas (Alverson et al. 1988). The gradual loss of some plant species from these areas due to browsing may extend over many decades.

The operation of heavy equipment during ROW maintenance activities can result in soil compaction, affecting the establishment of some native plant species. ROW corridors occasionally provide a route for the introduction or expansion of invasive species populations into new areas. Significant changes in vegetation cover, such as removal of the tree canopy, and compaction of upland soils within the watershed of a wetland generally result in increased runoff and reduced infiltration to shallow groundwater, causing an increase or decrease in hydrologic input to nearby wetlands (EPA 1993, 1996; Wright et al. 2006). Effects include changes in the frequency or duration of inundation or soil saturation and greater fluctuations in wetland water levels. Runoff often contains sediments, contaminants from road and parking surfaces, or herbicides used in ROW or site vegetation management. Erosion of wetland substrates and plants can result from increased flow velocities that result from the changes in runoff and surface drainage patterns.

The presence of the ROWs would continue to affect the habitats within and adjacent to the transmission line corridors during the license renewal term; there would be more light and less soil moisture than found in undisturbed habitats. The plant communities that became established during the years of the initial operating license would generally remain altered communities, with a different species composition and community structure than undisturbed habitats. In many areas, ROW management would prevent the development of mature plant communities. Plant species that are typically associated with high-quality, undisturbed native habitats and are intolerant of disturbed conditions would generally continue to be excluded from ROWs. Although species diversity may be high in these disturbed habitats, many of the species may be common or weedy native species or non-natives. However, in some areas, rare or protected species that require open canopies, such as the golden sedge (*Carex lutea*), Cooley's meadowrue (*Thalictrum cooleyi*), and rough-leaf loosestrife (*Lysimachia asperulaefolia*), which occur within the Brunswick Steam Electric Plant ROWs in North Carolina, would continue to occur under the conditions existing within the ROWs. Invasive upland or wetland species that became established within the ROWs during the initial operating license would continue to exclude native species and reduce species diversity (BPA 2000). Invasive species populations may continue to expand unless aggressive management efforts are implemented.

Plant communities in and along ROWs are generally maintained in a modified condition for safe and efficient operation of the transmission lines. To protect the electric conductors, ROW management typically includes the periodic cutting of tall trees and application of herbicides. Tree cutting is a minor management activity in regions where tree growth in ROWs is limited, such as in grasslands, desert, or shrubland areas. Mowing is also frequently used as a management method to control the growth of woody species and promote the establishment of grassland or other herbaceous habitat types. Management activities and transmission line repair occasionally result in the erosion of exposed soils where vegetation has been removed or where soils are disturbed by equipment. Management activities that result in the disturbance, compaction, or exposure of soils may promote the establishment of invasive species (BPA 2000). Erosion of upland soils may result in sedimentation or increased turbidity in wetlands within the watershed. Herbicides used to manage undesirable species may drift onto nontarget species or affect wetland communities through runoff from treated areas (BLM 2007). The operation of heavy equipment in wetlands during ROW maintenance or transmission line repair can damage or compact wetland soils and vegetation.

Many of the nuclear power plants incorporate mitigation into their ROW management plans to protect wetlands or other sensitive or high-quality habitats. For example, within the ROWs of the Millstone plant in Connecticut, precautions are taken to protect and promote quality habitats. Herbicide use is prohibited within 10 ft of wetlands or surface water, and mowing is conducted only from November through April to protect saturated soils and minimize loss of fruit and seeds (NRC 2005c). ROW maintenance practices used at the Brunswick plant in North Carolina, such as methods of herbicide use, are designed to preserve and protect rare and listed plant species and sensitive natural areas known to occur within the ROWs. Established procedures are in place to protect rare and listed plant species if they are encountered by maintenance crews (NRC 2006b). At the Browns Ferry plant in Alabama, field studies are conducted to inventory and protect listed plant species and sensitive habitats. Species populations are monitored, and habitats are managed and maintained. In the most sensitive areas, vehicles and equipment are prohibited, and all vegetation clearing is done by hand (NRC 2005d).

Most data on the impacts of transmission line ROWs on wildlife are for relatively moist areas of the United States where vegetation growth is rapid and vegetation must be controlled to prevent its interference with the transmission lines. In arid regions, little or no vegetation control is required, and the potential effects on wildlife are small. Potential effects are also small where lines cross croplands, because no vegetation management is required. The following discussion is therefore applicable primarily to forested regions where the utility must control vegetation on transmission line ROWs.

The maintenance of a transmission line ROW could directly affect wildlife as the result of (1) continued habitat loss or alteration; (2) displacement due to noise during maintenance activities; (3) mortality from maintenance equipment, conductors, or wires; (4) reduced mobility of some species, such as amphibians, across the cleared ROW; and (5) toxicity from herbicide or fuel spills. ROW creation establishes, and maintenance activities maintain, a new habitat type that divides a pre-existing and usually much larger habitat type, such as a forest (Yahner et al. 2004). The increased amount of edge along the boundary of the two habitats may affect wildlife by (1) increasing rates of predation among nesting birds, (2) restricting wildlife dispersal and migration patterns, (3) negatively affecting wildlife species that require large undisturbed areas, or (4) increasing local wildlife abundance and diversity.

Many studies identify the potential effects of ROW maintenance on wildlife populations. Transmission line ROWs may represent a barrier for species, such as large mammalian carnivores, that require large tracts of contiguous forested habitat (Crooks 2002). ROW maintenance may also have negative effects on smaller, less mobile wildlife species. For example, studies have shown that some amphibian species have difficulty crossing disturbed habitat and may experience increased rates of mortality as a result of physiological stress (Gibbs 1998; Rothermel 2004).

Traditionally, habitat edges have been considered to be beneficial to wildlife because species diversity is usually greater there (Yahner 1988). However, some species such as neotropical migrating songbirds that prefer interior forest habitat may be adversely affected by the increase in edge habitat associated with ROW clearings. These species require large blocks of forest for successful reproduction and survival (Wilcove 1988). Studies have found that nests of these bird species placed near edges are more likely to fail as a result of predation or nest parasitism than nests located near the forest interior (Paton 1994; Robinson et al. 1995). This failure is often due to an increase in the abundance of predators (e.g., skunks and raccoons) and nest parasites (e.g., brown-headed cowbirds [*Molothrus ater*] that lay their eggs in the nests of other birds), which are capable of proliferating in disturbed areas and edge habitats (Evans and Gates 1997; Crooks and Soulé 1999). Increased predation and nest parasitism rates along edge habitats have reduced the populations of some neotropical bird species to the point where they have become locally extinct (Crooks and Soulé 1999).

Numerous studies indicate that wildlife populations can benefit from ROW management. Ongoing research on the effects of ROW management on wildlife has been conducted for more than 50 years at the State Game Lands 33 Research Project in Pennsylvania (Yahner 2004). Results of the studies conducted at that site indicate that long-term management of the ROW may provide an essential food source and cover habitat for insects, amphibians and reptiles, numerous bird species, and mammals such as black bear (*Ursus americanus*) and white-tailed deer (*Odocoileus virginianus*). Even species of concern, such as neotropical migrant birds, have been commonly observed using the brushy habitats provided by the ROW. Yahner et al. (2002, 2004) found that herbicide treatments in the ROW did not have any adverse effects on the nesting success of neotropical migrating bird species like the eastern towhee (*Pipilo erythrophthalmus*). King and Byers (2002) discovered that songbird nesting success was greater within the brushy ROW habitat than in nearby vegetation communities.

In a study of rodent populations in Oregon, Wolff et al. (1997) found higher densities of gray-tailed voles (*Microtus canicaudus*) in disturbed open habitats than in other habitats. They also found no effect of habitat disturbance on vole survival, reproductive success, or population size. Johnson et al. (1979) found that the diversity of small mammals was greater in ROW habitats than in adjacent forest habitats. There is also evidence that ROW maintenance can provide suitable habitat for some important insect populations, such as butterflies (Bramble et al. 1999). Thus, the management of ROW habitats may provide suitable habitat for a number of wildlife species, including some sensitive species such as neotropical migrant songbirds.

An important aspect of ROW management is the consideration of management strategies that limit the adverse effects on wildlife species. Herbicides are generally not highly toxic to wildlife when they are properly applied for ROW management. Therefore, toxic effects of herbicides on wildlife are generally of little concern to wildlife biologists or wildlife managers. Of the papers reviewed for this analysis, none expressed serious concern about toxic effects. In fact, some management techniques using herbicides have been proposed to maintain the function of the ROW and maximize the amount of suitable habitat for wildlife species. Yahner et al. (2002) proposed a phased approach to control the growth of undesirable plants, such as large trees, and maintain an early successional shrub-like plant community along the ROW. This objective could be accomplished through a combination of mechanical treatments (e.g., mowing) and selective herbicide applications. This approach could minimize the costs associated with vegetation management along a ROW and might be an important conservation tool for numerous wildlife species (Marshall and Vandruff 2002; Yahner et al. 2002).

The overall impact of transmission line ROW areas appears to be neither significantly adverse nor significantly beneficial. The consensus among wildlife biologists appears to be that although the initial habitat destruction associated with ROW clearing can have numerous consequences on wildlife populations, the proper management of transmission line ROW areas does not have significant adverse impacts on current wildlife populations, and ROW management can provide valuable wildlife habitats. Of the papers reviewed for this evaluation, none identified any significant impact of transmission line corridors on wildlife. The evidence supports a conclusion that continued ROW management during the license renewal term will not lower habitat quality or cause significant changes in wildlife populations in the surrounding habitat. On the basis of these considerations, the NRC concludes that the impact of continued transmission line ROW management on terrestrial resources is SMALL for all nuclear plants and remains a Category 1 issue.

Electromagnetic Fields on Flora and Fauna (Plants, Agricultural Crops, Honeybees, Wildlife, Livestock)

As described in Section 3.1.6.5 and further in 3.1.1, in-scope transmission lines include only those lines that connect the plant to the first substation that feeds into the regional power distribution system. This substation is frequently, but not always, located on the plant property. The effects of electromagnetic fields on terrestrial biota are considered to be of SMALL significance if the overall health, productivity, and reproduction of individual species appear unaffected.

The EMFs produced by operating transmission lines up to 1,100 kV have not been reported to have any biologically or economically significant impact on plants, wildlife, agricultural crops, or livestock (Lee et al. 1989; Miller 1983). Areas under and in the vicinity of the lines have been studied numerous times. Vegetation, foliar damage due to EMF-induced corona at leaf margins, agricultural crop production, wildlife population abundance, livestock production, and potential livestock avoidance of the lines have been investigated. Also, many laboratory experiments with plants and laboratory animals have been conducted, often using electric fields much stronger than those occurring under transmission lines.

Plants—Studies have shown that minor damage to plant foliage and buds can occur in the vicinity of strong electric fields. For example, tree foliage and buds that are close to transmission lines can be damaged and upward or outward growth of branches can be reduced. Damage typically occurs only to the tips and margins of leaves in the uppermost plant parts that are the closest to the lines. The damage in the form of a leaf burn is most prevalent on small pointed leaves and is similar to leaf damage that might occur as a result of drought or other environmental stresses. The damage generally does not interfere with overall plant growth (Miller 1983).

The damage is thought to result from heating caused by induced corona at the leaf tips and margins. The electric field is greatly focused by leaf points or marginal teeth, thus increasing its strength to the point that corona (Section 4.6.1.3) occurs. Night-vision instruments have shown this corona as a glow of light concentrated at leaf tips and margins. The damage apparently does not extend to lower levels of the plant because the electric field weakens with distance from the lines and because the upper plant parts shield the lower parts from the electric field.

In one experiment under an 1,100-kV prototype line, the upward growth of alder and Douglas fir trees was reduced by this damage, with the result that the crowns of the trees became somewhat flattened on top and the overall crown developed a broader appearance than usual (Rogers et al. 1984). The growth of the lower parts of the trees and of lower-growing plants such as pasture grass, barley, and peas appeared unaffected (Rogers and Hinds 1983). In another experiment, 50-kV/m fields had no apparent effect on corn germination or the growth of corn seedlings; and the growth of corn, bluegrass, and alfalfa apparently was not affected by fields of 25–50 kV even though minor damage occurred to the outer fringes of the uppermost leaves (Bankoske et al. 1976). Germination of sunflower seeds in a 5-kV/m electric field was reduced by about 5 percent in some cases [4 out of 11 replicates (Marino et al. 1983)]. An experiment with several species of agricultural plants found that a maximum of about 1 percent of the total plant tissue was damaged by exposing the plants to 50-kV/m fields (Poznaniak and Reed 1978).

Lee et al. (1989) reviewed several papers reporting studies in Indiana, Tennessee, and Arkansas. The productivity of corn and other crop plants was not affected by electric fields of 12 to 16 kV/m under a 765-kV line and a UHV test line in Indiana, although plants under the larger line suffered some leaf tip damage from induced corona. Corn production in Tennessee may have been reduced by electric fields up to 8.5 kV/m, but the authors indicated the results were inconclusive. An Arkansas study found normal yields of rice and soybeans, but a 15 percent reduced yield of cotton beneath a 500-kV line (see Section 4.3.1.1). The researchers could not determine whether the reduced cotton yield resulted from electric field or ineffective aerial application of agricultural chemicals beneath the line.

Honeybees—Several studies have shown that honeybees in hives under transmission lines are affected by EMF (Greenburg et al. 1985; Rogers and Hinds 1983; Warren et al. 1981). Adverse effects include increased propolis (a reddish resinous cement) production, reduced growth, greater irritability, and increased mortality. These effects can be greatly reduced by shielding the hives with a grounded metal screen or by moving the hives away from the lines (Rogers and Hinds 1983; Lee 1980). Bindokas et al. (1988) showed that these impacts were not caused by direct effects of the electric fields on the bees but by voltage buildup and electric currents within the hives and the resultant shocks to bees. Bees kept in moisture-free nonconductive conditions were not adversely affected, even in electric fields as strong as 100 kV/m.

Wildlife and Livestock—Chronic exposure to EMF is experienced by small birds and mammals that primarily inhabit ROW corridors and by birds (primarily raptors) that nest in transmission line towers. EMF exposures to larger animals and livestock are usually relatively brief because these animals inhabit relatively large areas instead of small areas beneath the lines. Exposures occur as these larger animals pass beneath the lines or as birds fly by the lines.

The voluminous literature on population studies of small bird and mammal species in transmission line corridors (presented earlier in this section) has expressed virtually no concern for possible impacts of EMFs. These species apparently thrive underneath the lines, where their abundance appears to depend on habitat quality rather than on the strength of the electric fields to which they are exposed or the size of the line. For example, the density of breeding birds under 500-kV lines in eastern Tennessee is greater than that in adjacent forests (Kroodsma 1984, 1987) and appears to be greater than bird density in most grassland habitats or agricultural fields. Also, the density of small mammal populations near these lines appears to depend on habitat type rather than on the presence of the lines (Schreiber et al. 1976). A Minnesota study of a 500-kV line found little evidence of either a positive or negative effect of the power line on bird populations (Niemi and Hanowski 1984). Bird and small mammal populations under an 1,100-kV line in Oregon were also apparently unaffected by line operations (Rogers and Hinds 1983). Habitat use by elk in western Montana was apparently unaffected by operation of a 500-kV line, as the elk used habitats along the power line in proportion to their availability (Canfield 1988).

Raptors, ravens, and some water bird species frequently nest and perch on transmission line towers, particularly in grassland areas where other suitable nest sites are lacking. Thus, the birds are able to use habitats without suitable nest sites—habitats that they otherwise would not have used (Gilmer and Stewart 1983; Williams and Colson 1989). On high-voltage lines supported by metal lattice towers, the birds usually nest on the top (bridge) of the tower where the strength of the electric field is minimal (e.g., 5 kV/m or less) (Lee 1980). Lee found 80 percent of 110 nests on towers to be located on the tower bridge and cited previous studies that showed similar results.

The success of these tower nests in producing young appears to be no different from nests located in areas not exposed to EMF. In central North Dakota, 113 ferruginous hawk nests in high-voltage transmission line towers (18 percent of a total of 628 nests found) had a higher success rate (87 percent) than nests in other locations (however, a hail storm that missed the lines reduced the success of some other nests). The number of fledglings per occupied nest was 2.8 for ground nests (which were larger than tower or tree nests), 2.6 for tower nests, 2.3 for haystack nests, and 2.0 for tree nests (Gilmer and Stewart 1983). In Idaho, Steenhof et al. (1993) studied nesting success of ravens and raptors on a 370-mile (576-km) segment of 500-kV transmission line constructed in 1981. From 1981 through 1989 (the last year reported by Steenhof et al. 1993), the numbers of these species nesting on transmission towers increased to 133 pairs, including roughly 64 percent common ravens, 21 percent red-tailed hawks, 9 percent ferruginous hawks, 6 percent golden eagles, and 0.3 percent great horned owls. Nesting success of these birds averaged 65 percent to 86 percent and was similar to or better than that of the same species nesting on other structures. Lee (1980) reported finding 110 hawk and raven nests on 260 miles (418 km) of 230-kV and 500-kV lines of the Bonneville Power Administration. Although the success of these nests was not monitored, the author reported that, based on a literature review, it was unlikely that nesting would be adversely affected by EMF found in most locations in transmission line towers.

Livestock in both field and laboratory studies have shown no significant impacts when exposed to EMF. Lee et al. (1989) reviewed about 10 reports on effects of transmission lines on livestock in the United States and Sweden. These studies found no evidence that the growth, production, or behavior of beef and dairy cattle, sheep, hogs, or horses were affected by EMFs. The studies involved 11 farms along a 765-kV line in Indiana, 55 dairy farms near 765-kV lines in Ohio, 36 herds of cattle near 400-kV lines in Sweden, a mail survey of 106 farms in Sweden, a study of fertility of 58 cows under a 400-kV line in Sweden compared with 58 in a control area, 30 swine raised beneath a 345-kV line in Iowa compared with 30 raised in a control area, and cattle behavior under an 1,100-kV prototype line in Oregon. Cattle under the 1,100-kV test line in Oregon were startled by the first occurrence of corona noise when the line was re-energized after a reactor shutdown period (Rogers and Hinds 1983). From 1977 through 1981, grazing of cattle in pasture under the line appeared to be unaffected by line operation. In 1980–1981, the cattle spent more time near the line during periods when it was de-energized than when it was operating, but spent an increasing amount of time under the line when it was operating as the growing season progressed (Rogers and Hinds 1983).

In the Indiana study (Amstutz and Miller 1980), performance of livestock frequently under a 765-kV line on 11 farms was studied during a 2-year period (1977–1979; 9 farms participated for the full 2 years). Animals included 10 horses, 55 sheep, 149 beef cattle, 337 hogs, and 429 dairy cattle. Maximum field voltage levels recorded near ground level were about 9.1 kV/m. General health, behavior, and performance of the animals were not affected by the transmission line EMF.

In the Swedish study of cow fertility, 58 heifers were exposed to a 400-kV, 50-Hz transmission line from June to mid-October 1985 (Algers and Hultgren 1987). The length of exposure was 15 to 20 times longer than the average exposure per year for Swedish dairy herds exposed to 400-kV lines. No effects were observed on the frequency of malformations, the length or variation of the estrous cycle, the mid-cycle plasma progesterone level, the intensity of estrus, the number of inseminations per pregnancy, the overall conception rate, or the fetal viability. Previous studies of cattle showed no significant effects of EMFs on reproduction.

Conclusion—No significant impacts of EMFs on terrestrial biota have been identified. Although foliage very close to lines can be damaged, the overall productivity and reproduction of native and agricultural plants appear unaffected. Also, no evidence suggests significant impacts on individual animals or wildlife populations that are chronically exposed to EMFs under transmission lines or in the towers. Livestock behavior and production also appear unaffected by line operation. Therefore, the potential impact of EMFs on terrestrial biota is expected to be of SMALL significance for all plants. The only potential mitigation would be to exclude plants and animals from the right of way, a measure with very severe impacts of its own. However, because the impact is of small significance and because mitigation measures could create additional environmental impacts and would be costly, no mitigation measures beyond those implemented during the current term license would be warranted. This remains a Category 1 issue.

4.6.1.2 Aquatic Resources

Continued operations of the nuclear power plants during the 20-year license renewal term includes the operation of the cooling system (once-through, cooling ponds, or cooling towers), transmission line ROW maintenance, releases of gaseous and liquid effluents, facility maintenance, and refurbishment-related construction activities. Aquatic organisms would continue to be subject to impingement, entrainment, thermal discharges, chemical and radiological contaminants, and erosion and sedimentation. This section considers eleven issues concerning impacts of the proposed action on aquatic resources:

- Impingement and entrainment of aquatic organisms (plants with once-through cooling systems or cooling ponds) (consolidation of two issues from the 1996 GEIS: (1) entrainment of fish and shellfish in early life stages and (2) impingement of fish and shellfish (for plants with once-through cooling and cooling pond heat dissipation systems)).

- Impingement and entrainment of aquatic organisms (plants with cooling towers) (consolidation of two issues from the 1996 GEIS: (1) entrainment of fish and shellfish in early life stages and (2) impingement of fish and shellfish (for plants with cooling tower-based heat dissipation systems)).

- Entrainment of phytoplankton and zooplankton (all plants) (issue in the 1996 GEIS);

- Thermal impacts on aquatic organisms (plants with once-through cooling systems or cooling ponds) (issue was modified and renamed from the 1996 GEIS issue, “Heat shock (for plants with once-through and cooling pond heat dissipation systems)”);

- Thermal impacts on aquatic organisms (plants with cooling towers) (issue was modified and renamed from the 1996 GEIS issue, “Heat shock (for plants with cooling-tower-based heat dissipation systems)”);

- Infrequently reported thermal impacts (all plants) (consolidation of five issues from the 1996 GEIS: (1) cold shock, (2) thermal plume barrier to migrating fish, (3) distribution of aquatic organisms, (4) premature emergence of aquatic insects; and (5) stimulation of nuisance organisms (e.g., shipworms));

- Effects of cooling water discharge on dissolved oxygen, gas supersaturation, and eutrophication (consolidation of three issues from the 1996 GEIS: (1) eutrophication, (2) gas supersaturation (gas bubble disease), and (3) low dissolved oxygen in the discharge);

- Effects of nonradiological contaminants on aquatic organisms (issue was modified and renamed from the 1996 GEIS issue, accumulation of contaminants in sediments or biota, to include contaminant effects other than just accumulation);

- Exposure of aquatic organisms to radionuclides (new issue not considered in the 1996 GEIS);

- Effects of dredging on aquatic organisms (new issue not considered in the 1996 GEIS);

- Water use conflicts with aquatic resources (plants with cooling ponds or cooling towers using makeup water from a river) (new issue not considered in the 1996 GEIS);

- Effects on aquatic resources (non-cooling system impacts) (issue was modified and renamed from the 1996 GEIS issue, "Refurbishment," to include non-refurbishment impacts);

- Impacts of transmission line ROW management on aquatic resources (new issue not considered in the 1996 GEIS);

- Losses from predation, parasitism, and disease among organisms exposed to sublethal stresses (issue in the 1996 GEIS).

Overview of Impingement and Entrainment

Impingement occurs when organisms are held against the intake screen or netting placed within intake canals. Most impingement involves fish and shellfish. Table 4.6-4 lists some of the fish species commonly impinged at power plants. At some nuclear power plants, other vertebrate species may also be impinged on the traveling screens or on intake netting placed within intake canals. These include five species of sea turtle: loggerhead (*Caretta caretta*), green (*Chelonia mydas*), Kemp's

Impingement

Impingement is the entrapment of all life stages of fish and shellfish on the outer part of an intake structure or against a screening device during periods of water withdrawal (40 CFR 125.83).

Entrainment

Entrainment is incorporation of all life stages of fish and shellfish with intake water flow entering and passing through a cooling-water intake structure and into a cooling water system (40 CFR 125.83).

Table 4.6-4. Fish Species Commonly Impinged or Entrained at Power Plants

Ecosystem Type	Fish Species
Rivers	Alewife (*Alosa pseudoharengus*)
	Gizzard shad (*Dorosoma cepedianum*)
	Common carp (*Cyprinus carpio*)
	White bass (*Morone chrysops*)
	Sunfish (*Lepomis* spp.)
	Crappie (*Pomoxis* spp.)
	Yellow perch (*Perca flavescens*)
	Freshwater drum (*Aplodinotus grunniens*)
Great Lakes	Alewife (*Alosa pseudoharengus*)
	Gizzard shad (*Dorosoma cepedianum*)
	Yellow perch (*Perca flavescens*)
	Rainbow smelt (*Osmerus mordax*)
Estuaries	Bay anchovy (*Anchoa mitchilli*)
	Tautog (*Tautoga onitis*)
	Atlantic menhaden (*Brevoortia tyrannus*)
	Gulf menhaden (*Brevoortia patronus*)
	Winter flounder (*Pleuronectes americanus*)
	Weakfish (*Cynoscion regalis*)
Oceans	Bay anchovy (*Anchoa mitchilli*)
	Striped anchovy (*Anchoa hepsetus*)
	Silver perch (*Bairdiella chrysura*)
	Cunner (*Tautogolabrus adspersus*)
	Scaled sardine (*Harengula jaquana*)
	Queenfish (*Seriphus politus*)

ridley (*Lepidochelys kempi*), leatherback (*Dermochelys coriacea*), and hawksbill (*Eretmochelys imbricata*). Impingement of these sea turtles has occurred at the Diablo Canyon and San Onofre plants on the Pacific coast; at the Salem, Oyster Creek, Brunswick, and St. Lucie plants on the Atlantic coast; and at the Crystal River plant on the Gulf coast on the either Atlantic and Gulf of Mexico coasts or east coast (Gunter et al. 2001). Waterfowl have also been impinged at several plants; examples are double-crested cormorants (*Phalacrocorax auritus*) at Point Beach plant in Wisconsin (NRC 2005b), lesser scaup (*Aythya affinis*) at Cook in Michigan (Mitchell and Carlson 1993), and lesser scaup and greater scaup (*A. marila*) at Nine Mile Point in New York (NRC 2006d). Isolated incidents of impingement or other impacts from power plants have been reported for other vertebrates, such as the American crocodile (*Crocodylus acutus*) at Turkey Point in Florida and the West Indian manatee (*Trichechus manatus*) at Turkey Point and St. Lucie in Florida (Gunter et al. 2001). Small numbers of harbor (*Phoca vitulina*), gray (*Halichoerus grypus*), harp (*Pagophilus groenlandicus*), and hooded (*Cystophora cristata*) seals have been impinged at Seabrook in New Hampshire (67 FR 61). Impingement impacts are expected to continue during the license renewal term. The impacts of impingement are different for once-through and closed-cycle cooling systems and are therefore discussed separately below.

Entrainment occurs when organisms pass through the intake screens and travel through the condenser cooling system. Aquatic organisms typically entrained include ichthyoplankton (fish eggs and larvae), larval stages of shellfish and other macroinvertebrates, zooplankton, and phytoplankton. Juveniles and adults of some species may also be entrained if they are small enough to pass through the intake screen openings, which are commonly 0.38 in. (1 cm) at the widest point. Table 4.6-4 lists fish species commonly entrained at power plants.

<u>Impingement and Entrainment of Aquatic Organisms (Plants with Once-Through Cooling Systems and Cooling Ponds)</u>

In the 1996 GEIS, the NRC considered that for plants with a once-through cooling systems or cooling ponds, the impacts of impingement and entrainment of aquatic organisms were SMALL at many plants but MODERATE to LARGE at a few nuclear plants. Therefore, impingement and entrainment were considered Category 2 issues. For plants that operate in a hybrid mode, impingement and entrainment would be SMALL at most nuclear plants, but could be MODERATE or LARGE at a few plants, and were also considered Category 2 issues.

Impingement is more of a concern at nuclear plants that have once-through cooling because these plants require a larger amount of water than plants that operate under closed-cycle (NRC 1996). Impingement monitoring at the Palisades nuclear power plant in Michigan demonstrated this difference. In 1972, when the plant used once-through cooling, 654,000 fish were impinged yearly at a water withdrawal rate of 400,000 gpm. In 1976, cooling towers were added to the plant, and it began operating as a closed-cycle plant. Intake withdrawal rate was reduced to

78,000 gpm, and impingement dropped to 7,200 fish per year (Consumers Energy Company and Nuclear Management Company 2001). McLean et al. (2002) reported that the magnitude of impingement at Maryland power plants with similar intake designs within Chesapeake Bay differed greatly according to the location of the intake.

Impingement at the Quad Cities plant in Illinois is often an order of magnitude higher from February through April than during summer and fall, even though the cooling water intake flow is only half that of the rest of the year (Bodensteiner and Lewis 1992). Impingement at Quad Cities was primarily composed of young-of-year and juveniles; in the case of gizzard shad (*Dorosoma cepedianum*) and freshwater drum (*Aplodinotus grunniens*), fish of these ages cannot tolerate near-freezing to freezing temperatures during winter and early spring. Other species, such as the bluegill (*Lepomis macrochirus*), channel catfish (*Ictalurus punctatus*), and white bass (*Morone chrysops*), are also prominent in winter impingement collections (Bodensteiner and Lewis 1992, 1994; LaJeone and Monzingo 2000). Although the number of fish impinged at Quad Cities was relatively high (e.g., nearly 3 million in 1989), most (up to 90 percent) of the fishes that entered the intake forebay were dead or moribund. Therefore, even if these fish were not impinged, they would have still been lost from the fishery (LaJeone and Monzingo 2000). Similar results have been noted for impingement of threadfin shad (*Dorosoma petenense*) at the McGuire plant in North Carolina (NRC 2002c) and gizzard shad at the Summer plant in South Carolina (NRC 2004b).

For the Pilgrim plant in Massachusetts, the NRC concluded that impingement during continued operation of the plant would have a MODERATE impact on the Jones River population of the rainbow smelt (*Osmerus mordax*) on the basis of an observed decline of that population, uncertainty about the stock's status, impingement rates, and low impingement survivability. Impingement had a SMALL to MODERATE impact on all other species (NRC 2007c).

For the Wolf Creek plant in Kansas, the NRC concluded that impingement during continued operation of the plant could have SMALL to MODERATE impacts at the makeup water screen house during periods when river water levels were low, because fish would have less available habitat to use as a refuge and would likely be exposed to greater pumping frequency and volume removals from the Neosho River. During most of the license renewal term, the impacts of impingement would be SMALL (NRC 2008a).

Various methods that have been used to reduce impingement include returning impinged fish to the water source, bypassing fish at the intake screens, and preventing the approach of fish to the intake area (Lieberman and Muessio 1978). Various deflection methods that have been used at power plants to reduce impingement include physical barriers, visual stimuli (e.g., air-bubble screens and static or strobe lights), water velocity and pressure changes, electrical shocks, and sound (Maes et al. 2004). These methods have variable effectiveness. For example, sound has been most effective at plants that primarily impinge clupeids

(Maes et al. 2004; Ross et al. 1993, 1996; NRC 2005a,b). Stocking, restoring habitat, and installing cooling towers are also mitigation options.

At the Surry plant in Virginia, about 94 percent of all fish impinged were returned alive to the river through the fish return system. Only five species had less than 80 percent survival. These were the spot (*Leiostomus xanthurus*), Atlantic menhaden (*Brevvortia tyrannus*), blueback herring (*Alosa aestivalis*), threadfin shad, and bay anchovy (*Anchoa mitchilli*) (NRC 2002d). These species generally are susceptible to physical injuries while impinged (e.g., because of their delicate scales). A mitigation program at St. Lucie involves Florida Power and Light Company periodically trapping fish from the intake canal, tagging them, and releasing them in the ocean. The goal is to tag and release 1000 fish per year (NRC 2003a). At the Calvert Cliffs plant in Maryland, about 5.25 million blue crabs (*Callinectes sapidus*) were impinged between 1975 and 1982, but impingement survival was 99 percent (NRC 1999b).

Physical stresses experienced by organisms during impingement are affected by screen wash frequency, screen rotation speed, and screen modifications intended to reduce stress associated with fish separation and handling. Low pressure spray is often used to return organisms to a water body, whereas high pressure spray is used for debris removal. When screens are infrequently washed, impinged organisms may become moribund from repeated attempts to free themselves and may suffocate against the screen (Jinks 2005). Generally, species with heavier skeletal structures, thick scales or bony scutes, thick protective slimes, or hard exoskeletons are most likely to resist physical injury and desiccation during impingement (Jinks 2005).

Although fish return systems can decrease impingement mortality, some stressed and injured fish returned to the water body may take a number of days to die. Even those with minor damage may develop a bacterial or fungal infection that eventually leads to mortality. Also, returned fish may be exhausted, disoriented, and damaged, which makes them more susceptible to predation (Henderson et al. 2003). Replacing conventional intake screens with Ristroph screens is unlikely to result in a significant reduction in impingement mortality at localities where clupeid and sciaenid species predominate (Henderson et al. 2003).

While planktonic organisms are generally not uniformly distributed throughout a water body, it is often assumed that withdrawal of a certain percentage of the source water would result in entrainment of that percentage of the planktonic organisms that pass by a plant (EPA 2002). At Browns Ferry in Alabama, the portion of the river flow that passed through the plant was found to be higher than the percentage of larval fishes in the river that were entrained (NRC 2005c). Fish species with free-floating early life stages are those most susceptible to entrainment (EPA 2002). For power plants (nuclear and fossil) located in the Great Lakes, the number of fish entrained increased with increasing power capacity (Kelso and Milburn 1979).

Entrained organisms are exposed to heat, mechanical, pressure, and chemical stresses (NRC 1996). Entrained organisms are exposed to a rapid temperature rise that is essentially equivalent to the temperature rise across the condensers during their passage through the plant (Schubel et al. 1977). It has been conservatively concluded that mortality of planktonic organisms is assumed to be 100 percent. For ichthyoplankton, this assumption is based on the extreme delicacy of eggs and the fact that their skeleton, musculature, and integument are soft, thereby providing only a minimal amount of protection for vital organs (EPA 2002). Nevertheless, these killed organisms provide food for consumers and decomposers in the receiving water body (Fox and Moyer 1973). Conversely, bacteria and other microorganisms that are entrained may increase in number as a result of prolonged exposure to increased heat (Fox and Moyer 1973; see Section 3.9.3). At the Quad Cities plant in Illinois, LaJeone and Monzingo (2000) concluded that as long as discharge temperatures do not exceed 100°F (37.8°C), some entrainment survival would occur.

Fish eggs and larvae have a high natural mortality rate; thus, the number of entrained ichthyoplankton that would have survived to become adult fish is much lower than the number of eggs and larvae entrained (EPA 2002). In a laboratory study on the exposure of larval common shrimp (*Crangon crangon*) and lobster (*Homarus gammarus*) and adult copepods (*Acartia tonsa*) to simulated entrainment stresses (i.e., thermal, mechanical, chlorine, and pressure effects, both alone and in combination), it was concluded that most individuals of each species would survive passage through a nuclear power station under normal operating conditions. Since the experiments on these crustaceans demonstrated that each species has different responses to different stressors, the only generalization that could be made is that mortality from the totality of entrainment passage would be 10 to 20 percent (Bamber and Seaby 2004).

Mitigation has been used to minimize entrainment losses. This includes several measures that also minimize impingement impacts (e.g., using closed-cycle cooling and designing intakes to minimize velocities through the intake screens). At the McGuire plant in North Carolina, about 45 percent of the cooling water is obtained from the low-level intake, which pulls water from the hypolimnion at a depth of about 100 ft (30 m), where few planktonic organisms occur. Therefore, entrainment is minimized (NRC 2002c). Skimmer walls inside the intake bays at the Robinson plant in South Carolina similarly reduce entrainment (NRC 2003b). At the Millstone plant, potential mitigation measures that were identified included reducing intake flows during the winter flounder (*Pleuronectes americanus*) spawning season; conducting regular inspections, maintenance, or refueling during the spawning season; importing fish into the areas; installing fine mesh screens on the intakes; or installing cooling towers (NRC 2005c).[(b)]

Section 316(b) of the CWA requires that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing impingement and entrainment of aquatic organisms. Section 316(b) is regulated under the NPDES program. Two rulemaking phases initiated by EPA associated with Section 316(b) are relevant to nuclear power plant cooling water intake structures. Phase I (enacted in December 2001) is for new facilities (40 CFR 125.83) with a design intake flow greater than 2 million gpd (7.6 million L/d) and that use at least 25 percent of water withdrawn used for cooling purposes (40 CFR Part 125, Subpart I). Phase II (enacted in July 2004) applies to existing large electric generating facilities with a design intake flow of 50 million gpd (189 million L/d) or more and that use at least 25 percent of the water withdrawn for cooling purposes (40 CFR Part 125, Subpart J). The Phase II Rule was suspended on July 9, 2007, after several of its key provisions were remanded by the U.S. Court of Appeals.

As of late 2012, existing nuclear power plant facilities with a cooling water intake structure that are not currently subject to a national rule require Section 316(b) NPDES permit conditions that reflect best technology available for minimizing adverse environmental impact on a case-by-case, best professional judgment basis (40 CFR 125.90(b) and 401.14). The NRC expects that any site-specific mitigation required under the NPDES permitting process should result in a reduction in the impacts of continued plant operations.

In the 1996 GEIS, the NRC categorized the impacts of license renewal on impingement and entrainment of aquatic organisms to be SMALL, MODERATE, or LARGE at plants with once-through cooling or cooling ponds (i.e., a Category 2 issue). No new information has been identified in the plant-specific SEISs prepared to date or in the literature that would alter those conclusions.

On the basis of these considerations, the NRC concludes that the impingement and entrainment of aquatic organisms over the license renewal term at nuclear plants with once-through cooling or cooling ponds could be SMALL, MODERATE, or LARGE and remains a Category 2 issue. The magnitude of the impact would depend on plant-specific characteristics of the cooling system (including location, intake velocities, screening technologies, and withdrawal rates) and

(b) The NRC cannot impose water quality mitigation requirements on licensees. The Atomic Safety and Licensing Appeal Board, in the “Yellow Creek” case, determined that the EPA has sole jurisdiction over the regulation of water quality with respect to the withdrawal and discharge of waters for nuclear power stations, and it also determined that the NRC is prohibited from placing any restrictions or requirements on the licensees of those facilities with regard to water quality (Tennessee Valley Authority [Yellow Creek Nuclear Plant, Units 1 and 2], ALAB-515, 8 NRC 702, 712-13 [1978]).

characteristics of the aquatic resource (including population distribution, status, management objectives, and life history).

Impingement and Entrainment of Aquatic Organisms (Plants with Cooling Towers)

Removal of any substantial volume of water from a natural body of water by a cooling system will likely also remove or kill some of the aquatic organisms that live there through impingement or entrainment. However, the number of individuals that could be removed from a population before detectable negative effects would occur is often not known. The potential for impingement and entrainment of aquatic organisms is influenced by a variety of factors such as:

- Amount of water withdrawn relative to the size of the cooling water source,
- Location and configuration of intake structures,
- Type of water body from which water is withdrawn and the conditions within that water body,
- Proximity of withdrawal structures to sensitive biological habitats (e.g., spawning and nursery habitats),
- Sensitivity of populations of impinged and entrained organisms to potential losses of individuals, and
- Mitigation measures in place to reduce impingement and entrainment.

Of these factors, the volume of water withdrawn relative to the size of the water source appears to be the best predictor of the number of organisms that would be impinged or entrained within a given aquatic system (Henderson and Seaby 2000). Because the volume of water withdrawn by a power plant is minimized when a closed-cycle cooling system is employed, the impacts to aquatic organisms from impingement and entrainment would be smaller than the impacts from impingement and entrainment that would occur if that plant employed a once-through cooling system instead.

In the 1996 GEIS, the NRC determined that impingement and entrainment of fish and shellfish was a Category 1 issue for plants with cooling towers, because the level of impingement and entrainment of fish and shellfish with this type of cooling system was not found to be a problem at operating plants, and was not expected to be a problem during the license renewal term (NRC 1996). This finding was also based on the lower rates of water withdrawal required for plants with cooling towers when operating in a closed-cycle mode. Withdrawal rates would not be reduced in situations where cooling towers are used in a helper mode to cool discharge temperatures under once-through operating conditions. These types of systems are included under the evaluation of once-through systems above.

In considering the impingement and entrainment effects of closed-cycle cooling systems on aquatic ecology, the NRC evaluated the same issues that were evaluated for plants with once-through cooling systems or cooling ponds. On the basis of reviews of the literature and license renewal SEISs published to date, reduced populations of aquatic biota attributable to occurrences of impingement and entrainment have not been reported for any existing nuclear power plants with cooling towers operated in closed-cycle mode.

On the basis of these considerations, the NRC concludes that the impingement and entrainment of aquatic organisms at plants with cooling towers operating as a closed-cycle cooling system over the license renewal term would be SMALL and remains a Category 1 issue.

Entrainment of Phytoplankton and Zooplankton (All Plants)

In addition to the entrainment of fish and shellfish in early life stages, the entrainment of phytoplankton and zooplankton was evaluated in the 1996 GEIS, and entrainment was categorized as a Category 1 issue for all cooling systems.

As described in the previous sections, water that is withdrawn for power plant cooling carries with it a variety of aquatic organisms. Those organisms that are small enough to pass through the debris screens in the intake pass through the entire cooling system and are exposed to heat, mechanical and pressure stresses, and possibly biocides before being discharged to the receiving water. This process, called entrainment, may affect phytoplankton and zooplankton, as well as planktonic larval stages of benthic organisms such as shellfish (i.e., meroplankton), and fish eggs and larvae (ichthyoplankton), as separately evaluated above. Most nuclear power plants have been required to monitor for entrainment effects during the initial years of operation. Entrainment impacts to phytoplankton and zooplankton are considered to be of SMALL significance if there is no evidence of reductions of populations of phytoplankton or zooplankton.

For example, about 70 percent of the copepod entrained at the Millstone plant in Connecticut suffered mortality, but this loss only represented 0.1 to 0.3 percent of the copepod production of eastern Long Island Sound (Carpenter et al. 1974). At the Calvert Cliffs plant in Maryland, entrainment survival for the five most abundant zooplankton species was 65 to 100 percent (NRC 1999b). Except for one sample (when discharge temperatures at the Cook plant in Michigan exceeded 95°F [35°C] and resulted in a 14 to 22 percent mortality difference in zooplankton), there was no relationship between zooplankton mortality and discharge water temperatures, suggesting that mechanical stress was the major cause of zooplankton entrainment mortality. During the period of the study, chlorination was infrequent because entrained sand provided sufficient scouring action to negate the need for biocides. The sand may have added to the mechanical stress experienced by entrained zooplankton. Zooplankton mortality was significantly greater in the discharge waters than the intake waters, but differences averaged less than 3 percent. Such small losses due to entrainment cannot be detected in the lake. It was concluded that fish predation rather than entrainment was the major source of zooplankton mortality in inshore waters during most of the year (Evans et al. 1986).

Entrainment of phytoplankton and zooplankton is expected to have a SMALL impact on populations of these organisms in source water bodies for all plants. No change in operation of the cooling system is expected during the license renewal term, so no change in effects on entrainment of phytoplankton and zooplankton is anticipated. Effects on entrainment of phytoplankton and zooplankton could be reduced by changing to a closed cycle cooling system or by reducing the plant's generation rate. However, because the effects on entrainment of phytoplankton and zooplankton are considered to be impacts of SMALL significance, this issue continues to be Category 1.

Effects of Thermal Discharges on Aquatic Organisms

During the license renewal term, thermal discharges from the cooling system would continue to affect aquatic resources. The potential impacts of thermal discharges are different for once-through and closed-cycle cooling systems as discussed below.

Thermal Impacts on Aquatic Organisms (Plants with Once-Through Cooling Systems or Cooling Ponds)

In the 1996 GEIS, the NRC found that for plants with a once-through cooling system or cooling ponds, the level of impact for thermal discharge on aquatic biota (primarily due to heat shock) was SMALL at many plants and MODERATE or LARGE at some nuclear plants. Because characteristics of both the thermal discharges and the affected aquatic resources are specific to each site, NRC classified heat shock as a Category 2 issue that required a site-specific assessment for license renewal. The NRC (1996) found the potential for thermal discharge impacts to be greatest at plants with once-through cooling systems (NRC 1996), primarily because of the higher discharge temperatures and larger thermal plume area compared to plants with cooling towers.

In the revised GEIS, the NRC assessed potential impacts of thermal discharges during the renewal term (the remaining years of the original license plus 20 additional years) by reviewing published applicant's Environmental Reports, NRC's license renewal SEISs, and the relevant scientific literature. For most nuclear plants involved in license renewal, NRC projected that the impact levels of thermal discharges during the license renewal term would be SMALL. The NRC found impact levels at the Crystal River plant, for example, to be SMALL to MODERATE. According to York et al. (2005), thermal discharges from the Diablo Canyon and San Onofre plants, both located on the California coast and employing once-through cooling systems, have had significant impacts on aquatic habitats. The NRC is reviewing the Diablo Canyon plant's application for license renewal, and the San Onofre plant has not submitted an application at the time of this review, so NRC has neither completely assessed impacts at these two plants nor assigned impact levels. Other site-specific considerations for thermal discharges during the license renewal term for plants with once-through cooling systems can occur for plants located in areas where restoration efforts are under way to increase natural resource populations or reestablish migratory fish species or where thermal discharge plumes could encompass otherwise high-quality habitats. Site-specific design features, such as locating the discharge structures in areas where warmer water would be rapidly diluted, may mitigate adverse thermal effects (Beitinger et al. 2000). Hall et al.'s (1978) finding that the potential for thermal discharge impacts is greatest in shallow, enclosed, and poorly mixed water bodies illustrates the site-specific influence of receiving water body characteristics on environmental impact.

One form of thermal impact is heat shock, which NRC defines as occurring when the water temperature meets or exceeds the thermal tolerance of a species for some duration of exposure (NRC 2007d). In most situations, fish are capable of moving out of an area that exceeds their thermal tolerance limits, although many aquatic resource species lack such mobility. Heat shock is typically observable only for fish species, particularly those that float when dead, so the following discussion emphasizes fish.

Some nuclear plants have reported occasional fish kills from heat shock. At the Pilgrim plant in Massachusetts, only two fish mortality incidents have been attributed to heat shock. In 1975, about 3,000 Atlantic menhaden (*Brevoortia tyrannus*) were killed, and in 1978, about 2,300 clupeids (schooling fish such as menhaden sardines, and shad (*Alosa* spp.)) were killed (NRC 2007d). At the McGuire plant in North Carolina, five dead striped bass (*Morone saxatilis*) were found in and near the discharge, although their deaths may or may not have been related to heat shock (NRC 2002c). Over 94,000 dead fish, mostly bluefill (*Lepomis macrochirus*), were killed when cooling lake temperatures near the La Salle County Station in Illinois exceeded upper lethal temperatures for most species (Exelon 2001c). Similar heat shock kills happened at the Braidwood Nuclear Station's cooling lake when about 1,000 fish, mostly gizzard shad (*Dorosoma cepedianum*), died (NRC 2005e); on July 22, 2001, when about 700 unidentified fish were killed (Exelon 2001b); and on June 28, 2005, when about 10,000 unidentified fish were killed (Exelon 2005).

Another form of thermal impact involves the sublethal effects from thermal discharges (e.g., stunning or disorientation) that could alter predator-prey interactions by increasing the susceptibility of affected individuals to predation. Schubel et al. (1977) concluded that the exposure of fish larvae (e.g., blueback herring (*Alosa aestvalis*), American shad (*A. sapidissima*), striped bass) to an excess of 59°F (15°C) would significantly increase their vulnerability to predation. However, the 1996 GEIS did not report population- or community-level effects from power plant influences on predator-prey relationships in the field, and such effects are difficult to prove from field studies. Organisms overwintering within thermal plumes can also experience chronic malnutrition (Hall et al. 1978). Thermal discharges can also increase the susceptibility of fishes to diseases and parasites as a result of a combination of the increased density of fish within the thermal plume (potentially leading to increased exposure to infectious diseases or other stresses), the fish being more prone to infection in warmer water, and the ability of diseases and parasites to develop faster at higher temperatures. Examples of other temperature-related impacts on aquatic resources could include the loss of smolt characteristics in salmon (McCormick et al. 1999) and premature spawning (Hall et al. 1978).

A number of mitigative measures can reduce thermal discharge effects. These include lowering the effluent temperatures before discharges reach the receiving water body (e.g., the cooling pond at the Dresden plant in Illinois or the cooling canal system at the Turkey Point plant in Florida) or enhancing rapid mixing and heat dissipation (e.g., high-velocity jet diffusers at FitzPatrick in New York) (NRC 1996). At the Surry plant in Virginia, the thermal discharge lies about 6 mi (9.7 km) upstream of the intake structure to protect downstream oyster beds from potential thermal discharge impacts (NRC 2002d). After several fish kills at the Summer plant in the 1980s, South Caroline Electric & Gas Co. removed a hump in the discharge canal, limited reservoir drawdowns, and dredged the discharge canal to reduce the likelihood of future fish kills (NRC 2004b).

The NRC (1996) concluded that the impact levels of heat shock on aquatic biota during the license renewal term could be SMALL, MODERATE, or LARGE at plants with once-through cooling or cooling ponds (i.e., a Category 2 issue). The present review identified no new information that would alter those conclusions for effects of thermal discharges in the plant-specific SEISs prepared to date or in other literature. Based on these considerations, the NRC concludes that the issue of thermal discharges on aquatic organisms at nuclear plants with once-through cooling systems or cooling ponds over the license renewal term could have SMALL, MODERATE, or LARGE impact levels and is a Category 2 issue. The impact level at any plant depends on the characteristics of its cooling system (including location and type of discharge structure, discharge velocity and volume, and three-dimensional characteristics of the thermal plume) and characteristics of the affected aquatic resources (including the species present and their physiology, habitat, population distribution, status, management objectives, and life history).

Thermal Impacts on Aquatic Organisms (Plants with Cooling Towers)

In the 1996 GEIS, the NRC determined that for plants with cooling towers, the effects of thermal discharges with respect to heat shock (i.e., the potential for heated effluents to directly kill aquatic organisms) was a Category 1 issue. This determination was made because thermal effects associated with this type of cooling system were not found to be a problem at operating plants and are not expected to be a problem during the license renewal term (NRC 1996). This finding was based, in part, on the presence of smaller thermal plumes at plants with closed-cycle cooling towers than would occur if a once-through cooling system was used at those plants. Other sublethal effects of thermal discharges are discussed and evaluated separately below (see Infrequency Reported Thermal Impacts (All Plants)).

In the 1996 GEIS, the NRC considered the impacts of thermal discharges on aquatic organisms during the license renewal term to be SMALL at nuclear plants with cooling towers (i.e., a Category 1 issue). No new information has been identified in the plant-specific SEISs prepared to date or in the literature that would alter those conclusions. On the basis of these considerations, the NRC concludes that the direct impact of thermal discharges on aquatic organisms at nuclear plants with cooling towers over the license renewal term would be SMALL and remains a Category 1 issue.

Infrequently Reported Thermal Impacts (All Plants)

In addition to the effects of heat shock as described above for plants with once-through cooling systems or cooling ponds and those using cooling towers, other potential effects common to the operation of plant cooling systems include cold shock, the creation of thermal plume migration barriers, changes in the distribution of aquatic organisms, accelerated development of aquatic insect maturation, and stimulation of the growth of aquatic nuisance species. The 1996 GEIS addressed these uncommon impacts individually; this revised GEIS consolidates them. The components of the consolidated issue are further described below.

Cold shock can occur when organisms acclimated to the elevated temperatures of a thermal plume are abruptly exposed to temperature decreases when the artificial source of heating stops. Such events are most likely to occur during winter. Cold shock events have only rarely occurred at nuclear plants (e.g., Haddam Neck [no longer operating], Prairie Island, Monticello, and Oyster Creek). Fish mortalities usually involved only a few fish and did not result in population-level effects (NRC 1996). Gradual shutdown of plant operations generally precludes cold shock events.

The potential exists for thermal plumes to create a barrier to migrating fishes if the mixing zone covers an extensive cross-sectional area of a river and exceeds the fish avoidance temperature (NRC 1996). For example, concerns were expressed that thermal discharge from the Vermont Yankee plant could affect both spawning and outmigration of American shad (*Alosa sapidissima*) and Atlantic salmon (*Salmo salar*) and potentially cause a reduction in Atlantic salmon smoltification, particularly since a hydroelectric facility was located immediately downstream of the plant and because the fish passage facility and thermal discharge were located on the same side of the river (NRC 2007a). In the 316(b) demonstration to support increased discharge temperature limits at the Vermont Yankee plant, it was determined that the smolts would not be delayed because the thermal plume covered only a small cross section of the Connecticut River. To date, significant impacts on migratory fishes have not been reported for nuclear power plants.

Impacts of thermal discharges on the geographic distribution of aquatic organisms are considered to be of SMALL significance if populations in the overall region are not reduced. Based on review of literature, operational monitoring reports, consultations with utilities and regulatory agencies, and license renewal SEISs published to date, thermal discharges have not been shown to constrain the regional geographic distribution of aquatic organisms at any existing nuclear power plant. This is because heat is usually dissipated rapidly from power plant discharge plumes, and heated plumes are often small relative to the size of the receiving water body.

Heated effluents could accelerate the development of immature stages of aquatic insects in freshwater systems, resulting in premature emergence. If adults emerge before the normal seasonal cycle, they may be unable to feed or reproduce. Premature emergence has been observed in laboratory investigations (e.g., Nebeker 1971) but not in field investigations (e.g., Langford 1975). Heated effluents could also stimulate population growth of macroinvertebrates. Thermal discharges from the Oconee plant in South Carolina stimulated the population growth of oligochaetes (aquatic worms) in the immediate vicinity of the power plant (less than 5 percent of the total cooling reservoir surface). However, the local changes in oligochaete populations could not be linked to the direct increases in water temperatures, but they may have been directly or indirectly affected by increases in zooplankton, vegetation, and current velocities in the area of the discharge (Nichols 1981).

An aquatic nuisance species is “a nonindigenous species that threatens the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquacultural or recreational activities dependent on such waters” (Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990). A wide variety of nuisance or non-native species may become established or proliferate as a result of power plant operations, including fouling organisms such as the Asiatic clam and the recently introduced zebra mussel. Aspects of the operation of the power plants (e.g., warm temperatures or high flow rates that bring food to filter-feeding organisms) may be conducive to the growth and development of these organisms. *Asiatic clams* and zebra mussels may become so abundant as to cause operational difficulties for the power plant and may out-compete native clams and mussels in thermally enriched waters. A population of tropical, nonnative blue tilapia (*Oreochromis aureus*) became established in the Susquehanna River in Pennsylvania by congregating in thermal effluents during the winter. Exposure to rapid temperature decreases (cold shock) killed these fish and eradicated the population from the vicinity of the plant.

Langford (1983) reports a number of instances in which wood-boring crustaceans and mollusks, notably "shipworms," have caused concern in British waters. Although increased abundance of shipworms in the area influenced by heated power plant effluents caused substantial damage to wooden structures, replacement of old wood with concrete or metal structures eliminated the problem. Langford concluded that increased temperatures could enhance the activity and reproduction of wood-boring organisms in enclosed or limited areas but that elevated temperature patterns were not sufficiently stable to cause widespread effects.

Thermal discharges can allow nuisance species, such as the Asiatic clam (*Corbicula fluminea*) and zebra mussel (*Dreissena polymorpha*), to become established or proliferate (NRC 1996). At the North Anna plant in Virginia, the higher water discharges related to plant operation were found to increase the growing season of the water hyacinth (*Hydrilla verticillata*). Nuisance levels of this plant resulted. The water hyacinth was brought under control by stocking triploid (sterile) herbivorous grass carp (*Ctenopharyngodon idella*) (NRC 2002e).

The influence of the operation of Oyster Creek Nuclear Generating Station on abundance and distribution of a nonnative, tropical-subtropical, wood-boring shipworm (*Teredo bartschi*) has been extensively studied (see summary in Richards et al. 1984). Although numerous studies have varied somewhat in their conclusions, there is agreement that heated effluents from the plant increased the distribution and abundance of shipworms (Kennish et al. 1984). This species has not been found in Oyster Creek or Barnegat Bay since 1982, perhaps because of low water temperatures in Oyster Creek during a station outage in the winter of 1981–82 and the pathological effects of a parasite (GPU Nuclear Corporation response to a Nuclear Management and Resources Council [NUMARC] survey [NUMARC 1990]). In addition, the removal of substantial amounts of driftwood and the replacement of untreated structural wood is thought to have contributed to reducing the populations of wood-boring organisms in Oyster Creek. No other concerns about nuisance organisms were cited by the regulatory or resource agencies contacted for this GEIS revision (Appendix F). Measures taken by licensees to control nuisance species (e.g., increased chlorination or use of molluscicides) may result in impacts on other species. This impact is also controlled by NPDES permitting procedures.

The effects of stimulating the growth of nuisance organisms are considered to be of SMALL significance to aquatic resources if these organisms are restricted to the condenser cooling system (e.g., Asiatic clam; zebra mussel) or do not proliferate beyond the immediate vicinity of the plant. Mitigation measures were effective at the one plant that experienced problems with nuisance organisms (e.g., shipworms). Effects on nuisance organisms could be reduced by changing to a closed-cycle cooling system or by reducing the plant's generation rate, but, based on the review conducted by NRC for this GEIS revision, NRC categorizes the impact level as SMALL and would expect it to be SMALL for all plants.

The NRC's review revealed only small levels of impact in the aquatic resources due to the infrequently reported thermal impacts and expects the same at all plants. As a result, NRC classifies this combined issue as Category 1.

Effects of Cooling Water Discharge on Dissolved Oxygen, Gas Supersaturation, and Eutrophication

The potential effects on aquatic biota from low dissolved oxygen levels, gas supersaturation (gas bubble disease), and eutrophication in the cooling water discharge of nuclear power plants were identified as Category 1 issues in the 1996 GEIS. These three issues are combined and discussed together here.

The availability of oxygen is a requirement for the metabolism of aerobic organisms. It also influences inorganic chemical reactions. For aquatic organisms with gills, the concentration of dissolved oxygen in the water is one of the most important parameters to consider for evaluating water quality. In general, dissolved oxygen concentrations of less than 3 ppm in warmwater habitats or less than 5 ppm in coldwater habitats can adversely affect fish (Morrow and Fischenich 2000). Oxygen dissolves into water via diffusion from the surrounding air, by aeration (i.e., mixing with atmospheric air due to turbulent movement of the water), and as a product of photosynthesis. The level of dissolved oxygen in water is highly dependent on temperature, and the amount of oxygen that can dissolve in a given volume of water (i.e., the saturation point) is inversely proportional to the temperature of the water. Thus, when other chemical and physical conditions are equal, the warmer the water is, the less dissolved oxygen it can hold. An increase in water temperature also affects the amount of oxygen that aquatic organisms need by increasing the chemical reaction rates and metabolic rates. The rates of many chemical reactions in water approximately double for every 18°F (10°C) increase in temperature. Thus, the addition of a heat load to an aquatic ecosystem via the discharge of cooling water has the potential to stress aquatic biota by simultaneously increasing metabolic rates and the need for oxygen and by reducing dissolved oxygen concentrations to suboptimal levels.

The potential for effects on biota from a reduction in the dissolved oxygen concentration is greater in ecosystems where dissolved oxygen levels are already approaching suboptimal levels as a result of other factors that affect the environment. Thus, organisms in ecosystems where (1) the biological demand for dissolved oxygen is elevated as a result of increased levels of detritus or nutrients (e.g., eutrophication from runoff containing fertilizers or manure or from the release of dead, entrained organisms in the discharge of once-through cooling systems) or (2) low flow levels and high ambient temperatures already exist (e.g., as a result of drought conditions or hot weather) may be more susceptible to negative effects if dissolved oxygen levels are reduced further. For this reason, the EPA and States often regulate dissolved oxygen to ensure that minimum levels will be maintained. The following discussion focuses on dissolved oxygen because it directly affects aquatic resources rather than focusing on the contributing causes of low dissolved oxygen levels associated with cooling water system operation (e.g., eutrophication due to increased temperature, lower dissolved oxygen capacity with increased temperature, higher biological oxygen demand (BOD), and chemical oxygen demand (COD) with increased temperature, etc.).

After cooling water is discharged, additional oxygen dissolves in the water as a result of diffusion and the introduction of oxygen released by aquatic plants and algae as a by-product of photosynthesis (during daylight hours only). The saturation point for the water increases as it cools, and aeration due to turbulent movement can further increase the rate of oxygenation. For these reasons, effects on aquatic biota due to low dissolved oxygen levels are not expected to extend beyond the thermal mixing zone. Thus, even in cases where dissolved oxygen levels in the immediate vicinity of the discharge structures of power plants may be too low to support some aquatic biota, the amount of aquatic habitat affected is typically small relative to that available in the receiving water body as a whole. Discharge systems are typically designed to minimize the affected area by promoting mixing of introduced warmer water with ambient water from the receiving system, by increasing turbulence near the discharge point, or by introducing air into the water.

The impacts of low dissolved oxygen concentrations in the discharge are considered to be of SMALL significance if populations of aquatic organisms in the vicinity of the plant are not reduced. On the basis of reviews of literature and operational monitoring reports, dissolved oxygen concentrations have been adequate for maintaining aquatic ecosystems in the water bodies that receive cooling water from currently operating nuclear power plants. Operational mitigation measures (increasing the oxygenation of water released from an upstream dam) have been effective at the one plant (Sequoyah plant in Tennessee) for which periodic low dissolved oxygen levels in the receiving water (Chickamauga Reservoir) were identified as potentially affecting downstream mussel beds and sauger (*Sander canadensis*) reproduction during the initial license term.

In addition to the effects of cooling systems on dissolved oxygen described above, rapid heating of water in the condenser cooling system also decreases the solubility and saturation point for other dissolved gases. Thus, as the water passing through the cooling system is heated, the water becomes supersaturated with gases. Although the levels of dissolved gases will equilibrate to normal values as the water cools and mixes with ambient waters, tissues of aquatic organisms that remain in the supersaturated effluent for extended periods can become equilibrated to the increased partial pressures of gases within the effluent. If these organisms are subsequently exposed to water with lower partial pressures (which occurs when the water cools or when the organisms move to water in other locations or at other depths), dissolved gas (especially nitrogen) within the tissues may come out of solution and form embolisms (bubbles) within the affected tissues, most noticeably the eyes and fins. The resulting condition is known as gas bubble disease. Swelling and hemorrhages in tissues can cause behavioral abnormalities or death, depending on the number of bubbles that form and the tissues that are affected (Noga 2000). Fish mortalities generally occur at gas supersaturation levels above 110 to 115 percent (EPA 1986). Aquatic insects and crustaceans appear to be more tolerant of supersaturated water than fish (Nebeker et al. 1981).

The ability to detect and avoid supersaturated waters varies among species. A fish can avoid supersaturated waters by either not entering the affected area or by diving to avoid the onset of supersaturated conditions near the surface. Some species, however, may not avoid supersaturated waters until symptoms of gas bubble disease occur; at that point, some fish may already have been lethally exposed. Other species may be attracted to supersaturated waters due to stimuli such as warmwater discharges (Gray et al. 1983).

Gas supersaturation and gas bubble disease have resulted in the death of fish in the discharge of some steam-electric power plants, as has been reported in the past from the Pilgrim plant in Massachusetts (NRC 1996, 2007c). Gas supersaturation and gas bubble disease are also commonly associated with hydroelectric dams, typically resulting when water that is mixed with air while traveling over spillways is subsequently pushed to depth within stilling basins (Parametrix, Inc. 1975). The death of organisms due to gas supersaturation in heated effluents from power plants appears to be most likely at plants that have discharge canals where fish may reside for extended periods of time (i.e., long enough to equilibrate with supersaturated effluents). Gas solubility tends to increase with decreases in water temperatures; therefore, gas bubble disease at steam-electric stations would be most likely to occur during winter months (McInerny 1990). As reported in the 1996 GEIS, observed incidences of gas bubble disease at the Waukegan Generating Station (a coal-fired plant on Lake Michigan), Marshall Steam Station (a coal-fired plant on Lake Norman), and the Pilgrim plant involved fish residing in discharge canals. At the Pilgrim plant, the loss of approximately 43,000 Atlantic menhaden in 1973 was attributed to gas bubble disease (McInerny 1990), and other species of fish may also have been affected (Fairbanks and Lawton 1977). Promoting the rapid mixing of effluents with receiving waters (e.g., with jet diffuser systems) appears to effectively prevent such mortalities by inhibiting residence of organisms in the thermal plume (Lee and Martin 1975) and by limiting the extent of the area where supersaturated conditions may occur. Restricting entry of fish into discharge canals may also be effective at controlling mortality. A fish barrier net was installed in the discharge canal at the Pilgrim plant after the mortality events observed during the 1970s, although subsequent implementation of engineering controls have mitigated conditions so that the use of the net has not been required since then.

Impacts from gas supersaturation are considered to be of SMALL significance if populations of aquatic organisms in the vicinity of the plant are not reduced. On the basis of reviews of the available scientific literature, plant-specific ERs, and the SEISs that have been completed to date, deaths of aquatic organisms attributable to gas supersaturation have not been a concern at most existing nuclear power plants. Operational and structural mitigation measures have been effective at controlling effects on fish at the Pilgrim plant, where fish kills attributable to gas supersaturation occurred during the initial license period. In no case has a substantial effect on populations of aquatic organisms been observed. Use of engineering controls (e.g., use of jet diffusers for cooling water discharge systems) that prevent the occurrence of mortality due to gas bubble disease at individual power plants also reduces the likelihood that discharges from cooling systems would contribute to cumulative effects.

Unless the operation of the cooling system or the ambient conditions that affect levels of dissolved oxygen or gas supersaturation in the receiving waters were to change substantially, it is anticipated that there would be no change in effects of low dissolved oxygen concentrations or gas supersaturation on aquatic biota during the license renewal term. Overall, effects of low dissolved oxygen concentrations and gas supersaturation attributable to cooling water discharges are considered to be of SMALL significance for all plants.

For some plants, the potential for effects of low dissolved oxygen concentrations or gas supersaturation on aquatic resources could be further reduced by changing from a once-through cooling system to a closed-cycle cooling system or by reducing the plant's generation rate. However, because the continued effects of operations on dissolved oxygen concentrations and gas supersaturation are considered to be of SMALL overall significance to populations of aquatic resources and because implementation of these changes would be costly, it is believed that such changes are not warranted on the basis of controlling levels of dissolved gases. Impacts of license renewal on dissolved oxygen levels and on the incidence of gas bubble disease were considered to be SMALL for all nuclear plants and were designated as Category 1 issues in the 1996 GEIS. No new information has been identified in the plant-specific SEISs prepared to date or in the literature that would alter those conclusions.

On the basis of these considerations, the NRC concludes that the impact on aquatic biota from the alteration of dissolved oxygen levels and gas supersaturation associated with continued operations over the license renewal term would be SMALL for all nuclear plants and remains a Category 1 issue.

Effects of Nonradiological Contaminants on Aquatic Organisms

The potential for nonradiological contaminants to accumulate in sediments or aquatic biota was identified as a Category 1 issue in the 1996 GEIS. This was originally raised as an issue of concern at a few power plants that used copper alloy condenser tubes, but this concern has been successfully mitigated by replacing copper alloy tubes with those made from other metals (e.g., titanium). An operating nuclear power plant can contribute other contaminants by concentrating existing constituents from the water body (e.g., in blowdown at closed-cycle plants) or by the addition of chemicals to cooling water during plant operations (e.g., biocides).

Biocides are used in cooling water systems to prevent the buildup of microorganisms that can impede heat transfer across heat exchange surfaces. Biocides are also used to prevent excessive growth of algae or other organisms that attach to structures, which can reduce cooling water flow by blocking pipes, tubing, and other water conveyances. For example, zebra mussels and Asiatic clams within the intakes or cooling systems of power plants can cause partial to total blockage of grates and pipes or cause damage to pipes and facilities, requiring the plants to temporarily suspend operations in order to remove the blockage or repair the damage. To prevent this from happening, plants in areas where these mollusks occur generally use nonoxidizing molluscicides (e.g., quaternary ammonium salts, glutaraldehyde, isothiazoline, triazine, and carbamates). The amount of a biocide that is applied to the cooling waters is controlled so that the concentrations that are discharged from the cooling system are too low to cause adverse effects to native mussels in the receiving water body. Allowable concentrations for biocides in discharged cooling waters are governed by NPDES permit restrictions to reduce the potential for toxic effects on nontargeted organisms (e.g., native mussels and fishes). At the Browns Ferry plant in Alabama, small sponge rubber balls are continuously recirculated through the condenser tubes to keep them clear of Asiatic clams and thus reduce the use of molluscicides (NRC 2005c). Also, various means can be used to minimize the discharged concentrations of biocides in the blowdown, including closing the blowdown valve before biocides are added, discharging blowdown to large sediment or retention ponds, and dechlorination (Veil et al. 1997).

As reported in the 1996 GEIS, heavy or toxic metals (e.g., copper, zinc, and chromium) may be leached from condenser tubing and other heat exchangers and discharged by power plants as small-volume waste streams or corrosion products. Although heavy metals are found in small quantities in natural waters (and many are essential micronutrients), concentrations in the power plant discharge are typically controlled in the NPDES permit because excessive concentrations of heavy metals can be toxic to aquatic organisms. Discharge of metal and other toxic contaminants may also be subject to individual control strategies developed by the States to control toxic pollutants under the CWA. These strategies for point source discharges of toxic pollutants are implemented through the NPDES permit program. Heavy metal concentrations in discharges during normal operations are generally low. However, reactor shutdowns for testing and refueling keep stagnant water in contact with condenser tubes and other metal structures for extended periods and may allow abnormally large amounts of metals to be leached into the water.

The ability of aquatic organisms to bioaccumulate heavy metals, even at low concentrations, has led to concerns about toxicity both to the humans and biota that consume contaminated fish and shellfish. For example, the bioconcentration of copper discharged from the Chalk Point plant (a fossil fuel power plant on Chesapeake Bay) resulted in discoloration (“greening”) effects on eastern oysters (*Crassotrea virginica*) (Roosenburg 1969), and the bioaccumulation of copper released from the Robinson plant in South Carolina resulted in malformations and decreased reproductive capacity among bluegill in the cooling reservoir. Replacement of copper alloy tubes with tubes made from other metals (e.g., titanium) alleviated the elevated copper levels in both of these cases (NRC 1996, 2003b).

Concentrations of heavy metals and other contaminants in the discharges of nuclear power plants are normally quickly diluted or flushed from the area by the large volumes of the receiving water. The discharge of metals and other toxic contaminants may also be subject to controls implemented by State or Federal agencies through the NPDES permit process. Impacts of contaminant discharges are considered to be of SMALL significance if water quality criteria (e.g., NPDES permits) are not violated and if aquatic organisms in the vicinity of the plant are not bioaccumulating the contaminants.

The accumulation of contaminants in sediments and biota was designated as a Category 1 issue in the 1996 GEIS. No new information has been identified in plant-specific SEISs prepared to date or in the reviewed literature that would alter those conclusions. However, this issue has been modified to look at contaminant effects other than accumulation. As long as changes to the cooling system, such as during refurbishment, do not occur during the license renewal term and the discharge requirements of the NPDES permit are met, no impact of contaminants on aquatic biota would be anticipated. On the basis of these considerations, the NRC concludes that the impact of contaminants on aquatic organisms associated with continued operations and refurbishment would be SMALL for all nuclear plants and remains a Category 1 issue.

Exposure of Aquatic Organisms to Radionuclides

The potential impact of radionuclides on aquatic organisms from normal operations of a nuclear power plant during the license renewal term was not identified as an issue in the 1996 GEIS. However, the impact of radionuclides on aquatic organisms has been raised as an issue by the public for several of the plants that have undergone license renewal, and that issue is reviewed here.

Aquatic biota can be exposed externally to ionizing radiation from radionuclides in water, sediment, and other biota, and aquatic biota can be exposed internally via ingested food and water and, in certain situations, absorption through the skin and respiratory organs (Blaylock et al. 1993). No evidence of significant differences in sensitivity to radionuclides between marine and freshwater organisms has been reported (Blaylock et al. 1993). Some radionuclides tend to follow pathways similar to their nutrient analogs and can therefore be transferred rapidly through the food chain. These include (1) radionuclides such as strontium-90, barium-140, radon-226, and calcium-46 that behave like calcium and are therefore accumulated in bony tissues; (2) radionuclides such as iodine-129 and iodine-131 that act like stable iodine and accumulate in thyroid tissue; (3) radionuclides such as potassium-40, cesium-137, and rubidium-86 that follow the general movement of potassium and can be distributed throughout the body; and (4) radionuclides such as tritium, which resembles stable hydrogen, that are distributed throughout the body of an organism (Ahier and Tracy 1995).

Fish, especially developing eggs and young, appear to be the aquatic organisms that are the most sensitive to the effects of ionizing radiation, while phytoplankton and zooplankton are relatively resistant to effects from exposure (NCRP 1991; Blaylock et al. 1993). DOE's guideline for radiation dose rates from environmental sources recommends limiting the radiation dose to aquatic biota to no more than 1 rad/d (0.01 Gy/d). As described in Blaylock et al. (1993), this guideline was derived by reviewing the results of experimental data (NCRP 1991) that indicated there would not be any negative population-level effects on aquatic biota at doses up to 1 rad/d (0.01 Gy/d). That review reported that significant histological effects on the gonads of small tropical fish were detected at a dose of 1 rad/d (0.01 Gy/d), although the majority of controlled studies that examined the potential chronic effects of ionizing radiation on aquatic organisms did not find significant effects unless the dose was much greater than 1 rad/d (0.01 Gy/d) (NCRP 1991). Real et al. (2004) summarized several chronic irradiation studies on fish (mostly from gamma radiation at dose rates of 0.2 to 120 rad/d [0.02 to 1.2 Gy/d]) that reported effects, such as lowered fecundity, delayed spawning, reduced testis mass and sperm production, reduced immune response, reduced larval survival, and increased vertebral anomalies. They concluded that dose rates of less than approximately 10 rad/d (0.1 Gy/d) to any life stage are unlikely to affect survival (Real et al. 2004). Kryshev and Sazykina (1998) reported that ecological effects of ionizing radiation on aquatic biota occur at dose rates between 0.2 and 80,000 rad/d (0.002 and 800 Gy/d)]. For comparison, Brown et al. (2004) used models to estimate doses to aquatic biota from naturally occurring radionuclides as ranging from 0.00024 to 0.11 rad/d (2.4×10^{-6} to 1.1×10^{-3} Gy/d) for European freshwater ecosystems and 0.00024 to 0.06 rad/d (2.4×10^{-6} to 6.0×10^{-4} Gy/d) for European marine waters.

Dose rates for aquatic biota were calculated with the RESRAD-BIOTA dose evaluation model (DOE 2004e) using site-specific radionuclide concentrations in water and sediments reported in the REMP reports for 15 NRC-licensed power plants (Table 4.6-5). (See Section D.5 in Appendix D for a description of the methodology used.) These 15 plants represent plants with a range of radionuclide concentrations in environmental media. The total estimated dose rates for aquatic biota for these plants were all less than 0.2 rad/d (0.002 Gy/d), considerably less than the guideline value of 1 rad/d (0.01 Gy/d). Thus, it is anticipated that normal operations of these facilities would not result in negative effects on aquatic biota. Effects on populations of aquatic biota from such doses would be SMALL. A 25-year study of gamma-ray-emitting radionuclide levels near the Susquehanna plant in Pennsylvania indicated that there have been no known environmental impacts on aquatic resources (Patrick et al. 2007). On the basis of the reviewed literature and the dose rates that have been estimated for aquatic biota from site-specific data, the NRC concludes that the impact of radionuclides on aquatic biota from past operations would be SMALL for all plants, and it would not be expected to change appreciably during the renewal

Table 4.6-5. Estimated Radiation Dose Rates to Aquatic Animals from Radionuclides Measured in Water and Sediments at U.S. Nuclear Power Plants

Plant	Estimated Dose Rates (rad/d)[a]		
	Water	Sediment	Total
Arkansas Nuclear	1.87×10^{-4}	1.98×10^{-6}	1.89×10^{-4}
Browns Ferry	1.43×10^{-2}	2.88×10^{-5}	1.43×10^{-2}
Calvert Cliffs	1.53×10^{-7}	1.09×10^{-10}	1.54×10^{-7}
Columbia	5.01×10^{-2}	2.17×10^{-5}	5.01×10^{-2}
Comanche Peak	5.82×10^{-2}	1.03×10^{-4}	5.83×10^{-2}
D.C. Cook	5.01×10^{-2}	1.46×10^{-4}	5.02×10^{-2}
Hatch	5.02×10^{-2}	1.22×10^{-5}	5.02×10^{-2}
Fort Calhoun	1.06×10^{-1}	5.71×10^{-6}	1.06×10^{-1}
Indian Point	5.01×10^{-2}	2.03×10^{-5}	5.01×10^{-2}
Millstone	5.02×10^{-2}	5.73×10^{-4}	5.08×10^{-2}
Nine Mile Point	5.02×10^{-2}	1.02×10^{-5}	5.02×10^{-2}
Palisades	1.34×10^{-7}	3.65×10^{-6}	3.78×10^{-6}
Point Beach	2.67×10^{-3}	2.73×10^{-4}	2.95×10^{-3}
San Onofre	1.12×10^{-2}	3.00×10^{-4}	1.15×10^{-2}
Vermont Yankee	5.02×10^{-2}	1.11×10^{-3}	5.13×10^{-2}

(a) Dose rates were estimated with RESRAD-BIOTA (DOE 2004e) by using site-specific radionuclide concentrations in water and sediments obtained from REMP reports.

period. Therefore, the impact of radionuclides on aquatic biota that would result from continued operations is considered a Category 1 issue.

Effects of Dredging on Aquatic Organisms

Dredging is an activity that is performed at some power plants to remove accumulated sediments from intake and discharge areas (or, more rarely, to maintain barge slips) and may have localized impacts on aquatic biota. The impacts of dredging were not evaluated in the 1996 GEIS.

Sediment (especially sand and silt) that enters water bodies through the process of erosion can accumulate and gradually fill in some areas. Because of this, maintenance dredging may be required at some power plants to keep cooling water intakes and discharges clear of sediment

(Allen et al. 2004; NRC 2007b,c). Dredging may also occur as part of power plant operation to maintain appropriate water circulation in water bodies that provide cooling water (e.g., at the Millstone plant; NRC 2005c) or to maintain access for barges (e.g., at the Calvert Cliffs plant in Maryland; NRC 1999b). Dredging can be accomplished in a number of ways (e.g., using various types of mechanical or hydraulic dredges), but it generally entails excavating a layer of sediment from the affected areas and transporting it to onshore or offshore areas for disposal.

Dredging can affect aquatic biota in a variety of ways. Except for some deep-burrowing animals or motile animals, such as larger crustaceans and fish, that may survive dredging through avoidance, it is assumed that organisms living on or in the affected sediments will be killed. Sediments suspended in the water column during dredging activities may settle onto and bury adjacent habitats, clog the feeding structures of filter-feeding organisms, or reduce light penetration. The potential for impacts on aquatic organisms as a result of direct effects of suspended sediment depends on the types of organisms present in the affected area, the amount and particle sizes of the sediment, and the duration of dredging activities (Nichols et al. 1990; Wilber and Clarke 2001).

The recovery of benthic communities in habitats disturbed by dredging depends, in part, on the characteristics of the remaining sediments (Diaz 1994; Haynes and Makarewicz 1982), the sources and types of organisms available to recolonize from surrounding areas, and the size of the disturbed area (Whitlatch et al. 1998). In soft-sediment environments, such as those that are most likely to require dredging in the vicinity of power plant intakes, recovery of animal communities generally occurs relatively quickly (sometimes within weeks) especially if the dredged areas are relatively small (e.g., Diaz 1994). In some cases, however, recovery of benthic communities may take several years (e.g., Kaplan et al. 1975; Guerra-García et al. 2003). Recovery of benthic communities following dredging also tends to be faster in areas exposed to periodic disturbances, such as tidally influenced habitats (Diaz 1994).

Sediments in and around cities and industrial areas are often contaminated with a variety of pollutants. These pollutants are introduced to waterways from point sources such as combined sewer overflows, municipal and industrial discharges and spills, or may be introduced from nonpoint sources such as surface runoff and atmospheric deposition. Contaminants that have accumulated in buried layers of sediment are often less readily bioavailable or less chemically active (EPA 2004). Depending on the concentrations of specific contaminants in accumulated sediments, there could be increased bioavailability and increased toxicity of those contaminants if they are resuspended in the water column due to dredging activities (Petersen et al. 1997; Su et al. 2002; EPA 2004). On the basis of a review of the information in the ERs and SEISs that have been prepared for previous renewal applications, the levels of chemical and radionuclide contamination of sediments in the areas near power plant intakes and discharges that would need to be dredged are likely to be relatively low. For example, as reported in the

SEIS for license renewal for the Pilgrim Nuclear Power Station in Massachusetts, the toxicity of sediments to marine organisms, which was evaluated prior to dredging the intake channel, was found to be low (NRC 2007c).

In general, maintenance dredging for nuclear power plant operations would occur infrequently, would be of relatively short duration, and would affect relatively small areas. For example, at the Peach Bottom Atomic Power Station in Pennsylvania, it is estimated that dredging of the intake basins is performed approximately once every 20 years and a total area of approximately 6 ac (2.4 ha) would need to be dredged (NRC 2003a). Portions of either the intake or the discharge canals at the Oyster Creek Nuclear Generating Station in New Jersey have been dredged approximately every 10 years (NRC 2007b), and the intake area for the Monticello Nuclear Generating Plant in Minnesota requires dredging every 6 to 8 years (NRC 2006c). It is anticipated that maintenance dredging would be primarily undertaken in areas containing soft sediments that would be recolonized fairly rapidly by benthic organisms in surrounding areas. In addition, permits from the USACE, State environmental agencies, or other applicable regulatory authorities would be required prior to initiating dredging. Site-specific evaluation of potential environmental impacts, including potential impacts on listed species of aquatic organisms, would be considered as part of the permitting process, and appropriate mitigation measures, if needed, could be identified and implemented.

Available scientific literature, plant-specific ERs, and the SEISs that were reviewed indicate that the effects of these dredging activities on populations or communities of aquatic organisms would likely be SMALL at all plants where they occur. On the basis of these considerations, the NRC concludes that the impact of dredging on aquatic resources would be SMALL for all nuclear plants and is considered a Category 1 issue.

Water Use Conflicts with Aquatic Resources (Plants with Cooling Ponds or Cooling Towers Using Makeup Water from a River)

In the 1996 GEIS, water use conflicts was listed as a site-specific, surface water quantity issue that included within it ecological impacts on aquatic and riparian communities. The NRC separated out the ecological impacts in this revised GEIS because the effects of water use conflicts on aquatic resources in stream communities could occur under many scenarios.

Increased temperatures and/or decreased rainfall would result in lower river flows, increased cooling pond evaporation, and lowered water levels in the Great Lakes or reservoirs. Regardless of overall climate change, droughts could result in problems with water supplies and allocations. Because future agricultural, municipal, and industrial users would continue to share their demands for surface water with power plants, conflicts might arise if the availability of this resource decreased.

Water use conflicts with aquatic resources could occur when water to support these resources is diminished either because of decreased water availability due to droughts; increased demand for agricultural, municipal, or industrial usage; or due to a combination of such factors. Water use conflicts with biological resources in stream communities is a concern due to the duration of license renewal and potentially increasing demands on surface water.

For example, Wolf Creek uses Coffee County Lake for cooling (NRC 2008a). Makeup water for the lake is withdrawn from the Neosho River downstream of John Redmond Reservoir. The Neosho River is a river with low water flow during drought conditions. The aquatic communities in the Neosho River downstream include an endangered fish species, the Neosho madtom (*Noturus placidus*), that may be affected by the plant's water use during periods when the lake level is low and makeup water is obtained from the Neosho River. For the Wolf Creek plant, the water use conflict impact is SMALL to MODERATE and a site-specific condition. For future license renewals, the potential range of impact levels at plants with cooling ponds or cooling towers using makeup water from a river with low flow cannot be determined at this time. The impact of water use conflicts with stream communities is considered a plant-specific Category 2 issue.

Effects on Aquatic Resources (Non-Cooling System Impacts)

Impacts on aquatic resources from continued operations and refurbishment activities could occur at all operating nuclear power plants during the license renewal term as a result of (1) direct disturbance of aquatic habitats within project areas, (2) sedimentation of nearby aquatic habitats as a consequence of soil erosion, (3) changes in water quantity or water quality (e.g., grading that affects surface runoff patterns or depletions or discharges of water into aquatic habitats), or (4) releases of chemical contaminants into nearby aquatic systems. In some cases, impacts have a potential to continue to occur throughout the period covered by license renewal. In the 1996 GEIS, the NRC considered only the impact of refurbishment on aquatic habitats and concluded that the impact would be SMALL for all nuclear plants (i.e., a Category 1 issue).

The surface area disturbed during construction of new waste storage facilities (e.g., ISFSIs) would be expected to range from about 2.5 to 10 ac (1 to 4 ha). Other supporting activities that could occur at specific sites may include the construction of new parking areas for plant employees, utility corridors, access roads, or new buildings or facilities, or the demolition of existing buildings. Land used for equipment storage, worker parking, and material laydown areas could result in disturbance to aquatic resources within the plant boundaries. Surface water habitats could also be affected by draining ponds, blocking or redirecting streams, or placing rip-rap along shorelines. Depending on the size and nature of the water body, and other project-specific aspects, organisms within the affected habitats could be displaced or killed, or the community structure within the water body could be altered.

The potential for soil erosion and sediment loading of nearby aquatic habitats is typically proportional to the amount of surface disturbance, erosion potential of the soil, slope, condition of disturbed areas at any given time, and proximity to aquatic habitats. Ground-disturbing activities have a higher erosion potential. Mitigation measures include controlling surface runoff with ditches, berms, and sedimentation basins; prompt revegetation to control erosion; stockpiling and reusing excavated topsoil; and various other techniques used to control soil erosion and water pollution. These mitigation measures (often referred to as BMPs) are expected to be implemented as part of project activities undertaken during the license renewal term to minimize impacts on surface water quality and aquatic resources.

During refurbishment, effluent discharges from the cooling system of a nuclear power plant would either remain similar to those occurring during normal operations during refurbishment or would decrease if the plant was partially or totally shut down. Consequently, effects of changes in water withdrawals and discharges during refurbishment would be of SMALL significance. The impact on aquatic biota from water use would not be expected to substantially change during refurbishment or maintenance activities from the impact during existing operations.

During ground-disturbing activities, contaminants could enter aquatic habitats as a result of runoff from project sites or from accidental releases of fuels or lubricants. The level of impacts from releases of toxicants would depend on the type and volume of chemicals entering the waterway, the location of the release, the nature of the water body (e.g., size, volume, flow rates, and water chemistry), and the types and life stages of organisms present in the affected area. In general, lubricants and fuel would not be expected to enter waterways as long as construction machinery and fuel storage areas and fueling locations were located away from water bodies, and spill prevention and control measures are in place.

Obstructions to fish movement could occur in streams with low flows. Restrictions on fish movement would likely be most significant if they occurred in streams that supported species that need to move to specific areas in order to reproduce.

The impact of refurbishment on aquatic habitats was evaluated in the 1996 GEIS and considered a Category 1 issue. Permits from various Federal, State, and local governmental authorities are typically required for ground-disturbing activities. For example, refurbishment may require the issuance of permits under Section 404 of the CWA if the activities were to directly affect aquatic habitats. With proper application of environmental reviews, permitting processes, and BMPs, impacts on sensitive aquatic habitats would likely be avoided. The NRC concludes that the impact of continued operations and refurbishment activities on aquatic resources is SMALL and is considered a Category 1 issue.

Impacts of Transmission Line ROW Management on Aquatic Resources

Impacts on aquatic resources from transmission line ROW management could occur as a result of the direct disturbance of aquatic habitats, soil erosion, changes in water quality (from sedimentation and thermal effects), or inadvertent releases of chemical contaminants from herbicide use. These impacts could occur throughout the license renewal term. The NRC did not evaluate the impact of transmission line ROW maintenance on aquatic biota in the 1996 GEIS, but this issue has been identified by the NRC for consideration in this GEIS revision on the basis of past environmental reviews conducted for plant-specific SEISs.

Water quality impacts could result from maintaining transmission line ROWs and, as necessary, service roads. Where access roads cross or border on surface waters, soil erosion could cause elevated turbidity and sedimentation. Application of appropriate control techniques (e.g., establishing and maintaining vegetated buffer strips between the road and the body of water) would reduce impacts. Because ROWs are normally maintained by mowing, selective cutting, and/or selective application of herbicides, soil erosion from transmission line corridors should not normally be a problem. Potential toxic effects of herbicides that are applied to transmission line ROWs and subsequently transported to surface waters should be considered in the ROW maintenance program. By using herbicides approved for ROW use in accordance with the Federal Insecticide, Fungicide, and Rodenticide Act, significant adverse effects of herbicides on aquatic ecosystems should be minimized. Maintenance activities in the vicinity of stream and river crossings employ procedures to minimize erosion and shoreline disturbance (e.g., control of vegetation within streamside buffer zones is generally accomplished by manual techniques) while encouraging small tree, shrub, and other low-growth vegetative cover. The nature or frequency of these activities is not expected to change substantially during the license renewal term.

For small streams in particular, trees may have grown sufficiently between cutting cycles to provide stream shading. Removal of these trees to maintain required conductor clearance could increase water temperature. Coldwater species may avoid such areas. The normal reaction of fish exposed to stressful temperatures is to move along the temperature gradient until preferred temperatures are encountered. Fish could avoid elevated temperatures within the opened ROW by swimming upstream or downstream to areas of groundwater inflow, to deep holes, or to shaded areas. However, effects that result in avoidance of specific areas by some species could represent a partial loss of available habitat. Thermal conditions of larger streams (e.g., those that are 10 ft [3 m] wide or wider) would be generally unaltered, since they are mostly unshaded.

Most transmission line ROWs are maintained on a 3- to 6-year cycle, so impacts on a water body would be infrequent. Any adverse impacts would be localized and temporary and would occur primarily on small streams. To minimize potential impacts from siltation and sedimentation, herbicide application, and stream warming, the licensee or owner of the transmission line typically adheres to standard mitigation practices (application of herbicides according to label instructions and by licensed personnel) listed in the vegetation management plan. Most operators establish stream buffer setbacks within which herbicides cannot be applied, and most widely used herbicides (e.g., glyphosate, fosamine, and imazapyr) pose minimal risks to aquatic organisms.

Changes in aquatic species diversity, abundance, or health from transmission line ROW maintenance are likely to be SMALL. The continued use of proper management practices with respect to soil erosion and application of herbicides is expected. Consequently, it is anticipated that the impact of transmission lines on surface water quality and aquatic resources would be SMALL. The decision to renew the license for a specific plant would affect only the portion of the transmission line that connects the power plant to the first substation. In many cases, the first substation is within or near the boundary of the plant property, and only a short distance of transmission line would be affected by the license renewal decision. Consequently, the amount of aquatic habitat crossed by this portion of a transmission line is also likely to be SMALL.

The impact on aquatic resources of maintaining transmission line ROWs was not identified as an issue in the 1996 GEIS. However, the impact is expected to be SMALL, short term, and localized. The NRC concludes that the impact of transmission line ROW maintenance on aquatic resources would be SMALL for all nuclear plants and is considered a Category 1 issue.

Losses from Predation, Parasitism, and Disease Among Organisms Exposed to Sublethal Stresses

Sublethal power plant stresses may alter predator-prey interactions in the receiving body of water, as evaluated in the 1996 GEIS. Aquatic organisms that are stunned but not killed by entrainment, impingement, or thermal effects may still suffer “indirect” mortality through increased susceptibility to predators. Numerous laboratory studies have been carried out to evaluate the level of indirect mortality that might occur following heat and cold shocks or entrainment (reviews in Cada et al. 1981; Coutant 1981). These studies have commonly demonstrated increased susceptibility to predation, but field evidence of such effects is often limited to anecdotal information such as observations of enhanced feeding activity of seagulls and predatory fish near power plant outfalls. For example, Barkley and Perrin (1971) and Romberg et al. (1974) reported increased concentrations of predators feeding on forage fish attracted to thermal plumes. Neither quantification of the levels of stress needed to increase predation rates, nor prediction of the subsequent population- and community-level effects of such changes can be made easily in the field. It is likely that operation of once-through cooling systems will cause some changes in predator-prey relationships, but the best evidence for impacts (or lack of impacts) may come from long-term monitoring of fish populations. Neither the literature reviews nor consultations with agencies and utilities (Appendix F) have revealed studies that demonstrate population- or community-level effects from power-plant-induced alterations of predator-prey relationships.

Elevated water temperatures in power plant discharges have been hypothesized to increase the susceptibility of fish to diseases and parasites. Langford (1983) cites a number of factors that could contribute to such an effect, including the tendency for fish to congregate in the heated discharge area in greater than normal concentrations, increased stresses on fish in warmer water that makes them more prone to infection, and the ability of some diseases and parasites to develop faster at higher temperatures. Additionally, it has been suggested that stress and injury from entrainment and impingement contribute to increased susceptibility of fish to disease, parasites, and predation. Coutant (1981) noted that although some studies of increased disease and parasitism in heated waters have found localized effects, most were not adequately designed to determine the significance of the effects to the overall population. The greatest risks appear to be associated with changes in animal concentrations; crowding can occur among fish that are attracted to heated effluents in the winter or that avoid heated water in the summer by occupying limited cool-water refugia. Crowding increases the chances of exposure to infectious diseases and may also lead to other stresses (decreased food supply or reduced oxygen concentrations) that increase susceptibility to disease (Coutant 1987). Despite limited laboratory studies that confirm this phenomenon, population-level effects in the vicinity of plants have not been observed.

Impact levels due to sublethal stresses on the susceptibility of aquatic organisms to predation, parasitism, and disease are considered to be of SMALL significance if changes are localized and populations in the receiving water body are not reduced. Based on reviews of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, these forms of indirect, power plant-induced mortality have not been shown to cause reductions in the overall populations near any existing nuclear power plants. Levels of impact are SMALL for all plants reviewed. Although sublethal power plant stresses contribute to cumulative impacts experienced by aquatic biota, monitoring has revealed no evidence for significant effects; the regulatory and resource agencies consulted in the preparation of this GEIS did not express concerns about the contribution of sublethal power plant stresses to cumulative impacts.

On the basis of its review, the NRC concludes that the level of impact due to sublethal stresses has been SMALL at plants reviewed and expects it to be SMALL for all nuclear plants. The issue remains Category 1.

4.6.1.3 Special Status Species and Habitats

Threatened, Endangered, and Protected Species and Essential Fish Habitat

The impacts associated with continued nuclear power plant operations and refurbishment activities during the license renewal term that could affect threatened, endangered, and protected species, critical habitat, and essential fish habitat (EFH) are similar to those described for terrestrial resources (Section 4.6.1.1) and aquatic resources (Section 4.6.1.2). Continued operations during the license renewal term would be expected to include such stressors as operation of cooling towers, operation of once-through cooling systems and cooling ponds, transmission line ROW management, maintenance of site facilities, releases of gaseous and liquid effluents, withdrawal of surface water, and potentially refurbishment activities. Details are presented in Section 3.6.3. There are several Federal Acts that provide protection to certain species and habitats that are treated here under a single issue. The issue includes impacts to biological resources such as threatened and endangered species and their critical habitat under the ESA, EFH as protected under the Magnuson-Stevens Fishery Conservation and Management Act (MSA), and impacts to mammalian species protected under the Marine Mammal Protection Act.

Terrestrial Species

Continued operations and refurbishment activities at all nuclear plants could have an impact on Federally or State-listed threatened and endangered species during the license renewal term. Factors that could potentially result in impacts on listed terrestrial species include habitat disturbance, cooling tower drift, operation and maintenance of cooling systems, transmission line ROW maintenance, collisions with cooling towers and transmission lines, and exposure to radionuclides. In the 1996 GEIS, the NRC considered the impacts of refurbishment and continued operation on threatened and endangered terrestrial species and concluded that the impacts would not necessarily be the same at all sites (i.e., a Category 2 issue) and could range from SMALL to LARGE.

Federally listed threatened and endangered terrestrial species are protected under the ESA, while State-listed species are protected under provisions of various State regulations. Prior to license renewal, the NRC must consult with the USFWS to determine the presence of any Federally listed species or critical habitat at or near the site and assess the potential for impacts from continued operation of the plant or associated transmission lines. The impacts of refurbishment activities on threatened or endangered species must also be considered during project planning, and consultation with the USFWS must be initiated if the possibility for impacts exists. Guidance for the consultation process is provided in the *Endangered Species Consultation Handbook* (USFWS and NMFS 1998).

Site-specific factors related to continued operations and refurbishment activities may vary widely among nuclear power plants. The listed species on or in the vicinity of nuclear power plants also range widely, depending on numerous factors such as the plant location and habitat types present (see Section 3.6.3.1). In addition, the list of threatened and endangered species is not static and is frequently modified by the USFWS and NMFS, with new listings being added as some species are determined to be eligible, other species being delisted (removed from the list), or the listing category of some species being changed because of changes in the status of or threats to the species population. Therefore, a generic determination of potential impacts on listed species during a nuclear power plant's license renewal term is not possible. Impacts on threatened and endangered species would depend on site-specific factors, and impact assessments would need to be conducted on a site-specific basis. Nuclear plants known to support terrestrial listed species on the site or along transmission line ROWs generally have monitoring programs to identify changes in populations and report impacts to the USFWS and State agencies. Monitoring provides information that can be used for developing or adjusting mitigation during the license renewal term.

Aquatic Species and Essential Fish Habitats

Potential impacts of continued operations and refurbishment activities on Federally or State-listed threatened and endangered species, protected marine mammals, and EFH could occur during the license renewal term. This issue applies to all operating nuclear power plants. Factors that could potentially result in impacts to these species and habitats include impacts of refurbishment, other ground-disturbing activities, release of contaminants, effects of cooling water discharge on dissolved oxygen, gas supersaturation, eutrophication, thermal discharges, entrainment, impingement, reduction in water levels due to the cooling system operations, dredging, radionuclides, and transmission line ROW maintenance. In the 1996 GEIS, the NRC considered potential impacts on threatened and endangered aquatic species from the operation of all nuclear power plants as a Category 2 issue and concluded that the impacts could range from SMALL to LARGE.

Power plants (nuclear and otherwise) that use estuarine or marine waters for cooling could entrain or impinge sea turtles (National Research Council 1990). The impingement mortality of sea turtles (all of which are Federally listed) has received the most attention to date with regard to the effects of nuclear power plant operations on listed species. Sea turtles are commonly encountered at some coastal nuclear plants, including the St. Lucie plant in Florida, the Oyster Creek plant in New Jersey, and the Brunswick plant in North Carolina. Between 1977 and 1997, the average number of sea turtles removed from the intake canal at the St. Lucie plant was 266 per year (Gunter et al. 2001). These included loggerhead, green, leatherback, hawksbill, and Kemp's ridley sea turtles. Most were loggerhead and green sea turtles, with an average of 150 and 103 removed per year, respectively. Among the sea turtles removed, about 4 percent of the loggerheads, 2 percent of the green, and 13 percent of the Kemp's ridley sea turtles were dead (Gunter et al. 2001). Sixty-eight sea turtles were impinged on intake screens at the Oyster Creek plant between 1992 and 2005, and 28 (41 percent) of those individuals died (NRC 2007c). The incidental take limit established by the NMFS for Kemp's ridley sea turtles was exceeded at the Oyster Creek plant in 2004, which required re-initiation of ESA Section 7 consultation with the NMFS (NRC 2007c). All three sea turtle species have been collected, as recently as 2004, in the vicinity of the Brunswick plant intake canal in North Carolina (NRC 2006e). Seventy-five percent of these turtles were released unharmed to the ocean or transported to a sea turtle facility for rehabilitation. Special panels have been installed at the diversion structure of the Brunswick plant, located at the entrance to the intake canal, to minimize the potential for sea turtles to enter the intake canal (NRC 2006e).

The licensees of the St. Lucie, Oyster Creek, and Brunswick plants have also implemented programs to monitor the intake canals for sea turtles and to capture and release to the wild any sea turtles observed in the intake canals (NRC 2003a, 2007c, 2006e). In addition, the licensee of the St. Lucie plant has initiated programs to monitor turtle nests on nearby beaches and has implemented facility lighting restrictions (NRC 2003a). Incidental takes of sea turtles have also been recorded for other plants that use estuarine or marine waters for cooling, including the Crystal River and Salem plants (Sackschewsky 2004). Sea turtles also have the potential to occur in the vicinity of other nuclear power plants located near estuarine or marine ecosystems, including the Calvert Cliffs, Diablo Canyon, Hope Creek, and Millstone plants (Sackschewsky 2004). In the SEISs prepared for the Calvert Cliffs plant (NRC 1999b) and the Millstone plant (NRC 2005c), it was determined that continued operations would not adversely affect endangered sea turtles.

Many nuclear plants whose operations are known to affect special status aquatic species have been required to establish monitoring programs and implemented mitigations in consultation with the USFWS or NMFS. For some plants, NMFS or FWS have developed incidental take limits to ensure that effects on species do not exceed specific levels. If takes exceed these incidental take limits, the NRC would be required to reinitiate consultation with USFWS or NMFS. Continued implementation of these actions would reduce the potential for adverse impacts to listed species during the license renewal term.

Prior to license renewal, the NRC consults with the USFWS and NMFS to determine the presence of and possible impacts on any ESA-listed aquatic species. Guidance for the ESA consultation process is provided in the *Endangered Species Consultation Handbook* (USFWS and NMFS 1998). The NRC also contacts the NMFS for license renewal applications for plants located in areas that may contain EFH for Federally managed marine or anadromous fisheries or for plants that may have an effect on protected marine mammals. In addition, the appropriate State agencies are contacted to determine the potential for State-listed species to be affected by continued operations and refurbishment activities during the license renewal term.

Subsequent consultation could be required for specific maintenance or refurbishment activities undertaken at a plant during the license renewal term.

Site-specific factors related to operations and refurbishment varies widely among nuclear power plants. The special status aquatic species and habitats in the vicinity of nuclear power plants and their transmission lines also vary widely, depending on numerous factors such as the plant location and habitat types present (see Section 3.6.3.2). In addition, the lists of special status species and habitats are not static and are frequently modified by the USFWS, NMFS, and State agencies, with new listings being added as some species are determined to be eligible, other species being delisted (removed from the list), or the listing category of some species being changed because of changes in the status of or threats to the species population. EFH designations and status also can change through time. Therefore, a generic determination of potential impacts on species and habitats during a nuclear power plant's license renewal term is not possible. Impacts on special status species and habitats would depend on site-specific factors, and impact assessments would need to be conducted on a site-specific basis in the plant-specific SEISs prepared for license renewal applications.

In preparing this revised GEIS, the NRC staff has determined that the levels of impact that it developed to implement the National Environmental Policy Act (NEPA) (i.e., SMALL, MODERATE, or LARGE) are not sufficiently clear with respect to the ESA and MSA, as these laws define and require other findings. So, in complying with the ESA, the NRC will report in its plant-specific environmental reviews and future SEISs the effects of continued operations and refurbishment in terms of its ESA findings of (1) no effect, (2) not likely to adversely affect, (3) likely to adversely affect, or (4) is likely to jeopardize the listed species or adversely modify the designated critical habitat of Federally listed species populations or their critical habitat. For listed species where the NRC has found that its action is "likely to adversely affect" the species or habitat, the NRC may further characterize the effects as "is [or is not] likely to jeopardize listed species or adversely modify designated critical habitat." Similarly, in complying with the MSA, the NRC will report the effects of continued operations and refurbishment in terms of its MSA findings of (1) no adverse impact, (2) minimal adverse impact, or (3) substantial adverse impact to the essential habitat of Federally managed fish populations during the license renewal term.

On the basis of these considerations, the NRC concludes that the impact of continued operations and refurbishment activities on threatened, endangered, and protected species and habitats as well as essential fish habitat would depend on plant-specific design and operating characteristics, environmental review procedures established for ground-disturbing activities, the occurrence of species and habitats, and other site-specific considerations. Consequently, this issue remains a plant-specific, or Category 2, issue.

4.6.2 Environmental Consequences of Alternatives to the Proposed Action

Construction—For all alternatives discussed in this section, the impacts of construction on ecological resources would be qualitatively similar. Ecological impacts are site-dependent. Impacts would depend on the type and location of a proposed facility, the technologies to be employed, the size of the area affected, and the specific ecological characteristics of the area to be developed. Vegetation would be removed from construction and material storage areas, and along utility pathways. Some disturbed areas would be re-vegetated after plant construction. Native vegetation could be displaced by invasive species in areas disturbed by construction. Some areas near access roads may be affected by the release of fugitive dust.

Construction-related noise could disturb wildlife. Permanent habitat loss could occur for some species. Despite reclamation efforts, a certain amount of natural habitat at greenfield sites could be permanently lost. Industrial development at brownfield and existing nuclear power plant sites have already affected or altered the natural habitat.

Operations—Various impacts on ecological resources can be anticipated throughout the operating period of an electrical power plant. Impacts include fugitive dust; impingement and entrainment of fish and other aquatic organisms; heated effluent from cooling water discharge and blowdown; gasifier and boiler blowdowns; steam water treatment; cooling tower drift (fogging and ice); salt deposition; maintenance of transmission line ROWs; bird collisions; and wildlife avoidance behavior due to operational activities and noise. Aquatic ecosystems would be affected by cooling water discharge, steam-cycle blowdown, and other (NPDES-permitted) wastewater. Onsite maintenance, accumulation of contaminants in sediment or biota, changes in levels of dissolved oxygen in surface water, dredging, and possible deposition of radionuclides would also impact aquatic resources. The magnitude of potential impacts from a proposed facility could be greater than or less than renewing the license for an existing facility depending upon site-specific and project-specific factors.

4.6.2.1 Fossil Energy Alternatives

Operations—Many of the potential ecological impacts from operations of a fossil energy facility (coal- or gas-fired) would essentially be similar to those for a nuclear facility.

Unique features of a coal-fired power plant that could impact ecological resources include:

- Coal delivery, cleaning and storage—periodic maintenance dredging (if coal is delivered by barge), noise, dust, loss of habitat, sedimentation and turbidity, and introduction of minerals and terrace elements (including contaminants that can cause impacts similar to acid mine drainage);

- Limestone preparation and storage—dust and runoff can affect soil and vegetation and increase water hardness and turbidity;

- Air emissions—most notably, acid precipitation can cause direct and indirect effects on terrestrial and aquatic organisms including injury to foliage, leaching of nutrients, decreased biodiversity, and elimination of certain fish species from lakes and streams; and

- Disposal of combustion wastes—habitat loss and potential seepage of trace and other elements into groundwater, soils, and surface waters.

The unique feature of a gas-fired power plant that could impact ecological resources would be the need for a gas pipeline. The main impact of a pipeline would be the loss, modification, and fragmentation of habitat.

Overall, ecological impacts from a fossil energy facility would depend on whether it would be located at a new site or replace an existing energy facility and whether the fossil energy facility would use once-through or closed-cycle cooling. The range of ecological impacts would be SMALL to MODERATE at an existing industrial site using closed-cycle cooling to MODERATE to LARGE at a new location using open-cycle cooling.

4.6.2.2 New Nuclear Alternatives

Operations—Since 1997, the NRC has certified four new standard designs for light-water nuclear power plants under 10 CFR Part 52, Subpart B. Therefore, impacts on ecological resources from construction and operation of a new nuclear power plant are considered in this section. The NRC assumes that the new nuclear reactor would have a 40-year lifetime. The extent of ecological impacts would depend on the location of the facility. A new nuclear plant located at the site of the existing nuclear facility would limit the amount of habitat disturbance that would be required (e.g., a new reactor at an alternative site would require about 500 to 1,000 acres [202 to 405 ha]). Additionally, existing transmission facilities, roads, parking areas, and possibly cooling system could be used if the new nuclear facility is located at the site of the existing facility. Ecological communities would experience reduced productivity and biological diversity from land disturbance. Regardless of whether a new reactor was constructed at an existing or alternative site, the amount of habitat disturbance would be greater than for license renewal of an existing nuclear facility.

Operational impacts on terrestrial ecology from a new nuclear reactor would be similar to those for the existing facility (Section 4.6.1.1). It is expected that a new nuclear reactor facility would use a closed-cycle cooling system. If the existing nuclear facility had once-through cooling, then impacts on aquatic resources for the new nuclear reactor would be reduced. Otherwise, operational impacts on aquatic ecology would be similar.

Overall, the ecological impacts of the nuclear alternative would be SMALL to MODERATE at an existing site and MODERATE to LARGE at an alternative site.

4.6.2.3 Renewable Alternatives

Construction—Dams and reservoirs would alter river flow and temperature, which could affect aquatic and terrestrial resources downstream. Dams create a barrier to fish migration if fish passages are not installed. Aquatic and terrestrial resources would have to adapt to the newly created reservoir. Disruptions to the sea bottom for installation of power and communication cables would affect benthic populations and other species that rely on benthic organisms for food. Unique ecological impacts could result from construction of offshore facilities from boat traffic to and from the construction site. Other impacts include underwater noise, alteration of sediment transport and deposition patterns, and possible disruption of onshore and nearshore nesting areas.

Operations—The operational impacts of alternative energy technologies on terrestrial and aquatic ecology are summarized in the following subsections.

Hydroelectric Energy Sources

Downstream conditions could be affected by dam operations (store-and-release of water) that could vary river flow conditions. Aquatic and terrestrial resources would be affected by fluctuating water levels downstream of the dam. Aquatic organisms could become stranded temporarily when river levels are lowered. Temperature and nutrient stratification in the reservoir and reduced levels of dissolved oxygen could result in hypotoxic or anoxic conditions for aquatic organisms. Aquatic and riparian ecosystems downstream would be affected by a variety of dam-induced conditions, such as changes in sediment transport and deposition patterns, and channel erosion or scouring. Hydropower operations could enhance populations of nonnative aquatic biota and riparian plants.

Geothermal

Birds and bats could be affected by contact with geothermal fluids temporarily stored in surface impoundments.

Wind

Aerodynamic and mechanical noise from wind turbines would affect wildlife. Collisions with wind turbines would increase bird and bat mortality. However technological advances allow rotors to turn at lower speeds, thus reducing the potential for bird and bat strikes. Underwater noise impacts from offshore facilities would extend to great distances due to the density of water. Offshore facilities could impact threatened and endangered species, marine mammals, birds, or sea turtles. Other impacts include disturbance of nesting areas, alteration of key habitat, underwater noise, or fuel spills.

Biomass

Habitat loss could occur from the cultivation of energy crops. Deposition of toxic constituents from municipal solid waste feedstock could affect aquatic and terrestrial ecosystems.

Solar Thermal and Photovoltaic

Solar fields occupy large areas of land that could reduce or preclude natural vegetation communities and wildlife use. Synthetic organic heat transfer fluids could affect surrounding vegetation. Misalignment of mirrors could also increase fire risk.

Ocean Wave and Current

Boat traffic, noise, navigation safety lights, inspection and maintenance activities could affect marine mammals, fish, and sea turtles. Sea turtles could be affected by wave-topping devices. Onshore nesting areas could be affected. Fish, sea turtles, and marine mammals could collide with underwater turbines.

4.7 Historic and Cultural Resources

4.7.1 Environmental Consequences of the Proposed Action—Continued Operations and Refurbishment

Section 106 of the National Historic Preservation Act requires Federal agencies to take into account the effects of their undertakings (license renewal) on historic properties. As discussed in Section 3.7.1, the NRC fulfills its Section 106 requirements through the NEPA process (see 36 CFR 800.8). In license renewal, only one impact issue is evaluated:

- Historic and cultural resources; issue encompasses the impact of continued operations and refurbishment activities on historic properties located onsite and in transmission line

ROWs (issue was modified and renamed from the1996 GEIS issue, “Historic and archaeological resources”).

This issue was addressed in the 1996 GEIS; however, the process for considering historic properties has been updated, and the range of historic properties has been expanded to include traditional cultural properties.

Many facilities were constructed prior to the implementation of Section 106 regulations; therefore, many nuclear plant sites were not investigated for the presence of historic and cultural resources prior to construction. As most licensees are not aware of the presence or status of historic and cultural resources on their site, a review of the site and plant activities since construction should be conducted by qualified cultural resource professionals and approved by the appropriate State Historic Preservation Office (SHPO). A variety of historic and cultural resources can be found at plant sites. Archaeological sites are generally identifiable only through field investigations. Traditional cultural properties (TCPs), historic and cultural resources that are important for a community to maintain its cultural heritage, can also be found in the immediate environs of a nuclear power plant. In some cases, the nuclear power plant itself may be considered a historic property for its design or engineering. Ultimately, historic and cultural resources at each site can be quite different and must be assessed at a plant-specific level and in consultation with SHPOs, Tribal representatives, and other interested parties.

The NRC will identify historic and cultural resources within a defined Area of Potential Effect (APE). The license renewal APE is the area that may be impacted by land-disturbing, or other operational, activities associated with continued plant operations and maintenance during the license renewal term and/or refurbishment. The APE typically encompasses the nuclear power plant site, its immediate environs including viewshed, and the transmission lines within this scope of review (see Sections 3.1.1 and 3.1.6.5 in this GEIS). The APE may extend beyond the nuclear plant site and transmission lines when these activities may affect historic and cultural resources. This determination is made irrespective of land ownership or control. If any historic properties are present, their significance is determined through application of the *National Register of Historic Places* (NRHP) criteria.

Continued operations during the license renewal term and refurbishment activities at a nuclear power plant can affect historic and cultural resources through (1) ground-disturbing activities associated with plant operations and ongoing maintenance (e.g., construction of new parking lots or buildings), landscaping, agricultural or other use of plant property, (2) activities associated with transmission line maintenance (e.g., maintenance of access roads or removal of danger trees), and (3) changes to the appearance of nuclear power plants and transmission lines. Licensee renewal environmental reviews have shown that the appearance of nuclear power plants and transmission lines have not changed significantly over time; therefore additional viewshed impacts to historic and cultural resources are not anticipated.

Extensive ground-disturbing activities occurred during nuclear power plant construction at nuclear power plant sites, and much of the land immediately surrounding the power block was disturbed down to bedrock. This activity would have eliminated any potential for historic or cultural resources to be present in this portion of the power plant site. However, to effectively determine areas that could potentially contain historic and cultural resources, a survey of any area which may be disturbed by continued operations during the license renewal term or by refurbishment associated with license renewal, including previously disturbed areas of the nuclear power plant site (other than the land immediately surrounding the power block), should be conducted by qualified professionals and in consultation with the appropriate SHPO and other consulting parties.

In the 1996 GEIS, the NRC considered the impact of continued operations and refurbishment on historic and archaeological resources at nuclear power plants and concluded that impacts would not be the same at all plants (i.e., a Category 2 issue) and could range from SMALL to LARGE. Subsequent license renewal environmental reviews conducted by the NRC support the Category 2 designation.

The National Historic Preservation Act of 1966 (NHPA) requires the NRC to conduct a site-specific assessment to determine whether historic properties are present in the APE, and if so, whether the license renewal decision would result in any adverse effect upon such properties. Thus, the NRC concludes that it is more appropriate to make one of the following determinations in its plant-specific environmental reviews instead of assigning a significance level (i.e., SMALL, MODERATE, or LARGE): (1) no historic properties present; (2) historic properties are present, but not adversely affected; or (3) there is an adverse effect on a historic property. On the basis of these considerations, the impact of continued operations and refurbishment activities on historic properties (and cultural resources) remains a Category 2 issue.

4.7.2 Environmental Consequences of Alternatives to the Proposed Action

Construction—Impacts to historic and cultural resources from the construction of a replacement power facility are primarily related to ground disturbance and are dependent on the location of the power plant. Before constructing a new replacement power plant or a facility at a greenfield, brownfield, or existing nuclear power plant site, a historic and cultural resource inventory would need to be performed by a qualified cultural resource professional. Any land needed to support the replacement power plant including roads, transmission corridors, rail lines, or other ROWs would also need to be surveyed for historic properties.

4.7.2.1 Fossil Fuel Alternatives

Operations—Ground-disturbing activities during power plant operations and maintenance could impact historic and cultural resources at the power plant site. Other ongoing activities at the power plant site could also affect historic and cultural resources. These activities include, but are not limited to, grading, excavating, landscaping, and operating large vehicles over previously undisturbed portions of the site.

4.7.2.2 New Nuclear Alternatives

Operations—Ground-disturbing activities during power plant operations and maintenance could impact historic and cultural resources at the power plant site. Other ongoing activities at the power plant site could also affect historic and cultural resources. These activities include, but are not limited to, grading, excavating, landscaping, and operating large vehicles over previously undisturbed portions of the site.

4.7.2.3 Renewable Alternatives

Hydroelectric Energy Sources

Operations—Fluctuations of river flow could erode embankments affecting downstream historic properties. Ground-disturbing activities during power plant operations and maintenance could impact historic and cultural resources at the dam site. It is assumed that impacts to historic properties would have been addressed prior to construction.

Wind

Operations—Historic properties would be affected by the presence of wind turbines in the viewshed. Ground-disturbing activities during power plant operations and maintenance could impact historic and cultural resources at the wind farm site. It is assumed that impacts to historic properties would have been addressed prior to construction.

Ocean Wave and Current

Operations—Historic properties located offshore could be affected by kinetic energy by ocean wave and/or current-energy-capturing devices. Ground-disturbing activities during power plant operations and maintenance could impact historic and cultural resources on the ocean floor. It is assumed that impacts to historic properties would have been addressed prior to construction.

Geothermal, Biomass, and Solar Thermal and Photovoltaic

Operations – Ground-disturbing activities during power facility operations and maintenance could impact historic and cultural resources at the power plant site. Other ongoing activities at the power facility site could also affect historic and cultural resources. These activities include, but are not limited to, grading, excavating, landscaping, operating large vehicles over previously undisturbed portions of the site.

4.8 Socioeconomics

4.8.1 Environmental Consequences of the Proposed Action—Continued Operations and Refurbishment Activities

The socioeconomic impact of ongoing power plant operations has become well established during the current license term for all nuclear power plants. Changes in employment and tax payments caused by license renewal and associated refurbishment activities can have a direct and indirect effect on community services and housing demand, as well as traffic volumes in the communities around each nuclear power plant.

A review of license renewal applications provides no evidence that the number of permanent power plant operations workers would increase during the license renewal term. This differs from the conservative assumption that up to 60 additional workers per reactor unit (upper bound) could be needed to support aging management-related maintenance and inspection activities (see 1996 GEIS). Licensees, however, indicated that they had no plans to add non-outage workers during the license renewal term and that increased maintenance and inspection activities could be managed using the current workforce. This review also revealed that refurbishment activities, such as steam generator and vessel head replacement, have not required the large numbers of workers and months of time that was conservatively predicted in the 1996 GEIS. Therefore, people living in the vicinity of a nuclear power plant are not likely to experience any changes in socioeconomic conditions during the license renewal term beyond what is currently being experienced. In addition, refurbishment impacts are expected to be similar to what has been experienced during regularly scheduled power plant refueling and maintenance outages.

The environmental review conducted for this GEIS revision identified five socioeconomic impact issues, which include all of the original socioeconomic license renewal term and refurbishment impact issues addressed in the 1996 GEIS. These five issues are:

- Employment and income, recreation and tourism (new, consolidated issue that adds impacts on employment and income that were not addressed in the 1996 GEIS). Also included in this issue are the impacts on recreation and tourism (impacts on tourism and recreation were addressed in the 1996 GEIS as part of the issue, “Public services: public safety, social services, and tourism and recreation”);

- Tax revenues (new issue; issue was considered and discussed in the 1996 GEIS, but not identified as a separate environmental review issue);

- Community services and education (consolidation and reclassification of the following issues in the 1996 GEIS: (1) public services: public safety, social services [excluding public services: tourism and recreation]; (2) public services: public utilities; (3) public services: education [license renewal term]; and (4) public services: education [refurbishment]);

- Population and housing (issue was reclassified and renamed from the 1996 GEIS issue, “Housing impacts”; these impacts were considered in the 1996 GEIS, although the population impacts component was not identified as a separate issue); and

- Transportation (issue was reclassified and renamed from the 1996 GEIS issue, “Public services: transportation”).

4.8.1.1 Employment and Income, Recreation, and Tourism

As discussed in Chapter 3, the nuclear power plant and the communities that support it can be described as a dynamic socioeconomic system. The communities provide the people, goods, and services required to operate the nuclear power plant. Power plant operations, in turn, provides employment and income and pays for goods and services from the communities.

Employees receive income from the nuclear power plant in the form of wages, salaries, and benefits. Employees and their families, in turn, spend this income on goods and services within the community thereby creating additional opportunities for employment and income. In addition, people and businesses in the community receive income for the goods and services sold to the power plant. Payments for these goods and services create additional employment and income opportunities in the community. The measure of a communities’ ability to support the operational demands of a power plant depends on the ability of the community to respond to changing socioeconomic conditions.

As previously discussed, it is unlikely that the number of power plant operations workers would change at a nuclear power plant during the license renewal term. While it was conservatively estimated in the 1996 GEIS that up to 60 additional workers per unit could be required during the license renewal term, subsequent license renewal environmental reviews have shown little or no need to hire additional operations workers. In addition, refurbishment activities, such as steam generator and vessel head replacement, have not required the numbers of workers and the months of time conservatively estimated in the 1996 GEIS. Consequently, employment levels at a nuclear power plant are not expected to change as a result of license renewal.

Some communities experience seasonal transient population growth due to local tourism and recreational activities. Income from tourism and recreational activities creates employment and income opportunities in the communities around nuclear power plants. Communities located near nuclear power plants in coastal regions, notably Pilgrim near Plymouth and Cape Cod, Massachusetts; the D.C. Cook and Palisades plants on the eastern shore of Lake Michigan, and the Oyster Creek plant on the New Jersey shore north of Atlantic City, experience summer, weekend, and retirement population increases due to the recreational and tourism activities that attract visitors. Some communities, such as those located in the region around the Vermont Yankee plant in Vermont, attract visitors interested in outdoor recreational activities, such as camping, hiking, and skiing.

As discussed in Section 4.2.1.2, the NRC considered the impacts of continued plant operations during the license renewal term and refurbishment on visual resources, which could affect tourism and recreational business interests. The NRC concluded in the 1996 GEIS that the impacts on visual resources would be SMALL for all plants and was a Category 1 issue, primarily because the impact had already occurred and the visual profile of nuclear power plants were not expected to change as a result of license renewal. Also, visual impacts tend to wear off over time when viewed repeatedly.

However, a case study performed for the 1996 GEIS found situations where nuclear power plants have had a negative effect on visual resources. Negative perceptions were based on aesthetic considerations (for instance, the plant is out of character or scale with the community or the viewshed), physical environmental concerns, safety and perceived risk issues, an anti-power plant (or utility) attitude, or an anti-nuclear orientation. It is believed that some of these negative perceptions would persist regardless of mitigation measures. Subsequent license renewal reviews have not revealed any new information that would change this perception.

Nevertheless, the effects of power plant operations on employment, income, recreation, and tourism are ongoing and have become well-established during the current license term for all nuclear power plants. The impacts from power plant operations during the license renewal term on employment and income in the region around each nuclear power plant are not expected to change from what are currently being experienced. In addition, tourism and recreational activities in the vicinity of nuclear plants are not expected to change as a result of license renewal. On the basis of these considerations, the NRC concludes that the impact of continued nuclear plant operations and refurbishment activities on employment, income, recreation, and tourism would be SMALL and is therefore considered a Category 1 issue.

4.8.1.2 Tax Revenues

Nuclear power plants and the workers who operate them are an important source of tax revenue for many local governments and public school systems. Tax revenues from nuclear power plants mostly come from property tax payments or other forms of payments such as payments in lieu of (property) taxes, or PILOT payments, although taxes on energy production have also been collected from a number of nuclear power plants. County and municipal governments and public school districts receive tax revenue either directly or indirectly through State tax and revenue-sharing programs.

Counties and municipal governments in the vicinity of a nuclear power plant also receive tax revenue from sales taxes and fees from the power plant and its employees. Changes in the number of workers and the amount of taxes paid to county, municipal governments, and public schools can affect socioeconomic conditions in the counties and communities around the nuclear power plant.

A review of license renewal applications received by the NRC since the 1996 GEIS has shown that refurbishment activities, such as steam generator and vessel head replacement, have not had a noticeable effect on the assessed value of nuclear plants, thus changes in tax revenues are not anticipated from future refurbishment activities. Refurbishment activities involving the one-for-one replacement of existing components and equipment are generally not considered a taxable improvement. Also, property tax assessments; proprietary payments in lieu of tax stipulations, settlements, and agreements; and State tax laws are continually changing the amount of taxes paid to taxing jurisdictions by nuclear plant owners. These changes are independent of license renewal and refurbishment activities.

The primary impact of license renewal would be the continuation or change in the amount of taxes paid by nuclear power plant owners to local governments and public school systems. The impact of nuclear plant operations on tax revenues in local communities and the impact that the expenditure of tax revenues has on the region are not expected to change appreciably from the amount of taxes paid during the current license term. Tax payments during the license renewal term would be similar to those currently being paid by each nuclear plant. On the basis of these considerations, the NRC concludes that the impact of continued nuclear plant operations and refurbishment on tax revenue would be SMALL and is therefore considered a Category 1 issue.

4.8.1.3 Community Services and Education

In the 1996 GEIS, impacts on public (community) services and education were evaluated based on the projected number of “in-migrating” workers accompanied by their families. In addition, impacts on (1) public services: public safety, social services…; (2) public services: public utilities; (3) public services, education (license renewal term); and (4) public services, education (refurbishment) were considered as separate impact issues in the 1996 GEIS but have been consolidated and reclassified under this issue. All but the “public services: tourism and recreation” component of the 1996 GEIS issue, “Public services: public safety, social services, and tourism and recreation” are considered here.

The four 1996 GEIS issues have been consolidated because all public services are equally affected by changes in nuclear power plant operations and refurbishment activities. Any changes in the number of workers at a nuclear plant will affect the demand for public services from local communities. Environmental reviews conducted by NRC since the 1996 GEIS have shown, however, that the number of workers at relicensed nuclear plants has not changed significantly because of license renewal, so demand-related impacts on community services, including public utilities, are no longer anticipated from future license renewals.

In addition, refurbishment activities, such as steam generator and vessel head replacement, have not required the large numbers of workers and the months of time that was conservatively analyzed in the 1996 GEIS, so significant impacts on community services are no longer anticipated. Because of the relatively short duration of refurbishment-related activities, workers are not expected to bring families and school-age children with them; therefore, impacts from refurbishment on educational services are also no longer anticipated.

Taxes paid by nuclear power plant owners support a range of community services, including public water, safety, fire protection, health, and judicial, social, and educational services.
In some communities, tax revenues from power plants can have a noticeable impact on the quality of services available to local residents. Although many of the community services paid for by tax revenues from power plants are used by plant workers and their families, the impact of nuclear plant operations on the availability and quality of community services and education is SMALL and is not expected to change as a result of license renewal. On the basis of these considerations, the NRC concludes that the impact of continued nuclear plant operations and refurbishment activities on community services and education would be SMALL and is therefore considered a Category 1 issue.

4.8.1.4 Population and Housing

Socioeconomic impact analyses of resources (e.g., housing) affected by changes in regional population are based on employment trends at nuclear power plants. Population growth from increased employment and spending at a nuclear power plant is important because it is one of the main drivers of socioeconomic impacts. Plant-induced population growth, while not an impact itself, was studied as a potential influence on a number of impact issues analyzed in the 1996 GEIS. As previously discussed, however, employment levels at nuclear power plants are expected to remain relatively constant with little or no population growth or increased demand for permanent housing during the license renewal term. The operational effects on population and housing values and availability in the vicinity of nuclear power plants are not expected to change from what is currently being experienced, and no demand-related impacts are expected during the license renewal term.

The increased number of workers at nuclear power plants during regularly scheduled plant refueling and maintenance outages does create a short-term increase in the demand for temporary (rental) housing units in the region around each plant. However, because of the short duration and the repeated nature of these scheduled outages and the general availability of rental housing units (including portable trailers) in the vicinity of nuclear power plants, employment-related housing impacts have had little or no long-term impact on the price and availability of rental housing. Refurbishment impacts would be similar to what is experienced during routine plant refueling and maintenance outages.

License renewal reviews conducted since the 1996 GEIS have shown that housing has not been an issue at relicensed nuclear plants including those plants located in “sparsely populated areas.” Therefore, impacts to these resources are no longer anticipated from future license renewals. On the basis of these considerations, the NRC concludes that the impact of continued nuclear plant operations and refurbishment activities on population and housing would be SMALL and is therefore considered a Category 1 issue.

4.8.1.5 Transportation

Transportation impacts depend on the size of the workforce, the capacity of the local road network, traffic patterns, and the availability of alternate commuting routes to and from the plant. Because most sites have only a single access road, there is often congestion on these roads during shift changes.

Nevertheless, license renewal is not likely to affect local transportation conditions in the vicinity of a nuclear power plant beyond what is currently being experienced. Transportation impacts are ongoing and have become well established during the current licensing term for all nuclear power plants. As previously discussed, it is unlikely that the number of permanent operations workers would increase at a nuclear power plant during the license renewal term. While it was estimated in the 1996 GEIS that up to 60 additional workers per unit could be required during the license renewal term, subsequent environmental reviews have shown little or no need for additional operations workers. In addition, refurbishment activities, such as steam generator and vessel head replacement, have not required the numbers of workers and the months of time conservatively estimated in the 1996 GEIS. Consequently, employment at nuclear power plants during the license renewal term is expected to remain unchanged. Refurbishment impacts would be similar to what has been experienced during routine plant refueling and maintenance outages.

The increased number of workers at nuclear power plants during regularly scheduled plant refueling and maintenance outages have caused short-term increases in traffic volumes on roads in the vicinity of each plant. However, because of the relative short duration of these outages, increased traffic volumes have had little or no lasting impact. Therefore, there would be no transportation impacts during the license renewal term beyond those already being experienced. On the basis of these considerations, the NRC concludes that the impact of continued operations and refurbishment activities on local transportation would be SMALL and is therefore considered a Category 1 issue.

4.8.2 Environmental Consequences of Alternatives to the Proposed Action

The impacts of power plant development on local and regional socioeconomic conditions would be qualitatively similar for all alternatives discussed in this section. Local economies have the potential to be directly or indirectly affected by power plant construction and operation. The power plant and the communities that support it can be described as a dynamic socioeconomic system. The communities provide the people, goods, and services required by power plant construction and operation. Activities at the plant, in turn, create the demand and pay for the people, goods, and services in the form of wages, salaries, and benefits for jobs and dollar expenditures for goods and services. The measure of the communities' ability to support the demands of the power plant depends on their ability to respond to changing environmental, social, economic, and demographic conditions.

Construction—The scale of the socioeconomic impacts of construction activities associated with each alternative would be related to the cost and complexity of the facility and the size of the workforce. The duration of the impact would be determined by the time required to complete construction. The impacts of the construction of power plants on employment and income in the local area and region around a new plant would vary depending on the location of major equipment suppliers and local labor availability. Impacts may be more dramatic and larger at greenfield sites located in rural areas than areas on the periphery of larger urban areas. Overall, construction is expected to have a temporary effect on the local economy.

While some construction workers would be local, additional workers may be required from outside the immediate area depending on the local availability of appropriate trades and occupational groups. At plants in rural locations, a larger number of construction workers would come from outside the local area, while most of the workforce in semi-urban locations would likely commute to the job site rather than relocate. Construction is likely to have some impact on local services such as public utilities, public safety, tourism, and recreation, depending on the number of workers required to in-migrate into the area around each plant. Materials needed for construction (e.g., sand, gravel, fill, etc.) are expected to be provided locally. However, the majority of construction materials and technology components are expected to be purchased in other parts of the United States or overseas. Transportation impacts during construction would include commuter and truck material and equipment delivery traffic to and from the construction site.

Operations—Operations of a new power plant would have an ongoing effect on the local economy, which would be directly or indirectly affected by power plant operation. As would be the case for construction, the impacts of the operation of power plants on employment and income in the local area and region around a new plant would vary depending on the location of major equipment suppliers and the availability of local labor. In addition, operations impacts may have a larger relative impact on communities in rural locations, with smaller relative impacts in semi-urban locations. The operations workforce would increase demand for social services, depending on the number of workers required to migrate into the area around each plant. Property values for nearby private residences could be affected positively if plant workers were to live locally. Property values could also be affected negatively, if there were impacts associated with noise, traffic, or if there were visual impacts associated with the plant.

Declining property values may mean increased local taxes to support existing levels of service in local public and educational services, which combined with declining quality of life, may lead to some population out-migration. The loss of recreational opportunity could mean the loss of employment and income in local communities hosting recreational suppliers and providing temporary accommodation. Transportation impacts would include increased commuter traffic during shift changes and deliveries of materials and equipment to the power plant.

The following sections briefly highlight socioeconomic impacts that would be characteristics of particular energy alternatives.

4.8.2.1 Fossil Fuel Alternatives

A relatively large workforce would be required to construct and operate fossil-fuel alternative-technology power plants, and, as a consequence, impacts on local employment and income and the local public and educational services that would be needed with the in-migration of workers during each phase could be large. Fossil-fuel alternatives, including natural gas- and coal-fired plants, could have substantial impacts, depending on various key aspects of each technology. Differences in stack heights and emissions between the two technologies and the transportation impacts associated with coal deliveries to the power plant (primarily by rail) and the removal of wastes and byproducts may affect property values and recreation and tourism opportunities in the vicinity of plants.

4.8.2.2 New Nuclear Alternatives

A relatively large workforce would be required to construct and operate new nuclear power plants, and, as a consequence, impacts on local employment and income and the local public and educational services that would be needed with the in-migration of workers during each phase could be large. Impacts of the construction and operation of new nuclear plants would also depend on key features of these plants. In addition to the heights of cooling towers and other tall or large structures, the existence of a nuclear power plant could affect property values and recreation and tourism through the perception of risk that people may have related to nuclear technology itself, and also the presence and visibility of nuclear waste storage facilities.

4.8.2.3 Renewable Alternatives

Operations –The impacts of alternative energy technologies on socioeconomics are presented in the following subsections. A relatively small workforce would be required to operate renewable alternative technology power plants and, as a consequence, impacts on employment and income and the local public and educational services that would occur with the in-migration of workers during each phase for each alternative technology would be SMALL.

Hydroelectric Energy Sources

Although there may be economic losses in the local area and region associated with development of hydroelectric resources, notably with the loss of agricultural land, transportation infrastructure, and recreational opportunities, the reservoir would create new recreational opportunities including parks, campgrounds, and boat ramps. Traffic in the vicinity of the dam and reservoir, typically a rural agricultural area, could increase as a result of recreational opportunities created by the reservoir.

Geothermal

Depending on the location of geothermal plants and the amount of land required for power plant development, recreation and property values in the area could be adversely affected by noise, sights, and odors from plant operations. Transportation impacts are expected to be limited, although large vehicle traffic could be required for the deployment and replacement of equipment.

Wind

Depending on the location of wind energy development, the visual impact of wind turbines, and to a lesser extent the associated noise, may have adverse impacts on recreation in the local area and on property values and quality of life in local rural communities. Transportation impacts are expected to be limited. Large vehicles could be required for the deployment and replacement of equipment.

Biomass

Truck and rail traffic bringing biomass fuel to the facility and removing solid wastes to offsite disposal facilities could impact local transportation networks and may affect property values and recreation and tourism opportunities in the vicinity of plants.

Ocean Wave and Current

Tourist and recreational activities on coastal beaches could be affected by the visual and noise impacts of helicopter and boat traffic. Wave energy devices that float on the ocean surface could affect navigation and water-borne recreational activities.

4.9 Human Health

4.9.1 Environmental Consequences of the Proposed Action—Continued Operations and Refurbishment Activities

Human health conditions at all nuclear power plants and associated transmission lines have been well established during the current licensing term. These conditions are expected to remain unchanged during the 20-year license renewal term.

4.9.1.1 Environmental Consequences of Normal Operating Conditions

This section provides an evaluation of the impacts of radiological, chemical, microbiological, EMFs, and other hazards on occupational personnel and members of the public from continued operation and refurbishment activities during the license renewal term. This evaluation extends to all U.S. commercial nuclear power reactors. For safe and reliable operation of a nuclear power plant, it is necessary to perform routine maintenance on plant systems and components. Maintenance activities conducted at nuclear power plants include inspection, surveillance, and repair and/or replacement of material and equipment to maintain the current licensing basis of the plant and ensure compliance with environmental and public safety requirements. Certain activities can be performed while the reactor is operating, and others require that the reactor be shut down. Long-term outages are scheduled for refueling and for certain types of repairs or maintenance activities, such as the replacement of steam generators for PWRs.

4.9.1.1.1 Radiological Impacts

Two environmental issues related to radiological exposure and risk are reviewed here: (1) radiation exposures to plant workers and (2) radiation exposures to the public, both of which would result from continued operation and refurbishment activities during the license renewal term. All aspects of these consolidated issues were evaluated in the 1996 GEIS, but the impacts of refurbishment were considered separately from those of operations.

For the purposes of assessing radiological impacts, impacts are considered to be SMALL if releases and doses do not exceed permissible levels in the NRC's regulations. This definition of SMALL applies to occupational doses as well as to doses to individual members of the public. Accidental releases or noncompliance with the standards could conceivably result in releases that would cause MODERATE or LARGE radiological impacts. Such conditions are beyond the scope of regulations for controlling normal operations and providing an adequate level of protection. Environmental consequences and human health effects of potential accidents are addressed in Section 4.9.1.2.

Radiation Exposures to Plant Workers

The occupational radiological exposures from current operations at nuclear power plants are discussed in Section 3.9.1.2, and the risk estimates from this radiation exposure are discussed in Section 3.9.1.4.

In the 1996 GEIS, the impacts from occupational radiological exposure from refurbishment and continued operations were evaluated separately. To estimate radiation-related impacts on workers over the license renewal term, occupational radiation exposure was used as the environmental impact initiator that was quantified. It was assumed that occupational radiation exposure would change relative to current nuclear plant operations as a result of actions taken to support license renewal. To evaluate the impacts, two types of license renewal programs were considered: a "typical" or "mid-stream" license renewal program, and a "conservative" or "bounding" program (NRC 1996). Each program applied to both PWRs and BWRs. Thus, in all, four scenarios were considered. It was assumed that activities carried out in support of license renewal would be performed primarily during selected outages. Five types of outages were considered: normal refuelings, 5-year in-service inspection (ISI) outages, 10-year ISI outages, current-term refurbishment outages, and major refurbishment outages. The potential actions and activities that would be undertaken during these outages were identified. All of the rules and regulations, in particular, the Maintenance Rule (10 CFR 50.65, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants"), were taken into account in developing typical license renewal or plant-life extension (NRC 1996). The occupational exposure for each of the five types of outages was estimated for all four scenarios (see Table 4.9-1).

For refurbishment efforts, dose estimates for activities during each of the four current-term refurbishment outages were 11 and 10 person-rem for PWRs and BWRs, respectively, for the typical case; and 200 and 191 person-rem, respectively, for the conservative case. Dose estimates for the assumed single period of major refurbishment were 79 and 153 person-rem for

Table 4.9-1. Additional Collective Occupational Dose (person-rem) for Different Actions under Typical and Conservative Scenarios during the License Renewal Term

Outage Type	Typical BWR	Conservative BWR	Typical PWR	Conservative PWR
Normal refueling[a]	4	10	3	7
5-yr ISI[b] refueling[c]	71	27	30	35
10-yr ISI refueling[d]	91	108	51	66
Current-term refurbishment[e]	10	191	11	200
Major refurbishment outage[f]	153	1,561	79	1,380
Total all occurrences	457	2,666	261	2,374

(a) 8 occurrences, 2-month duration each.
(b) ISI = in service inspection.
(c) 2 occurrences, 3-month duration each.
(d) 1 occurrence, 4-month duration for conservative and 3-month duration for typical scenario.
(e) 4 occurrences, 4-month duration for conservative and 3-month duration for typical scenario.
(f) 1 occurrence, 9-month for conservative and 4-month duration for typical scenario.
Source: Tables 2.8 and 2.11 in the 1996 GEIS

PWRs and BWRs, respectively, for the typical case; and 1380 and 1561 person-rem, respectively, for the conservative case. The issue was designated as a Category 1 issue in the 1996 GEIS.

For continued operations during the license renewal term, the NRC observed in the 1996 GEIS that the greatest increment to occupational dose over the present dose would occur during a 10-year ISI refueling. In a typical case, the occupational dose would increase over the present dose by 91 person-rem for a BWR and by 51 person-rem for a PWR. In a conservative case, the occupational dose would increase over the present dose by 108 person-rem and 66 person-rem, respectively, for BWRs and PWRs. It was noted that there is about an 8 percent increase in collective radiation dose over current operating experience. The individual occupational doses would be well below regulatory limits (i.e., the impact would be SMALL), and the issue was designated as a Category 1 issue.

For estimating the impacts from continued operation and refurbishment activities during the license renewal term in this GEIS revision, the occupational exposure histories for all commercial nuclear power plants were evaluated for trends.

Throughout the nuclear power industry, modification and upgrade activities have continued at each operating plant. They have included a broad range of activities in response to NRC requirements and industry initiatives, including post-Three Mile Island upgrades, radioactive waste system modifications, and spent fuel storage upgrades. In addition, several nuclear power plants have undergone major refurbishment efforts, such as PWR steam generator replacement and the replacement of coolant recirculation piping in BWRs. These activities offered a significant potential for occupational exposure. Thus, occupational exposure histories accumulated to date reflect normal operation plus modifications and additions to existing systems. This information forms the basis for evaluating the occupational doses that result from refurbishment and continued operations during the license renewal term. The data in Tables 3.9-8 and 3.9-9 show that there are variations in occupational dose from year to year, but there is no consistent trend that shows that occupational doses are increasing over time.

Since 1996, over 70 operating reactors at over 40 nuclear power plant sites have undergone an environmental review for license renewal. Many nuclear power plants have already replaced major components like steam generators during their current license term. Moreover, as part of the license renewal application, the plants have conducted an aging management review. All of the plants expect to conduct the activities related to managing impacts from aging during plant operation or normal refueling and other outages, but they do not plan any outage specifically for the purpose of refurbishment. The applicants have indicated that the activities conducted during the license renewal term are expected to be within the bounds of normal operations; thus, even the typical scenario in the 1996 GEIS can be considered conservative.

Overall, data presented in Tables 3.9-3 to 3.9-13 provide ample evidence that occupational doses at all commercial power plants are far below the occupational dose limit of 5 rem/yr established by 10 CFR Part 20 and that the continuing efforts to maintain doses at ALARA levels have been successful.

The wide range of annual collective doses experienced at PWRs and BWRs in the United States results from a number of factors, such as the reactor design, amount of required maintenance, and amount of reactor operations and in-plant surveillance. Because these factors can vary widely and unpredictably, it is very difficult to determine in advance a specific year-to-year annual occupational radiation dose for a particular plant throughout its operating lifetime. On occasion, relatively high collective occupational doses (as compared with the average annual collective dose) may be unavoidable, even at plants with radiation protection programs designed to ensure that occupational doses will be kept to ALARA levels.

During 2005, with occupational radiation protection programs in place, nuclear power plants maintained an annual average individual dose of 0.12 rem and 0.18 rem for PWRs and BWRs, respectively (Table 3.9-11), compared with an exposure limit of 5 rem. For all nuclear power plants combined, the occupational doses to individual workers are estimated to average 0.15 rem/yr (Table 3.9-4). At these dose levels, the average increase in fatal individual cancer risk to a worker is approximately 6×10^{-5}/yr (using the ICRP risk coefficient of 4×10^{-4}/rem from Table 3.9-20). If the reactor operates for 60 years, the cumulative increase in fatal cancer to an individual worker is estimated to be 3.6×10^{-3} (a 50 percent increase over the baseline of 40 years of operations). However, it is very unlikely that the same worker would be employed for all 60 years of plant operations.

The average collective occupational exposure for the year 2005 was roughly 171 person-rem per plant at BWRs and about 79 person-rem per plant at PWRs (Table 3.9-10). For 2005, 50 percent of the PWRs reported collective doses between 44 and 107 person-rem, while 50 percent of the BWRs reported collective doses between 94 and 198 person-rem (see Figure 3.9-1). For 2005, no worker received doses greater than 3 rem. Only 17 workers (0.01 percent) received an occupational dose exceeding 2 rem during 2005. At BWRs, less than 0.03 percent of the workers received doses greater than 2 rem. At PWRs, no worker received a dose greater than 2 rem, and less than 0.3 percent of the workers received doses greater than 1 rem (Table 3.9-12).

Over the years, ALARA programs continue to limit occupational doses. Occupational doses have shown a declining trend over the past 10 years and have recently leveled off. As plants age, there may be slight increases in radioactive inventories, which would result in slight increases in occupational radiation doses, but that trend has not yet appeared.

Overall, data presented in Tables 3.9-1 to 3.9-13 provide evidence that doses to nearly all radiation workers are far below the worker dose limit established by 10 CFR Part 20 and that the continuing efforts to maintain doses at ALARA levels have been successful.

It is expected that occupational doses from refurbishment activities associated with license renewal and occupational doses for continued operations during the license renewal term would be similar to the doses during the current operations and bounded by the analysis conducted in the 1996 GEIS. It is estimated that the occupational doses would be much less than the regulatory dose limits, as described above. Expected occupational radiation exposures meet the standard for being of SMALL significance. No mitigation measures beyond those implemented during the current license term would be warranted, because the ALARA process continues to be effective in reducing radiation doses. The risks to an individual worker from radiological exposure would increase by 50 percent as a result of the plant operating for 20 more years, but it is unlikely that the same worker would be employed for all 60 years of plant operations.

In the 1996 GEIS, the NRC concluded that the occupational radiological exposure impact during license renewal and refurbishment would be SMALL for all plants; it was therefore designated as a Category 1 issue. No new information has been identified in the SEISs prepared to date or the literature that would alter that conclusion. On this basis, the NRC concludes that the impact of continued operations and refurbishment activities on occupational radiological exposure would be SMALL for all nuclear plants and remains a Category 1 issue.

Radiation Exposures to the Public

Radiological exposures to the public from current operations at nuclear power plants are discussed in Section 3.9.1.3. That section includes a discussion of the effluent pathways used in calculating dose and the radiological monitoring performed by each site to ensure that unanticipated buildup of radioactivity have not occurred in the environment. The risk estimates for the public from radiation exposure are discussed in Section 3.9.1.4.

Refurbishment Activities—To determine the relative significance of the estimated public dose from refurbishment, the public dose during the year refurbishment activities occurred was compared with the doses in consecutive years. Exposure from other ongoing support activities similar to those that occurred during the current license term (e.g., construction of new parking lots, access roads, and buildings) would be less than or equal to the impacts associated with refurbishment.

In the 1996 GEIS, the NRC identified the replacement of steam generators at PWRs and the replacement of recirculation piping at BWRs as the major anticipated refurbishment activities. Public radiation exposures from refurbishment activities during the license renewal term can be evaluated on the basis of information derived from past occurrences and projections for other repairs. Effluents anticipated during major refurbishment actions were estimated on the basis of historical information derived for steam generator replacements at PWRs and replacements of recirculation piping at BWRs. These refurbishment tasks have already taken place several times within the commercial nuclear power reactor industry. From these estimates, the maximum individual dose to the member of the public was compared with the design objective of Appendix I to 10 CFR Part 50 (Table 3.9-2) and with baseline effluents produced during normal reactor operations.

Public radiation exposures from gaseous and liquid effluents produced during refurbishment can be evaluated on the basis of effluent data from the replacement of steam generators and recirculation piping. During the replacement of steam generators and recirculation piping, releases of effluents have occurred under controlled conditions and in accordance with ALARA principles. Similar refurbishment efforts that may occur as part of the license renewal process would also take place under controlled conditions and in accordance with ALARA principles.

The first several plants to replace steam generators estimated the amounts of radioactivity expected to be released in liquid and gaseous effluents as a result of the repair (Parkhurst et al. 1983). Actual effluent measurements were performed in several cases. In the 1996 GEIS, the NRC listed the radioactive effluent releases for early steam generator replacements and compared them with typical 1986 effluent releases for PWRs and BWRs (see Table 3.10 in NRC 1996). It was found that the effluent releases were approximately the same or much less than those from normal operations for a year. For BWR recirculation piping replacement, the NRC compared the annual release and dose commitment information for five reactor sites (Cooper, Monticello, Nine Mile Point, Peach Bottom, and Vermont Yankee) during recirculation piping replacement with the data from normal operations of the same plants. It was found that the radiation doses to the public were similar to or less than those resulting from normal operations (see Table 3.11 in NRC 1996). On the basis of this finding, the NRC concluded in the 1996 GEIS that gaseous effluents and liquid discharges occurring during a 9-month refurbishment action would not be expected to result in maximum individual doses exceeding the design objectives of Appendix I to 10 CFR 50 or the allowable EPA standards of 40 CFR Part 190 (Table 3.9-2).

For estimating the impacts from refurbishment activities during the license renewal term in this GEIS revision, radioactive effluent releases and the dose to the public from the gaseous and liquid effluent releases were evaluated for the three sites that have gone through steam generator replacement in recent years. The effluent releases and the doses that occurred during the year refurbishment was done are compared with the values for prior and subsequent years.

Table 4.9-2 presents the radioactive effluent releases at three sites that have had their steam generators replaced in recent years. For Arkansas Unit 2, the steam generator was replaced in 2000, and the effluent releases are listed from 1999 to 2003. For Calvert Cliffs Unit 1, the steam generator was replaced in 2002, for Unit 2, it was replaced in 2003. The effluent releases are listed from 2000 to 2004. For Palo Verde Unit 2, the steam generator was replaced in 2003. The effluent releases are listed from 2001 to 2005. For this site, there are no liquid effluent releases beyond the site boundary. The data show that the effluent releases for the year that the steam generators were replaced are on the same order of magnitude or much less than the effluent releases for the following year. The effluent releases were also much less than or on the same order of magnitude as those shown in Table 3.10 of the 1996 GEIS.

Table 4.9-3 presents the dose to the public from the gaseous and liquid effluent releases for the same three sites. No significant difference in the dose from normal operations was observed when the steam generator was replaced. All doses are much less than the design objectives shown in Table 3.9-2. Tables 4.9-2 and 4.9-3 show that effluents and dose impacts during the year when a steam generator replacement is performed do not differ significantly from those in years of normal operations.

It is expected that doses during any future recirculation piping replacement would not be much different than the doses shown in Table 3.11 in the 1996 GEIS. The NRC is updating these tables for recent year data. The NRC will also assess dose contributions from the numerous plants that have replaced reactor vessel heads.

When a major refurbishment is performed, it is expected that more work will be performed and thus the amounts of some of the effluents, especially atmospheric particulates and possibly

Table 4.9-2. Radioactive Effluent Releases for Three Nuclear Power Plants That Recently Replaced Steam Generators

	Releases (Ci) in Gaseous Effluent					Releases (Ci) in Liquid Effluent			
Year[a]	Fission and Activation Products	Gross Alpha	Iodines	Particulates	Tritium	Dissolved and Entrained Gases	Fission and Activation Products	Gross Alpha	Tritium
Arkansas Unit 2									
1999	3.9×10^{1}	0	0	3.9×10^{-5}	3.7×10^{1}	2.3×10^{-2}	8.5×10^{-2}	4.4×10^{-4}	5.9×10^{2}
2000	**4.5**	$\mathbf{3.4 \times 10^{-7}}$	**0**	$\mathbf{7.4 \times 10^{-6}}$	$\mathbf{2.0 \times 10^{1}}$	$\mathbf{2.1 \times 10^{-1}}$	$\mathbf{2.6 \times 10^{-1}}$	$\mathbf{1.2 \times 10^{-1}}$	$\mathbf{5.0 \times 10^{2}}$
2001	1.7×10^{-1}	0	0	0	2.4×10^{1}	5.0×10^{-3}	7.2×10^{-2}	8.9×10^{-4}	4.9×10^{2}
2002	4.6×10^{-1}	0	1.7×10^{-5}	0	2.8×10^{1}	5.3×10^{-2}	2.0×10^{-2}	0	5.6×10^{2}
2003	3.9×10^{-1}	0	1.0×10^{-6}	0	2.5×10^{1}	9.9×10^{-2}	3.7×10^{-2}	0	7.0×10^{2}
Calvert Cliffs Units 1 and 2[b]									
2000	9.7×10^{1}	ND[c]	5.8×10^{-4}	ND	3.7×10^{1}	1.2×10^{-1}	2.7×10^{-1}	1.4×10^{-4}	1.1×10^{3}
2001	7.3×10^{1}	ND	1.2×10^{-3}	ND	2.0×10^{1}	6.3×10^{-2}	6.8×10^{-1}	4.7×10^{-5}	1.4×10^{3}
2002	$\mathbf{1.1 \times 10^{2}}$	**ND**	$\mathbf{2.7 \times 10^{-3}}$	**ND**	$\mathbf{2.4 \times 10^{1}}$	$\mathbf{1.9 \times 10^{-1}}$	$\mathbf{3.1 \times 10^{-1}}$	**ND**	$\mathbf{9.6 \times 10^{2}}$
2003	$\mathbf{1.6 \times 10^{2}}$	**ND**	$\mathbf{1.8 \times 10^{-3}}$	**ND**	$\mathbf{2.8 \times 10^{1}}$	$\mathbf{8.9 \times 10^{-2}}$	$\mathbf{6.7 \times 10^{-2}}$	**ND**	$\mathbf{8.1 \times 10^{2}}$
2004	1.6×10^{2}	ND	1.5×10^{-3}	2.7×10^{-4}	2.5×10^{1}	3.5×10^{-1}	2.8×10^{-2}	ND	1.5×10^{3}
Palo Verde Unit 2[d]									
2001	1.9×10^{2}	ND	7.2×10^{-4}	2.8×10^{-4}	6.3×10^{2}	None	None	None	None
2002	1.7×10^{2}	ND	9.7×10^{-3}	2.2×10^{-4}	2.7×10^{2}	None	None	None	None
2003	$\mathbf{9.2 \times 10^{1}}$	**ND**	$\mathbf{6.4 \times 10^{-3}}$	$\mathbf{7.3 \times 10^{-4}}$	$\mathbf{1.1 \times 10^{3}}$	**None**	**None**	**None**	**None**
2004	8.7×10^{-1}	ND	1.2×10^{-5}	3.3×10^{-10}	4.8×10^{2}	None	None	None	None
2005	4.6	ND	1.1×10^{-4}	5.6×10^{-5}	6.2×10^{2}	None	None	None	None

(a) Years in which steam generators were replaced are presented in bold text.
(b) Steam generator was replaced for Unit 1 in 2002 and for Unit 2 in 2003. The site reported releases from both units together.
(c) ND = Not detected.
(d) There were no liquid effluent releases beyond the site boundary.
Sources: Sites' annual effluent release reports

Table 4.9-3. Dose to the Maximally Exposed Individual (MEI) from Gaseous and Liquid Effluent Releases for Three Nuclear Power Plants That Recently Replaced Steam Generators

	Gaseous Effluents				**Liquid Effluents**	
Year[(a)]	**Total Body (mrem)**	**Gamma (mrad)**	**Beta (mrad)**	**Critical Organ (mrem)**	**Total Body (mrem)**	**Critical Organ (mrem)**
Arkansas Unit 2						
1999	2.3×10^{-2}	1.2×10^{-3}	3.8×10^{-3}	2.4×10^{-2}	1.7×10^{-3}	2.1×10^{-3}
2000	3.15×10^{-2}	2.70×10^{-3}	2.21×10^{-3}	3.15×10^{-2}	3.00×10^{-3}	3.90×10^{-3}
2001	1.5×10^{-2}	0	0	1.5×10^{-2}	1.0×10^{-3}	1.2×10^{-3}
2002	1.7×10^{-2}	0	1.0×10^{-4}	2.1×10^{-2}	1.6×10^{-3}	1.9×10^{-3}
2003	1.6×10^{-2}	0	1.0×10^{-4}	1.6×10^{-2}	1.3×10^{-3}	1.5×10^{-3}
Calvert Cliffs Units 1 and 2[(b)]						
2000	NR[(c)]	1.0×10^{-3}	7.0×10^{-3}	7.6×10^{-1}	3.0×10^{-1}	2.1×10^{-1}
2001	NR	1.0×10^{-3}	4.0×10^{-3}	3.5×10^{-2}	5.0×10^{-3}	4.3×10^{-1}
2002	**NR**	$\mathbf{1.0 \times 10^{-3}}$	$\mathbf{6.0 \times 10^{-3}}$	$\mathbf{1.7 \times 10^{-2}}$	$\mathbf{6.0 \times 10^{-3}}$	$\mathbf{2.0 \times 10^{-1}}$
2003	**NR**	$\mathbf{2.0 \times 10^{-3}}$	$\mathbf{1.0 \times 10^{-2}}$	$\mathbf{5.0 \times 10^{-2}}$	$\mathbf{2.0 \times 10^{-3}}$	$\mathbf{2.0 \times 10^{-2}}$
2004	NR	2.0×10^{-3}	8.0×10^{-3}	4.0×10^{-2}	2.0×10^{-3}	5.0×10^{-3}
Palo Verde Unit 2[(d)]						
2001	NR	1.6×10^{-2}	6.1×10^{-2}	2.4×10^{-1}	None	None
2002	NR	1.8×10^{-2}	5.3×10^{-2}	3.7×10^{-1}	None	None
2003	**NR**	$\mathbf{9.3 \times 10^{-3}}$	$\mathbf{3.1 \times 10^{-2}}$	$\mathbf{4.8 \times 10^{-1}}$	**None**	**None**
2004	NR	1.0×10^{-3}	5.0×10^{-4}	1.7×10^{-1}	None	None
2005	NR	2.9×10^{-3}	2.0×10^{-3}	2.2×10^{-1}	None	None

(a) Years in which steam generators were replaced are presented in bold text.
(b) Steam generator was replaced for Unit 1 in 2002 and for Unit 2 in 2003. The site reported doses from both units together.
(c) NR = Not reported in the site's effluent release report.
(d) There were no liquid effluent releases beyond the site boundary.
Sources: Sites' annual effluent release reports

some liquid effluents associated with decontamination, may be slightly greater than those found during the steam generator changeouts or recirculation piping replacements.

Continued Operations—During normal operations after license renewal, small quantities of radioactivity (fission, corrosion, and activation products) will continue to be released to the environment in a manner similar to that occurring during present operations (see Section 3.9.1).

The concentration of radioactive materials in soils and sediments increases in the environment at a rate that depends on the rate of release and the rate of removal. Removal can take place through radioactive decay or through chemical, biological, or physical processes. For a given rate of release, the concentrations of longer-lived radionuclides and, consequently, the dose rates attributable to them would continue to increase if license renewal was granted.

Regulatory Guide 1.109 (NRC 1977) provides guidance for calculating the dose for significant release pathways. To account for the buildup of radioactive materials, buildup factors are included in the calculations. Initially, most of the calculations for the construction and operating stage permits used 15 years as the approximate midpoint of a facility's operating life. This value is now more often taken to be 20 years. The potential license renewal term is an additional 20 years; thus, the effective midlife is 30 years.

The accumulation of radioactive materials in the environment is of concern not only with regard to license renewal but also with regard to operation under current licenses. NRC reporting rules require that pathways that may arise as a result of unique conditions at a specific site be considered in licensees' evaluations of radiation exposures. If an exposure pathway is likely to contribute significantly to total dose (10 percent or more to the total dose from all pathways), it must be routinely monitored and evaluated. Environmental monitoring programs are in place at all sites to provide a backup to the calculated doses based on effluent release measurements. Since these programs are ongoing for the duration of the license, locations where unique situations give rise to significant pathways that are not detailed in NRC Regulatory Guide 1.109 are to be identified if and when they become significant. If such pathways result in doses at a plant exceeding the design objectives of Appendix I to 10 CFR Part 50, action is required.

The radiation dose to the public from current operations results from gaseous effluent releases and from liquid effluent releases, as presented in Section 3.9.1.3. At present, for all operating nuclear plants, doses to the maximally exposed individual (MEI) are much less than the design objectives of Appendix I to 10 CFR Part 50 (Table 3.9-2). No aspect of future operation has been identified that would substantially alter this situation.

Maximum individual doses are reported in annual effluent release reports, and if these doses exceed Appendix I to 10 CFR Part 50 design objectives, the NRC would pursue remedial action. Thus these issues are handled on a case-by-case basis. Many plants have gone through license renewal, and no aging phenomenon that would increase public radiation doses has been identified. The operating reactors are not expected to reach regulatory dose limits more often in the period after license renewal than they do at present. For these reasons, dose impacts on MEIs in the public during future operation under license renewal are judged to be unchanged from those during present operations. The MEI dose ranges from 0.02 to 15.3 mrem/yr (see Table 3.9-16). At these dose levels, the increase in fatal cancer risk (using ICRP risk coefficients) to the MEI ranges from 1×10^{-8} to 7.7×10^{-6} for 1 year of reactor operations. Although dose rates (mrem/yr) are not expected to change during license renewal, the cumulative dose (total mrem) would increase as a result of 20 more years of operations. If the reactor operates for 60 years, it is estimated that the increase in fatal cancer risk to the MEI would range from 6×10^{-7} to 4.6×10^{-4} (a 50 percent increase over the baseline of 40 years of operation). However, it is unlikely that the same person would be exposed to these doses for 60 years of plant operations.

One of the pathways considered in calculating the MEI doses is direct radiation from operating plants. Radiation fields are produced around nuclear plants as a result of radioactivity within the reactor and its associated components, low-level storage containers, and components such as steam generators that have been removed from the reactor (as described in Section 3.9). Direct radiation from sources within a light water reactor (LWR) plant is due primarily to nitrogen-16, a radionuclide produced in the reactor core by neutron activation of oxygen-16 from the water. Because the primary coolant of an LWR is contained in a heavily shielded area, dose rates in the vicinity of LWRs are generally undetectable and less than 1 mrem/yr at the site boundary. Some plants (mostly BWRs) do not have completely shielded secondary systems and may contribute some measurable offsite dose. However, these sources of direct radiation will be unaffected by license renewal.

In addition to the regulations within 10 CFR 20.1101 that speak directly to required operation under ALARA principles, 10 CFR 50.36a imposes conditions on licensees in the form of technical specifications on effluents from nuclear power reactors. These specifications are intended to keep releases of radioactive materials to unrestricted areas during operations to ALARA levels. Appendix I to 10 CFR Part 50 provides numerical guidance on dose-design objectives and limiting conditions for the operation of LWRs to meet the ALARA requirements. These regulations will remain in effect during the period of license renewal (see Section 3.9.1.1).

To date, more than 70 operating reactors at over 40 nuclear power plant sites have gone through license renewal since 1996. In all cases, the radiation dose to members of the public from routine operations was within NRC regulations. This information was used to support the conclusion that the radiation dose to the public will continue at current levels associated with normal operations and are expected to remain much lower than the applicable standards.

Offsite doses to the public attributable to refurbishment activities were examined for the MEI. Because the focus of the analysis is on annual dose, only the results based on the most likely major refurbishment action were examined (i.e., replacing steam generators in PWRs and primary recirculation piping in BWRs). For this action, doses to the public were found to be SMALL. To date, effluents and doses during periods of major refurbishments have not been seen to differ significantly from those during normal operations. Consequently, gaseous effluents and liquid discharges occurring during major refurbishment actions are not expected to result in maximum individual doses exceeding the design objectives of Appendix I to 10 CFR Part 50 or the allowable EPA standards of 40 CFR Part 190 (Table 3.9-2).

Radiation doses to members of the public from the current operations of nuclear power plants have been examined from a variety of perspectives, and the impacts were found to be well within design objectives and regulations in each instance. No effect of aging that would significantly affect the radioactive effluents has been identified. Public doses are expected to remain well within design objectives and regulations. The cumulative cancer risk to the MEI would increase by 50 percent because the plant would operate for 20 more years, but the risk would still be small when compared with the cancer risk from background radiation.

Because there is no reason to expect effluents to increase in the period after license renewal, doses from continued operation are expected to be well within regulatory limits. No mitigation measures beyond those implemented during the current term license would be warranted, because current mitigation practices have kept public radiation doses well below regulatory standards and are expected to continue to do so.

Public radiological exposure impacts during license renewal and refurbishment were considered to be SMALL for all plants and were designated as Category 1 issues in the 1996 GEIS. No new information has been identified in the plant-specific SEISs prepared to date, the literature, or effluent and monitoring reports prepared by operating plants that would alter that conclusion. On the basis of these considerations, the NRC concludes that the impact of continued operations and refurbishment activities on public radiological exposure would be SMALL for all nuclear plants and remains a Category 1 issue.

4.9.1.1.2 Chemical Hazards

In nuclear power plants, chemical effects could result from discharges of chlorine or other biocides, small-volume discharges of sanitary and other liquid wastes, chemical spills, or heavy metals leached from cooling system piping and condenser tubing. Impacts of chemical discharges to human health are considered to be SMALL if the discharges of chemicals to water bodies are within effluent limitations designed to ensure protection of water quality, and if ongoing discharges have not resulted in adverse effects on aquatic biota. During the license renewal term, human health impacts from chemicals are expected to be the same as those experienced during operations in the original license term (see Section 3.9.2 for more details).

One environmental issue related to chemical hazards is reviewed here: human health impact from chemicals. This issue was not evaluated in the 1996 GEIS.

Human Health Impact from Chemicals

The types of chemical hazards that exist at a nuclear power plant are discussed in Section 3.9.2. Plant workers may encounter hazardous chemicals when the chemistries of the primary and secondary coolant systems are being adjusted, biocides are being applied to address the fouling of cooling system components, equipment containing hazardous oils or other chemicals is being repaired or replaced, solvents are being used for cleaning, or other equipment is being repaired. Exposures to hazardous chemicals are minimized when plant workers follow good industrial hygiene practices.

Reviews of the literature and operational monitoring reports and consultations with utilities and regulatory agencies that were done for the 1996 GEIS indicated that the effects of the discharge of chlorine and other biocides on water quality would be of SMALL significance for all plants. Small quantities of biocides are readily dissipated and/or chemically altered in the body of water receiving them, so significant cumulative impacts to water quality would not be expected. Major changes in the operation of the cooling system are not expected during the license renewal term, so no change in the effects of biocide discharges on the quality of the receiving water is anticipated. Major proposed changes in cooling system operations (e.g., those affecting the plant's licensing basis and possibly triggering a license amendment) would require a separate NEPA review including an examination of human health effects. In addition, proposed changes in the use of cooling water treatment chemicals would require review by the plant's NPDES permit-issuing authority and possible modification of the existing NPDES permit, including examination of the human health effects of the change. Effects of biocide discharges could be reduced by increasing the degree to which discharge water is treated, reducing the concentration of biocides, or treating only a portion of the plant cooling and service water systems at one time. Discharges of sanitary wastes are regulated by NPDES permit, and discharges that do not violate the permit limits are considered to be of SMALL significance.

The effects of minor chemical discharges and spills at nuclear plants on water quality have been of SMALL significance and mitigated as needed. Significant cumulative impacts on water quality would not be expected because the small amounts of chemicals released by these minor discharges or spills are readily dissipated in the receiving water body. Spills and off-specification discharges occur so seldom that regulatory agencies have not expressed any concern about them with regard to operating nuclear power plants. While there may be additional management practices or discharge-control devices that could further reduce the frequency of accidental spills and off-specification discharges, they are not warranted because impacts are already SMALL and occur at a low frequency.

Heavy metals (e.g., copper, zinc, and chromium) may be leached from condenser tubing and other heat exchangers and discharged by power plants as small-volume waste streams or corrosion products. Although all are found in small quantities in natural waters (and many are essential micronutrients), concentrations in the power plant discharge are controlled in the NPDES permit because excessive concentrations of heavy metals can be toxic to aquatic organisms.

Nuclear power plants may be required in some instances to submit annual reports on the environmental releases of listed toxic chemicals manufactured, processed, or otherwise used that are above identified threshold quantities depending on State regulations or other specific circumstances. The disposal of essentially all of the hazardous chemicals used at nuclear power plants is regulated by Resource Conservation and Recovery Act (RCRA) or NPDES permits. The NRC requires nuclear power plants to operate in compliance with all of its permits, thereby minimizing adverse impacts to the environment and on workers and the public. It is anticipated that all plants will continue to operate in compliance with all applicable permits, and no mitigation measures beyond those implemented during the current term license would be warranted as a result of license renewal.

On the basis of these considerations, the health impact from chemicals to workers and the public is considered SMALL for all nuclear plants. This is a Category 1 issue.

4.9.1.1.3 Microbiological Hazards

Some microorganisms associated with nuclear power plant cooling towers and thermal discharges can have deleterious impacts on the health of plant workers and the public. Certain microorganisms can benefit from thermal effluents. The potential for adverse health effects from microorganisms on nuclear power plant workers is an issue for plants that use cooling towers. Potential adverse health effects on the public from microorganisms in thermal effluents is an issue for nuclear plants that use cooling ponds, lakes, or canals, and that discharge to rivers. During the license renewal term, plant workers and members of the public would be exposed to microbiological hazards in the same way that they are exposed during operations in the original license term (see Section 3.9.3 for details).

Two environmental issues related to microbiological hazards are reviewed here:
(1) microbiological hazards to plant workers (issue was renamed from the 1996 GEIS) and
(2) microbiological hazards to the public (plants with cooling ponds or canals or cooling towers that discharge to a river) (issue was renamed and modified from the 1996 GEIS to include all rivers).

Microbiological Hazards to Plant Workers

The types of microbiological hazards that exist for nuclear power plant workers are discussed in Section 3.9.3. Pathogens of concern include *Salmonella* spp., *Shigella* spp., *Pseudomonas aeruginosa,* thermophilic fungi, *Legionella* spp., and *N. fowleri*. These species are all associated with nuclear plants that use cooling towers as part of their cooling water system. Because of the presence of these microorganisms, workers at nuclear power plants are typically required to use respiratory protection when cleaning cooling towers and condensers. Prairie Island Nuclear Generating Plant, which had high concentrations of *N. fowleri* in the circulating water, successfully controlled the pathogen and protected workers through chlorination before its yearly downtime operation (NRC 1980). The NRC has concluded that microorganisms that live in high-radiation and extreme heat conditions typical of the spent fuel pool do not pose a risk to plant workers (NRC 1999a).

No change in existing microbiological hazards is expected over the license renewal term. It is considered unlikely that any plants that have not already experienced occupational microbiological hazards would do so during the license renewal term or that hazards would increase over that period. It is anticipated that all plants will continue to employ proven industrial hygiene principles so that adverse occupational health effects associated with microorganisms will be of SMALL significance at all sites, and no mitigation measures beyond those implemented during the current term license would be warranted. Aside from continued application of accepted industrial hygiene procedures, no additional mitigation measures are expected to be warranted as a result of license renewal. This remains a Category 1 issue.

Microbiological Hazards to the Public (Plants with Cooling Ponds or Canals or Cooling Towers That Discharge to a River)

N. fowleri, which is the pathogenic strain of the free-living amoebae *Naegleria* spp., appears to be the most likely microorganism that may pose a public health hazard resulting from nuclear power plant operations. Increased populations of *N. fowleri* may have significant adverse impacts. On entry into the nasal passage of a susceptible individual, *N. fowleri* will penetrate the nasal mucosa. The ensuing infection results in a rapidly fatal form of encephalitis. Fortunately, humans in general are resistant to infection with *N. fowleri*. Hallenbeck and Brenniman (1989) have estimated individual annual risks for primary amebic meningoencephalitis caused by the free-living *N. fowleri* to swimmers in freshwater to be approximately 4×10^{-6}. Exposure to *Legionella* spp. from power plant operations would not generally impact the public because concentrated aerosols of the bacteria would not traverse plant boundaries. The information available on microorganisms that may inhabit high-radiation, high-temperature environments (such as the spent fuel pool) indicates that they are very unlikely to significantly increase in number in the environment and that they would not have a deleterious effect on public health (NRC 1999a).

From the studies presented in Section 3.9.3, it is clear that heavily used bodies of freshwater merit special attention and also possibly routine monitoring for pathogenic *Naegleria*. Since *Naegleria* concentrations in freshwater can be enhanced by thermal effluents, nuclear power plants that use cooling lakes, canals, ponds, or rivers experiencing low-flow conditions may enhance the populations of naturally-occurring thermophilic organisms. There are currently 23 reactor sites that fit this category. Data for 14 sites from this category that have gone through license renewal were reviewed to predict the level of thermophilic microbiological organism enhancement at any given site with current knowledge. For all 14 sites, no actual hazards to public health from enhancement of thermophilic microbiological organisms were identified, documented, or substantiated. However, without site-specific data, the same conclusion cannot be drawn for all reactor sites that would go through license renewal.

Changes in microbial populations and in the public use of water bodies might occur after the operating license is issued and the application for license renewal is filed. Other factors could also change, including the average temperature of the water, which could result from climate change that affected water levels and air temperature. Finally, the long-term presence of a power plant might change the natural dynamics of harmful microorganisms within a body of water. Therefore, the magnitude of the potential public health impacts associated with thermal enhancement of thermophilic organisms could be SMALL, MODERATE, or LARGE, depending on plant-specific conditions. This is considered a Category 2 issue.

4.9.1.1.4 Electromagnetic Fields

Nuclear power plants use power-transmission systems that consist of switching stations or substations located on the plant site and transmission lines located primarily offsite that connect the power plant to the regional electric grid. Electric fields and magnetic fields, collectively referred to as EMF, are produced by operating transmission lines. During the license renewal term, plant workers and members of the public who live, work, or pass near an associated operating transmission line may be exposed to the EMF in the same way that they are exposed during the current license term (see Section 3.9.4 for more detail). One environmental issue related to EMFs is reviewed in this section: chronic effects of electromagnetic fields (EMFs) (issue was renamed from the 1996 GEIS). The issue is further evaluated below by reviewing the relevant literature.

It should be noted that the scope of the evaluation of transmission lines in this revised GEIS is reduced from that of the 1996 GEIS. For this revision, only those transmission lines currently needed to connect the nuclear power plants to the regional electric distribution grid are considered within scope (see Sections 3.1.1 and 3.1.6.5 in this GEIS). Thus, the number and length of the transmission lines within the scope of license renewal environmental review are greatly reduced.

<u>Ongoing Research on the Effect of Electromagnetic Fields</u>

In 1990, the EPA's Office of Health and Environmental Assessment reviewed epidemiology studies, chronic lifetime animal tests, and laboratory studies of biological phenomena related to carcinogenesis. The review indicated that some epidemiological studies found an association between EMF and certain types of cancers, but others did not find any association. It was concluded that the scientific issues concerning the relationship between EMF and adverse health effects are very complex and difficult to interpret (EPA 1990). Without an understanding of how these EMF fields are interacting with biological functions, the knowledge gained from scientific studies was of limited value both in evaluating the importance of the study results and in devising protection strategies for the public and for utility workers.

A substantial body of evidence has been accumulated indicating that EMFs may influence biological function at exposure levels capable of producing relatively high current densities (10 to 100 mA/m^2) (IRPA/INIRC 1990). Such exposures have been suggested to induce chromosome aberrations, alter the distribution in molecular weights during protein synthesis, inhibit production of melatonin, alter calcium binding in brain tissue, influence ribonucleic acid (RNA) transcription, and produce a variety of other effects (OTA 1989). Questions concerning the potential carcinogenic effects of EMF field exposure have been raised as a result of suggestive epidemiological findings and some laboratory experiments. One accepted model on the development of cancer is the initiation-promotion paradigm (Easterly 1981). Most investigators conclude that EMFs are not likely to act as initiators because they have not been shown to cause genetic damage (Aldrich and Easterly 1987). EMF effects on RNA transcription, however, could imply increased reduction of oncogene products, and some investigators consider such data to be indicative of genetic effects (Goodman et al. 1987; Goodman and Henderson 1986, 1988). It has not been shown that EMF fields are cancer promoters, but the presence of some reported EMF biological effects reveals the need for further study of this issue (Byus et al. 1987).

Section 2118 of the Energy Policy Act of 1992 (Public Law 102-486, codified at 42 U.S.C. 13478) authorized the Electric and Magnetic Fields Research and Public Information Dissemination Program. The National Institute of Environmental Health Sciences (NIEHS), National Institutes of Health (NIH), and DOE were designated to direct and manage a program of research and analysis aimed at providing scientific evidence to clarify the potential for health risks from exposure to EMF (NIEHS 1999).

Over the course of this program, DOE and NIEHS managed more than 100 cellular and animal studies, exposure assessment studies, and engineering studies. No additional epidemiology studies were conducted; however, analyses of the studies that had already been conducted were an important part of the assessments (NIEHS 2002). In 1998, NIEHS completed the review of a comprehensive body of scientific research on the potential health effects of EMF.

NIEHS organized several technical symposia and a working group meeting to review EMF research. The working group was made up of scientists representing a wide range of disciplines (including engineering, epidemiology, cellular biology, medicine, toxicology, statistics, and pathology) brought together to review and evaluate the RAPID research and other research.

In June 1999, the NIEHS submitted the report, *NIEHS Report on Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields* (i.e., extremely low frequency electromagnetic fields [ELF-EMFs]) to Congress. In part, the report (NIEHS 1999) concluded the following:

> The scientific evidence suggesting that ELF-EMF exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults…. In contrast, the mechanistic studies and the animal toxicology literature fail to demonstrate any consistent pattern across studies and the animal toxicology literature fail to demonstrate any consistent pattern across studies although some sporadic findings of biological effects have been reported. No indication of increased leukemia in animals has been observed…. Virtually all of the laboratory evidence in animals and humans and most of the mechanistic work done in cells fail to support a causal relationship between ELF-EMF at environmental levels and changes in biological function or disease status. The lack of consistent, positive findings in animal or mechanistic studies weakens the belief that this association is actually due to ELF-EMF, but it cannot completely discount the epidemiological findings.

The NIEHS concluded that ELF-EMF exposure cannot be recognized as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In the NIEHS opinion, this finding is insufficient to warrant aggressive regulatory concern. However, because virtually everyone in the United States uses electricity and is therefore routinely exposed to ELF-EMF, passive regulatory action is warranted, such as a continued emphasis on educating both the public and the regulatory community on ways in which to reduce exposure. NIEHS suggested that the power industry continue its current practice of siting power lines to reduce exposure and continue to explore ways to reduce the creation of magnetic fields around transmission and distribution lines without creating new hazards. NIEHS also encourages the use of technologies that lower exposures from neighborhood distribution lines, provided they do not increase other risks, such as those from accidental electrocution or fire. NIEHS does not believe that other cancers or noncancer outcomes provide sufficient evidence of a risk to warrant concern (NIEHS 1999).

In the United Kingdom, the National Radiological Protection Board (NRPB) established an independent Expert Advisory Group on Non-Ionizing Radiation (AGNIR) that reviewed scientific evidence relating possible adverse health effects to low-frequency EMFs (NRPB 2001, 2004). The earlier review (NRPB 2001) provided no firm evidence of a carcinogenic hazard to children or adults from exposure to normal levels of low-frequency EMFs, but made a number of recommendations for epidemiological studies and experimental work. The NRPB review in 2004 (NRPB 2004) concluded that currently, the results of these studies on EMF and health do not warrant quantitative restrictions on exposure to EMF. However, such studies, together with people's concerns, provide a basis for precautionary measures (NRPB 2004).

The World Health Organization (WHO) published an environmental health criteria monograph (WHO 2007) that addresses the possible health effects of ELF-EMF exposure. It reviewed the scientific literature on biological effects to assess the health risk from ELF-EMF exposure. It concluded the following about childhood leukemia:

> Scientific evidence suggesting that everyday, chronic low-intensity (above 0.3 to 0.4 μT) low-frequency magnetic field exposure poses a health risk is based on epidemiological studies demonstrating a consistent pattern of increased risk for childhood leukemia. Uncertainties in the hazard assessment include the role that control selection bias and exposure misclassification might have on the observed relationship between magnetic fields and childhood leukemia. In addition, virtually all of the laboratory evidence and the mechanistic evidence fail to support a relationship between low-level ELF magnetic fields and changes in biological function or disease status. Thus, on balance, the evidence is not strong enough to be considered causal, but sufficiently strong to remain a concern.

The potential for transmission line EMF to cause adverse health impacts in humans has been reviewed by many scientific groups. The hazard is assessed by a standard scientific approach that considers data from epidemiologic, laboratory, and biophysical studies. A number of epidemiologic studies have reported a small degree of association between measures of EMF and several diseases such as childhood leukemia. Other studies have failed to find an association. A causal basis for the EMF associations is not supported by laboratory and biophysical evidence, and the actual basis remains unexplained. Nonetheless, in 2002, the International Agency for Research on Cancer (IARC 2002) designated EMF as a class 2B carcinogen ("possibly carcinogenic"), on the basis of "consistent statistical associations of high-level residential magnetic fields with a doubling of the risk of childhood leukemia." The WHO (2007) monograph did not change the EMF classification on the basis of new human, animal, and in vitro studies published since the IARC (2002). In 2002, the California Department of Health Services issued a report (CADHS 2002) concluding that "EMFs can cause some degree of increased risk of childhood leukemia, adult brain cancer, Lou Gehrig's disease, and miscarriage." Kheifets et al. (2005) assessed the potential susceptibility of children to EMFs and recommended additional research and the development of precautionary policies.

The WHO (2007) monograph also reviewed literature that looked at a number of other diseases such as cancers in children and adults, depression, suicide, reproductive dysfunction, developmental disorders, immunological modifications, and neurological disease. On the basis of this review, it concluded the following:

> The scientific evidence supporting a linkage between ELF magnetic fields and any of these diseases is much weaker than for childhood leukemia and in some cases (for example, for cardiovascular disease or breast cancer) the evidence is sufficient to give confidence that magnetic fields do not cause the disease.

Extensive investigations of animals exposed at much higher levels of magnetic fields (up to 5 mT) have not demonstrated adverse health effects (Boorman et al. 2000). The elevated levels of EMF exposure in occupational settings likewise do not show a consistent pattern of increased risk for acute myocardial infarction or chronic coronary heart disease (Sahl et al. 2002). Laboratory studies of cells and tissues do not support the hypothesis that EMF exposure at ambient levels is a significant risk factor for human disease (NIEHS 1999). The failure to observe biological effects from EMF exposure may be due to the fact that, mechanistically, effects of EMF on biology are very weak (Valberg et al. 1997) or the association between the epidemiological results on childhood leukemia and EMF be the result of chance or a confounding factor (Draper et al. 2005).

Chronic Effects of Electromagnetic Fields (EMFs)

An important question regarding regulations is whether transmission line exposures contribute significantly to total EMF exposures. In most cases, fields produced inside the home by appliances and electrical wiring are greater than the contributions from transmission line fields. Exceptions to this rule are individuals living next to a high-voltage transmission line ROW. Also relevant is the fact that exposures to transmission line fields are considered more continuous than those to appliance fields because transmission line fields permeate large areas (e.g., an entire home). Fields generated by appliances are generally more localized, resulting in intermittent exposures as individuals move around and as the appliances are turned on and off.

The earth's atmosphere produces slowly varying electric fields that average less than a few hundred V/m, and the earth's core produces a steady magnetic field in a range from about 0.3 to 0.6 G. Near appliances, the magnetic fields can be high, but they diminish sharply with distance. Table 4.9-4 shows the magnetic fields at different distances from household appliances (HCCP 2007). Typical house wiring and appliances contribute a 60-Hz magnetic field that can be up to about 3 mG (not in the vicinity of appliances). Some comparisons

Table 4.9-4. Magnetic Fields at Different Distances from Household Appliances

Household Appliance	Magnetic Fields (mG) at Different Distances		
	3 cm	30 cm	100 cm
Microwave oven	750–2,000	40–80	3–8
Fluorescent lamp	400–4,000	5–20	0.1–3
Electric cooking stove	60–2,000	4–40	0.1–1
Television	25–500	0.4–20	0.1–2
Clothes washer	8–400	2–30	0.1–2

Source: HCCP 2007

(of induced currents) among transmission line exposures, domestic exposures, and exposures used in biological effects experiments can be made by using induced current density as an exposure metric. According to data provided in OTA (1989), field strengths on the ROW of a 500-kV line induce body currents that are higher than those induced by domestic exposures produced by typical electrical appliances. A comparison with the results of biological effects experiments (OTA 1989) shows that while current densities in many biological effects experiments are higher than those typically induced by household exposures, some current densities are significantly lower. These comparisons are based, however, on average current densities predicted in humans, because EMF dosimetry has not advanced to the point of determining specific current densities in various tissues and organs. Moreover, researchers have not identified what field characteristics are important biologically.

Conclusion on Electromagnetic Fields

A review of the biological and physical studies of 60-Hz EMFs did not find any consistent evidence that would link harmful effects with field exposures. EMFs are unlike other agents that have a toxic effect (e.g., toxic chemicals and ionizing radiation) in that dramatic acute effects cannot be forced, and longer-term effects, if real, are subtle. Nonetheless, a wide range of biological responses have been reported to be affected by EMFs.

Even if clear adverse effects were apparent in the epidemiology literature or with some biological assay, considerable additional work would be required to determine how and what to mitigate, because evidence suggests that some EMF biological effects do not follow the typical “more intensity is worse” relationship. Furthermore, there may be a subtle relationship between the intensity of the local geomagnetic field and the appearance of effects for some intensities of 60-Hz fields. This complicating evidence points to the fact that, while much experimental and epidemiological evidence has been accrued, the pieces still do not fit together very well.

Because of inconclusive scientific evidence, the chronic health effects of EMF are considered uncertain, and currently, no generic impact level can be assigned. The NRC will continue to monitor the research initiatives—both those within the national EMF program and others internationally—to evaluate the potential carcinogenicity of EMFs as well as other progress in the EMF study disciplines. If the NRC finds that the appropriate Federal health agencies have reached a consensus on the potential human health effects from exposure to EMF, the NRC will revise the GEIS to include the new information and determine what to require of all future license renewal applicants.

4.9.1.1.5 Other Hazards

Two additional human health issues are addressed in this section: (1) physical occupational hazards (new issue not considered in the 1996 GEIS) and (2) electric shock hazards (issue was renamed from the 1996 GEIS).

Nuclear power plants are industrial facilities that have many of the typical occupational hazards found at any other electric power generation utility. Workers at or around nuclear power plants would be involved in some electrical work, electric power line maintenance, repair work, and maintenance activities and exposed to some potentially hazardous physical conditions (e.g., excessive heat, cold, and pressure). The issue of physical occupational hazards is generic to all nuclear power plants.

Transmission lines are needed to transfer energy from the nuclear power plant to consumers. The workers and general public at or around the nuclear power plants and along the transmission lines are exposed to the potential for acute electrical shock from these lines. The issue of electrical shock is generic to all nuclear power plants. As described in Sections 3.1.1 and 3.1.6.5, in-scope transmission lines include only those lines that would not continue to operate if a plant's license was not renewed. Using this criterion, in-scope transmission lines are those lines that connect the plant to the first substation of the regional electric grid. This substation is frequently, but not always, located on the plant property.

During the license renewal term, human health impacts from physical occupational hazards and acute shock hazards would be the same as those from operations during the original license term (see Section 3.9.5 for more detail).

<u>Physical Occupational Hazards</u>

The types of occupational hazards that exist at a nuclear power plant are discussed in Section 3.9.5. The issue of occupational hazards is evaluated by comparing the rate of fatal injuries and nonfatal occupational injuries and illnesses in the utility sector with the rate in all industries combined. Occupational hazards can be minimized when workers adhere to safety standards and use appropriate personal protective equipment; however, fatalities and injuries from accidents can still occur. Data for occupational injuries from the U.S. Bureau of Labor Statistics (BLS) for 2005 (BLS 2005a,b,c) indicate that the rate of fatal injuries in the utility sector is less than the rate for many sectors (construction; transportation and warehousing; agriculture, forestry, fishing, and hunting; wholesale trade; and mining) and that the incidence rate for nonfatal occupational injuries and illnesses is the least for electric power generation, followed by electric power transmission control and distribution (see Section 3.9.5). The fatality rate for electric power line installers and repairers can be estimated at 0.032 percent (BLS 2005a). It is expected that over the license renewal term, workers would continue to adhere to safety standards and use protective equipment, so adverse occupational impacts would be of SMALL significance at all sites, and no mitigation measures beyond those implemented during the current license term would be warranted. The impact of these hazards is a Category 1 issue.

Electric Shock Hazards

The greatest hazard from a transmission line is direct contact with the conductors. Tower designs preclude direct public access to the conductors. However, electrical contact can be made without physical contact between a grounded object and the conductor. Secondary shock currents are produced when humans make contact with (1) capacitively charged bodies, such as a vehicle parked near a transmission line, or (2) magnetically linked metallic structures, such as fences near transmission lines. A person who contacts such an object could receive a shock and experience a painful sensation at the point of contact. The intensity of the shock would depend on the EMF strength, size of the object, and how well the object and person were insulated from ground.

Design criteria for nuclear power plants that limit hazards from steady-state currents are based on the National Electrical Safety Code (NESC), adherence to which requires that utility companies design transmission lines so that the short-circuit current to ground produced from the largest anticipated vehicle or object is limited to less than 5 mA (IEEE 2007). With respect to shock safety issues and license renewal, three points must be made. First, in the licensing process for the earlier licensed nuclear plants, the issue of electrical shock safety was not addressed. Second, some plants that received operating licenses with a stated transmission line voltage may have chosen to upgrade the line voltage for reasons of efficiency, possibly without reanalysis of induction effects. Third, since the initial NEPA review for those utilities that evaluated potential shock situations under the provision of the NESC, land use may have changed, resulting in the need for a reevaluation of this issue. The electrical shock issue, which is generic to all types of electrical generating stations, including nuclear plants, is of SMALL significance for transmission lines that are operated in adherence with the NESC. Without a review of the conformance of each nuclear plant's transmission lines, within this scope of review, with NESC criteria, it is not possible to determine the significance of the electrical shock potential generically; it could be SMALL, MODERATE, or LARGE. The impact of this hazard remains a Category 2 issue.

4.9.1.2 Environmental Consequences of Postulated Accidents

Design-Basis Accidents and Severe Accidents

Chapter 5 of the 1996 GEIS assessed the impacts of postulated accidents at nuclear power plants (NPPs) on the environment. The postulated accidents included design-basis accidents and severe accidents (e.g., those with core damage). The impacts considered included:

- Dose and health effects of accidents (5.3.3.2 through 5.3.3.4);
- Economic impacts of accidents (5.3.3.5); and
- Impact of uncertainties on results (5.3.4).

The estimated impacts were based upon the analysis of severe accidents at 28 NPPs,[c] as reported in the environmental impact statements (EISs) and/or final environmental statements (FESs) prepared for each of the 28 plants in support of their operating licenses. With few exceptions, the severe accident analyses were limited to consideration of reactor accidents caused by internal events. The 1996 GEIS addressed the impacts from external events qualitatively. The severe accident analysis for the 28 plants was extended to the remainder of plants whose EISs did not consider severe accidents (since such analysis was not required at the time the other plants' EISs were prepared). The estimates of environmental impact contained in the 1996 GEIS used 95th percentile upper confidence bound (UCB) estimates whenever available. This provides conservatism to cover uncertainties, as described in Section 5.3.3.2.2 of the 1996 GEIS. The 1996 GEIS concluded that the probability-weighted consequences and impacts were SMALL compared to other risks to which the populations surrounding NPPs are routinely exposed.

Appendix E of this document provides an update on postulated accident risk. Since the NRC's understanding of accident risk has evolved since the issuance of the 1996 GEIS, Appendix E assesses more recent information on postulated accidents that might have had the potential to alter the conclusions in Chapter 5 of the 1996 GEIS. This update considers how these

(c) The 28 sites are listed in Table 5.1 of the 1996 GEIS. There are a total of 44 units included in this list, but 4 of these units never operated (Grand Gulf 2, Harris 2, Perry 2, and Seabrook 2). For the purpose of this document, this list will be referred to as containing 28 NPPs, but when mean values are calculated for this subset of NPPs, the 40 units that operated are considered.

developments would affect the conclusions in the original GEIS and provides comparative data where appropriate.

The different sources of new information can be generally categorized by their effect of either decreasing, not affecting, or increasing the best-estimate environmental impacts associated with postulated severe accidents. Those areas where a decrease in best-estimate impacts would be expected are:

- New internal events information (decreases by an order of magnitude), and
- New source term information (significant decreases).

Areas likely leading to either a small change or no change include:

- Use of BEIR-VII risk coefficients.

Lastly, those areas leading to an increase in best-estimate impacts would consist of:

- Consideration of external events (comparable to internal event impacts),
- Power uprates (small to moderate increase),
- Higher fuel burnup (small to moderate increases),
- Low power and reactor shutdown events (could be comparable to full-power event impacts), and
- Spent fuel pool accidents (could be comparable to full-power event impacts).

Given the difficulty in conducting a rigorous aggregation of these results with the differences in the information sources utilized, a fairly simple approach is taken. The latter group contains three areas where the increase could be comparable to the current risk and two areas where the increase could approach 30–40 percent. The net increase from these five areas would therefore be (in a simplistic sense) approximately 470 percent[d] (increase by a factor of 4.7). The reduction in risk due to newer internal event information would account for a decrease by a factor of 5 to 100. The net effect of an increase on the order of 500 percent and a decrease on the order of 500 percent to 10,000 percent would be lower estimated impacts (as compared to the 1996 GEIS assessment).

(d) This approximation simply assumes that each comparable area results in an increase of 100 percent and the other two areas (uprates and burnup) each result in an increase of 35 percent.

Furthermore, even if one assumed that the net effect of the new information was no change in risk, the information provided throughout Appendix E demonstrates that the level of conservatism in the upper bound estimates utilized in the 1996 GEIS is much larger than the individual (or cumulative) deltas from the updated information. In particular, Section E.3.1 of Appendix E demonstrates that the 1996 GEIS values were a factor of 2 to 4 higher than the underlying EIS values.

With respect to uncertainties, the 1996 GEIS contained an assessment of uncertainties in the information used to estimate the environmental impacts. Section 5.3.5 of the 1996 GEIS discusses the uncertainties and concludes that they could cause the impacts to vary anywhere from a factor of 10 to a factor of 1,000. This range of uncertainties bounds the uncertainties discussed in Section E.3.9 of Appendix E of this document, which ranged from a factor of 3 to 10, as well as the uncertainties brought in by the other sources of new information.

Given the discussion in Appendix E of this document, the staff concludes that the reduction in environmental impacts from the use of new information (since the 1996 GEIS analysis) outweighs any increases resulting from this same information. As a result, the findings in the 1996 GEIS remain valid. Therefore, design-basis accidents remain a Category 1 issue, and although the probability-weighted consequences of severe accidents are SMALL for all plants, severe accidents remain a Category 2 issue to the extent that only alternatives to mitigate severe accidents must be considered for all plants that have not previously considered such alternatives.

In addition, it is reasonable based on the discussion in Appendix E that, in license renewal applications, the impacts from reactor accidents at full power (including internal and external events) should continue to be considered in assessing severe accident mitigation alternatives (SAMAs). The impacts of all other new information do not contribute sufficiently to the environmental impacts to warrant their inclusion in the SAMA analysis since the likelihood of finding cost-effective plant improvements is small. Alternatives to mitigate severe accidents still must be considered for all plants that have not considered such alternatives; however, as discussed further in Appendix E, those plants that have already had a SAMA analysis considered by the NRC as part of an EIS, supplement to an EIS, or EA, need not perform an additional SAMA analysis for license renewal. Table 4.9-5 provides a summary of the conclusions discussed above.

Table 4.9-5. Summary of Issues Covered in Appendix E

Topic (Section)	Conclusions
New Internal Events Information (Section E.3.1)	New information on the risk and environmental impacts of severe accidents caused by internal events indicates that PWR and BWR core damage frequencies (CDFs) are generally comparable to or less than those forming the basis of the 1996 GEIS. In some cases, these differences are significant (approaching 1 order of magnitude). Comparison of population dose from newer assessments illustrates a reduction in impact by a factor of 5 to 100 when compared to older assessments, and an additional factor of 2 to 4 due to the conservatism built into the 1996 GEIS values. This would also mean that contamination of open bodies of water and economic impacts would, in most cases, be significantly less. Additionally, the likelihood of basemat melt-through accidents is less than that used in the analysis supporting the 1996 GEIS.
Consideration of External Events (Section E.3.2)	The 1996 GEIS did not quantitatively consider severe accidents initiated by external events in assessing environmental impacts. When the environmental impacts of external events are considered, they can be comparable to those from internal events; however, they are generally lower than the estimates used in the 1996 GEIS for internal events. This conclusion would also apply to the contamination of open bodies of water, groundwater and economic impacts.
New Source Term Information (Section E.3.3)	More recent source term information indicates that the timing from dominant severe accident sequences, as quantified in NUREG/CR-6295, is comparable to the analysis forming the basis of the 1996 GEIS. In most cases, the release frequencies and release fractions are significantly lower for the more recent estimate. Thus, the environmental impacts used as the basis for the 1996 GEIS are higher than the impacts that would be estimated using the more recent source term information.
Power Uprates (Section E.3.4)	Based on a comparison of the change in large early release frequency (LERF) for extended power uprates, a small to moderate increase in environmental impacts results from the increase in operating power level.
Higher Fuel Burnup (Section E.3.5)	Increased peak fuel burn-up from 42 to 75 GWd/MT for PWRs and 60 to 75 GWd/MT for BWRs is estimated to result in small to moderate increases in the environmental impacts in the event of a severe accident.
Consideration of Low Power and Reactor Shutdown Events (Section E.3.6)	The environmental impacts from accidents at low power and reactor shutdown conditions are generally comparable to those from accidents at full power when comparing the values in NUREG/CR-6143 and NUREG/CR-6144 to those in NUREG-1150. Even so, the 1996 GEIS estimates of the environmental impact of severe accidents bound the potential impacts from accidents at low power and reactor shutdown. Finally, as cited above and discussed in SECY-97-168, industry initiatives taken during the early 1990s have also contributed to the improved safety of low power and reactor shutdown operation.
Consideration of Spent Fuel Pool Accidents (Section E.3.7)	The environmental impacts from accidents at spent fuel pools (SFPs) (as quantified in NUREG-1738) can be comparable to those from reactor accidents at full power (as estimated in NUREG-1150). Subsequent analyses performed and mitigative measures employed since 2001 have further lowered the risk of this class of accidents. In addition, the conservative estimates from NUREG-1738 are much less than the impacts from full-power reactor accidents that are estimated in the 1996 GEIS.

Table 4.9-5. (cont.)

Topic (Section)	Conclusions
Use of BEIR-VII Risk Coefficient (Section E.3.8)	Use of newer risk coefficients such as in BEIR VII is expected to have a small impact on the results presented in the 1996 GEIS.
Uncertainties (Section E.3.9)	The impact and magnitude of uncertainties, as estimated in the 1996 GEIS, bound the uncertainties introduced by the new information and considerations.
SAMAs (Section E.4)	The current process and scope of SAMA analysis is sufficient for determining the need for additional mitigative measures.
Summary/Conclusion (Section E.5)	Given the new and updated information, the reduction in estimated environmental impacts from the use of new internal event and source term information outweighs any increases from the consideration of external events, power uprates, higher fuel burnup, low power and reactor shutdown risk, and SFP risk.

4.9.2 Environmental Consequences of Alternatives to the Proposed Action

Construction—Impacts on workers are expected to be similar to those experienced during construction of any major industrial facility. Impacts from construction of combustion-based renewable energy facilities are expected to be the same as those for construction of fossil fuel facilities. Construction would increase traffic on local roads, which could affect the health of the general public. Human health impacts would be the same for all facilities whether located on greenfield sites, brownfield sites, or at an existing nuclear plant. Personal protective equipment, training, and engineered barriers would protect the workforce.

Summaries of statistics maintained by the U.S. Department of Labor, Bureau of Labor Statistics (Meyer and Pegula 2006) indicate that construction activities are responsible for a significant share of workplace accidents. In 2004, the construction industry accounted for 1 in 5 fatal workplace injuries and 1 in 10 nonfatal workplace injuries. With a workforce of 10,272,000 workers in 2004, the private construction industry registered 1,234 total fatalities in the following categories: falls, 445 (36 percent); transportation incidents, 287 (23 percent) (highway 148, non-highway 45, worker struck by vehicle/mobile equipment, 78); contact with objects and equipment, 267 (18 percent) (struck by object, 150; caught in or crushed in collapsing materials 71); exposure to harmful substances and environments, 170 (14 percent); and contact with electric current, 122 (10 percent). Over that same period, of a total of 401,000 nonfatal injuries and illnesses in the construction industry (nonfatal injuries that resulted in at least one day away from work) totaled 153,200 in the following categories: overexertion, 30,460 (20 percent); struck by object, 27,950 (18 percent); fall to lower level, 20,950 (14 percent); fall to same level, 12,700 (8 percent); and struck against object, 12,720 (8 percent).

4.9.2.1 Fossil Energy Alternatives

Environmental Consequences of Normal Operating Conditions

Operations—In 2006, the U.S. Department of Labor's (DOL's) Bureau of Labor Statistics revealed 134,400 individuals employed in the fossil fuel electric power generation industrial sector (North American Industry Classification System (NAICS) Code 221112) (DOL 2007a). For 2006 (DOL 2007b), DOL documented 17 total fatalities for all of the electric power generating industrial sector (NAICS Code 22111) and 5 fatalities for fossil fuel electric power generation. In 2006, the nonfatal injury and illness incident rate was 3.9 cases per 100 fulltime workers, slightly higher than the incident rate of 3.1 cases per 100 full-time workers for the entire electric power generation sector. Total reportable incidents occurred at a rate of 2.2 per 100 full-time workers. Those incidents that resulted from lost time at work occurred at a rate of 1.2 cases per 100 full-time workers.

Human health risks are associated with the management and disposal of coal combustion waste. Human health risks may extend beyond the facility workforce to the public and are proximate to the coal combustion waste disposal facility. The character and the constituents of coal combustion waste depend on both the chemical composition of the source coal and the technology used to combust it. Generally, the primary sources of adverse consequences from coal combustion waste are the presence of leachable, toxic (and, in some cases, carcinogenic) heavy metals primarily contained in fly ash and bottom ash, especially arsenic, selenium, and mercury. With future implementation of regulations limiting mercury emissions, the amount of mercury present in coal combustion waste is expected to rise, and, depending on the particular chemical speciation, the amount of leachable mercury in coal combustion waste may also increase. Depending on the coal source, radionuclides may also be present in coal combustion waste.

The EPA is considering regulations specific to disposal of coal combustion waste under the authority of Subtitle D of RCRA (EPA 2007). Preliminary (draft) risk assessments of historical disposal practices for coal combustion waste in landfills and surface water impoundments identified both direct and indirect (food chain contamination) pathways for human exposure. Overall, when all types of landfills and surface impoundments are evaluated in aggregate, the cancer risk criterion for arsenic (1×10^{-6}) can be exceeded for both unlined units (5×10^{-4}) and clay-lined units (2×10^{-4}). Arsenic cancer risks are higher for unlined surface impoundments (9×10^{-3}) and for clay-lined units (3×10^{-3}). Composite (synthetic) liners, which have been used in the majority of the most recently constructed landfills and surface impoundments, greatly reduce infiltration of leachable constituents, so much so that risks at all percentiles fall below both the cancer and noncancer risk criteria for both landfills and surface impoundments.

Although future alternative power generating facilities are most likely to use offsite disposal of coal combustion waste, some short-term storage of coal combustion waste (either in open piles or in surface impoundments) is likely to take place onsite, thus establishing the potential for leaching of toxic constituents into the local environment. Mobility studies indicate that toxic constituents take hundreds to thousands of years to leach through the bottoms of landfills and less than 100 years to leach through the bottom surface impoundments. However, because each batch of coal combustion waste would likely remain in interim onsite storage for only a short period, the potential for release of toxic constituents into the environment is greatly reduced. Offsite disposal facilities would be designed and operated in a manner that minimizes impacts from leached constituents.

Environmental Consequences of Accidents

Operations—Accidents involving fossil fuel energy sources that affect the functionality of the boiler or the steam cycle would have the most significant impacts. Steam explosions and other mechanical failures have the potential for adverse consequences on the workforce, but are not likely to directly affect the surrounding public or natural resources. Failures of pollution control devices would have an immediate but short-term impact on the environment because of the resulting release of pollutants. However, operating permits would require immediate shutdown of combustion sources whose pollution control devices became inoperative and prohibit continued operation that bypasses the failed control device. However, pollution control device failures, as well as other accidents that are sufficiently severe so as to require the shutdown of operations, would result in indirect impacts on the public in the form of reduced available power and possible short-term brownouts or blackouts. Although power might be restored relatively quickly, longer-term impacts may include a temporary rise in the levelized cost of electricity.

Overall, impacts on the environment from accidents at a fossil-fuel fired plant are expected to be short-lived and small. Longer-term impacts on socioeconomics could be anticipated both as a result of job loss and (temporary) higher costs of energy, but overall would be expected to be SMALL.

4.9.2.2 New Nuclear Alternatives

Environmental Consequences of Normal Operating Conditions

Operations—Operational human health impacts for a new nuclear plant would include radiation exposure to the public (at very low levels) and to the operational workforce; impacts from exposure to microbiological organisms; occupational safety risks; impacts from electromagnetic fields; and exposure to chemicals used onsite by the workers. Impacts on human health, in most cases, were determined to be SMALL in 10 CFR Part 51, Appendix B, Table B-1, and although the table is specific to license renewal, similar human health impacts would be expected from the operation of a new nuclear facility. Human health impacts would be the same for all facilities, whether located on greenfield sites, brownfield sites, or sites located at a previously existing nuclear plant, and are expected to be SMALL.

Environmental Consequences of Accidents

A detailed analysis of postulated accidents in currently operating reactors (affected by license renewal) is provided in Section 4.9.1.2. Although the analysis is specific to license renewal, the impacts are representative of the impacts expected for new reactors. New reactor designs incorporate additional safety features not found in currently operating reactors. As a result, it is expected that the risks associated with the new reactors would be comparable to or less than the risks associated with currently operating reactors. Before a license is granted, the application for a new reactor would undergo a detailed safety and environmental review to ensure that the plant, if constructed, would operate in accordance with all applicable NRC rules and regulations.

4.9.2.3 Renewable Alternatives

Operations—The operational impacts of alternative energy technologies on human health are presented in the following subsections.

Hydroelectric Energy Sources

Impacts on workers include working near energized systems and high pressure water.

Geothermal

Operating workers could be affected by exposure to toxic gases and other constituents present in geothermal fluids, energized systems, including high pressure and high temperature gases and fluids, and electromagnetic fields associated with the generation, conditioning, and transmission of electricity. Workers could be affected by exposure to toxic constituents, including boron, arsenic, radon, and mercury.

Wind

Operational hazards for the workforce include working at heights, near rotating mechanical or energized equipment, and working in extreme weather. Additional hazards unique to offshore wind farms include navigating and working in heavy seas. Potential impacts to workers and the public include ice thrown from rotor blades and blades thrown from mechanical failure and disintegration. Potential impacts also include EMF exposure, aviation safety, electromagnetic interference, and exposure to low-frequency sound.

Biomass

Human health risks to workers are expected to be similar to workers in a coal combustion facility. Work hazards include exposure to heat, gases, chemicals, high temperature liquids, and energized mechanical and electrical equipment. The potential exists for exposure to inhalable particulates and polycyclic aromatic hydrocarbons (PAHs) resulting from incomplete combustion of complex organic molecules. The public could be affected by fugitive dust and contaminated water.

Municipal Solid Waste, Refuse-Derived Fuel, and Landfill Gas

Combustion of municipal solid waste and/or refuse-derived fuel may result in the release of constituents that are persistent, bioaccumulative, and toxic, PAHs, and chlorinated hydrocarbons. The workforce as well as nearby residents could be affected by the release of toxic constituents to the air. The workforce could also be affected by exposure to toxic wastes.

Solar Thermal

Potential hazards to workforce include exposure to extremely hot heat transfer fluids or burned from misaligned mirrors and contact with energized system components.

Solar Photovoltaic

Workers could be exposed to airborne toxic heavy metals (e.g., cadmium) and silicon if the photovoltaic cell loses integrity from a fire. Workers could also inhale silicon dust if the integrity of photovoltaic cells was compromised by an accident.

Ocean Wave and Current

Operation of wave- and current-energy capturing systems would not be expected to affect human health. Workers could be affected by possible exposure to energized systems, inclement weather conditions, and high sea states. Workers could be affected by work underwater inspecting and repairing cables and tethers.

4.10 Environmental Justice

4.10.1 Environmental Consequences of the Proposed Action—Continued Operations and Refurbishment Activities

Impacts of nuclear plant operations and refurbishment on minority and low-income populations living in the vicinity of nuclear power plants were not addressed in the 1996 GEIS because guidance for implementing Executive Order 12898 was not available at the time. Environmental justice was listed in Table B-1 in Appendix B, Subpart A, of 10 CFR Part 51, but was not assigned an issue category or impact significance. The finding in Table B-1 stated that "the need for and the content of an analysis of environmental justice will be addressed in plant-specific reviews." Therefore, impacts to "minority and low-income populations," was evaluated as a new issue for this GEIS revision.

The NRC addresses environmental justice matters for license renewal through (1) identifying the location of minority and low-income populations that the continued operation of the nuclear power plant may affect during the license renewal term, (2) determining whether there would be any potential human health or environmental effects to these populations and special pathway receptors, and (3) determining if any of the effects may be disproportionately high and adverse.

Minority and Low-Income Populations

The environmental justice impact analysis considers the potential for disproportionately high and adverse human health and environmental effects on minority and low-income populations that could result from continued nuclear plant operations and refurbishment activities at a nuclear power plant. Adverse health effects are measured in terms of the risk and rate of fatal or nonfatal adverse impacts on human health. Disproportionately high and adverse human health effects occur when the risk or rate of exposure to an environmental hazard for a minority or low-income population is significant and exceeds the risk or exposure rate for the general population or for another appropriate comparison group. Disproportionately high environmental effects refer to impacts or risk of impact on the natural or physical environment in a minority or low-income community that are significant and appreciably exceed the environmental impact on the larger community. Such effects may include biological, cultural, economic, or social impacts. Some of these potential effects have been identified in resource areas discussed in this section. For example, increased demand for rental housing during replacement power plant construction could disproportionately affect low-income populations. Minority and low-income populations are subsets of the general public residing around the site, and all are exposed to the same risks and hazards generated from operating a nuclear power plant.

Continued reactor operations and other activities associated with license renewal could have an impact on air, land, water, and ecological resources in the region around each nuclear power plant site, which might, create human health and environmental effects on the general population. Depending on the proximity of minority and low-income populations in relation to each nuclear plant, the environmental impacts of license renewal could have a disproportionate effect on these populations.

There is considerable variation in the representation of minority and low-income populations within 50 mi (80 km) of each nuclear power plant site. Sites located in the southern and southwestern United States have large minority populations (e.g., Browns Ferry, Brunswick, Catawba, Farley, North Anna, Robinson, Summer, and Surry plants). Sites located close to metropolitan areas also have larger minority populations as well as larger low-income populations (e.g., Dresden, Ginna, Indian Point, and Pilgrim plants).

The location and significance of environmental impacts may affect population groups that are particularly sensitive because of their resource dependencies or practices (e.g., subsistence agriculture, hunting, or fishing) that reflect the traditional or cultural practices of minority and low-income populations. The analysis of special pathway receptors can be an important part of the identification of resource dependencies or practices. Special pathways take into account the levels of contaminants in native vegetation, crops, soils and sediments, surface water, fish, and game animals on or near the power plant sites in order to assess the risk of radiological exposure through subsistence consumption of fish, native vegetation, surface water, sediment, and local produce; the absorption of contaminants in sediments through the skin; and the inhalation of airborne particulates. All licensed nuclear plants have a comprehensive radiological environmental monitoring program to assess the impact of site operations on the environment. Samples are collected from the aquatic and terrestrial pathways applicable to these sites. Aquatic pathways include fish, surface water, and sediment; terrestrial pathways include airborne particulates, radioiodine, milk, food products, crops, and direct radiation. Concentrations of contaminants in native vegetation, crops, soil, sediment, surface water, fish, and game animals in areas surrounding nuclear power plants have generally been found to be quite low (at or near the threshold of detection) and seldom above background levels.

Pathways associated with continued operations and other activities at nuclear plants associated with the license renewal might affect human populations were considered. Also considered was the extent to which minority and low-income populations in the area around these plants could be disproportionately affected, through resource dependencies and practices (e.g., subsistence agriculture, hunting, or fishing). In addition, plant-specific impacts that could affect minority and low-income populations were also identified at nuclear power plants. Although the overall impact of nuclear plants on the general population has usually been found to be small, because of these unique considerations, the additional examination of the nature and geographic extent of impacts and population demographics should be considered on a plant-specific basis.

While not binding upon independent regulatory agencies such as the NRC, Executive Order 12898 requires certain specified Federal agencies to identify and address, as appropriate, “disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations.” The NRC’s “Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions” (69 FR 52040, August 24, 2004) requires a determination of whether human health and environmental effects of continued operations during the license renewal term and refurbishment associated with license renewal on minority populations and low-income populations would be disproportionately high and adverse. This determination will be made by the NRC in each plant-specific SEIS. On the basis of these considerations, the impact of continued operations and other activities on minority populations and low-income populations would depend on site-specific conditions and is therefore a Category 2 issue.

4.10.2 Environmental Consequences of Alternatives to the Proposed Action

Construction—Minority and low-income populations could be directly or indirectly affected by the construction of a new replacement power plant. The extent of effect experienced by these populations is difficult to determine since it would depend on the location of the power plant. For example, increased demand for rental housing during construction could disproportionately affect low-income populations. However, demand for rental housing could be mitigated if the plant is constructed near a metropolitan area. Replacement power plants would likely be sited at existing power plant or industrial brownfield sites, which are often located in or near low-income and minority communities. Construction would also create employment opportunities for minority and low-income individuals. However, construction at a brownfield site could disproportionately affect minority and low-income populations residing in the vicinity of the proposed plant site. Minority and low-income populations may be disproportionately affected by air emissions and noise from construction and by increased truck and commuter traffic.

Increased fossil fuel consumption may affect employment opportunities and environmental conditions in low-income regions that supply the fossil fuel. Power plants that rely on fossil fuels would likely be sited at brownfield sites situated near low-income and minority populations.

Operation—Low-income populations that rely on subsistence consumption of fish and wildlife, living near power plants could be disproportionately affected. Minority and low-income populations may be disproportionately affected by air emissions and noise from facility operation and by increased truck and commuter traffic.

4.11 Waste Management and Pollution Prevention

4.11.1 Environmental Consequences of the Proposed Action—Continued Operations and Refurbishment Activities

The effects of license renewal (including operations and refurbishment that would occur during the license renewal term) on waste management is presented in this section. Baseline conditions at operating reactors are discussed in Section 3.11. License renewal is expected to result in a continuation of these conditions for an extended period commensurate with the license renewal term, usually 20 years. The annual quantities of waste generated during the license renewal term are not expected to change from the amount generated during the current licensed term. However, the accumulated quantity of waste material needing long-term storage or disposal is expected to be approximately 50 percent larger.

The impacts associated with onsite waste management activities at nuclear plants are addressed in other parts of Chapter 4 under various resource discussions. These activities include waste collection, treatment, packaging, and loading onto conveyance vehicles for shipment offsite. These activities are considered to be part of the normal operations at the site. For example, the annual radioactive effluent release reports issued by the sites include a summary of radioactive effluent releases from all the facilities on the site, including the waste management and storage facilities. The same reports also provide data on volume and radioactivity content of solid radioactive waste shipped offsite for processing and disposal. Similarly, the radiological environmental monitoring program conducted at each site measures the direct radiation as well as environmental concentrations of all radionuclides originating at the site as well as background radiation. The impact from the transportation of wastes from the reactor to a third-party waste treatment center or directly to a disposal site is addressed generically in Table S-4 in 10 CFR 51.52 (see Section 4.12.1.1).

The issues that are addressed in this section are

- Low-level radioactive waste (LLW) storage and disposal (issue from the 1996 GEIS);
- Onsite storage of spent nuclear fuel (issue was renamed from the 1996 GEIS);
- Offsite radiological impacts of spent nuclear fuel and high-level waste disposal (issue was renamed from the 1996 GEIS);
- Mixed waste storage and disposal (issue from the 1996 GEIS); and
- Nonradiological waste storage and disposal (issue was renamed from the 1996 GEIS).

These are five of the nine issues evaluated in the 1996 GEIS (NRC 1996) in the chapter on the uranium fuel cycle and waste management. They relate to waste management at all nuclear fuel cycle facilities, including nuclear power plants. The other four issues, which pertain specifically to aspects of the uranium fuel cycle other than the nuclear power plants themselves, are addressed in Section 4.12.1.1. As discussed in Section 4.12.1.1, the other nuclear fuel cycle facilities include uranium mining and milling, uranium hexafluoride (UF_6) production, isotopic enrichment, fuel fabrication, fuel reprocessing, and disposal facilities.

4.11.1.1 Low-Level Waste Storage and Disposal

Section 3.11.1.1 provides the quantities and characteristics of LLW that are normally generated at nuclear plants under routine operating conditions. As stated in the introduction to Section 4.11.1, these baseline conditions are expected to continue during the license renewal term.

Prior to July 1, 2008, most of the LLW generated at reactor sites is shipped offsite for disposal either immediately after generation or after a brief storage period onsite (see Section 3.11.1.1). This trend is expected to continue. However, the Barnwell disposal facility in South Carolina ceased accepting waste from States that are not a part of the Atlantic compact as of July 2008. As a result, the only remaining disposal facility that is available to the nuclear power plant operators in those States is the EnergySolutions facility in Clive, Utah, which is licensed to accept only Class A LLW. Under these circumstances, the options available to the nuclear power plants in those States are to store their Class B and C (and Class A as appropriate) wastes onsite or offsite until a disposal facility becomes available. Such activities are conducted in accordance with NRC regulations and any applicable State or local requirements. One new facility is being developed by the Waste Control Specialists in Texas for the Texas compact, comprised of Texas and Vermont. That facility has been licensed by the State of Texas (an NRC agreement State) and is authorized to dispose of Class A, B, and C LLW (WCS 2009). The owners of the facility are in the process of developing rules governing the disposal of commercial LLW and other types of waste from waste generators in States other than Texas and Vermont. When this process is finalized, the facility could provide an outlet for disposal of LLW generated on those States that used to ship their waste to Barnwell prior to July 2008.

The NRC believes that the comprehensive regulatory controls that are in place and the low public doses being achieved at reactors ensure that the radiological impacts on the environment will remain SMALL during the term of a renewed license. The maximum additional onsite land that may be required for LLW storage during the term of a renewed license and associated impacts would be SMALL. Nonradiological impacts on air and water would be negligible. The radiological and nonradiological environmental impacts of long-term disposal of LLW from any individual plant at licensed sites are SMALL. In addition, the NRC concludes that there is reasonable assurance that sufficient LLW disposal capacity will be made available when needed for facilities to be decommissioned consistent with NRC decommissioning requirements.

On the basis of the above considerations, the impact of LW storage and disposal during the renewal term is considered SMALL for all sites. As in the 1996 GEIS, this issue is considered to be and remains Category 1.

In addition to being generated at the reactor sites, LLW is also generated from the rest of the uranium fuel cycle as part of the front-end operations during the mining and milling of uranium ores and during the steps leading up to the manufacture of new fuel. If the recycling option is made available and the decision is made to reprocess the spent fuel in the United States, the reprocessing operations would also generate LLW. The impacts associated with management of LLW from these other fuel cycle operations are addressed in Table S-3 in 10 CFR 51.51 (see Section 4.12.1.1).

4.11.1.2 Onsite Storage of Spent Nuclear Fuel

The NRC first adopted the Waste Confidence Decision and Rule in 1984. The NRC amended the decision and rule in 1990, reviewed them in 1999, and amended them again in 2010 (49 FR 34694 (August 31, 1984); 55 FR 38474 (September 18, 1990); 64 FR 68005 (December 6, 1999); and 75 FR 81032 and 81037 (December 23, 2010)). The Waste Confidence Decision and Rule are codified in the NRC regulation 10 CFR 51.23. Under the Waste Confidence Rule and Decision, the NRC had determined that spent fuel can be stored onsite safely and with minimal environmental impact for at least 30 years beyond the current licensed operating life (which may include the term of a revised or renewed license) of nuclear power plants. The Commission determined, in the 1996 GEIS, that onsite storage of spent fuel during the term of a renewed operating license is a Category 1 issue. Further, the Commission also concluded in the 1996 GEIS that continued storage of existing spent fuel and storage of spent fuel generated during the license renewal term can be accomplished safely and without significant environmental impacts, as radiation doses will be well within regulatory limits. Thus, the environmental impacts were classified as SMALL for this Category 1 issue. The following new discussion provides information regarding the potential impacts of onsite storage of spent nuclear fuel during the license renewal term.

As discussed in Section 3.11.1.2, spent nuclear fuel is currently stored at reactor sites either in spent fuel pools or in ISFSIs. The storage of spent fuel in spent fuel pools was considered for each plant in the safety and environmental reviews at the construction permit and operating license stage. This onsite storage of spent fuel and high-level waste (HLW) is expected to continue into the foreseeable future.

Interim storage needs vary among plants, with older units likely to lose pool storage capacity sooner than newer ones. Given the uncertainties regarding the final disposition of spent fuel and high-level waste, it is expected that expanded spent fuel storage capacity will be needed at all nuclear power plants.

As discussed above, current and potential environmental impacts from spent fuel storage onsite at the current reactor sites have been studied extensively, are well understood, and the environmental impacts during the license renewal term were found to be SMALL. No new information was found during the development of this GEIS revision that would alter that conclusion.

For the time period after permanent reactor shutdown, the Waste Confidence Decision and Rule represented the Commission's generic determination that spent nuclear fuel can continue to be stored safely and without significant environmental impacts for a period of time after the end of the licensed life for operation of a nuclear power plant (after the permanent shutdown of the power reactor and expiration of the plant's operating license). This generic determination meant that the NRC did not need to consider the storage of spent nuclear fuel after the end of a reactor's licensed life for operation in the NEPA documents that support its reactor and spent-fuel storage license application reviews.

On December 23, 2010, the Commission published a revision of the Waste Confidence Decision and Rule to reflect information gained from experience in the storage of spent nuclear fuel and the increased uncertainty in the siting and construction of a permanent geologic repository for the disposal of spent nuclear fuel and high-level waste. In response to the 2010 Waste Confidence Decision and Rule, the states of New York, New Jersey, Connecticut, and Vermont, along with several other parties, challenged the Commission's NEPA analysis in the decision, which provided the regulatory basis for the rule. On June 8, 2012, the United States Court of Appeals, in *New York v. NRC*, 681 F.3d 471 (D.C. Cir. 2012), vacated the NRC's Waste Confidence Decision and Rule, after finding that it did not comply with NEPA.

The court concluded that the Waste Confidence Decision and Rule is a major federal action necessitating either an EIS or an environmental assessment that results in a "finding of no significant impact." In vacating the 2010 decision and rule, the court identified three specific deficiencies in the analysis:

1. As to the Commission's conclusion that permanent disposal will be available "when necessary," the court held that the Commission did not evaluate the environmental effects of failing to secure permanent disposal;

2. As to the storage of spent fuel on-site at nuclear plants after the expiration of a plant's operating license, the court concluded that the Commission failed to properly examine the risk of spent fuel pool leaks in a forward-looking fashion; and

3. Also related to the post-license storage of spent fuel, the court concluded that the Commission failed to properly examine the consequences of spent fuel pool fires.

In response to the court's ruling, the Commission issued CLI-12-16 on August 7, 2012, in which the Commission determined that it would not issue licenses that rely upon the Waste Confidence Decision and Rule until the issues identified in the court's decision are appropriately addressed by the Commission (NRC 2012). CLI-12-16 provided, however, that the decision not to issue licenses only applied to final license issuance; all licensing reviews and proceedings should continue to move forward. In SRM-COMSECY-12-0016, dated September 6, 2012, the Commission directed the NRC staff to proceed with a rulemaking that includes the development of a generic EIS to support a revised Waste Confidence Decision and Rule and to publish both the EIS and the revised decision and rule in the *Federal Register* within 24 months (by September 6, 2014). The Commission indicated that both the EIS and the revised Waste Confidence Decision and Rule should build on the information already documented in various NRC studies and reports, including the existing environmental assessment that the NRC developed as part of the 2010 Waste Confidence Decision and Rule. The Commission directed that any additional analyses should focus on the three deficiencies identified in the D.C. Circuit's decision. The Commission also directed that the NRC staff provide ample opportunity for public comment on both the draft EIS and the proposed Waste Confidence Decision and Rule.

In accordance with CLI-12-16, the NRC will not approve any site-specific license renewal applications until the deficiencies identified in the D.C. Circuit's decision have been resolved. Two Table B-1 license renewal issues that rely, wholly or in part, upon the Waste Confidence Decision and Rule are the "onsite storage of spent nuclear fuel" and "offsite radiological impacts of spent nuclear fuel and high-level waste disposal." Both of these issues were classified as Category 1 in the 1996 GEIS; the draft revised GEIS that was published for comment in 2009 continued the Category 1 classification for both of these issues. As part of the NRC's response to the *New York v. NRC* decision, the NRC has revised these two issues accordingly.

Specifically, the NRC has revised the Category 1 "Onsite storage of spent nuclear fuel" issue to narrow the period of onsite storage to the license renewal term. In the 1996 GEIS and in the 2009 draft revised GEIS, the NRC relied upon the Waste Confidence Decision and Rule to make a generic finding that spent nuclear fuel could be stored safely onsite with no more than a small environmental impact for the term of the extended license (from approval of the license renewal application to the expiration of the operating license) plus a 30 year period following the permanent shutdown of the power reactor and expiration of the operating license.

The Waste Confidence Decision and Rule provided the basis for the 30 year period following the permanent shutdown of the reactor and expiration of the operating license. The 2010 Waste Confidence Decision and Rule extended this post-reactor shutdown onsite storage period from 30 years to 60 years. Given the *New York v. NRC* decision, and pending the issuance of a generic EIS and revised Waste Confidence Decision and Rule (as directed by SRM-COMSECY-12-0016), the period of onsite storage of spent nuclear fuel following the permanent shutdown of the power reactor and expiration of the operating license is now excluded from this GEIS issue. This issue now only covers the onsite storage of spent fuel during the license renewal term.

4.11.1.3 Offsite Radiological Impacts of Spent Nuclear Fuel and High-Level Waste Disposal

As a result of the *New York v. NRC* decision, and pending the issuance of a generic EIS and revised Waste Confidence Decision and Rule (see the discussion in section 4.11.1.2 above), the NRC has revised the Category 1 issue, “Offsite radiological impacts of spent nuclear fuel and high-level waste disposal.” This issue pertained to the long-term disposal of spent nuclear fuel and high-level waste, including possible disposal in a deep geologic repository. Although the Waste Confidence Decision and Rule did not assess the impacts associated with disposal of spent nuclear fuel and high-level waste in a repository, it did reflect the Commission’s confidence, at the time, in the technical feasibility of a repository and when that repository could have been expected to become available. Without the analysis in the Waste Confidence Decision, the NRC cannot assess how long the spent fuel will need to be stored onsite. Therefore, the NRC reclassifies this GEIS issue from a Category 1 issue with no assigned impact level to an uncategorized issue with an impact level of uncertain.

Moreover, the ultimate disposal of spent nuclear fuel in a potential future geologic repository is a separate and independent licensing action that is outside the regulatory scope of license renewal. However, because of questions and concerns that have been raised regarding this issue during scoping for the revised GEIS, the following discussion provides relevant information with respect to developments pertaining to the consideration of an ultimate repository site for the disposal of spent nuclear fuel.

At the time the 1996 GEIS was issued, there were no established regulatory limits for offsite releases of radionuclides from the ultimate disposal of spent nuclear fuel and HLW, since a candidate repository site had not been established. It was assumed that for such a site, limits would eventually be developed along the lines of those given in the 1995 National Academy of Sciences (NAS) report, *Technical Bases for Yucca Mountain Standards*.

On February 15, 2002, on the basis of a recommendation by the Secretary of Energy, the President recommended the Yucca Mountain site for the development of a repository for the geologic disposal of spent nuclear fuel and HLW. Congress approved this recommendation on July 9, 2002, in Joint Resolution 87, which designated Yucca Mountain as the repository for spent nuclear waste. On July 23, 2002, the President signed Joint Resolution 87 into law. Public Law 107-200, 116 *Statutes at Large* (Stat.) 735, 42 U.S.C. 10135 (note), designates Yucca Mountain as the site for the development of the repository for spent nuclear waste.

Subsequently, the EPA developed Yucca-Mountain-specific repository release standards, which were also adopted by the NRC in 10 CFR Part 63. These standards:

- Establish a dose limit of 15 millirem (0.15 mSv) per year for the first 10,000 years after disposal;

- Establish a dose limit of 100 millirem (1.0 mSv) exposure per year between 10,000 years and 1 million years;

- Require the Department of Energy (DOE) to consider the effects of climate change, earthquakes, volcanoes, and corrosion of the waste packages to safely contain the waste during the 1 million-year period; and

- Consistent with the recommendations of the NAS by establishing a radiological protection standard for this facility at the time of peak dose up to 1 million years after disposal.

On June 3, 2008, the DOE submitted a license application to the NRC, seeking authorization to construct a geologic repository for the disposal of spent nuclear fuel and high-level waste at Yucca Mountain, Nevada. As part of the site characterization and recommendation process for the proposed geologic repository at Yucca Mountain, Nevada, the DOE was required by the Nuclear Waste Policy Act of 1982, 42 U.S.C. 10101 *et seq*. (NWPA), to prepare an EIS. In accordance with the NWPA (42 U.S.C. 10134(f)(4)), the NRC was required to adopt DOE's EIS, to "the extent practicable," as part of any possible NRC construction authorization decision. DOE submitted the following NEPA documents along with its application, which include analyses that address radiological impacts to workers and the public.

- *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (FEIS) (February 2002) (DOE/EIS-0250F) (ML032690321)

- *Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain,* *Nye County, Nevada* (Repository SEIS) (June 2008) (DOE/EIS-0250F-S1) (ML081750191)

The NRC formally accepted for docketing DOE's license application for Yucca Mountain, Nevada on September 8, 2008. In its acceptance, NRC staff also recommended that the Commission adopt, with further supplementation, the EIS and supplements prepared by DOE (73 FR 53284). With respect to radiological impacts, DOE's FEIS and Repository SEIS indicate that the disposal of spent nuclear fuel and high-level waste would be SMALL with exposures well below regulatory limits. However, on March 3, 2010, the U.S. Department of Energy (DOE) filed a motion with the Atomic Safety and Licensing Board (Board) seeking permission to withdraw its application for authorization to construct a high-level waste geological repository at Yucca Mountain, Nevada. The Board denied that request on June 29, 2010, in LBP-10-11 (ADAMS Accession No. ML101800299), whereuponthe parties involved in the preceding filed petitions asking the Commission to uphold or reverse this decision.

On September 9, 2011, the Commission issued a Memorandum and Order, CLI-11-07, stating that it found itself evenly divided on whether to take the affirmative action of overturning or upholding the Board's June 29, 2010, decision. Exercising its inherent supervisory authority, the Commission directed the Board to complete all necessary and appropriate case management activities by September 30, 2011. On September 30, 2011, the Board issued a Memorandum and Order suspending the proceeding.

On October 1, 2010, the NRC staff initiated an orderly closure of its Yucca Mountain activities. As part of the orderly closure, the NRC staff prepared three technical evaluation reports documenting its work.

The NRC's non-sensitive Yucca Mountain-related documents are being preserved and made available to the public as part of the NRC staff's activities to retain the accumulated knowledge and experience gained as a result of its Yucca Mountain-related activities. These documents can be viewed on the NRC's public Web site, http://www.NRC.gov/waste/hlw-disposal.html.

NRC decisions and recommendations concerning the ultimate disposition of spent nuclear fuel are ongoing and outside the scope of license renewal, and as such, of this GEIS.

Separate from the regulatory actions taken by the NRC, in 2009 and early 2010, the president and his administration decided not to proceed with the Yucca Mountain nuclear waste repository. Instead, on January 29, 2010, the Secretary of Energy announced the formation of a Blue Ribbon Commission to conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle (DOE 2010). The Blue Ribbon Commission will provide advice and make recommendations on issues including alternatives for the storage, processing, and disposal of civilian and defense spent nuclear fuel and HLW. The Blue Ribbon Commission issued its recommendations to the Secretary of Energy on January 26, 2012 (www.brc.gov). The report contained eight key elements:

1. A new, consent-based approach to siting future nuclear waste management facilities.

2. A new organization dedicated solely to implementing the waste management program and empowered with the authority and resources to succeed.

3. Access to the funds nuclear utility ratepayers are providing for the purpose of nuclear waste management.

4. Prompt efforts to develop one or more geologic disposal facilities.

5. Prompt efforts to develop one or more consolidated storage facilities.

6. Prompt efforts to prepare for the eventual large-scale transport of spent nuclear fuel and high-level waste to consolidated storage and disposal facilities when such facilities become available.

7. Support for continued U. S. innovation in nuclear energy technology and for workforce development.

8. Active U. S. leadership in international efforts to address safety, waste management, non-proliferation, and security concerns.

DOE will be the lead Federal agency responsible for developing a new national strategy for nuclear waste management; the NRC will play a supporting role in those areas associated with its regulatory review.

4.11.1.4 Mixed Waste Storage and Disposal

This issue addresses the storage and disposal of mixed waste generated at nuclear power plants and other uranium fuel-cycle facilities during the license renewal term. As discussed in Section 3.11.3, nuclear power plants generate small quantities of mixed waste. Other uranium fuel-cycle facilities are also expected to generate small quantities of mixed waste. Mixed waste is regulated both by the EPA or the authorized State agency under RCRA and by the NRC or the Agreement State agency under the Atomic Energy Act (AEA; Public Law 83-703). The waste is either treated onsite or sent offsite for treatment followed by disposal at a permitted landfill. The comprehensive regulatory controls and the facilities and procedures that are in place at nuclear power plants ensure that the mixed waste is properly handled and stored and that doses to and exposure to toxic materials by the public and the environment are negligible at all plants. License renewal will not increase the small but continuing risk to human health and the environment posed by mixed waste at all plants. The radiological and nonradiological environmental impacts from the long-term disposal of mixed waste at any individual plant at licensed sites are considered SMALL for all sites. The issue was considered a Category 1 issue in the 1996 GEIS, and no new information that would alter this conclusion has been identified.

4.11.1.5 Nonradioactive Waste Storage and Disposal

This issue addresses the storage and disposal of nonradioactive waste generated at commercial nuclear power plants and during the rest of the uranium fuel cycle during the license renewal term. Nonradioactive waste consists of hazardous and nonhazardous waste. Storage and disposal of hazardous waste generated at nuclear plants is discussed in Section 3.11.2. As indicated in that section, nuclear plants generate small quantities of hazardous waste during operation and refurbishment. A special class of hazardous waste, known as universal waste, consisting of commonly used yet hazardous materials (batteries, pesticides, mercury-containing equipment, and lamps), is also generated. Similar types of hazardous wastes are also generated at other uranium fuel-cycle facilities. The management of hazardous wastes generated at all of these facilities, both onsite and offsite, is strictly regulated by the EPA or the responsible State agencies per the requirements of RCRA.

As does any industrial facility, nuclear power plants and the rest of the uranium fuel-cycle facilities also generate nonradioactive nonhazardous waste (see Section 3.11.4). These wastes are managed by following good housekeeping practices and are generally disposed of in local landfills permitted under RCRA Subtitle D regulations.

In the 1996 GEIS, the impacts associated with managing nonradioactive wastes at uranium fuel cycle facilities, including nuclear power plants, were found to be SMALL. It was indicated that no changes to nonradioactive waste generation would be anticipated for license renewal, and that systems and procedures are in place to ensure continued proper handling and disposal of the wastes at all plants. The issue was considered a Category 1 issue in the 1996 GEIS, and no new information that would alter this conclusion has been identified.

4.11.2 Environmental Consequences of Alternatives to the Proposed Action

Construction—Construction-related wastes include various fluids from the onsite maintenance of construction vehicles and equipment (e.g., used lubricating oils, hydraulic fluids, glycol-based coolants, spent lead-acid storage batteries) and incidental chemical wastes from the maintenance of equipment and the application of corrosion-control protective coatings (e.g., solvents, paints, coatings), construction-related debris (e.g., lumber, stone, and brick), and packaging materials (primarily wood and paper). All materials and wastes would be accumulated onsite and disposed of or recycled through licensed offsite disposal and treatment facilities. Life-cycle management of chemicals and wastes generated during construction and pollution prevention initiatives (such as spill prevention plans) will serve to mitigate the impact of wastes. The impacts of waste management are expected to be the same for greenfield, brownfield, and existing nuclear power plant sites.

Operations—Solid wastes would be generated throughout the period of plant operations. The character of wastes would depend on chemical constituents of the fuel, efficiency of combustion, and operational efficiencies of the various air pollution control devices. Wastes routinely associated with the maintenance of mechanical and electrical equipment include: used lubricating oils and hydraulic fluids, cleaning solvents, corrosion control paints and coatings, and dielectric fluids.

4.11.2.1 Fossil Fuel Alternatives

Operations—Solid wastes in the form of coal combustion waste (and, in some instances, flue gas desulfurization sludge and spent catalysts) would be generated during plant operations. The exact character of the coal combustion waste would depend on the chemical constituents of the coal, efficiency of the combustion device, and operational efficiencies of the various air pollution control devices.

4.11.2.2 New Nuclear Alternatives

Operations—Liquid, gaseous, and solid radioactive waste management systems would be used to collect and treat radioactive materials during operations. Waste processing systems would be designed so that radioactive effluents released to the environment would meet the objectives of Appendix I to 10 CFR Part 50. The primary source of radioactive waste from a new nuclear facility is fission products that escape from the fuel rods into the reactor coolant. Coolant could also become contaminated from neutron activation of the primary cooling system. LLW disposal is assumed to occur at an offsite location, while spent fuel would be stored onsite either in spent fuel pool storage or dry cask storage.

Nonradioactive effluent and wastes include cooling water and steam condensate blowdowns that contain various water-treatment chemicals or biocides, wastes from the onsite treatment of cooling water and steam cycle water, floor and equipment drain effluent, stormwater runoff, laboratory waste, trash, hazardous waste, effluent from the sanitary sewer system, miscellaneous gaseous emissions, and liquid and solid effluent. Wastes discharged to waters of the United States would be regulated by NPDES permits. All other wastes would be properly disposed of in accordance with Federal, State, and local regulations. Waste impacts for a nuclear plant are described in Section 4.11.1 and in 10 CFR Part 51, Appendix B, Table B-1. Impacts are expected to be SMALL for all facilities, whether located on greenfield sites, brownfield sites, or at existing nuclear plant sites.

4.11.2.3 Renewable Alternatives

Operations—The operational impacts of alternative energy technologies on waste management are presented in the following subsections.

Geothermal

Small amounts of industrial solid wastes associated with onsite maintenance of equipment and infrastructure would be generated, including: used oils, used glycol-based antifreeze, waste lead-acid storage batteries, spent cleaning solvents, and excess corrosion control coatings. Operational solid wastes could include precipitates (scale) resulting from cooling and depressurized hydrothermal fluids that must be periodically removed from equipment; some precipitates may include naturally occurring radioactive material (NORM).

Wind

Minimal amounts of wastes are generated from the maintenance of wind turbines; wastes consist mainly of spent lubricating and gear oils removed from equipment during routine preventive maintenance, small amounts of battery electrolyte from onsite back-up power systems, and minor amounts of solvents and coatings from ongoing corrosion control activities. Modern turbine designs allow for the easy removal of malfunctioning equipment for replacement and repair; consequently, wastes generated onsite would be limited to preventive maintenance-related wastes.

Biomass

Major operating wastes would include fly ash and bottom ash that results from the combustion of the carbonaceous fuels. Scrubbers for control of sulfur oxide emissions would not be expected to be needed for units combusting wood and energy crops that have little to no sulfur content. Temporary storage of operational solid wastes onsite could affect local ecological systems, especially surface waters.

Municipal Solid Waste, Refuse-Derived Fuel, and Landfill Gas

Small amounts of industrial solid wastes typically associated with maintenance of equipment and infrastructure would be generated, including used oils and lubricants, used glycol-based coolants, waste lead-acid batteries, spent cleaning solvents, and excess corrosion control wastes. Operating wastes also would include small amounts of sanitary wastewaters and sanitary solid wastes from support of the workforces. Toxic constituents in municipal solid waste or refuse-derived fuel could cause solid wastes from air pollution devices to become hazardous due to leachability of toxic constituents. Sanitary wastewater and well as wastewaters from industrial operations would be containerized and removed to offsite treatment; cooling water blowdown and steam cycle blowdown may be discharged to the land surface or to surface impoundments. Temporary storage of operational solid wastes on site could impact local ecological systems, especially surface waters.

Solar Thermal

Spills and leaks of the heat transfer fluids could occur; affected soil would need to be removed and disposed of properly. Routine maintenance-related wastes would be expected. Spills or leaks from electrical components could create waste dielectric fluids (all assumed to be free of PCBs).

Solar Photovoltaic

Proper precautions would have to be made for the disposal of solar cells, although recycling of materials would reduce impacts.

Ocean Wave and Current

Wastes associated with facility operation would include small amounts of wastes related to facility maintenance, including waste lubricating oils, hydraulic fluids, cleaning solvents, and protective corrosion-control paints and coatings. Wastes also include those associated with the application of antifouling agents to the underwater portions of components to control interference by marine organisms. Major repairs of electrical components could result in waste dielectric fluids (mineral oil).

4.12 Impacts Common to All Alternatives

This section describes impacts that are considered common to all alternatives discussed in the GEIS including the proposed action (license renewal) and replacement power alternatives. The continued operation of a nuclear power plant and replacement fossil fueled power plants both involve the mining, processing, and the consumption of fuel, which results in comparative environmental impacts. Environmental impacts associated with power plant fuel cycles are presented in Section 4.12.1. The termination of operations and the decommissioning of a nuclear power plant and replacement fossil fueled power plants as well as renewable energy systems are presented in Section 4.12.2. In addition, greenhouse gas emissions from the nuclear lifecycle as well as replacement fossil fueled power plants and climate change impacts are presented in Section 4.12.3.

4.12.1 Environmental Consequences of Fuel Cycles

This section describes the environmental impacts associated with fuel cycles associated with the proposed action (license renewal) and replacement power alternatives. Most, if not all, replacement power alternatives, including the continued operation of the nuclear power plant during the license renewal term, employ a set of steps in the utilization of its fuel source. These steps can include, but are not limited to, extraction, transformation, transportation, and, combustion. Emissions generally occur at each stage of a fuel cycle. Also, some aspects of the fuel cycle (e.g., storage and disposal) described here are common to each alternative.

4.12.1.1 Uranium Fuel Cycle

In the United States, all currently operating commercial plants are light water reactors and use uranium for fuel. Therefore, in this section and in the rest of this GEIS, the term "uranium fuel cycle" is used interchangeably with "nuclear fuel cycle."

Uranium Fuel Cycle Facilities

The NRC evaluated the environmental impacts that would be associated with operating uranium fuel cycle facilities other than the reactors themselves in two NRC documents: WASH-1248 (NRC 1974) and NUREG-0116 (NRC 1976). The types of facilities considered in these two documents include:

- Uranium mining—facilities where the uranium ore is mined.
- Uranium milling—facilities where the uranium ore is refined to produce uranium concentrates in the form of triuranium octaoxide (U_3O_8).
- Uranium hexafluoride (UF_6) production—facilities where the uranium concentrates are converted to UF_6.
- Isotopic enrichment—facilities where the isotopic ratio of the uranium-235 isotope in natural uranium is increased to meet the requirements of light water reactors.
- Fuel fabrication—facilities where the enriched UF_6 is converted to uranium dioxide (UO_2) and made into sintered UO_2 pellets. The pellets are subsequently encapsulated in fuel rods, and the rods are assembled into fuel assemblies ready to be inserted into the reactors. Two options were considered: (1) carrying out all steps involved in manufacturing the fuel assemblies at the same location and (2) carrying the steps out at two separate facilities (at one facility, UO_2 is produced in powder form from the enriched UF_6, and at the other facility, the fuel assemblies are manufactured).

- Reprocessing—facilities that disassemble the spent fuel assemblies, chop up the fuel rods into small sections, chemically dissolve the spent fuel out of sectioned fuel rod pieces, and chemically separate the spent fuel into reusable uranium, plutonium, and other radionuclides (primarily fission products and actinides).

- Disposal—facilities where the radioactive wastes generated at all fuel cycle facilities including the reactors, are buried. Spent nuclear fuel that is removed from the reactors and not reprocessed was also assumed to be disposed of at a geologic repository.

Environmental Impacts

In addition to impacts occurring at the above facilities, the impacts associated with the transportation of radioactive materials among these facilities, including the transportation of wastes to disposal facilities, were evaluated. The results were summarized in a table and promulgated as Table S-3 in 10 CFR 51.51(b). Table S-3 is provided as Table 4.12-1 for ease of reference. 10 CFR 51.51(a) states:

> Every environmental report prepared for the construction permit stage of a light-water-cooled nuclear power reactor, and submitted on or after September 4, 1979, shall take Table S-3, Table of Uranium Fuel Cycle Environmental Data, as the basis for evaluating the contribution of the environmental effects of uranium mining and milling, the production of uranium hexafluoride, isotopic enrichment, fuel fabrication, reprocessing of irradiated fuel, transportation of radioactive materials and management of low level wastes and high level wastes related to uranium fuel cycle activities to the environmental costs of licensing the nuclear power reactor. Table S-3 shall be included in the environmental report and may be supplemented by a discussion of the environmental significance of the data set forth in the table as weighed in the analysis for the proposed facility.

Specific categories of natural resource use included in Table S-3 relate to land use; water consumption and thermal effluents; radioactive releases; burial of transuranic waste, HLW, and LLW; and radiation doses from transportation and occupational exposures. The contributions in the table for reprocessing, waste management, and transportation of wastes are maximized for either of the two fuel cycles (uranium only and no recycle); that is, the cycle that results in the greater impact is used. For each resource area, Table S-3 presents a result that has been integrated over the entire fuel cycle except the reactors. The only exception to this is that the waste quantities provided under the entry called “solids (buried onsite)” also includes wastes generated at the reactor.

The environmental impact values are expressed in terms normalized to show the potential impacts attributable to processing the fuel required for the operation of a 1,000-MWe nuclear power plant for one year at an 80 percent availability factor to produce about 800 MW-yr (0.8 GW-yr) of electricity. This is referred to as 1 reference reactor year (RRY).

A detailed discussion of impacts associated with the production and processing of fuel needed for one reference reactor year operation of the model light water reactor was provided in the 1996 GEIS (NRC 1996). Included in the discussion were the collective offsite radiological impacts that would be associated with radon-222 and technetium-99 releases to the environment during the fuel cycle operations, which Table S-3 does not address. The 1996 GEIS also provided a discussion on the sensitivity of the impacts to recent changes in the fuel cycle (Section 6.2.3 in the 1996 GEIS). For example, when Table S-3 was originally prepared, the model reactor was assumed to be refueled once a year, and the fuel was assumed to remain in the reactor to a burnup level of 33,000 MWd/MTU. The 1996 GEIS discussed the effects of higher fuel burnups up to 62,000 MWd/MTU and the fact that most reactors now refuel once every 18 months or 24 months. The technological changes in the various fuel cycle operations (e.g., the in situ mining of uranium rather than the open pit mining assumed in WASH-1248, and the potential for using more efficient isotopic enrichment processes through the gaseous centrifuge rather than the energy-intensive gaseous diffusion process that was and is still being used in the United States) were also discussed. It was concluded that even though certain fuel cycle operations and fuel management practices have changed over the years, the assumptions and methodology used in preparing Table S-3 were conservative enough that the impacts described by the use of Table S-3 would still be bounding. The NRC believes that this conclusion still holds.

One part of the fuel cycle that was not discussed either in the technical support documents for the original Table S-3 or in the 1996 GEIS was the disposition of the depleted UF_6 tails generated during the enrichment process. Originally, these tails were intended to be used as a feedstock to make fuel for proposed fast breeder reactors. However, the United States abandoned the fast breeder reactor program in 1978. Before the creation of the United States Enrichment Corporation in 1993, DOE was the custodian of all the depleted UF_6 generated in the United States at the three gaseous diffusion plants (in Oak Ridge, Tennessee; Portsmouth, Ohio; and Paducah, Kentucky). DOE prepared several NEPA documents evaluating the impacts associated with the disposition of approximately 700,000 MT (1.54 billion lb) of depleted UF_6 (DOE 1999, 2004a,b, 2007). DOE decided to convert the depleted UF_6 back to U_3O_8 and dispose of it as LLW (DOE 2004c,d). The results of these analyses indicate that the operational impacts of the depleted UF_6 management facilities would not be very different from the impacts estimated for other parts of the fuel cycle in Table S-3. In particular, the impacts of the depleted UF_6 conversion facilities, where the depleted UF_6 is converted to U_3O_8, would be similar to the impacts of the UF_6 production facilities, where U_3O_8 is converted to UF_6. If the depleted uranium oxide is disposed of as LLW, the conversion product corresponding to one reference reactor year would be in addition to the LLW quantities already listed in Table S-3. This value is

Table 4.12-1. Table S-3 Taken from 10 CFR 51.51 on Uranium Fuel Cycle Environmental Data
(Normalized to model light water reactor annual fuel requirement [WASH-1248] or reference reactor year [NUREG-0116])[a]

Environmental Considerations	Total	Maximum Effect per Annual Fuel Requirement or Reference Reactor Year of Model 1,000 MWe Light Water Reactor
Natural Resource Use		
Land (acres)		
Temporarily committed[b]	100	
Undisturbed area	79	
Disturbed area	22	Equivalent to a 110 MWe coal-fired power plant.
Permanently committed	13	
Overburden moved (millions of MT)	2.8	Equivalent to 95 MWe coal-fired power plant.
Water (millions of gallons)		
Discharged to air	160	Equal to 2 percent of model 1,000 MWe light water reactor with cooling tower.
Discharged to water bodies	11,090	
Discharged to ground	127	
Total	11,377	Less than 4 percent of model 1,000 MWe light water reactor with once-through cooling.
Fossil Fuel		
Electrical energy (thousands of MW-hour)	323	Less than 5 percent of model 1,000 MWe output.
Equivalent coal (thousands of MT)	118	Equivalent to the consumption of a 45 MWe coal-fired power plant.
Natural gas (millions of scf)	135	Less than 0.4 percent of model 1,000 MWe energy output.
Effluents – Chemical (MT)		
Gases (including entrainment)[c]		
SO_x	4,400	
NO_x[d]	1,190	Equivalent to emissions from 45 MWe coal-fired plant for a year.
Hydrocarbons	14	
CO	29.6	
Particulates	1,154	
Other gases		

Table 4.12-1. (cont.)

Environmental Considerations	Total	Maximum Effect per Annual Fuel Requirement or Reference Reactor Year of Model 1,000 MWe Light Water Reactor
F	0.67	Principally from UF_6 production, enrichment, and reprocessing. Concentration within range of State standards and below level that has effects on human health.
HCl	0.014	
Liquids		
SO^{-}_{4}	9.9	From enrichment, fuel fabrication, and reprocessing steps. Components that constitute a potential for adverse environmental effects are present in dilute concentrations and receive additional dilution by receiving bodies of water to levels below permissible standards. The constituents that require dilution and the flow of dilution water are NH_3: 600 cfs, NO_3: 20 cfs, fluoride: 70 cfs.
NO^{-}_{3}	25.8	
Fluoride	12.9	
Ca^{++}	5.4	
$C1^{-}$	8.5	
Na^{+}	12.1	
NH_3	10.0	
Fe	0.4	
Tailings solutions (thousands of MT)	240	From mills only—no significant effluents to environment.
Solids	91,000	Principally from mills—no significant effluents to environment.
Effluents – Radiological (curies)		
Gases (including entrainment)		
Rn-222	–	Presently under reconsideration by the Commission.
Ra-226	0.02	
Th-230	0.02	
Uranium	0.034	
Tritium (thousands)	18.1	
C-14	24	
Kr-85 (thousands)	400	
Ru-106	0.14	Principally from fuel reprocessing plants.
I-129	1.3	
I-131	0.83	
Tc-99	–	Presently under consideration by the Commission.
Fission products and transuranics	0.203	
Liquids		
Uranium and progeny	2.1	Principally from milling—included tailings liquor and returned to ground—no effluents; therefore, no effect on the environment.
Ra-226	0.0034	From UF_6 production.

Table 4.12-1. (cont.)

Environmental Considerations	Total	Maximum Effect per Annual Fuel Requirement or Reference Reactor Year of Model 1,000 MWe Light Water Reactor
Th-230	0.0015	
Th-234	0.01	From fuel fabrication plants—concentration 10 percent of 10 CFR Part 20 for total processing 26 annual fuel requirements for model light water reactor.
Fission and activation products	5.9×10^{-6}	
Solids (buried onsite)		
Other than high level (shallow)	11,300	9,100 Ci comes from low-level reactor wastes and 1,500 Ci comes from reactor decontamination and decommissioning—buried at land burial facilities. 600 Ci comes from mills—included in tailing returned to ground. Approximately 60 Ci comes from conversion and spent fuel storage. No significant effluent to the environment.
Transuranic and high level waste (deep)	1.1×10^{7}	Buried at Federal Repository.
Effluents – Thermal (billions of Btu)	4,063	Less than 5 percent of model 1,000 MWe light water reactor.
Transportation (person-rem)		
Exposure of workers and general public	2.5	
Occupational exposure	22.6	From reprocessing and waste management.

(a) In some cases where no entry appears, it is clear from the background documents that the matter was addressed and that, in effect, the table should be read as if a specific zero entry had been made. However, there are other areas that are not addressed in the table. Table S-3 does not include health effects from the effluents described in the table, estimates of releases of radon-222 from the uranium fuel cycle, or estimates of technetium-99 released from waste management or reprocessing activities. These issues may be the subject of litigation in the individual licensing proceedings.
Data supporting this table are given in the *Environmental Survey of the Uranium Fuel Cycle*, WASH-1248, April 1974; the *Environmental Survey of the Reprocessing and Waste Management Portion of the LWR Fuel Cycle*,' NUREG-0116 (Supp. 1 to WASH–1248); the *Public Comments and Task Force Responses Regarding the Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle*, NUREG-0216 (Supp. 2 to WASH-1248); and in the record of the final rulemaking pertaining to *Uranium Fuel Cycle Impacts from Spent Fuel Reprocessing and Radioactive Waste Management*, Docket RM-50-3. The contributions from reprocessing, waste management, and transportation of wastes are maximized for either of the two fuel cycles (uranium only and no recycle). The contribution from transportation excludes transportation of cold fuel to a reactor and of irradiated fuel and radioactive wastes from a reactor, which are considered in Table S-4 of Section 51.20(g). The contributions from the other steps of the fuel cycle are given in columns A–E of Table S-3A of WASH-1248.

(b) The contributions to temporarily committed land from reprocessing are not prorated over 30 years, since the complete temporary impact accrues regardless of whether the plant services one reactor for one year or 57 reactors for 30 years.

(c) Estimated effluents based upon combustion of equivalent coal for power generation.

(d) 1.2 percent from natural gas use and process.

Source: 10 CFR 51.51

estimated to be approximately 12 Ci (4.4×10^{11} Bq) (35 MT of uranium per RRY multiplied by 0.34 Ci/MT of depleted uranium).

Consideration of Environmental Justice

As stated in NRC's *Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions* (69 FR 52040), "An NRC EJ [environmental justice] analysis should be limited to the impacts associated with the proposed action (i.e., the communities in the vicinity of the proposed action). EJ-related issues differ from site to site and normally cannot be resolved generically. Consequently, EJ, as well as other socioeconomic issues, are normally considered in site-specific EISs. Thus, due to the site-specific nature of an EJ analysis, EJ-related issues are usually not considered during the preparation of a generic or programmatic EIS. EJ assessments would be performed as necessary in the underlying licensing action for each particular facility."

The environmental impacts of various individual operating uranium fuel cycle facilities are addressed in separate EISs prepared by NRC. These documents include analyses that address human health and environmental impacts to minority and low-income populations. Electronic copies of these EISs are available through the NRC's public Web site under Publications Prepared by NRC Staff document collection of the NRC's Electronic Reading Room at http://www.nrc.gov/reading-rm/doc-collections/; and the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html.

Transportation Impacts

The impacts associated with transporting fresh fuel to one 1,000 MWe model light water reactor and with transporting spent fuel and radioactive waste (LLW and mixed waste) from that light water reactor are provided in Table S-4 in 10 CFR 51.52. Similar to Table S-3, and as indicated in 10 CFR 51.52, every environmental report prepared for the construction permit stage of a commercial nuclear power plant must contain a statement concerning the transport of fuel and radioactive waste to and from the reactor. A similar statement is also required in license renewal applications. Table S-4 forms the basis of such a statement and is presented as Table 4.12-2.

A discussion of the values included in Table S-4 and how they may change during the license renewal term was included in Section 6.3 of the 1996 GEIS. However, after the 1996 GEIS was issued and during the rulemaking process for codifying Table B-1 in 10 CFR Part 51, a number of comments were received from the public that raised some questions about the adequacy of Table S-4 for license renewal application reviews. As a result, the NRC reevaluated the transportation issues and the adequacy of Table S-4 for license renewal application reviews. In

1999, the NRC issued an addendum to the 1996 GEIS (NRC 1999a) in which the agency evaluated the applicability of Table S-4 to future license renewal proceedings, given that the spent fuel is likely to be shipped to a single repository (as opposed to several destinations, as originally assumed in the preparation of Table S-4) and given that shipments of spent fuel are likely to involve more highly enriched fresh fuel (more than 4 percent as assumed in Table S-4) and higher-burnup spent fuel (higher than 33,000 MWd/MTU as assumed in Table S-4). In the addendum, the NRC evaluated the impacts of transporting the spent fuel from reactor sites to the candidate repository at Yucca Mountain and the impacts of shipping more highly enriched fresh fuel and higher-burnup spent fuel. On the basis of the evaluations, the NRC concluded that the values given in Table S-4 would still be bounding, as long as the (1) enrichment of the fresh fuel was 5 percent or less, (2) burnup of the spent fuel was 62,000 MWd/MTU or less, and

Table 4.12-2. Table S-4 Taken from 10 CFR 51.52 on the Environmental Impact of Transporting Fuel and Waste to and from One Light-Water-Cooled Nuclear Power Reactor[(a)]

Normal Conditions of Transport			
		Environmental Impact	
Heat (per irradiated fuel cask in transit)		250,000 Btu/hr	
Weight (governed by Federal or State restrictions)		73,000 lb per truck; 100 tons per cask per rail car	
Traffic density:			
Truck		Less than 1 per day	
Rail		Less than 3 per month	
Exposed Population	**Estimated No. of Persons Exposed**	**Range of Doses to Exposed Individuals[(b)] (per reactor year)**	**Cumulative Dose to Exposed Population (per reactor year)[(c)]**
Transportation workers	200	0.01 to 300 millirem	4 person-rem
General public:			
Onlookers	1,100	0.003 to 1.3 millirem	3 person-rem
Along route	600,000	0.0001 to 0.06 millirem	
Accidents in Transport			
		Environmental Risk	
Radiological effects		Small[(d)]	
Common (nonradiological) causes		1 fatal injury in 100 reactor years; 1 nonfatal injury in 10 reactor years; $475 property damage per reactor year	

(a) Data supporting this table are given in the Commission's *Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants*, WASH-1238, December 1972, and Supp. 1, NUREG-75/038, April 1975.
(b) The Federal Radiation Council has recommended that the radiation doses from all sources of radiation other than natural background and medical exposures should be limited to 5,000 millirem per year for individuals as a result of occupational exposure and should be limited to 500 millirem per year for individuals in the general population. The dose to individuals due to average natural background radiation is about 130 millirem per year.
(c) Man-rem is an expression for the summation of whole body doses to individuals in a group. Thus, if each member of a population group of 1,000 people received a dose of 0.001 rem (1 millirem), or if 2 people received a dose of 0.5 rem (500 millirem) each, the total man-rem dose in each case would be 1 man-rem.
(d) Although the environmental risk of radiological effects stemming from transportation accidents is currently incapable of being numerically quantified, the risk remains small, regardless of whether it is being applied to a single reactor or a multireactor site.

Source: 10 CFR 51.52

(3) higher-burnup spent fuel (higher than 33,000 MWd/MTU) was cooled for at least 5 years before being shipped offsite. The conditions evaluated in Addendum 1 have not changed, and no new conditions have been introduced that would alter the conclusions in Addendum 1 (NRC 1999a). A later study found that the impacts presented in Table S-4 would bound the potential environmental impacts that would be associated with transportation of spent nuclear fuel with up to 75,000 MWd/MTU burnup, provided that the fuel is cooled for at least 5 years before shipment (Ramsdell et al. 2001). Table S-4 as currently encoded in 10 CFR 51.52 is provided.

Consideration of Environmental Justice

The human health impacts of transporting spent nuclear fuel are addressed in an addendum to the 1996 GEIS (NRC 1999a) in which the agency evaluated the applicability of Table S-4 to future license renewal proceedings given that the spent fuel is likely to be shipped to a single repository. As part of the site characterization and recommendation process for the proposed geologic repository at Yucca Mountain, Nevada, the DOE is required by the Nuclear Waste Policy Act of 1982 to prepare an EIS. By law, the NRC is required to adopt DOE's EIS, to "the extent practicable," as part of any possible NRC construction authorization decision. As a result, DOE prepared and submitted to NRC the *Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (Repository SEIS) DOE/EIS-0250F-S1) (DOE 2008). This document includes analyses that address human health and environmental impacts to minority and low-income populations.

As noted in DOE's Repository SEIS, shipments of spent nuclear fuel (as well as fresh fuel) would use the nation's existing railroads and highways. DOE estimates that transportation-related impacts to land use; air quality; hydrology; biological resources and soils; cultural resources; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; and waste management would be SMALL. The small effect on the population as a whole would be likely for any segment of the population, including minority and low-income populations, as well as members of American Indian Tribes.

DOE did not identify any potentially high and adverse impacts to members of the public from the transport of spent nuclear fuel. DOE determined that subsections of the population, including minority or low-income populations, would not receive disproportionate impacts, and no unique exposure pathways, sensitivities, or cultural practices that would expose minority or low-income populations to disproportionately high and adverse impacts were identified. DOE concluded that no disproportionately high and adverse impacts would result from the national transportation of spent nuclear fuel to Yucca Mountain (DOE 2008). On September 8, 2008, NRC staff recommended that the Commission adopt, with supplementation, DOE's Repository EIS and supplements (73 FR 53284).

In light of the recent DOE decision to not proceed with the Yucca Mountain nuclear waste repository and conduct a comprehensive reevaluation of policies for managing the spent fuel from the nation's nuclear power plants (see Section 4.11.1.3), some or all of the evaluations DOE did for Yucca Mountain may have to be redone.

Environmental Impact Issues of the Uranium Fuel Cycle

Nuclear fuel is needed for the operation of light water reactors during the license renewal term in the same way that it is needed during the current license period. Therefore, the factors that affect the data presented in Tables S-3 and S-4 of 10 CFR 51.51 and 51.52, respectively, do not change whether a light water reactor is operating under its original license or a renewed license. In the 1996 GEIS, there are nine issues that relate to uranium fuel cycle and waste management. Five of these issues that relate to waste management are addressed in Section 4.11.1.

The remaining four impact issues include the following:

- Offsite radiological impacts—individual impacts from other than the disposal of spent fuel and high-level waste (issue was renamed from the 1996 GEIS);
- Offsite radiological impacts—collective impacts from other than the disposal of spent fuel and high-level waste (issue was renamed from the 1996 GEIS);
- Nonradiological impacts of the uranium fuel cycle (issue was renamed from the 1996 GEIS); and
- Transportation (issue from the 1996 GEIS).

Offsite Radiological Impacts—Individual Impacts from Other than the Disposal of Spent Fuel and High-Level Waste

This issue addresses the radiological impacts on individuals who live near uranium fuel cycle facilities. The primary indicators of impact are the concentrations of radionuclides in the effluents from the fuel cycle facilities and the radiological doses received by an MEI on the site boundary or at some location away from the site boundary. As discussed in Section 3.9.1, an MEI can be exposed to radiation from radionuclides found in the effluents of nuclear fuel cycle facilities and from radiation "shine" from buildings, storage facilities, and storage tanks containing radioactive material. The basis for establishing the significance of individual effects is the comparison of the releases in the effluents and the MEI doses with the permissible levels in applicable regulations. The analyses performed by the NRC in the preparation of Table S-3 and found in the 1996 GEIS indicate that as long as the facilities operate under a valid license issued by either the NRC or an agreement State, the individual effects will meet the applicable regulations. On the basis of these considerations, the NRC has concluded that the impacts on individuals from radioactive gaseous and liquid releases during the license renewal term would remain at or below the NRC's regulatory limits. Accordingly, the NRC concludes that offsite radiological impacts of the uranium fuel cycle (individual effects from sources other than the disposal of spent fuel and high-level waste) are SMALL. The efforts to keep the releases and doses at ALARA will continue to apply to fuel-cycle-related activities. This was considered a Category 1 issue in the 1996 GEIS. No new information has been identified that would alter this conclusion.

Offsite Radiological Impacts—Collective Impacts from Other than the Disposal of Spent Fuel and High-Level Waste

The focus of this issue is the collective radiological doses to and health effects on the general public resulting from uranium fuel cycle facilities over the license renewal term. The radiological doses received by the general public are calculated on the basis of releases from the facilities to the environment, as provided in Table S-3. These estimates were provided in the 1996 GEIS for the gaseous and liquid releases listed in Table S-3 as well as for radon-222 and technetium-99 releases, which are not listed in Table S-3. The population dose commitments were normalized for each year of operation of the model 1,000-MWe LWR (RRY).

On the basis of the analyses provided in the 1996 GEIS, the estimated involuntary 100-year dose commitment to the U.S. population resulting from the radioactive gaseous releases from uranium fuel cycle facilities (excluding the reactors and releases of Rn-222 and Tc-99) was estimated to be 400 person-rem (4 person-Sv) for 1 RRY. Similarly, the environmental dose commitment to the U.S. population from the liquid releases was estimated to be 200 person-rem (3 person-Sv) per RRY. As a result, the total estimated involuntary 100-year dose commitment to the U.S. population from radioactive gaseous and liquid releases listed in Table S-3 was given as 600 person-rem (6 person-Sv) per RRY (see Section 6.2.2 of NRC 1996).

The 1996 GEIS also provided a detailed analysis of potential doses to the U.S. population from Rn-222 releases, which primarily occur during mining and milling operations and as emissions from mill tailings, and Tc-99 releases, which primarily occur during the enrichment process (Section 6.2.2 of NRC 1996). The U.S. population doses resulting from the Rn-222 releases and Tc-99 releases for 1 RRY are summarized in Table 4.12-3. The total population dose from all releases to the environment, including the Rn-222 and Tc-99 releases, is given as 938.6 person-rem (9.386 person-Sv) per RRY. Because of an oversight in the 1996 GEIS, the sum of population doses was given as 740 person-rem, and the total dose over the 20-year renewal period was listed as 14,800 person-rem (148 person-Sv) (740 person-rem per RRY multiplied by 20 years). The correct values would be approximately 940 person-rem per RRY and 18,800 person-rem (188 person-Sv) for 20 years.

Table 4.12-3. Population Doses from Uranium Fuel Cycle Facilities Normalized to One Reference Reactor Year

Source	Collective Dose (person-rem)[(a)]
Gaseous releases	400
Liquid releases	200
Rn-222 releases from uranium mining and milling	140
Rn-222 releases from unreclaimed open-pit mines	96
Rn-222 releases from stabilized tailings piles	2.6
Tc-99 releases from enrichment plants	100
Total	938.6

(a) To convert person-rem to person-Sv, multiply by 0.01.
Source: modified from NRC 1996

As discussed in the 1996 GEIS, the dose estimates given above were based on highly conservative assumptions (i.e., the doses are overestimated). In actuality, the doses received by most members of the public would be so small that they would be indistinguishable from the variations in natural background radiation. The 1996 GEIS further estimated the health effects on the general public in terms of cancer fatalities by multiplying the calculated doses by risk conversion factors obtained from the literature. The estimated health effect was stated as 0.6 cancer fatality per RRY, or 12 cancer fatalities for each additional 20-year LWR operating term. The 1996 GEIS also stated that these estimates were highly uncertain and that much of the calculated doses, especially the contribution of radon releases from mines and tailing piles, consisted of tiny doses summed over large populations. It was stated that this practice may result in health effect estimates that may not be meaningful.

There are no regulatory limits applicable to collective doses to the general public from fuel cycle facilities. All regulatory limits are based on individual doses. All fuel cycle facilities are designed and operated to meet the applicable regulatory limits.

As discussed in the 1996 GEIS, despite the lack of definitive data, some judgment as to the regulatory NEPA implications of these matters should be made and it makes no sense to repeat the same judgment in every case. The Commission concludes that these impacts are acceptable in that these impacts would not be sufficiently large to require the NEPA conclusion, for any plant, that the option of extended operation under 10 CFR Part 54 should be eliminated. Accordingly, while the Commission has not assigned a single level of significance for the collective effects of the fuel cycle; this issue was considered Category 1. No new information has been identified that would alter this conclusion.

Nonradiological Impacts of the Uranium Fuel Cycle

This section addresses the nonradiological impacts associated with the uranium fuel cycle facilities as they relate to license renewal. Data on the nonradiological impacts of the fuel cycle are provided in Table S-3. These data cover land use, water use, fossil fuel use, and chemical effluents. The significance of the environmental impacts associated with these data was evaluated in the 1996 GEIS on the basis of several relative comparisons. The land requirements were compared to those for a coal-fired power plant that could be built to replace the nuclear capacity if the operating license is not renewed. Water requirements for the uranium fuel cycle were compared to the annual requirements for a nuclear power plant. The amount of fossil fuel (coal and natural gas) consumed to produce electrical energy and process heat during the various phases of the uranium fuel cycle was compared to the amount of fossil fuel that would have been used if the electrical output from the nuclear plant were supplied by a coal-fired plant. Similarly, the gaseous effluents SO_2, NO, hydrocarbons, CO, and PM released as a consequence of the coal-fired electrical energy used in the uranium fuel cycle were compared with equivalent quantities of the same effluents that would be released from a 45-MWe coal-fired plant. It was noted that the impacts associated with uses of all of the above resources would be SMALL. Any impacts associated with nonradiological liquid releases from the fuel cycle facilities would also be SMALL. As a result, the aggregate nonradiological impact of the uranium fuel cycle resulting from the renewal of an operating license for a plant would be SMALL, and it was considered a Category 1 issue in the 1996 GEIS. No new information has been identified that would alter this conclusion.

Transportation

This section addresses the impacts associated with transportation of fuel and waste to and from one light water reactor during the license renewal term. Table S-4 in 10 CFR 51.52 forms the basis for analysis of these impacts in evaluating the applications for license renewal from owners of light water reactors. As discussed previously in this section, the applicability of Table S-4 for license renewal applications was extensively studied in the 1996 GEIS (NRC 1996) and its Addendum 1 (NRC 1999a). The impacts were found to be SMALL, and the findings were stated as follows:

> The impacts of transporting spent fuel enriched up to 5 percent uranium-235 with average burnup for the peak rod to current levels approved by NRC up to 62,000 MWd/MTU and the cumulative impacts of transporting high-level waste to a single repository, such as Yucca Mountain, Nevada are found to be consistent with the impact values contained in 10 CFR 51.52(c), Summary Table S-4, “Environmental Impact of Transportation of Fuel and Waste to and from One Light-Water-Cooled Nuclear Power Reactor.” If fuel enrichment or burnup

conditions are not met, the applicant must submit an assessment of the implications for the environmental impact values reported in 10 CFR 51.52.

The issue was assigned to Category 1. No new information has been identified that would alter this conclusion.

4.12.1.2 Replacement Power Alternative Fuel Cycles

Fossil Fuel Energy Alternatives

The environmental consequences of the fuel cycle for a fossil-fuel-fired plant result from the initial extraction of the fuel from its natural setting, fuel cleaning and processing, transport of the fuel to the facility, and management and ultimate disposal of solid wastes resulting from combustion of the fuel.

The environmental impacts of coal mining vary with the location and type of mining technology employed, but generally includes:

- Significant change in land uses, especially when surface mining is employed.
- Degradation of visual resource values.
- Air quality impacts, including release of criteria pollutants from vehicles and equipment, release of fugitive dust from ground disturbance and vehicle travel on unpaved surfaces, release of VOCs from the storage and dispensing of vehicle and equipment fuels and the use of solvents and coatings in maintenance activities, and release of coalbed methane into the atmosphere as coal seams are exposed and overburden removed.
- Noise impacts from the operation of vehicles and equipment and the possible use of explosives.
- Impacts on geology and soils due to land clearing, excavations, soil and overburden stockpiling (for strip mining operations), and mining.
- Water resources impacts, including degradation of surface water quality due to increased sediment and runoff to surface water bodies, possible degradation of groundwater resources due to consumptive use and potential contamination (especially when shaft mining techniques are employed), as well as generation of wastewater from coal cleaning operations and other supporting industrial activities.

- Ecological impacts, including extensive loss of natural habitat, loss of native vegetative cover, disturbance of wildlife, possible introduction of invasive species, changes to surface water hydrology, and degradation of aquatic systems.

- Impacts on historic and cultural resources within the mine footprint, as well as additional potential impacts resulting from auxiliary facilities and appurtenances (e.g., access roads, rail spurs).

- Direct socioeconomic impacts from employment of the workforce and indirect impacts from increased employment in service and support industries.

- Potential environmental justice impacts as a result of the presence of low-income or minority populations in the surrounding communities and/or within the workforce.

- Potential health impacts on workers from exposure to airborne dust, gases such as methane, and exhaust from internal combustion engines on vehicles and mining machinery.

- Generation of coal wastes and industrial wastes associated with the maintenance of vehicles and equipment; increased potential for spills of fuels from onsite fuel storage and dispensing.

New Nuclear Energy Alternatives

Environmental impacts of the fuel cycle result from the initial extraction of the fuel from its natural setting, transport of the fuel to the facility, and management and ultimate disposal of solid wastes resulting from combustion of the fuel. For the fuel cycle associated with a nuclear power plant, these activities include uranium mining and milling, the production of uranium hexafluoride, isotopic enrichment, fuel fabrication, reprocessing of irradiated fuel, transportation of radioactive materials, and management of low-level wastes and high-level wastes (10 CFR Part 51). The NRC has summarized environmental data associated with the uranium fuel cycle in Table S-3 of 10 CFR 51.51. The analysis provides a basis for evaluating environmental effects of the fuel cycle for all nuclear power plants, regardless of site location. The information is based on a 1000-MW LWR with an 80 percent capacity factor. The impacts associated with the transportation of fuel and waste to and from a power reactor are summarized in Table S-4 of 10 CFR 51.52. Detailed analysis of the uranium fuel cycle is also considered in Section 4.12.1.1. Although it is specific to the impacts of license renewal, it is applicable to the new nuclear plant alternative because the advanced reactor designs use the same type of fuel as existing operational designs. One difference may be that the new reactor may have a power rating of greater than 1,000 MWe, which may exceed the power rating of the existing reactor. In those cases, the impacts would be proportionally higher. However, all impacts associated with the uranium fuel cycle, as discussed in Section 4.12.1.2, would still be SMALL.

Renewable Energy Alternatives

The term “fuel cycle” has varying degrees of relevance for renewable energy facilities. Clearly, the term has meaning for renewable energy technologies that rely on combustion of fuels such as biomass grown or harvested for the express purpose of power production. The term is somewhat more difficult to define for renewable technologies such as wind, solar, geothermal, and ocean wave and current. Those natural energy resources exist regardless of any effort to harvest them for electricity production. The common technological strategy for harvesting energy from such natural resources is to convert the kinetic or thermal energy inherent in that resource to mechanical energy or torque. The torque is then applied directly (e.g., as in the case of a wind turbine) or indirectly (e.g., for those facilities that utilize conventional steam cycles to drive turbines that drive generators) to produce electricity. However, because those renewable technologies capture very small fractions of the total kinetic or thermal energy contained in those resources, impacts from the presence or absence of the renewable energy technology are often indistinguishable.

Environmental consequences of fuel cycles for biomass (e.g., energy crops, wood wastes, municipal solid waste, refuse-derived fuel, landfill gas) include the following:

- Land use impacts from the growing and harvesting of the energy crops.
- Reduced impacts on land from the avoidance of land disposal of anthropogenic biomass feedstocks such as municipal solid waste and refuse-derived fuel.
- Visual impacts from the establishment of farm fields and forest areas and processing facilities for the growing, harvesting, and preparation of biomass feedstocks.
- Air impacts from operation of vehicles and equipment used in the planting, cultivating, and harvesting of energy crops.
- Reductions in greenhouse gas emissions from landfills as a result of the capture and destruction by combustion of landfill gas for energy production.
- Removal of greenhouse gases from the air (e.g., CO_2) by growing crops.
- Noise impacts from the operation of agriculture and silviculture equipment and transport vehicles in otherwise rural settings with low ambient noise levels.

- Soil impacts from the cultivation of fields and the potential for increased sediment in precipitation runoff.

- Hydrologic impacts from irrigation of the energy crops; impacts on groundwater resources from water removal for agricultural or silvicultural purposes or industrial water uses associated with the preparation of biomass feedstocks.

- Ecological impacts from the loss of habitat resulting from crop production; loss of hydrologic resources due to diversion for irrigation purposes; potential intrusion of invasive species on disturbed land surfaces, and potential contamination of adjacent habitat by pesticide and fertilizer runoff.

- Ecological impacts from the alteration of habitat due to human presence and activities in agricultural and silvicultural areas.

- Historic and cultural resource impacts from inadvertent destruction of resources in virgin fields that have not undergone appropriate efforts to survey, identify, and relocate cultural resources that may be present.

- Human health impacts from the exposure of workers to pesticides and fertilizers used in growing biomass fuels; work around mechanical planting, cultivating, and harvesting equipment; work in weather extremes; and exposure to dangerous plants and wildlife.

- Waste impacts in the form of residual wastes from the application of pesticides and fertilizers and wastes associated with the routine maintenance of equipment and vehicles used in crop production and transport (used lubricating oils, hydraulic fluids, glycol-based coolants, and battery electrolytes from maintenance of equipment and vehicles with internal combustion engines).

- Positive economic impacts from the creation of jobs in the agriculture, silviculture, and transportation sectors.

4.12.2 Environmental Consequences of Terminating Power Plant Operations and Decommissioning

This section describes the environmental impacts associated with the termination of operations and the decommissioning of a nuclear power plant and replacement power alternatives. All operating power plants will terminate operations and be decommissioned at some point after the end of their operating life or after a decision is made to cease operations. For the proposed action, license renewal would delay this eventuality for an additional 20 years beyond the current license period. The impacts of decommissioning nuclear plants were evaluated in the

Generic Environmental Impact Statement for Decommissioning Nuclear Facilities: Supplement 1, Regarding the Decommissioning of Nuclear Power Reactors, NUREG-0586 (NRC 2002a). For replacement power alternatives, the environmental consequences from the termination of power plant operations and the decommissioning a fossil fuel energy facility or renewable energy systems would be similar.

4.12.2.1 Termination of Operations and Decommissioning of Existing Nuclear Power Plants

This section describes and discusses the environmental consequences of terminating nuclear power plant operations and decommissioning, but the only impacts attributable to the proposed action (license renewal) are the effects of an additional 20 years of operations on the impacts of decommissioning. The majority of the impacts associated with plant operations would cease with reactor shutdown; however, some impacts would remain unchanged, while others would continue at reduced or altered levels. Some new impacts might also result directly from terminating nuclear power plant operations. Ancillary systems that are dedicated solely to reactor operations would cease operations completely; however, impacts from their physical presence could continue if they were not removed coincident with reactor shutdown. For sites with more than one unit, the operation of any ancillary systems that supported the units that continued to operate would be reduced in proportion to the reduced demand on them but would not stop entirely. Impacts associated with the mere physical presence of dedicated systems that remained in place or shared ancillary systems that continued to operate would remain unchanged.

Terminating nuclear power plant operations would result in the cessation of actions necessary to maintain the reactor, as well as a significant reduction in the workforce. NRC presumes that terminating nuclear power plant operations would not immediately lead to the dismantlement of the reactor or other infrastructure, much of which would still be in use to support other units onsite that continued to operate. Even for sites with just one unit, some facilities would remain in operation to ensure that the site was maintained in safe shutdown condition. Electrical generators might continue to operate as synchronous condensers to stabilize voltage on the bulk electricity grid to which the reactor was connected.

Three decommissioning options were analyzed in the decommissioning GEIS (NRC 2002a) and are referenced in this section: DECON, SAFSTOR, and ENTOMB. In the DECON option, the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed and safety buried in a low-level radioactive waste landfill or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations. In the SAFSTOR option, the nuclear facility is placed and maintained in such condition that the nuclear facility can be safely stored and subsequently decontaminated to levels that permit release for restricted or unrestricted use. Finally, with the ENTOMB option, radioactive contaminants are encased in a structurally long-lived material, such as concrete. The entombment structure is appropriately maintained and continued surveillance is carried out until the radioactivity decays to a level permitting unrestricted release of the property.

Land Use

The termination of nuclear power plant operations would cause a reduction in the workforce at a nuclear plant, and the value placed on the facility for tax purposes would likely depreciate. The impact on taxing authorities that receive revenue from the nuclear power plant would depend on the percentage of revenue that they derived from the plant. Depending on the future need to replace electrical generating capacity, a replacement power plant could change the tax base and impact offsite land use. However, existing substations are expected to remain and be maintained after the termination of reactor operations to support the power grid.

Temporary onsite land use changes during decommissioning are anticipated to be comparable to changes that occur during construction and operations and would not require additional land. The major activities that require land temporarily include the staging of equipment, accommodation of workers (e.g., parking, training, site security access, office space, changing facilities), and removal of large components. The locations of these areas would depend on the layout of the plant. Temporary changes in onsite land use would not change the fundamental use of the reactor site.

There would be no difference in offsite land use impacts whether decommissioning occurred at the end of its current 40-year operating license or following a 20-year license renewal term. In either case, the impact of license renewal after terminating plant operations and decommissioning on onsite and offsite land use would be SMALL and generic at all nuclear plants.

Visual Resources

Terminating nuclear power plant operations would not change the visual appearance of the nuclear power plant. The most notable change, however, would be the elimination of the condensate plumes from cooling towers (under certain meteorological conditions). The appearance of the plant would change as structures are removed.

Decommissioning may involve the demolition and dismantlement of one or more of the main buildings or structures at a nuclear power plant. A case study conducted for the 1996 GEIS found a limited number of situations in which the presence of nuclear power plants fostered perceptions of adverse impacts on visual resources. License renewal would delay decommissioning and prolong the visual impact. As discussed in the decommissioning GEIS

(NRC 2002a), the visual impact of the nuclear plant site may not improve following decommissioning because the site could remain in industrial use.

Transmission lines and ROWs are expected to continue operating and to cause little or no additional impacts beyond those that have already occurred. A 20-year delay caused by license renewal would have no visual impact from continued transmission line operation.

Visual resource impacts associated with terminating plant operations and decommissioning after a 20-year license renewal will not change as a consequence of the delay. The impact of license renewal on visual resources would be SMALL for all nuclear plants.

Air Quality

After the termination of operations, air emissions from the nuclear power plant would continue, but at greatly reduced levels. Air quality impacts would range from very small and would approach undetectable levels. Natural or mechanical draft cooling tower drift would be greatly reduced or would be eliminated. Air emissions from ancillary facility operations (e.g., boilers, emergency diesel generators) would continue until decommissioning.

The NRC evaluated the following activities in the decommissioning GEIS (NRC 2002a) that could impact air quality:

- Worker transportation to and from the site;
- Demolition of buildings and structures, including new structures added during refurbishment;
- Shipment of materials and debris to offsite locations;
- Operation of concrete batch plants (e.g., ENTOMB decommissioning option);
- Dismantling of systems and removing of equipment; and
- Movement and open storage of material onsite.

These activities typically occur over a period of years, from the time the facility ceases operation until the decommissioning is complete. The magnitude and the timing of the potential impacts of each decommissioning activity would vary from plant to plant.

Building and major plant structure demolition and the operation of the batch plant during decommissioning would have the greatest impact on air quality. Fugitive dust would vary in the size of the particles released. Depending on meteorological conditions, larger particles would settle to the ground near the demolition site.

Demolition would generally be limited to a small number of short-duration events. Mitigation measures, such as synchronized scheduling and the application of water sprays or chemical dust suppressants, could minimize the amount of fugitive dust released from the site.

The ENTOMB decommissioning option would require large amounts of concrete and aggregate. Unloading dry cement at the concrete batch plant and loading mixers or trucks would generate large amounts of dust. Depending on meteorological conditions, large particles of dust would settle out of the air quickly, and air quality impacts would be localized near the concrete batch plant. Dust control measures used at concrete batch plants include enclosed dumping and unloading areas and conveyors and filters and water sprays.

The NRC concluded that the impact of decommissioning on air quality would be SMALL for all plants in the decommissioning GEIS (NRC 2002a). The impact on air quality after the license renewal term is not expected to be different from the impact that would have occurred without license renewal.

Noise

During decommissioning, noise would generally be far enough away from sensitive receptors outside the plant boundaries that the noise would be attenuated to nearly ambient levels and would be scarcely noticeable offsite (NRC 2002a). However, during the demolition of concrete, the noise levels offsite could be loud enough (60 to 65 dB at the nearest receptor site) that activities might need to be curtailed during early morning and evening hours. It is highly unlikely, on the basis of past decommissioning experience, that the offsite noise level from a plant during decommissioning would be sufficient to cause hearing loss. However, in one case, noise from decommissioning of a spent fuel pool's cooling system was reported to be up to 107 dB near the source, but it dropped to 50 dB at distances less than 1 mi (1.6 km) away (NRC 2002a). Nearby residents complained about these noise levels; engineering changes were made to the fans that were causing the noise, and the issue was resolved. Noise abatement procedures could also be used during decommissioning in order to reduce noise.

The NRC concluded that the noise impact of decommissioning would be SMALL for all plants in the decommissioning GEIS (NRC 2002a). The noise impact from terminating nuclear plant operations and decommissioning after the license renewal is not expected to be different from the impact that would have occurred without license renewal.

Geology and Soils

Termination of nuclear plant operations is not expected to impact geology and soils. Heavy construction equipment would be engaged in demolition activities during decommissioning. These vehicles would primarily use paved surfaces, but would also cross open ground in some locations. This would create the possibility for soil erosion from areas formerly covered with lawns or natural grasses. The demolition and removal of buildings, foundation slabs, parking lots, and roads, would expose more soil to possible erosion.

High slopes and surface runoff increase erosion potential. The soil distribution across a site may include some soils that are more susceptible to water or wind erosion. The loss of soil increases the turbidity in surface water draining off the site.

Erosion problems could be mitigated by using BMPs during decommissioning. These include, but are not limited to, minimizing the amount of disturbed land; stockpiling topsoil before construction or regrading; replacing the topsoil and adding seed and mulch in disturbed areas as soon as possible after disturbance; using silt fences to reduce sediment loading to surface water; using check dams to minimize the erosive power of drainages or creeks; and installing proper culvert outlets to minimize erosion in creeks.

Site geologic resources would not be affected by decommissioning. Geologic resources in the form of gravel or crushed stone might be needed to construct temporary roads that would be used by the heavy equipment involved in demolition.

The impact from terminating plant operations and decommissioning on geology and soils after a license renewal is not expected to be significantly different from the impacts that would have occurred without license renewal.

Water Resources—Surface Water and Groundwater

After the termination of plant operations, water use would be dramatically reduced; however, water demands would continue for the service water system to support such activities as temperature control of the spent fuel pool and other miscellaneous industrial maintenance applications. Surface water or groundwater intake and consumptive use would be very low compared with use during the operational phase. Discharge of liquid wastes and biocides would also be proportionately reduced.

Because the site workforce would be reduced, the volume of sanitary sewage effluent would be less than it had been during the operational period. Pumping rates for groundwater used for the potable water system after the termination of plant operations would also decrease because of the reduced workforce.

Environmental Consequences and Mitigating Actions

Impacts to site hydrology and water quality from soil erosion and storm events are expected to be unchanged from the operational period. Such erosion would be mitigated as part of general site maintenance during any phase in the power plant's life cycle.

The possibility of groundwater becoming contaminated through chemical spills or radionuclide release would be smaller after operations cease.

Dewatering, if needed to maintain the stability of structure foundations, is expected to continue as it did during the operational phase.

During decommissioning, the activities that have the potential to affect water use include:

- Maintenance of the spent fuel pool,
- Staffing changes (generally the staff size is decreased),
- Cooling of cutting equipment during removal of the reactor vessel and internals,
- High-pressure sprays of water on surfaces during decontamination,
- Dust suppression during destruction of structures, and
- The making of concrete for facility entombment.

The activities identified in the decommissioning GEIS (NRC 2002a) that have the potential to affect water quality include:

- Maintenance of the spent fuel pool,
- Draining and flushing of the cooling systems and processing of the liquid,
- High-pressure sprays of water on surfaces during decontamination, and
- Management of water used in dust suppression during destruction of structures.

At individual sites, the source of water for each of these uses may be surface water or groundwater. The decision on which source of water to use may ultimately be based on a combination of availability, infrastructure, permitting, and water quality and chemistry.

Some of the activities listed above could affect surface water quality. These include the use of high-pressure sprays of water during decontamination, dust suppression, and equipment cooling, and the discharge of various process waters. For decontamination, BMPs would need to be followed to manage the sprayed water. Both the decontamination water and the process waters would need to be discharged in accordance with NPDES permit requirements.

The early stages of decommissioning and dismantling may involve a temporary, slight increase in the size of the overall workforce (NRC 2002a). The amount of sanitary system discharge would therefore increase slightly. Depending on when any onsite wastewater treatment plant, onsite septic system, or municipal sewage system connection would stop operating, temporary portable toilet facilities might be used for the decommissioning workforce. The number and capacity of such facilities would depend on the size of the workforce, which could vary during different phases of the decommissioning process.

In the decommissioning GEIS (NRC 2002a), evaluations focused on water use and water quality. The following activities were identified as having the potential to affect surface water:

- Cooling water systems,
- Discharge from dewatering systems, and
- Stormwater management and erosion control.

Surface water would remain the largest source of water used during decommissioning; it would be used to cool the spent fuel. However, this usage, as well as makeup water requirements, would be significantly smaller than during reactor cooling at an operating power plant. Demand for spent fuel cooling water would decrease over time as the fuel aged. Other activities listed above would also require amounts of water that would be low compared to cooling and makeup water requirements.

Dewatering systems would continue to discharge to surface water. The effect on surface water quality would be unchanged from the effect during the operational phase.

Stormwater management and erosion control would continue to be maintained during decommissioning to reduce the potential for effects on surface water quality, especially turbidity. Soil erosion can be minimized through BMPs, as discussed in Section 4.4.1. Chemical spills during decommissioning also have the potential to affect surface water quality. However, BMPs for handling fuels and other chemicals used in the operational phase should continue to be in place.

The natural variability in the climate, especially precipitation, has the potential to influence the availability of surface water. However, because it seems that there have not been any surface water availability problems at operating power plants with relatively higher water requirements for reactor cooling, severe drought is not expected to affect decommissioning.

In the decommissioning GEIS (NRC 2002a), the NRC concluded that the impacts on water use and water quality from decommissioning would be SMALL for all plants. The effect of license renewal on the water quality impacts from decommissioning was considered a Category 1 issue in the 1996 GEIS. On the basis of a review of current information, these conclusions are considered valid for surface water. An additional 20 years of operation during the license renewal term would not change the magnitude of these impacts.

The activities listed above include some that may affect groundwater quality through the infiltration of water used for various purposes (e.g., cooling of cutting equipment, decontamination spray, and dust suppression). Best management practices are expected to be employed as appropriate to collect and manage these waters.

In the decommissioning GEIS (NRC 2002a), evaluations focused on water use and water quality. The following activities were identified as having the potential to affect groundwater:

- Potable water from wells,
- Dewatering systems, and
- Leachate from rubble.

Potable water would be required during decommissioning. The typical source for this supply is onsite groundwater, though surface water or an offsite municipal source of surface water or groundwater may be used at some sites. The early stages of decommissioning and dismantling may involve a temporary, slight increase in the size of the workforce, and a proportional increase in the need for potable water may occur (NRC 2002a).

Dewatering is expected to continue as it does during the operational phase, without increased drawdown at nearby onsite or offsite wells.

The NRC proposed that groundwater chemistry may change as rainwater infiltrates through rubble. The increased pH could promote the subsurface transport of radionuclides and metals. However, this effect is expected to occur only over a short distance as a function of the buffering capacity of soil (NRC 2002a). Offsite transport of groundwater contaminants is not expected.

In the decommissioning GEIS (NRC 2002a), the NRC concluded that the impacts on water use and water quality from decommissioning would be SMALL for all plants. The effect of license renewal on the water quality impacts from decommissioning was considered a Category 1 issue in the 1996 GEIS. On the basis of a review of current information, these conclusions are considered valid for groundwater. An additional 20 years of operation during the license renewal term would not change the magnitude of these impacts.

Ecological Resources

The termination of nuclear power plant operations would reduce some impacts and eliminate others. Impacts from systems that continue operating to support other units (i.e., where the license term for each unit does not end at the same time) on the plant site may continue to affect terrestrial or aquatic biota, but at a reduced level of impact.

Impacting factors that would cease following reactor shutdown would include cooling tower drift, cooling system maintenance and effluent discharges, and atmospheric emissions of radionuclides. If there are other reactor units at the power plant and they continue to operate, these factors would be reduced, but not eliminated. A number of impacting factors would continue to affect terrestrial resources, however. Until removed during decommissioning, cooling towers and transmission lines would continue to be collision hazards for birds.

Impacting factors on aquatic resources that are expected to stop or decrease after reactor shutdown include the withdrawal of water for cooling, discharge of heated cooling water, dredging activities, and onsite construction activities. Cooling demands of a reactor in cold shutdown will be greatly reduced, as will be the rate of water withdrawal to maintain appropriate water volumes and chemical quality in the cooling system. However, water withdrawal may not be completely eliminated unless or until fuel assemblies are removed from the reactor core. Also, water withdrawal rates will continue unchanged to support other units and facilities onsite that remain operational. Nevertheless, the impingement and entrainment of aquatic organisms would substantially decrease after plant operations cease, and the potential for impacts on aquatic communities from these factors would be reduced. In general, the termination of entrainment and impingement would have positive effects on affected organisms.

As identified in Section 4.6.1.2, the discharge of heated cooling water during operations has the potential to affect aquatic resources by altering the thermal regimes to which aquatic organisms are exposed, lowering the level of dissolved oxygen, and promoting gas supersaturation. Because the plant would discharge significantly smaller volumes of heated water after operations cease, the NRC anticipates that the plant’s influence on the thermal conditions in the receiving waters would be greatly reduced.

During the years of plant operations, it is likely that an aquatic community that was acclimated to warmer temperatures and biocides would have developed within the mixing zone. Some aquatic organisms may have become established in the mixing zone because of the warmer environment, and these organisms likely would be adversely affected as the water temperature cooled and the original conditions were restored within the body of water. Organisms susceptible to cold shock could be affected, depending on the timing and rate of change in water temperatures. Such effects, which occur primarily during winter months, would occur only during the initial period after the plant ceases operations, and they could be minimized by initiating reactor shutdown during seasons when cold shock would be less likely to occur and by gradually reducing inputs of heated effluent to the system. As a consequence of the return to a more natural thermal regime, it is anticipated that the composition of the aquatic organisms in that area would return to a composition similar to that in the surrounding areas of the receiving waters. Recovery of an aquatic community to the normal background composition is a process of variable duration that depends on the mobility of the organisms, sources of colonists, rate of growth and maturation of the species, and other factors (Cairns 1990). Populations of some invasive species, such as the water hyacinth (*Hydrilla verticillata*) that proliferates at the North Anna plant in Virginia as a result of the elevated temperature of discharges, may decline as water temperatures in the receiving body of water fall.

The impacts from the termination of nuclear power plant operations on a cooling pond depend largely on whether the pond continues to exist. For cooling ponds that are maintained during plant operation by pumping water from another water body, the ponds would likely revert to a terrestrial system after pumping stopped. Even if ponds are maintained by natural flow, water may no longer be impounded. Restoration of these previously impounded areas may be necessary to minimize adverse ecological impacts associated with the exposure of previously inundated substrates. If the ponds continued to exist, the nuclear plant's thermal effects on them would cease. Cessation of the heated effluent would change the composition and dynamics of the pond community until it resembled that of other ponds in the region not used for cooling.

Because there would no longer be a need to withdraw or discharge cooling water, it is also anticipated that dredging would no longer be needed in the vicinity of cooling water structures. Therefore, the potential for dredging to affect aquatic biota would also be eliminated, unless the cooling water system was still needed to cool other electrical generating systems. As described in Section 4.6.1.2, gas supersaturation has the potential to occur within the mixing zone of some power plants. Even though such effects have been reduced with mitigation measures, such as the use of diffusers in the discharge area, the potential for gas supersaturation and subsequent effects on biota as a result of plant operations would be eliminated or decrease from the potential under the proposed action. Activities that result in ground disturbance (e.g., new construction, maintenance of some areas) may also cease or decrease at power plants that are shut down as a consequence of the no-action alternative, but there would be some level of maintenance needed until the plant was decommissioned. This would result in a decrease or the cessation of potential effects on aquatic resources from the direct disturbance of aquatic habitats and the sedimentation that could occur as a result of ground disturbance in adjacent areas.

Because some structures may be left in place until decommissioning has been completed or longer, there is a potential for some effects on aquatic resources to continue regardless of whether or not the reactor at a plant is operating. For example, dams and associated reservoirs constructed to maintain supplies of water for operational needs may continue to prevent migration of anadromous fish unless the structures are removed. In addition, maintenance activities would continue along the transmission line ROWs regardless of whether the plant is operating or not.

At coastal plants, the termination of nuclear plant operations could have a beneficial impact on the Federally listed loggerhead sea turtle (threatened), green sea turtle (*Chelonia mydas*, threatened), leatherback sea turtle (endangered), hawksbill sea turtle (endangered), and Kemp's ridley sea turtle (endangered), which have been impinged at several nuclear power plants (e.g., St. Lucie and Oyster Creek). Similarly, potential benefits to the Federally endangered West Indian manatee and pinnipeds, protected under the Marine Mammal Protection Act, could occur. For example, the West Indian manatee has been impinged at St. Lucie, and incidental takes of harbor seals, gray seals, harp seals, and hooded seals occur at the Seabrook plant. Elimination of high-temperature discharges at plants in Florida may reduce habitat suitability for the West Indian manatee, particularly during winter. However, the West Indian manatee occupies other habitats in Florida that do not have artificially elevated temperatures, and it uses a number of thermal discharges from fossil fuel plants along both coasts of Florida (Laist and Reynolds 2005). Potential impingement and entrainment losses of special status fish species could also decrease. Reactor shutdown could also decrease impacts on EFH, although only minimal adverse effects have been identified for the operating plants for which EFH assessments have been prepared (e.g., Pilgrim, Vermont Yankee, and Oyster Creek plants).

The NRC evaluated the potential impacts of decommissioning on ecological resources in the decommissioning GEIS (NRC 2002a). The conclusions of that evaluation are summarized here, but the focus of the present evaluation is on the incremental effects that would result from deferring decommissioning to a later date as a result of renewing the license for plant operations. In the 1996 GEIS, the NRC concluded that the ecological impacts of decommissioning activities would be the same with or without license renewal and was designated a Category 1 issue.

The NRC (2002a) evaluated potential impacts on terrestrial ecological resources during the decommissioning process via both direct and indirect disturbance of native plant or animal communities in the vicinity of the plant site. In most cases, the impacting factors and the potential impacts from decommissioning activities are similar to impacts that could occur as a consequence of continued operations and refurbishment activities at operating facilities. Direct impacts of decommissioning on terrestrial ecological resources could result from activities such as the clearing of native vegetation or filling of a wetland. Indirect impacts could result from erosion, dust, or noise. In most cases, land disturbances during decommissioning would result in relatively short-term impacts, and the land would either recover naturally or would be landscaped appropriately for an alternative use after completion of decommissioning (NRC 2002a). The NRC determined that impacts on terrestrial resources from dust generation, noise, surface erosion and runoff, and migratory bird collisions associated with decommissioning would be minor and would continue only until decommissioning activities were completed (NRC 2002a). The effects of such impacts could be minimized by using standard best management practices.

At most commercial nuclear facilities, there is a relatively distinct operational area where most or all site activities occur. This operational area usually includes all areas within the protected area fence; the intake, discharge, cooling, and other associated structures; and adjacent paved, graveled, and maintained landscaped areas. The operational area may include the entire area disturbed during facility construction, but it is often considerably smaller. In most cases, the amount of land required to support the decommissioning process is relatively small and is a small portion of the overall plant site. Usually, the areas disturbed or used to support decommissioning are within the operational areas of the site and are also within the protected area. Decommissioning activities conducted within the operational areas are not expected to have a detectable impact on important terrestrial resources (NRC 2002a). However, it is expected that some sites will require the reconstruction or installation of new transportation links, such as railroad spurs, road upgrades, or barge slips, for the completion of decommissioning. The NRC (2002a) concluded that for facilities at which the decommissioning activities would be limited to existing operational areas, the potential impacts on terrestrial ecology would be SMALL. It was further concluded that if habitat disturbance beyond the operational areas is anticipated, the impact on terrestrial resources could be SMALL, MODERATE, or LARGE and would have to be determined through a site-specific analysis.

In most cases, the impacting factors and the potential impacts on aquatic resources from decommissioning activities are similar in nature to impacts that could occur as a consequence of refurbishment activities for operating facilities. Direct impacts of decommissioning on aquatic resources could result from activities, such as removing shoreline or in-water structures (i.e., the intake or discharge facilities); dredging a stream, river, or ocean bottom; or depositing fill in a stream or bay. Indirect impacts could result from effects such as runoff and sedimentation from disturbed upland areas (NRC 2002a). During decommissioning, aquatic habitats at the plant site might also be disturbed in order to construct support facilities, such as a dock for barges or a bridge over a stream or some other body of water. In addition, aquatic environments away from the plant site could be disturbed during the upgrading or installation of new transportation systems (e.g., a new rail line to support the removal of large components) or during the installation or modification of transmission lines. In most cases, aquatic habitat disturbances from decommissioning would result in relatively short-term impacts on small areas, and either the affected aquatic habitats would recover naturally or the impacts could be mitigated

(NRC 2002a). Typically, these impacts would be temporary and would not detectably alter or destabilize important ecological attributes (NRC 2002a).

If decommissioning did not include removal of shoreline or in-water structures and if all decommissioning activities were confined to the plant operational areas, impacts from decommissioning on aquatic resources would be expected to be minor and would result primarily from increased sediment from physical alterations of the site. In such cases, it is expected that the impact on aquatic resources would be nondetectable, nondestabilizing, and easily mitigated (NRC 2002a). Greater impacts on aquatic resources could occur if decommissioning entailed the removal of structures from the shoreline or in-water environment, removal of contaminated soil in or near an aquatic environment, or dredging and significant modification of barge loading facilities (NRC 2002a).

Permits for discharge to the aquatic environment during operations are almost always for discharge amounts that are greater than planned or realized during decommissioning. In almost all cases examined, licensees expect to restrict activities to previously disturbed areas and operate within the limits of operational permits (NRC 2002a). The NRC (2002a) concluded that for facilities at which the decommissioning activities would be limited to existing operational areas, the potential impacts on aquatic resources would be SMALL. It further concluded that if habitat disturbance beyond the operational areas was anticipated, the impacts on aquatic resources could be SMALL, MODERATE, or LARGE and would have to be determined through site-specific analysis.

In most cases, the impacting factors and the potential impacts on threatened or endangered species (including other special status species or habitats) from decommissioning activities are similar in nature to impacts that could occur as a consequence of refurbishment activities for operating facilities. These species could be affected during the decommissioning process, either through direct effects or through disturbances of habitats on which the species rely for food or shelter. If a nuclear plant ceased operations for an extended period of time, the situation could allow the establishment of onsite populations of protected species that could be adversely affected by subsequent facility decommissioning at the end of the storage period (NRC 2002a).

The greatest potential for impacts from decommissioning on protected species is associated with physical alteration or dismantlement of the facilities, landscape, or aquatic environment. The impacts of decommissioning could result from activities similar to those described for terrestrial and aquatic resources. The NRC (2002a) concluded that the potential impacts on threatened and endangered species may be SMALL, MODERATE, or LARGE and that the adverse impacts and associated significance of the impacts must be determined on a site-specific basis.

The impacts of decommissioning on ecological resources depend primarily on the types of decommissioning activities that are conducted and whether those activities occur inside or outside the existing operational area. Although many of the activities that could affect ecological resources during decommissioning are the same as the activities that occur during the normal operation of a nuclear power plant, the length of time that operations have been ongoing will not change the level of impacts associated with decommissioning. Therefore, deferring decommissioning by renewing a plant's license would have the same impacts on ecological resources, if any, as would occur as a result of starting decommissioning sooner. The impact from the termination of plant operations and decommissioning on ecological resources attributable to license renewal would be SMALL for all nuclear plants.

Historic and Cultural Resources

The termination of nuclear plant operations would not affect historic or cultural resources.

The NRC conducted an analysis of the potential effects of decommissioning on historic and archaeological (cultural) resources and found that the potential onsite impacts at sites where the disturbance of lands would not go beyond the operational areas would be SMALL (NRC 2002a). The continued operation of a plant under a renewed license would not be expected to alter this conclusion. Similar activities are expected to continue before and after license renewal. The majority of impacts on historic and cultural resources would have occurred during the original construction of the plant. Continued use has the potential to affect these resources, as discussed in Section 4.7.1. There is nothing inherent in using a plant for a longer time that would increase or decrease the impact on these resources from decommissioning. Adherence to procedures that take into account the impact on historic and cultural resources would mitigate any additional impacts.

Delaying decommissioning is not expected to have any effect on historic and cultural resources within a transmission line ROW. Impacts on historic and cultural resources would likely have occurred during initial construction. On the basis of these considerations, the effect of license renewal on the impacts from the termination of plant operations and decommissioning would be SMALL for all nuclear plant sites.

Socioeconomics

Terminating nuclear plant operations would have a noticeable impact on socioeconomic conditions in the region around the nuclear power plant. There would be immediate socioeconomic impacts from the loss of jobs (some, though not all, employees would begin to leave after power plant shutdown); and tax revenues generated by plant operations would also be reduced. Depending on the tax formula used to determine property tax payments, the amount of money paid to local taxing jurisdictions may be reduced. However, property tax payments would continue. Demand for services and housing would likely decline. Indirect employment and income created as a result of nuclear power plant operations would also be reduced.

Loss of employment at nuclear plants located in rural communities would likely mean workers and their families would leave in search of jobs elsewhere. The decrease in the demand for housing and the increase in available housing would depress rural housing market prices. Conversely, at nuclear power plants located in semi-urban areas, workers and their families may remain because of greater opportunities for new employment.

The impacts from the loss or reduction of tax revenue due to the termination of plant operations on community and public education services could range from SMALL to LARGE. Nuclear power plants generally provide a significant amount of tax revenue to local communities and public school districts. The loss or reduction in tax revenues from the nuclear plant could mean the reduction and/or the elimination of some community and public educational services. Traffic congestion caused by commuting workers and truck deliveries during plant operations would also be reduced. License renewal would only delay the timing of these impacts. Therefore, the incremental effect of license renewal would be SMALL for all nuclear plants. See Appendix J to NUREG-0586, Supplement 1 (NRC 2002a), for a discussion of the potential socioeconomic impacts of plant decommissioning.

Human Health

With the termination of plant operations, there would be a period between the time when a reactor stopped operating and when the decommissioning of the plant began that could range from months to years. During that period, the reactor would be placed in a cold shutdown condition and maintained. The fuel might be removed from the core and put in the spent fuel storage pool. Workers would continue to receive radiation exposure during work activities related to placing the reactor in shutdown status. Radioactive gaseous and liquid effluent releases to the environment would continue, although at a lower level, that would result in radiation exposure to the public. The regulatory requirements and dose limits during this period for workers and the public are the same as those for operating reactors (see Section 3.9.1.1). The radiological impacts on workers and members of the public during this time period would be less than those during current operations and those expected during decommissioning.

Public exposure to EMFs would decrease after transmission lines were de-energized. Power would still be provided to the site, and workers might be exposed to EMFs during this period. It is expected that the impacts from EMFs during this period would be less than the impacts from current operations.

Because reactor shutdown would result in the cessation or reduction of cooling system operations, the public's exposure to chemical and microbiological hazards associated with these operations would be reduced. The plant workers might be exposed to chemical, microbiological, and other hazards during this period, but the hazards would be SMALL and bounded by the hazards either during operations or decommissioning.

The remainder of this section evaluates the effects of license renewal on the human health impacts from the termination of nuclear power plant operations and decommissioning. The issues considered here include the impacts from radiological exposure and risk, chemical hazards, microbiological hazards, physical occupational hazards, and electrical hazards. Work during decommissioning activities is generally done according to an environmental safety and health plan that serves as a guidebook for anticipating hazards and preventing any injury or harm. In the 1996 GEIS, the NRC considered the effect of license renewal on only the radiation dose impacts of decommissioning.

The human health impacts from physical, chemical, and microbiological hazards during the termination of plant operations and decommissioning would be SMALL for all plants. The effect of license renewal on the impact from terminating plant operations and decommissioning on human health also would be SMALL at all plants. Doses to the public would be well below applicable regulatory standards, regardless of which decommissioning option was used. Collective occupational doses would increase no more than 0.1 person-rem, attributable to the buildup of long-lived radionuclides during the license renewal term, but the individual worker doses would be well below the existing dose limits. On the basis of these considerations, the NRC concludes that the effect of license renewal on the impact from decommissioning on human health would be SMALL for all nuclear plants.

Radiological Exposure

During decommissioning activities, workers are exposed to radioactive materials that are present in the reactor and support facilities, and members of the public may be exposed to radioactive materials that are released to the environment. The regulatory requirements and dose limits during decommissioning are the same as those for operating reactors (see Section 3.9.1.1). Many activities during decommissioning are similar to the activities that occur during normal maintenance outages, such as decontamination of piping and surfaces; removal of piping, pumps, and valves; and removal of heat exchangers. Some of the activities, such as removal of the reactor vessel or demolition of facilities, are unique to decommissioning. The decommissioning GEIS (NRC 2002a) evaluated the potential radiological impacts of decommissioning activities for both PWRs and BWRs. Public and occupational radiation exposures from decommissioning activities were evaluated on the basis of information derived from recent decommissioning experience.

Radiation Exposures to Plant Workers

Both the 1996 GEIS and the decommissioning GEIS provide estimated collective occupational radiation doses for decommissioning PWRs and BWRs for the three decommissioning options: DECON, ENTOMB, and SAFSTOR. The decommissioning GEIS also includes the estimated collective occupational radiation dose for plants that are currently in the decommissioning process. The DECON method had the highest dose, followed by ENTOMB and then SAFSTOR. According to the decommissioning GEIS, occupational doses to individual workers during decommissioning activities are estimated to average approximately 5 percent of the regulatory dose limits established in 10 CFR Part 20 and to be similar to, or lower than, the doses experienced by workers in operating facilities.

A 20-year extension in operations would increase the occupational doses from long-lived radionuclides such as niobium-94, but these increases would not be significant for the DECON option because short-lived radionuclides (primarily cobalt-60) are the principal contributor to the occupational dose (NRC 1996). For the SAFSTOR option, an additional 20 years of operations would increase the amount of niobium-94 by 50 percent. The contribution of niobium-94 to the collective dose for this decommissioning option for 40 years of plant operation is less than 0.2 person-rem; therefore, the increase in dose during decommissioning after 20 additional years of operations would be less than 0.1 person-rem. Total worker doses may increase, but individual worker doses would be well below the regulatory limits. The NRC concluded that the impact of an additional 20 years of plant operation on the radiological doses to workers would be of SMALL significance for all nuclear plants.

Radiation Exposures to the Public

According to the 1996 GEIS, the radiation dose to the public during decommissioning would result primarily from waste shipment for both PWRs and BWRs, and the dose would be almost exclusively attributable to the shipment of short-lived radionuclides, mainly cobalt-60. During decommissioning, the estimated increased risk of fatal cancer to an average member of the public would be much less than 1×10^{-6} (NRC 2002a). If a plant operated an additional 20 years, only the quantities of long-lived radionuclides would increase, and only the dose caused by the long-lived radionuclides would increase. As discussed in the 1996 GEIS, the dose to the public from long-lived radionuclides after 40 years of plant operation is expected to be negligible, and the increase in quantities of long-lived radionuclides after an additional 20 years would result in a negligible dose (less than 0.1 person-rem). Accordingly, the NRC concluded that the contribution of license renewal to radiological impacts to the public from decontamination would be of SMALL significance at all nuclear plants.

Chemical Hazards

Decommissioning involves many activities that expose workers to chemical hazards, including paints, asbestos, lead, polychlorobiphenyls, mercury, quartz, and other hazardous materials in building materials. During decommissioning, workers may also be exposed to fumes (that often include lead and arsenic) and smoke from flame cutting and welding. According to the decommissioning GEIS, with proper planning, workplace design, and engineering controls, supplemented by the use of personal protective equipment and administrative solutions, the impact of chemical hazards on workers would be of SMALL significance at all nuclear plants. A 20-year delay caused by license renewal would not change the projected human health impact from chemical hazards because (1) there would not be any more hazardous chemicals present, (2) the workers would still would have a proper work plan, and (3) all required controls would be in place.

Microbiological Hazards

During decommissioning, workers may be exposed to molds and other biological organisms that grow in and on buildings. Proven industrial hygiene principles mitigate the risk of developing diseases from these organisms. According to the decommissioning GEIS, if a thorough inspection of the facility is conducted and proper cleansing and personal protective equipment are used when biological agents are identified, the impacts of biological agents on workers would be SMALL. A 20-year license renewal would not change the microbiological hazards associated with decommissioning at any nuclear plant because the workers would still be using proper cleansing and personal protective equipment when biological hazards were identified.

Electromagnetic Fields

Operating transmission lines produce an EMF. When a nuclear power plant ceases to operate, no electricity is transmitted. Therefore, the public's exposure to EMF could decrease unless the power that was no longer being generated at the plant was replaced by new power generation. Power would still be provided to the site, and workers might be exposed to EMF during decommissioning. It is expected that the impacts during decommissioning would be bounded by the impacts from current operations. The EMF impact associated with decommissioning after a 20-year license renewal term would not differ from that without renewal.

Other Hazards

The major sources of physical occupational hazards during decommissioning involve the operation and use of construction and transportation equipment. Workers may be exposed to extreme temperatures while working outdoors. They may operate cranes near power lines, dig near buried cables, and encounter electrical hazards. During demolition or dismantlement, the workers may use cutting torches, which can start fires. It is expected that all of the activities would be anticipated in advance, and that proper precautions would be taken to minimize any adverse impacts. A 20-year delay in decommissioning caused by license renewal would have no effect on the projected human health impact from other hazards, because the workers would have the proper work planning, workplace design, and controls in place. Moreover, the conditions would not be more hazardous after an additional 20 years.

Accidents during the Termination of Nuclear Plant Operations and Decommissioning

The impacts of postulated accidents during the license renewal term are discussed in Section 4.9.1.2. The general characteristics, including the source terms, of postulated accidents are expected to be similar after reactor shutdown; therefore, the consequences would also be expected to be similar. Because of the enhanced aging management activities and extended life of certain systems, structures, and components, there may be small differences in the probabilities of occurrence of these accidents after reactor shutdown. These differences, however, are not expected to be significant, and the risks of accidents after reactor shutdown would be expected to be similar to or less than the risks discussed in Section 4.9.1.2 for the proposed action.

The impacts associated with accidents that can occur during the decontamination and decommissioning of nuclear power plants were analyzed in the Decommissioning GEIS (NRC 2002a). The radiological impacts of accidents were discussed in Section 4.3.9 of the same document, and nonradiological impacts were discussed in Section 4.3.10. Radiological accidents that were considered in the analysis included both those that relate to onsite storage and handling of spent nuclear fuel and those that are unrelated to spent nuclear fuel. The non-fuel-related accidents centered on decontamination, dismantlement, and storage-type accidents. The accidents included fires, handling accidents, explosions (e.g., explosion of liquid propane gas tanks), and accidental releases of liquid radioactive wastes from storage tanks.

Nonradiological accidents were considered under occupational issues and included physical, chemical, ergonomic, and biological hazards. The category of physical hazards included potential injuries or deaths resulting from the operation and use of construction and transportation equipment. Electrical hazards, including the potential for electrocution, were also considered. The potential exposure of workers to chemical and biological agents was considered under both normal operations and accidents. Ergonomic conditions were evaluated from the point of view of ergonomic stress such as discomfort and fatigue affecting the workers' performance and safety.

The NRC made the following conclusions regarding radiological accidents associated with decommissioning on the basis of the evaluations conducted for the decommissioning GEIS (NRC 2002a):

> The NRC has considered available information, including comments received on the draft of Supplement 1 of NUREG-0586, concerning the potential impacts of non-spent-fuel-related radiological accidents resulting from decommissioning. This information indicates that, with the mitigation procedures in place, the impacts of radiological accidents are neither detectable nor destabilizing. Therefore, the NRC makes the generic conclusion that the impacts of non-spent-fuel-related radiological accidents are SMALL. The NRC has considered mitigation and concludes that no additional measures are likely to be sufficiently beneficial to be warranted.
>
> The NRC has considered available information, including comments received on the draft of Supplement 1 of NUREG-0586, on the potential impacts of spent-fuel-related radiological accidents resulting from decommissioning. The NRC concludes that the impacts of spent fuel storage during the license renewal term are SMALL. The NRC concludes that additional mitigation measures are not likely to be sufficiently beneficial to be warranted.

The conclusion regarding the occupational issues, which included nonradiological accidents, was as follows:

> The NRC has considered available information, including comments received on the draft of Supplement 1 of NUREG-0586, on the potential impacts of decommissioning activities on occupational issues. This information indicates that the impacts on occupational issues are not detectable or destabilizing. Therefore, the NRC makes a generic conclusion that, for all plants, the potential impacts on occupational issues are SMALL. The NRC has considered mitigation measures and concludes that no additional mitigation measures are likely to be sufficiently beneficial to be warranted.

License renewal would merely delay when accidents associated with the termination of nuclear power plant operations and decommissioning could occur and would not significantly affect their probability or consequence.

Environmental Justice

Termination of power plant operations and the resulting loss of jobs, income, and tax revenue could have a disproportionate effect on minority and low-income populations. The loss of tax revenue, for example, could reduce the availability or eliminate some of the community services that low-income and minority populations may depend on. This situation could be offset with the construction and operation of replacement power generating facilities and the creation of other employment opportunities at or near the nuclear plant site.

Decontamination and decommissioning activities could affect air and water quality in the area around each nuclear plant site. This could cause health and other environmental impacts in minority and low-income populations, if present. Population groups with particular resource dependencies or practices (e.g., subsistence agriculture, hunting, fishing) could also be disproportionately affected.

Environmental impacts associated with decommissioning activities at each nuclear plant and the extent to which minority and low-income populations could be affected, are discussed in the decommissioning GEIS (NRC 2002a). License renewal would only delay, but not alter the impact of decommissioning on minority and low-income populations around each nuclear plant.

Waste Management and Pollution Prevention

After termination of nuclear plant operations, there would be a period before the beginning of decommissioning when the reactor would be placed in a cold shutdown condition and maintained. The fuel might be removed from the core and put in the spent fuel storage pool. There might also be activities related to placing the reactor in shutdown status that could result in the generation of some waste. The types of waste generated during this period would be the same as the types of waste generated during operations and decommissioning. The quantities of waste generated would be smaller than the quantities generated during either operations or decommissioning. The impacts associated with the management of LLW, hazardous waste, mixed waste, and nonradioactive and nonhazardous waste during operations and decommissioning would be SMALL. These impacts would also be SMALL when the reactor was in shutdown status pending decommissioning. All pollution prevention and waste minimization measures instituted during operations would likely continue to be used to minimize releases to the environment and minimize the quantities of waste generated. As discussed in Section 4.11.1.2, the NRC has determined that spent nuclear fuel could be stored onsite safely and with a minimal environmental impact during the license renewal term and the NRC is working on a separate rulemaking and EIS for the Waste Confidence Decision and Rule to address the period after the cessation of reactor operations.

The decommissioning process, by its very nature, generates wastes. The wastes generated are shipped offsite, where they are permanently disposed of, or stored onsite for a certain period or indefinitely. Under the three decommissioning options analyzed in the decommissioning GEIS (NRC 2002a), the DECON process would generate the most waste. In this process, the equipment, structures, and portions of the facility and site that contain radioactive contaminants are removed and decontaminated to a level that permits termination of the license after cessation of operations. In the SAFSTOR process or ENTOMB process, the materials are left onsite temporarily or permanently, respectively.

The impacts from decommissioning that result in the generation of wastes and their onsite management until they are loaded onto vehicles to be shipped offsite are addressed under other disciplines discussed in Section 4.12.2.1. This section addresses the impacts from transporting the wastes to disposal facilities and from their disposal. If there are interim locations offsite where wastes undergo treatment before being sent to a disposal facility, they are also discussed here.

The types of wastes generated during decommissioning would include LLW, mixed waste, hazardous waste, and nonradioactive, nonhazardous waste (see Section 3.11 for waste type definitions). No spent fuel, HLW, or transuranic waste would be generated during decommissioning because spent fuel would have been removed from the reactor and stored in either the reactor's spent fuel pool or in an ISFSI before the start of decommissioning.

It is expected that most of the waste generated during decommissioning would be LLW and nonradioactive, nonhazardous waste. There would be small quantities of mixed waste (mostly paints, waste oils, solvents, and metals such as lead or cadmium) that would be managed per the requirements of RCRA for its hazardous component and the Atomic Energy Act (AEA) for its radioactive component, as described in Section 3.11.3. The quantities of hazardous waste that would be generated would also be small and would mainly consist of paints, solvents, and batteries. Some of the materials used to decontaminate surfaces could also end up being classified as mixed waste. Both mixed wastes and hazardous wastes could be sent to an authorized waste treatment center for incineration or some other form of treatment before being sent to a disposal facility authorized to accept such waste. All of these activities would be conducted according to permits and requirements established under RCRA. The nonradioactive, nonhazardous waste, consisting mainly of rubble and debris, would be sent to a local landfill.

The impacts associated with transporting equipment and materials (radiological and nonradiological) offsite during decommissioning are analyzed in Section 4.3.17 of the decommissioning GEIS (NRC 2002a). The materials transported offsite would include all wastes generated onsite. Radiological impacts would include exposure of transportation workers and the general public along the transportation routes. Nonradiological impacts would include increased traffic volume, additional wear and tear on roadways, and potential traffic accidents. It was concluded that the transportation impacts would not be destabilizing. Therefore, the NRC made the generic conclusion that for all plants, the potential transportation impacts would be SMALL.

There might be small differences in the quantities and characteristics of the waste that would be generated during decommissioning after the license renewal term and the waste that would be generated after the original license period. If the plant license was not renewed, the reactor could be decommissioned at the end of the current license term, whereas if the license was renewed, the decommissioning would take place approximately 20 years later. Additional waste might accumulate at the site, or the radioactivity of some components undergoing decommissioning might be slightly higher at the end of the license renewal term. For example, if there were any refurbishment activities during the license renewal term that resulted in equipment (e.g., steam generators) being taken out of service and subsequently stored onsite awaiting disposition during decommissioning, the amounts of certain types of waste (e.g., LLW) generated from decommissioning under the proposed action would be more than the amounts generated during the original license period. Because of the differences in timing, some of the materials in and around the core of the reactor might have slightly higher radioactivity under the proposed action as a result of a buildup in long-lived radionuclides. This situation would mainly affect the amount of greater-than-Class C LLW at the site. Assuming that the spent nuclear fuel continued to be stored onsite during the license renewal term, there would also be more spent fuel to manage. Similarly, if certain LLW classes (e.g., Class A, B, and C wastes) had to be stored onsite for long periods (for the reasons discussed in Section 4.11.1), the amounts of those wastes that would have to be addressed during decommissioning might be larger after the license renewal term. However, because all radioactive waste must be handled in accordance with NRC regulations, it is not expected that these differences would significantly alter the practices employed to manage the wastes or the impacts associated with managing the wastes generated during decommissioning.

The decommissioning activities would be designed and implemented in ways to prevent pollution and minimize the amount of waste generated. All the methods mentioned in Section 3.11.5, including source reduction and recycling of materials either onsite or offsite, would be used. Under source reduction, the licensees would use decontaminating agents and technologies that would generate less waste, particularly mixed and hazardous waste. They would also implement procedures and practices that would be aimed at preventing or minimizing gaseous and liquid releases to the environment and the quantities of waste generated.

The quantity of LLW that would be generated from the decommissioning of a model 1,000-MWe power plant is included in the quantities of LLW reported on in Section 4.12.1.1. The quantities of mixed waste and hazardous waste that would be generated from decommissioning of nuclear power plants would be relatively small and managed in a way that would protect human health and the environment to meet RCRA requirements. Clean wastes (wastes that are neither radioactive nor hazardous) would be disposed of at a local permitted landfill. The transportation of wastes from a model LWR is also reported on in Section 4.12.1.1. The offsite transportation of equipment and wastes from a power plant undergoing decommissioning was also analyzed in the decommissioning GEIS (NRC 2002a), and the impact was found to be SMALL. On the basis of these considerations, the effect of license renewal would be SMALL for all plants.

4.12.2.2 Termination of Power Plant Operations and Decommissioning of Replacement Power Plants

Fossil Energy Alternatives

The environmental consequences from the termination of power plant operations and the decommissioning a fossil fuel energy facility are dependent on the decommissioning plan. It is reasonable to expect that decommissioning plans would include the following elements and requirements:

- Removal of all unneeded structures and facilities to at least 3 ft (1 m) below grade (in order to provide an adequate root zone for site revegetation).
- Removal of all coal, all coal combustion waste, and all flue gas desulfurization (FGD) sludge and/or byproducts.
- Removal of water intake and discharge structures.
- Dismantlement and/or removal of all ancillary facilities, including rail spurs, coal handling and preparation facilities, cooling towers, natural gas pipelines, onsite wastewater treatment facilities, and access roads.
- Removal of all surface water intake and discharge structures.
- Removal of all accumulated sludge, and closure and removal of all surface water impoundments.
- Proper closure of all onsite groundwater wells.
- An aggressive recycling program for removed equipment and dismantled building components; materials awaiting recycling would be stored at an offsite facility.
- Minimal delay times for removed materials and equipment at temporary laydown areas.
- Expeditious disposal of solid and hazardous wastes at approved facilities; as necessary, remediation of waste handling and storage areas.
- Cleanup and remediation of all incidental spills and leaks.
- Successful execution of an approved revegetation plan for the site.

- Other actions as necessary to ensure restoration of the site to a condition equivalent in character and value to the greenfield or brownfield site on which the facility was first constructed.

Assuming that decommissioning occurs according to a decommissioning plan as described above, environmental consequences (at either a greenfield site or a brownfield site) would include:

- Short-term impacts on air quality and noise from the operation of vehicles and equipment used to deconstruct structures and facilities and the increased number of workforce vehicles traveling to and from the site; impacts include release of criteria pollutants and generation of fugitive dust and noise (including from the possible use of explosives to deconstruct buildings or structures); impacts would be similar to, but of shorter duration than, those experienced during facility construction.

- Short-term impacts on land use and visual resources due to increased human activities on the site and establishment of temporary holding areas for dismantled components and other deconstruction debris (some of which may be at offsite locations—e.g., at rail headers).

- Short-term increase in local traffic as a result of increases in workforce personnel onsite and truck and rail traffic bringing deconstruction equipment to the site and transporting dismantled structures, removed equipment, and deconstruction debris.

- Long-term reestablishment of vegetation and wildlife communities.

- Restoration of visual values through removal of manmade structures and restoration of native vegetative and wildlife communities.

- Short-term increase in local economic activity with the increased dismantlement workforce and other related functions such as transportation, followed by a longer-term downturn of local economy due to loss of jobs of operational personnel.

- Reestablishment of original land use opportunities.

- Elimination of health and safety impacts on operating personnel and the general public from routine operation of the facility and as a result of accidents involving the facility; short-term increase in health and safety risk to decommissioning workforce due to complex and concentrated industrial activities, and short-term increase in risk of transportation-related accidents, due to increased traffic densities throughout decommissioning.

New Nuclear Alternatives

According to 10 CFR Part 52, decommissioning impacts for a nuclear power plant include all activities related to the safe removal of the facility or site from service and the reduction of residual radioactivity to a level that permits release of the property under restricted conditions or unrestricted use and termination of a license. The decommissioning process and the activities occurring during decommissioning would be similar to those associated with current reactors, (see Sections 2.1.3 and 4.12.2.1).

Environmental consequences would also be similar to those discussed in Section 4.12.2.1 and would include:

- Temporary impacts on land use and visual resources, including the construction of temporary buildings and parking lots and the addition or expansion of laydown areas. (Many plants have existing, previously disturbed areas available for these temporary land use activities.)

- Reduced (small) water use and water quality impacts as water consumption decreases significantly after cessation of operations. Dewatering and water used for spent fuel cooling would continue until spent fuel was removed from the site. Surface water runoff or release of substances would be possible but should not have a detectable effect on the environment.

- Temporary increases in local traffic that would result from the additional workforce onsite; truck and rail traffic bringing deconstruction equipment to the site; and the transport of dismantled structures, removed equipment, and waste from the site.

- Long-term reestablishment of vegetation and wildlife communities.

- Short-term improvements in the local economy because of the increased workforce for decommissioning activities, followed by a long-term downturn of the local economy because of the loss of jobs of operational personnel.

- Potential (regulated) radiological doses to the public and decommissioning workforce at the facility from activities such as removal of the reactor vessel and demolition of facilities.

- Increased but temporary occupational safety and health risk to the workforce due to complex and concentrated industrial activities.

Renewable Alternatives

The termination of power plant operations and the decommissioning of renewable energy systems would be similar to the impacts discussed in the previous sections. Decommissioning would follow a decommissioning plan and would involve not only removal of facility components and operational wastes and residues, but also reclamation of the land to its original state. Decommissioning scenarios are expected to involve the following actions:

- Removal of all unneeded structures and facilities to at least 3 ft (1 m) below grade (to provide an unencumbered root zone for site revegetation).
- Removal of all unspent biomass fuel and all solid wastes from combustion and facility maintenance.
- Removal of water intake and discharge structures (if present to support combustion facilities and steam cycles).
- Dismantlement and/or removal of all ancillary facilities, including rail spurs, biomass (and coal) fuel handling and preparation facilities, cooling towers, natural gas pipelines, onsite wastewater treatment facilities, and access roads.
- Removal of all surface water intake and discharge structures.
- Removal of all accumulated sludge, and closure and removal of all surface water impoundments.
- Proper closure of all onsite groundwater wells.
- Aggressive recycling program for removed equipment and dismantled building components; materials awaiting recycling would be stored at an offsite facility.
- Minimal delay times for removed materials and equipment at temporary laydown areas.
- Expeditious disposal of solid and hazardous wastes at approved facilities; remediation as necessary of waste handling and storage areas.
- Cleanup and remediation of all incidental spills and leaks.
- Successful execution of an approved revegetation plan for the site.

- Offsite ancillary facilities (access roads, utilities, pipelines, electrical transmission towers) would be removed unless it is determined that they can serve other purposes; buried utilities and pipelines could be abandoned in place if their removal would result in significant disruption to ecosystems.

- Other actions as necessary to ensure restoration of the site to a condition equivalent in character and value to the greenfield or brownfield site on which the facility was first constructed.

Termination of operations and decommissioning of offshore facilities could involve the following unique actions and strategies, depending on location:

- Wind turbine tower foundations and communication and power cables buried in the seafloor could be allowed to remain to avoid the disruption that would result from their removal.

- Underwater structures could be allowed to remain in place to serve as artificial fish habitats.

- Structures that served as electrical service platforms could be allowed to remain in place to serve as artificial reefs.

The termination of operations and the decommissioning of hydroelectric facilities could follow unique paths. For large store-and-release facilities, eliminating the dam and reservoir and restoring the river to its natural flow could have dramatic consequences to both upstream and downstream ecosystems. Especially where store-and-release dams serve purposes other than power generation (e.g., flood control and irrigation), complete elimination of the structures and reservoir and restoration of original river conditions could be at cross purposes. While turbines, generators, and other equipment associated with power production could be removed, the dam and reservoir would be expected to remain largely intact, as would fish ladders and passages. Penstocks and other devices that control the release of water from the reservoir are expected to remain functional. A reduced workforce would also remain to operate the dam for flood control and irrigation purposes. Impacts on upstream land uses would remain generally unaltered from the impacts during the dam’s operating period.

Smaller scale, run-of-the-river dams (so called low-impact hydro facilities[(e)]) that have limited impact on upstream water levels and downstream water flow rates would likely be completely dismantled and removed during decommissioning.

(e) Low-impact hydro facilities are considered to have a power capacity of less than 30 MW.

4.12.3 Greenhouse Gas Emissions and Climate Change

The following sections discuss greenhouse gas (GHG) emissions from the nuclear lifecycle, replacement power alternatives, and climate change impacts.

4.12.3.1 Greenhouse Gas Emissions

This section discusses GHG emissions from the nuclear lifecycle and compares these emissions to those from fossil and other renewable energy sources. The nuclear lifecycle consists of the uranium fuel cycle phases, as discussed in Section 4.12.1.1, and nuclear power plant construction, operation, and decommissioning.

Existing Studies

The relative volumes of GHGs emitted by nuclear and other electricity generating methods have been widely studied. However, estimates and projections of the carbon footprint of the nuclear lifecycle vary depending on the type of study done. Additionally, considerable debate also exists among researchers on the relative effects of nuclear and other forms of electricity generation on GHG emissions. Existing studies on GHG emissions from nuclear power plants generally take two different forms:

(1) Qualitative discussions of the potential to use nuclear power to reduce GHG emissions and mitigate global warming.

(2) Technical analyses and quantitative estimates of the actual amount of GHGs generated by the uranium fuel cycle or entire nuclear lifecycle and comparisons to the operational or lifecycle emissions from other energy generation alternatives.

Qualitative Studies

The qualitative studies consist primarily of broad, large-scale public policy or investment evaluations of whether an expansion of nuclear power is likely to be a technically, economically, or politically workable means of achieving global GHG reductions. Studies found by the staff during the subsequent literature search include the following:

- Evaluations to determine if investments in nuclear power in developing countries should be accepted as a flexibility mechanism to assist industrialized nations in achieving their GHG reduction goals under the Kyoto Protocols (IAEA 2000; NEA and OECD 2002; Schneider 2000). Ultimately, the parties to the Kyoto Protocol did not approve nuclear power as a component under the Clean Development Mechanism due to safety and waste disposal concerns (NEA and OECD 2002).

- Analyses developed to assist governments, including the United States Government, in making long-term investment and public policy decisions in nuclear power (Hagen et al. 2001; Keepin 1988; MIT 2003).

Although the qualitative studies sometimes reference and critique the existing quantitative estimates of GHGs produced by the nuclear fuel cycle or lifecycle, their conclusions generally rely heavily on discussions of other aspects of nuclear policy decisions and investment such as safety, cost, waste generation, and political acceptability. Therefore, these studies are typically not directly applicable to an evaluation of GHG emissions associated with the proposed license renewal for a given nuclear power plant.

Quantitative Studies

A large number of technical studies, including calculations and estimates of the amount of lifecycle GHGs emitted by nuclear and other power generation options, are available in the literature and were useful to the staff's efforts in addressing relative GHG emission levels. Examples of these studies include—but are not limited to—Mortimer (1990), Andseta et al. (1998), Spadaro et al. (2000), Fritsche (2006), Parliamentary Office of Science and Technology (POST) (2006), AEA Technology (AEA) (2006), Weisser (2006), and Fthenakis and Kim (2007). In addition, Sovacool (2008) provides a review and synthesis of studies in existence through 2008. The Sovacool (2008) synthesis ultimately uses only 19 of the 103 studies initially considered; the remaining 84 were excluded because they were more than 10 years old, not publicly available, available only in a language other than English, or they presented methodological challenges by relying on inaccessible data, provided overall GHG estimates without allocating relative GHG impacts to different parts of the nuclear lifecycle, or they were otherwise not methodologically explicit. The Intergovernmental Panel on Climate Change (IPCC) has issued a special report on Renewable Energy Sources and Climate Change Mitigation (IPCC 2011). This report provides an assessment of previously published literature on lifecycle GHG emissions from various electricity generation technologies (nuclear, fossil fuel, and renewable energy sources). The IPCC report only included in its synthesis published literature that met the screening criteria for quality and relevance. Of the 2,165 references collected, 296 passed the screening criteria; for the nuclear lifecycle, 125 out of 249 references reviewed passed the screening criteria.

Comparing these studies and others like them is difficult because the assumptions and components of the lifecycles the authors evaluate vary widely. Examples of areas in which differing assumptions make comparing the studies difficult include the following:

- Energy sources that may be used to mine uranium deposits in the future

- Reprocessing or disposal of spent nuclear fuel

- Current and potential future processes to enrich uranium and the energy sources that will power them
- Estimated grades and quantities of recoverable uranium resources
- Estimated grades and quantities of recoverable fossil fuel resources
- Estimated GHG emissions other than carbon dioxide including the conversion to carbon dioxide equivalents per unit of electric energy produced
- Performance of future fossil fuel power systems
- Projected capacity factors for alternative means of generation
- Current and potential future reactor technologies.

Studies may vary with respect to whether all or parts of a power plant's lifecycle are analyzed. That is, a full lifecycle analysis will typically address plant construction, operations, resource extraction (for fuel and construction materials), and decommissioning, whereas a partial lifecycle analysis primarily focuses on operational differences. In addition, as Sovacool (2008) noted, studies vary greatly in terms of age, data availability, and in the disclosure of the study methods used.

In the case of license renewal, a GHG analysis for the portion of the plant's lifecycle attributable to license renewal (operation for an additional 20 years) would not involve GHG emissions associated with construction because construction activities have already been completed at the time of relicensing. In addition, the proposed action of license renewal would also not involve additional GHG emissions associated with facility decommissioning because decommissioning must occur whether the facility is relicensed or not. However, in many studies, the specific contribution of GHG emissions from construction, decommissioning, or other portions of a plant's lifecycle cannot be clearly separated from one another. In such cases, an analysis of GHG emissions would overestimate the GHG emissions attributed to a specific portion of a plant's lifecycle. As Sovacool (2008) noted, many of the available analyses provide markedly lower GHG emissions per unit of plant output, if one assumes that a power plant operates for a longer period of time. Nonetheless, available studies supply some meaningful information with respect to the relative magnitude of the emissions among nuclear power plants as compared to other forms of electric generation as discussed in the following sections.

In Tables 4.12-4, 4.12-5, and 4.12-6, the NRC presents the results of the above-mentioned quantitative studies to supply a weight-of-evidence evaluation of the relative GHG emissions that may result from the proposed license renewal as compared to the potential alternative use of coal-fired, natural gas-fired, and renewable generation. Most studies from Mortimer (1990) onward (through Sovacool 2008) indicate that uranium ore grades and uranium enrichment processes are leading determinants in the ultimate GHG emissions attributable to nuclear power generation. These studies show that the relatively lower order of magnitude of lifecycle GHG emissions from nuclear power, when compared to fossil-fueled alternatives (especially natural gas), could potentially disappear if available uranium ore grades drop sufficiently while enrichment processes continued to rely on the same technologies.

Table 4.12-4. Nuclear Greenhouse Gas Emissions Compared to Coal

Source	GHG Emission Results
Mortimer (1990)	Nuclear—230,000 tons CO_2/year Coal—5,912,000 tons CO_2/year Note: Future GHG emissions from nuclear to increase because of declining ore grade.
Andseta et al. (1998)	Nuclear energy produces 1.4 percent of the GHG emissions compared to coal. Note: Future reprocessing and use of nuclear-generated electrical power in the mining and enrichment steps are likely to change the projections of earlier authors, such as Mortimer (1990).
Spadaro et al. (2000)	Nuclear—2.5 to 5.7 g C_{eq}/kWh[a] Coal—264 to 357 g C_{eq}/kWh
Fritsche (2006) (values estimated from graph in Figure 4)	Nuclear—33 g C_{eq}/kWh Coal—950 g C_{eq}/kWh
POST (2006) (nuclear calculations from AEA 2006)	Nuclear—5 g C_{eq}/kWh Coal—>1,000 g C_{eq}/kWh Note: Decrease of uranium ore grade to 0.03 percent would raise nuclear to 6.8 g C_{eq}/kWh. Future improved technology and carbon capture and storage could reduce coal-fired GHG emissions by 90 percent.
Weisser (2006) (compilation of results from other studies)	Nuclear—2.8 to 24 g C_{eq}/kWh Coal—950 to 1,250 g C_{eq}/kWh
Sovacool (2008) (compilation of results from other studies)	Nuclear—1.4 to 288 g C_{eq}/kWh (average: 66 g C_{eq}/kWh) Coal —960 to 1,050 g C_{eq}/kWh (coal adopted from Gagnon et al. 2002)
IPCC (2011) (compilation of results from other studies)	Nuclear—1 to 220 g C_{eq}/kWh (median: 16 g C_{eq}/kWh) Coal—675 to 1689 g C_{eq}/kWh (median: 1001 g C_{eq}/kWh)

(a) g C_{eq}/kWh = grams of carbon equivalent per kilowatt-hour

Summary of Nuclear Greenhouse Gas Emissions Compared to Coal

Considering that coal fuels the largest share of electricity generation in the United States and that its burning results in the largest emissions of GHGs for any of the likely alternatives to nuclear power generation, many available quantitative studies focused on comparisons of the relative GHG emissions of nuclear to coal-fired generation. The quantitative estimates of lifecycle GHG emissions associated with nuclear power, as compared to an equivalent coal-fired plant, are presented in Table 4.12-4. The staff relied on current available information for its independent analysis. Although Table 4.12-4 does not include all existing studies, it gives an illustrative range of estimates developed by various sources.

Table 4.12-5. Nuclear Greenhouse Gas Emissions Compared to Natural Gas

Source	GHG Emission Results
Spadaro et al. (2000)	Nuclear—2.5 to 5.7 g C_{eq}/kWh[(a)] Natural Gas—120 to 188 g C_{eq}/kWh
Fritsche (2006) (values estimated from graph in Figure 4)	Nuclear—33 g C_{eq}/kWh Cogeneration Combined Cycle Natural Gas—150 g C_{eq}/kWh
POST (2006) (nuclear calculations from AEA 2006)	Nuclear—5 g C_{eq}/kWh Natural Gas—500 g C_{eq}/kWh Note: Decrease of uranium ore grade to 0.03 percent would raise nuclear to 6.8 g C_{eq}/kWh. Future improved technology and carbon capture and storage could reduce natural gas GHG emissions by 90 percent.
Weisser (2006) (compilation of results from other studies)	Nuclear—2.8 to 24 g C_{eq}/kWh Natural Gas—440 to 780 g C_{eq}/kWh
Sovacool (2008) (compilation of results from other studies)	Nuclear—1.36 to 288 g C_{eq}/kWh (average: 66 g C_{eq}/kWh) Natural Gas—443 g C_{eq}/kWh (natural gas adopted from Gagnon et al 2002)
IPCC (2011) (compilation of results from other studies)	Nuclear—1 to 220 g C_{eq}/kWh (median: 16 g C_{eq}/kWh) Natural gas—290 to 930 C_{eq}/kWh (median: 469 g C_{eq}/kWh)

(a) g C_{eq}/kWh = grams of carbon equivalent per kilowatt-hour

Table 4.12-6. Nuclear Greenhouse Gas Emissions Compared to Renewable Energy Sources

Source	GHG Emission Results
Mortimer (1990)	Nuclear—230,000 tons CO_2/year Hydropower—78,000 tons CO_2/year Wind power—54,000 tons CO_2/year Tidal power—52,500 tons CO_2/year Note: Future GHG emissions from nuclear to increase because of declining ore grade.
Spadaro et al. (2000)	Nuclear—2.5 to 5.7 g C_{eq}/kWh[a] Solar PV[b]—27.3 to 76.4 g C_{eq}/kWh Hydroelectric—1.1 to 64.6 g C_{eq}/kWh Biomass—8.4 to 16.6 g C_{eq}/kWh Wind—2.5 to 13.1 g C_{eq}/kWh
Fritsche (2006) (values estimated from graph in Figure 4 of study)	Nuclear—33 g C_{eq}/kWh Solar PV—125 g C_{eq}/kWh Hydroelectric—50 g C_{eq}/kWh Wind—20 g C_{eq}/kWh
POST (2006) (nuclear calculations from AEA 2006)	Nuclear—5 g C_{eq}/kWh Biomass—25 to 93 g C_{eq}/kWh Solar PV—35 to 58 g C_{eq}/kWh Wave/Tidal—25 to 50 g C_{eq}/kWh Hydroelectric—5 to 30 g C_{eq}/kWh Wind—4.64 to 5.25 g C_{eq}/kWh Note: Decrease of uranium ore grade to 0.03 percent would raise nuclear to 6.8 g C_{eq}/kWh.
Weisser (2006) (compilation of results from other studies)	Nuclear—2.8 to 24 g C_{eq}/kWh Solar PV—43 to 73 g C_{eq}/kWh Hydroelectric—1 to 34 g C_{eq}/kWh Biomass—35 to 99 g C_{eq}/kWh Wind—8 to 30 g C_{eq}/kWh
Fthenakis and Kim (2007)	Nuclear—16 to 55 g C_{eq}/kWh Solar PV—17 to 49 g C_{eq}/kWh
Sovacool (2008) (compilation of results from other studies)	Nuclear—1.36 to 288 g C_{eq}/kWh (average: 66 g C_{eq}/kWh) Wind—9 to10 g C_{eq}/kWh Hydroelectric (small, distributed) —10 to13 g C_{eq}/kWh Biogas digester—11 g C_{eq}/kWh Solar Thermal—13 g C_{eq}/kWh Biomass—14 to 35 g C_{eq}/kWh Solar PV—32 g C_{eq}/kWh Geothermal (hot, dry rock)—38 g C_{eq}/kWh (Note: Solar PV value adopted from Fthenakis et al. 2008; all other renewable-generation values adopted from Pehnt 2006)

Table 4.12-6. (cont.)

Source	GHG Emission Results
IPCC (2011) (compilation of results from other studies)	Nuclear—1 to 220 g C_{eq}/kWh (median: 16 g C_{eq}/kWh) Wind—2 to 81 g C_{eq}/kWh (median: 12 g C_{eq}/kWh) Hydropower—0 to 43 g C_{eq}/kWh (median: 4 g C_{eq}/kWh) Biopower[(c)]—[-]633 to 360 g C_{eq}/kWh (median: 18 g C_{eq}/kWh) Solar PV—5 to 217 g C_{eq}/kWh (median: 46 g C_{eq}/kWh) Solar CSP[(d)]—7 to 89 g C_{eq}/kWh (median: 22 g C_{eq}/kWh) Geothermal—6 to 79 g C_{eq}/kWh (median: 45 g C_{eq}/kWh) Ocean Energy—2 to 23 g C_{eq}/kWh (median: 8 g C_{eq}/kWh)

(a) g C_{eq}/kWh = grams of carbon equivalent per kilowatt-hour
(b) Solar PV = solar photovoltaic
(c) Negative values for biopower refer to avoided emissions. Negative values are based on assumptions of avoided emissions by using wastes and residues from landfill disposals to produce electricity that are credited to the lifecycle of biopower (i.e., biomass is diverted from landfills and emissions that would normally be produced at the landfill are avoided). Avoided emissions are those that may be misplaced in time and location but which do totally remove GHGs from the atmosphere.
(d) CSP = concentrating solar power.

Summary of Nuclear Greenhouse Gas Emissions Compared to Natural Gas

The quantitative estimates of lifecycle GHG emissions associated with the nuclear power, as compared to an equivalent natural gas-fired plant, are presented in Table 4.12-5. The staff relied on current available information for its independent analysis. The staff notes that Table 4.12-5 does not include all existing studies. Table 4.12-5, however, gives an illustrative range of estimates developed by various sources.

Summary of Nuclear Greenhouse Gas Emissions Compared to Renewable Energy Sources

The quantitative estimates of lifecycle GHG emissions associated with the nuclear power, as compared to equivalent renewable energy sources, are presented in Table 4.12-6. Calculation of GHG emissions associated with these sources is more difficult than the calculations for nuclear energy and fossil fuels because of the large variation in efficiencies and capacity factors due to their different technologies, sources, and locations. For example, the efficiencies of solar and wind energy are highly dependent on the wind or solar resource in a particular location. Similarly, the range of GHG emissions estimates for hydropower varies greatly depending on the type of dam or reservoir involved (if used at all). Additionally, for biopower, the biomass source (energy crops, agricultural and livestock waste, etc.) and broad range of bioenergy technologies (direct combustion, biomass integrated gasification combined cycle, co-firing with coal) impact lifecycle GHG emissions estimates. For instance, emissions can be avoided if agricultural waste, that would typically decompose and emit GHGs, is used as the biomass source to produce electricity. However, biomass power plant operation, construction, and transportation still emit GHGs. On the other hand, if energy crops are used, GHGs are emitted from the manufacturing or harvesting of biomass, transportation, construction, and operation of the plant. Therefore, lifecycle GHG emissions estimates for these energy sources have a greater range of variability than the estimates for nuclear and fossil fuel sources. Table 4.12-6 gives an illustrative range of estimates developed by various sources.

Conclusions: Relative Greenhouse Gas Emissions

The sampling of data presented in Tables 4.12-4, 4.12-5, and 4.12-6 demonstrates the wide distribution of lifecycle GHG emission estimates of various electricity generation technologies and the challenges of any attempt to determine the specific amount of GHG emissions attributable to nuclear energy production sources, as different assumptions and calculation methods will yield differing results. The differences and complexities in these assumptions and analyses will further increase when they are used to project future GHG emissions. Nevertheless, several conclusions can be drawn from the information presented.

First, the various studies show a general consensus that nuclear power generation has lower lifecycle GHG emissions than electrical generation based on fossil fuel. The studies also give estimates of lifecycle GHG emissions from renewable energy sources based on current and available technology. The range of these estimates is wide, but the general conclusion is that current lifecycle GHG emissions from nuclear power generation are of the same order of magnitude as from the surveyed renewable energy sources.

Second, the studies show no consensus on future relative GHG emissions from nuclear power and other sources of electricity. There is substantial disagreement among the various authors about the GHG emissions associated with declining uranium ore concentrations, future uranium enrichment methods, and other factors, including changes in technology. Similar disagreement exists about future GHG emissions associated with coal and natural gas for electricity generation. Even the most conservative studies conclude that nuclear power generation currently produces fewer lifecycle GHG emissions than sources based on fossil fuel and is expected to continue to do so in the near future. The primary difference among the authors is the projected cross-over date (the time at which GHG emissions from the nuclear lifecycle exceed those of sources based on fossil fuel) or whether cross-over will actually occur.

Considering the current estimates and future uncertainties, it appears that GHG emissions associated with nuclear power plant relicensing actions are likely to be lower than those associated with energy sources based on fossil fuel. This conclusion is based on the following rationale:

- As shown in Tables 4.12-4 and 4.12-5, the current estimates of lifecycle GHG emissions from nuclear power generation are below those for energy sources based on fossil fuel.

- License renewal will involve continued GHG emissions due to uranium mining, processing, and enrichment but will not result in increased GHG emissions associated with plant construction or decommissioning (as the plant will have to be decommissioned at some point whether the license is renewed or not).

- Few studies predict that nuclear lifecycle emissions will exceed those of fossil fuels within a time frame that includes periods of extended operation. Several studies suggest that future extraction and enrichment methods, the potential for higher grade uranium resource discovery, and technology improvements could extend this time frame.

With respect to the comparison of GHG emissions among nuclear power plant license renewal and renewable energy sources, it appears likely that there will be future technology improvements and changes in the type of energy used for mining, processing, manufacturing, and constructing facilities of all types. Currently, lifecyle GHG emissions associated with nuclear power and renewable energy sources are within the same order of magnitude. Because nuclear fuel production is the most significant contributor to possible future increases in GHG emissions from nuclear power—and because most renewable energy sources lack a fuel component—it is likely that GHG emissions from renewable energy sources would be lower than those associated with nuclear power plant license renewal at some point during the period of extended operation.

4.12.3.2 Climate Change Impacts

This section briefly describes the environmental impacts that could occur from changes in global and regional climate conditions due to GHG emissions. Each subsection generically describes potential long-term impacts and provides examples of the resource changes that could occur due to climate change.

Land Use

Sea level rise could result in the loss of coastal lands, as well as the possible loss of man-made infrastructure as a result of inundation, flooding during storm events, or storm-triggered erosion. This could necessitate more-frequent infrastructure redesign and replacement or relocation away from potential hazards. As noted by the U.S. Global Change Research Program (USGCRP) (2009), the projected rapid rate and large amount of climate change over the next century will challenge the ability of society and natural systems to adapt. For example, it is difficult and expensive to alter or replace infrastructure designed to last for decades (such as buildings, bridges, roads, airports, reservoirs, and ports) in response to continuous and/or abrupt climate change. Sea-level rise and storm surge place many U.S. coastal areas at increasing risk of erosion and flooding, especially along the Atlantic and Gulf coasts, the Pacific

Islands, and parts of Alaska. Energy and transportation infrastructure and other property in coastal areas are also likely to be adversely affected.

Air Quality and Meteorology

The EPA annually publishes the official United States inventory of GHG emissions that identifies and quantifies the primary man-made sources and sinks of GHGs. The EPA estimates that energy-related activities in the United States account for more than three-quarters of human-generated GHG emissions, mostly in the form of carbon dioxide emissions from burning fossil fuels. More than half of the energy-related emissions come from major stationary sources like power plants, and approximately one-third comes from transportation. Industrial processes (production of cement, steel, and aluminum), agriculture, forestry, other land use, and waste management are also important sources of GHG emissions in the United States (EPA 2011).

Section 4.12.3.1 presents a discussion of the relative GHG emissions from nuclear power and other electricity generation options. The impacts of GHG emissions do not vary with the locations of the emissions sources, so the same impacts would result from the operation of those power plants regardless of where they are located. The USGCRP indicates that as much as 87 percent of GHG emissions are the result of generating electricity and heat using carbon-based fuels (USGCRP 2009).

With regard to the impact of GHG emissions, the USGCRP concludes in part that climate-related changes have already been observed globally and across the United States. Specifically, it notes the following changes: increases in air and water temperatures, reduced frost days, increased frequency and intensity of heavy downpours, a rise in sea level, and reductions in snow cover, glaciers, permafrost, and sea ice. Longer ice-free periods on lakes and rivers, lengthening of the growing season, and increased water vapor in the atmosphere have also been observed. These climate-related changes are expected to continue while new ones develop. Likely future changes for the United States and surrounding coastal waters include more-intense hurricanes with related increases in wind, rain, and storm surges (but not necessarily an increase in the number of these storms that make landfall), as well as drier conditions in such areas as the Southwest (USGCRP 2009). Climate model simulations presented by the U.S. National Oceanic Atmospheric Administration indicate a greater rate of warming (average temperature increase) over the entire continental United States for the 21st century than the 20th century observed rates, an increase in the number of days with a maximum temperature greater than 95˚F (35°C) in the Southwest and Southeast regions, a decrease in the number of days with minimum temperatures less than 10˚F (–12°C) in the Rocky Mountains and Northern regions, and an increase in the number of days with little or no precipitation (less than 0.04 in. [0.1 mm]) for Western and Southern regions by mid-century for a high-emissions scenario (continued increases in greenhouse gas emissions through the end of the century) (NOAA 2013). Observed changes in meteorological and climatological indicators specific to the continental United States are further discussed in Section 3.3.1 of this GEIS.

Water Resources

Climate change will affect water availability in every region of the United States, but the nature of the potential impacts varies. Drought—related to reduced precipitation, increased evaporation, and increased water loss from plants in response to higher temperatures—is an important issue in many regions, especially in the West. Floods, as well as water quality problems, are likely to be amplified by climate change in most regions. Declines in mountain snowpack are important in the West and Alaska where snowpack provides vital natural water storage. In some regions, reductions in water supply due to decreases in precipitation and/or reduced snowmelt will increase competition for water among various sectors, including energy production (USGCRP 2009).

More specifically, the USGCRP projects a high likelihood that water shortages will limit power plant electricity production in some regions. USGCRP projects water constraints on electricity production by 2025 in Arizona, Utah, Texas, Louisiana, Georgia, Alabama, Florida, California, Oregon, and Washington State. Additional parts of the United States could face similar constraints as a result of drought, growing populations, and increasing demand for water for various uses during some or all seasons.

Finally, the issue related to water resources is not only one of water availability, but also of water temperature. Warmer water and higher air temperatures reduce the efficiency of thermal power plant cooling technologies. In addition, discharge-permit conditions may limit operations for some power plants as water temperatures rise (this has already occurred at some power plants during peak summer heat). In the aggregate, these changes may reduce the available power generating capacity during the summer, when demand is typically high. A relatively small change in available generating capacity could have significant implications for the total national electric power supply. An average reduction of 1 percent in electricity generated by thermal power plants nationwide would mean a loss of 25 billion kilowatt-hours per year—equivalent to the amount of electricity consumed by 2 million Americans. Such a power loss would need to be replaced or otherwise offset through improvements in energy efficiency (USGCRP 2009).

Terrestrial Resources

Climate change could affect terrestrial resources. Sea level rise could result in the loss of coastal marsh and cause saltwater intrusion into coastal forests (USGCRP 2009), thus eliminating habitat for wildlife. Global climate change could also cause shifts in species' ranges and migratory corridors, as well as changes in ecological processes (NRC 2011).

Climate change is already having effects on terrestrial animal and plant species throughout the United States. Some of the most obvious changes are related to the timing of the seasons, including when plants bud in spring and when birds and other animals migrate. Spring now arrives an average of 10 days to two weeks earlier than it did 20 years ago, and the growing season is lengthening over much of the continental United States. The ranges of many species in the United States have shifted northward in latitude and upward in elevation. As an example, the ranges of many butterfly species have expanded northward, contracted at their southern edges, and shifted to higher elevations as warming has continued. Also, horticultural hardiness zones (each zone represents a 10°F (5.6°C) change in minimum temperature) in the Midwest are likely to shift one-half to one full zone about every 30 years. Impacts on forests are likely to be mixed, with limited, positive effects of higher carbon dioxide levels potentially negated by the negative effects of decreased water supply (in the West) and more-frequent severe weather events like storms and droughts throughout the United States. On a broader scale, some common forests types are projected to expand, such as oak-hickory; others are projected to contract, such as maple-beech-birch. Still others, such as spruce-fir, are likely to disappear from the United States altogether (USGCRP 2009).

The potential for animals to shift their ranges to keep pace with the changing climate may be inhibited by major urban areas and by natural barriers like the Great Lakes. Insect pests that have historically been controlled by cold winters will more easily survive milder winters and may produce larger populations in areas that are already within their ranges. Further, increased temperatures, decreased rainfall, and more-severe droughts could also lead to the drying of lakes, ponds, and wetlands and the loss of riparian species (USGCRP 2009).

The Intergovernmental Panel on Climate Change has estimated that if a warming of 3.5 to 5.5°F (1.9 to 3°C) occurs, 20 to 30 percent of species that have been studied would be located in climate zones that are outside of their current ranges and would, therefore, likely be at risk of extinction. This high percentage is partly a result of pre-existing stresses, including habitat loss and continued overharvesting of some species (USGCRP 2009).

Aquatic Resources

The potential effects of climate change, whether from natural cycles or related man-made activities, could result in a variety of changes that would affect inland and coastal aquatic resources.

Water temperatures in lakes, streams, and rivers have been increasing across most of the United States and will continue to do so as air temperatures increase. According to USGCRP (2009), in some lakes for example, "this will lead to an earlier and longer period in summer during which mixing of the relatively warm surface lake water with the colder water below is reduced. In such cases, this stratification can cut off oxygen from bottom layers, increasing the risk of oxygen-poor or oxygen-free 'dead zones' that kill fish and other living things." In lakes with contaminated sediment, warmer water and low-oxygen conditions can more readily mobilize mercury and other persistent pollutants. In cases where increasing quantities of contaminants are taken up in the aquatic food chain, there will be additional potential for health hazards for species, including humans, that eat fish from the lakes. "Populations of coldwater fish, such as brook trout, lake trout, and whitefish, are expected to decline dramatically, while populations of coolwater fish such as muskellunge, and warmwater species such as smallmouth bass and bluegill, will take their places" (USGCRP 2009). Overall, large declines in trout populations are projected to occur around the United States "Over half of the wild trout populations are likely to disappear from the southern Appalachian Mountains because of the effects of rising stream temperatures. Losses of western trout populations may exceed 60 percent in certain regions" (USGCRP 2009). Aquatic ecosystem disruptions are likely to be compounded by invasions of non-native species that tend to thrive under a wide range of environmental conditions.

The environmental factors of significance that could affect estuarine systems include sea level rise, temperature increases, salinity changes, and wind and water circulation changes (Kennedy 1990). Changes in sea level could result in effects to nearshore communities, including the reduction or redistribution of submerged and emergent aquatic vegetation, changes in marsh communities, and influences to other wetland areas adjacent to nearshore systems. Sea level rise may outpace the ability of estuarine systems to migrate, and thus some habitats may be lost altogether. Water temperature changes could affect spawning patterns and success, and may influence the distribution of important species (e.g., cold water species may move northward while the ranges of warm water species expand). Changes in salinity could also influence the spawning and distribution of important species and the range of invasive species. Fundamental changes in precipitation could influence water circulation, salinity and mixing patterns, and change the nature of sediment and nutrient inputs to the system. This could result in changes to primary production and influence the estuarine food web. Some fisheries and aquaculture enterprises might benefit from climate change while others might suffer (Kennedy 1990). However, climate change could increase the frequency of red tide blooms, with adverse impacts to many fish species (USFWS and NMFS 2009).

In marine ecosystems, climate change may trigger effects similar to those in estuarine ecosystems. Effects may additionally include adverse impacts to corals, clams, shrimp, and other organisms with calcium carbonate shells or skeletons due to increased acidity (a side-effect that occurs when increased atmospheric carbon dioxide concentrations diffuse into the oceans); coral bleaching and increases in the rate of disease in corals; and more-frequent die-offs of sponges, seagrasses, and other organisms could occur as sea temperatures increase (Florida Oceans and Coastal Council 2009).

Historic and Cultural Resources

Sea level rise and changes in meteorological conditions due to climate change could result in the loss of historic and cultural resources due to short-term flooding, erosion, or long-term inundation. Due to the differences in timing and rate of climate and sea-level changes, it is possible that some resources could be lost before they could be documented or otherwise studied.

Socioeconomics

Changes in climate conditions could have an impact on the availability of jobs in certain industries. For example, the USGCRP noted that tourism and recreation are major job creators in some regions, bringing billions of dollars to regional economies. Across the nation, fishing, hunting, skiing, snowmobiling, diving, beach-going, and other outdoor activities make important economic contributions and are also a part of tradition. A changing climate would mean reduced opportunities for some activities in some locations and expanded opportunities for others. Hunting and fishing opportunities will change as animals' habitats shift and as relationships among species are disrupted by their different responses to climate change. Water-dependent recreation in areas projected to get drier, such as the Southwest, and beach recreation in coastal areas (which are expected to see rising sea levels) will suffer. Some regions will see an expansion of the season for warm weather recreation such as hiking and bicycle riding, while other areas will see a decline in—or elimination of—cold-weather recreation (USGCRP 2009).

Human Health

Increasing temperatures due to changes in climate conditions could have an impact on human health. The ranges of disease-carrying insects and animals may expand. At the same time, hotter weather may increase the incidence of health-threatening air pollution events (USGCRP 2009). This is in addition to the risk to life and property resulting from sea-level rise, intense precipitation events, flooding, erosion, and storm surge. Unusually intense storm events can also overload drainage systems and water treatment facilities, increasing the risk of waterborne diseases (USGCRP 2009).

Environmental Justice

Changes in climate conditions could disproportionately affect minority and low-income populations. The USGCRP (2009) indicates that "infants and children, pregnant women, the elderly, people with chronic medical conditions, outdoor workers, and people living in poverty are especially at risk from a variety of climate-related health effects." Examples of these effects include increased heat stress, air pollution, extreme weather events, and diseases carried by food, water, and insects. The greatest health burdens related to climate change are likely to fall on the poor, especially those lacking adequate shelter and access to other resources such as air conditioning. Elderly people, who are more likely to be poor, are also more likely to have debilitating chronic diseases or limited mobility. In addition, the elderly have a reduced ability to regulate their own body temperature or sense when they are too hot. According to the USGCRP (2009), they "are at greater risk of heart failure, which is further exacerbated when cardiac demand increases in order to cool the body during a heat wave." The USGCRP study also found that people taking medications, such as diuretics for high blood pressure, have a higher risk of dehydration.

Cumulative Impacts

The USGCRP found that climate change will combine with other social, economic, and environmental stresses to create larger impacts than from any of these factors alone (USGCRP 2009). In addition, the cumulative impacts of climate change will be further examined in each site-specific SEIS.

4.13 Cumulative Impacts of the Proposed Action

Cumulative impact is defined by the CEQ in 40 CFR 1508.7. Actions to be considered in cumulative impact analyses include new and continuing activities, such as license renewal, that are conducted, regulated, or approved by a Federal agency. The cumulative impacts analysis takes into account all actions, however minor, since impacts from individually minor actions may be significant when considered collectively over time. The goal of the cumulative impact analysis is to identify potentially significant impacts to improve decisions and move toward more sustainable development (CEQ 1997; EPA 1999).

> ***Definition of Cumulative Impact***
>
> The impact on the environment that results from the incremental impact of an action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency (Federal or non-Federal) or person undertakes such other actions.

The analysis of cumulative impacts focuses on resources that could be affected by the incremental impacts from continued operations and refurbishment of the nuclear power plant associated with license renewal. The CEQ discusses the assessment of cumulative effects in detail in its report entitled, *Considering Cumulative Effects Under the National Environmental Policy Act* (CEQ 1997). On the basis of the guidance provided in the CEQ report, a cumulative impact analysis would consider the following:

- The geographic scope (i.e., regions of influence). The regions of influence encompass the areas of affect and the distances at which impacts associated with license renewal may occur. Geographic boundaries may vary by resource area and the distances over which an impact may be experienced (e.g., the evaluation of impacts on air quality may have a greater regional extent than that of impacts on historic and cultural resources).

- The time frame for the analysis. The time frame incorporates the sum of the effects of license renewal in combination with past, present, and reasonably foreseeable future actions since impacts may accumulate or develop over time. The time frame for future actions is the 20-year license renewal term after the end of the original license term. Past and present actions include all actions up to and including the time of the license renewal application. Future actions are those that are "reasonably foreseeable"; that is, they are ongoing (and will continue into the future), are funded for future implementation, or are included in firm, near-term plans. Past and present actions are generally accounted for in the baseline assessment presented in the affected environment sections for each resource area in Chapter 3 of this GEIS. The direct and indirect impact analyses present in Chapter 4 address the incremental impacts of license renewal. These analyses are carried forward to the cumulative impact analysis, which expands the analysis to consider other past, present, and reasonably foreseeable future actions.

- The potential effects of each past, present, or reasonably foreseeable future action. Both the license renewal and other actions (related and nonrelated, including trends such as global climate change) will generate effects that could contribute to cumulative impacts. The impacts of activities associated with the proposed action (license renewal) are discussed for each resource area in this chapter. In cases where the contributions of activities to an impacting factor are uncertain or not well known, a qualitative evaluation is made.

For some resource areas (e.g., water and aquatic resources), the contributions of ongoing actions within a region to cumulative impacts are regulated and monitored through a permitting process (e.g., NPDES) under State or Federal authority. In these cases, it may be assumed that cumulative impacts are managed as long as these actions (facilities) are in compliance with their respective permits.

The following sections describe the environmental resource areas that could be affected by past, present, and reasonably foreseeable future actions that, combined with the effects of the proposed license renewal action, could result in cumulative impacts. For the most part, environmental conditions in the vicinity of nuclear power plants are not expected to change during the license renewal term much beyond what is currently being experienced. Cumulative impacts are considered a Category 2 issue requiring a plant-specific analysis as part of the license renewal environmental review.

4.13.1 Air Quality

Regional air quality conditions could deteriorate from the cumulative effects of emissions associated with past, present, and reasonably foreseeable urban, industrial, commercial, agricultural, and transportation development. These activities give rise to dust, exhaust, and evaporative emissions that degrade air quality. The magnitude of cumulative impacts would depend on the location of the nuclear power plant and the number, type, and intensity of development within the airshed and its location relative to air quality nonattainment areas.

4.13.2 Noise

Noise levels in the vicinity of a nuclear power plant could increase from planned activities associated with urban, industrial, and commercial development. The magnitude of cumulative impacts would depend on a nuclear plant's proximity to other noise sources.

4.13.3 Geology and Soils

Cumulative impacts on geologic resources relate to issues concerning access to mineral or energy resources, destruction of unique geologic features, and mass movement induced by construction activities. These impacts typically result from land disturbance activities (e.g., earthmoving, blasting, grading, and excavation) associated with urban development, industrial and commercial development, water projects, and transportation development. Existing land uses may also affect the access to mineral or energy resources. Impacts on soil resources relate to increases in the potential for soil erosion, which also occurs as a result of land disturbance activities. Vegetation clearing and grading can increase the potential for soil erosion in the absence of soil erosion protection measures. The magnitude of cumulative impacts would depend on the nature and location of the actions and whether appropriate mitigation measures are implemented to reduce the impacts.

4.13.4 Surface Water Resources

Cumulative impacts on surface water resources relate to issues concerning water use and quality. Impacts typically result from activities (e.g., water withdrawal, effluent discharges, accidental spills and releases) associated with urban development, industrial and commercial development, agricultural development, water projects (e.g., dredging), and grazing. Short-duration construction projects (e.g., road construction) can also result in surface water impacts if they increase soil erosion, which, in turn, increases sediment loading to nearby surface water bodies. The magnitude of cumulative impacts would depend on the nature and location of the actions relative to surface water bodies, the number of actions (facilities or projects), and whether facilities comply with regulating agency requirements (e.g., permitted discharge limits).

Perhaps the most important source of surface water impacts is the withdrawal of water for plant cooling systems (both once-through and closed-cycle). These impacts relate to water use conflicts with other users. Although once-through systems return most of their withdrawn water (minus evaporative losses of less than 3 percent), surface water withdrawals for closed-cycle cooling systems can have significant impacts. This is because consumptive losses are much higher (up to 60 percent), resulting in the return of less water (see Section 4.5). These impacts may be greater during times of drought, especially when temperatures are high.

4.13.5 Groundwater Resources

Cumulative impacts on groundwater resources relate to issues concerning water use and quality. Impacts typically result from the water demands associated with urban, industrial and commercial, and agricultural development. Short-duration construction projects could also result in groundwater impacts over time (e.g., from spills), unless BMPs (e.g., spill prevention and control plans and spill containment measures) are employed. The magnitude of cumulative impacts would depend on the number of actions (facilities or projects) that withdraw water from the aquifer, the overall demand on the aquifer, the hydrogeologic characteristics of the aquifer, and whether facilities follow BMPs to protect groundwater resources from degradation and overpumping.

4.13.6 Ecological Resources

Cumulative impacts on terrestrial habitats and wildlife include habitat loss and degradation, disturbance and displacement, injury and mortality, and obstruction of movement. Impacting factors include exposure to elevated noise levels and contaminants, altered surface water and groundwater quality and flow patterns, and hazards associated with direct contact with physical structures (e.g., bird collisions with buildings and other structures). Adverse impacts typically result from activities (e.g., construction) associated with urban sprawl, industrial and commercial development, agricultural development, transportation development, water projects, and regional tourism and recreation. Migratory species may be affected by activities carried out in locations remote from the nuclear plant sites. Plant communities (including floodplain and wetland communities) also may be affected by activities (e.g., clearing and grading) associated with these actions, creating conditions that favor the encroachment of invasive species. The magnitude of cumulative impacts resulting from all actions taking place within the region in which a power plant is located would depend on the nature and location of the actions relative to important wildlife habitats and plant communities, the number (and density) of actions, and the extent to which these actions (facilities or projects) employ mitigation measures to minimize such impacts.

Three scales of cumulative impacts on aquatic resources can be identified: (1) cumulative impacts due to the various impacts from an individual power plant (e.g., entrainment, impingement, thermal discharges, and chemical discharges), (2) cumulative impacts due to closely sited power plants, and (3) cumulative impacts due to multiple activities that affect the water body (e.g., dams, agriculture, urban, and industrial development) (York et al. 2005). Cumulative impacts on aquatic habitats and species include the (1) loss and degradation of habitat; (2) species disturbance, displacement, injury, and mortality; (3) obstruction of movement; and (4) the introduction and spread of invasive species. These impacts result from activities (e.g., increased water use and discharges to natural water bodies, increased and contaminated runoff) associated with urban sprawl; industrial, commercial, agricultural, and transportation development; water projects; and regional tourism and recreation. The magnitude of cumulative impacts would depend on the nature and location of the actions relative to important water bodies, the number (and density) of actions, and the extent to which these actions (facilities or projects) employ mitigation measures to minimize such impacts.

4.13.7 Historic and Cultural Resources

Cumulative impacts on historic and cultural resources relate to the damage or destruction of historic and cultural resources (i.e., archaeological sites, historic structures, and traditional cultural properties, or their context). These impacts typically result from land disturbance (e.g., earthmoving, blasting, grading, and excavation) or maintenance activities associated with urban, industrial and commercial, agricultural, and transportation development (e.g., vegetation clearing). Such activities may directly damage or destroy cultural artifacts or increase the potential for their exposure by accelerating erosion, leaving them vulnerable to theft and vandalism. The magnitude of cumulative impacts would depend on the nature and location of the actions and whether appropriate mitigation measures (in consultation with the SHPO) are implemented.

4.13.8 Socioeconomics

Employment and income are generated by the construction and operation of new industries, including the construction of new nuclear power plants, which can have a significant cumulative socioeconomic effect. Income generated by wages, salaries, and the increased demand for services creates additional demand for goods, public services, and housing. Employment in new industries increases the size of the population and the demand for public services, housing, and transportation. The magnitude of cumulative impacts would depend on the location of the existing nuclear power plant subject to license renewal and the number, type, and intensity of industrial development within the region of impact.

4.13.9 Human Health

Cumulative human health impacts relate to public exposure to radiological, chemical, and microbiological hazards and the potentially chronic effects of EMF exposure. Public exposures may occur as a result of environmental accumulations of harmful constituents released from various facilities associated with urban development, agriculture, and industrial and commercial development. The cumulative impacts of EMF exposure, while uncertain, would relate to activities (e.g., transmission lines and substations) associated with urban, industrial, and commercial development.

The magnitude of cumulative impacts would depend on the nature and location of the actions, the number of actions (facilities or projects), the level of the public's exposure, and whether facilities comply with regulating agency requirements (e.g., permitted discharge limits).

4.13.10 Environmental Justice

Cumulative impacts can result when impacts on various individual resources (air, land, water, and ecology) combine to produce human health and environmental impacts that could be cumulatively high and adverse. Whether these impacts are disproportionately high and adverse to minority and low-income populations depends on the unique characteristics of these populations residing in the vicinity of the nuclear power plant. Potentially adverse human health and environmental impacts from activities associated with industrial, commercial, agricultural, and transportation development can affect the resources on which these populations depend (e.g., fish, game animals, and native vegetation).

4.13.11 Waste Management and Pollution Prevention

Radioactive Waste—There are facilities other than the commercial nuclear power reactors and other uranium fuel cycle facilities that generate radioactive waste. Depending on the locations of these facilities and the locations of treatment and disposal facilities, there could be cumulative impacts resulting from the cumulative effects of transportation, treatment, and disposal activities. However, some nuclear power plants are likely to be the only significant generators of radioactive waste within the region. As a result, the cumulative impacts from radioactive waste management and pollution prevention would be similar to the impact from the overall incremental contribution of license renewal, as discussed in Sections 4.11.1 and 4.12.1.1.

Other Wastes—Waste-generating facilities must comply with Federal and State regulations in terms of storage, treatment, and disposal. In addition, facilities must employ procedures that ensure the proper handling and storage of wastes and monitoring for releases.

4.13.12 Global Climate Change

Global climate change is a global problem resulting from emissions of GHGs both within and beyond the region in which a power plant is located. Changes in climate over the license renewal term have the potential to contribute significantly to cumulative impacts on air and water resources, ecological resources, and human health as a consequence of changes in precipitation, temperature, frequency and severity of storms, sea level, floods, and droughts. Climate change observations and future climate scenarios are documented in reports developed by the U.S. National Oceanic Atmospheric Administration (NOAA 2013) and Intergovernmental Panel on Climate Change (IPCC 2007). The direction and nature of these changes are predicted to vary widely across the country and the regions in which operating nuclear power plants exist. Such effects are documented in the U.S. Global Change Research Program state of knowledge report, *Global Climate Change Impacts in the United States* (USGCRP 2009).

4.14 Resource Commitments Associated with the Proposed Action

This section addresses the resources that would be committed under the proposed action. In particular, it describes unavoidable adverse environmental impacts (Section 4.14.1), the relationship between short-term uses of the environment and the maintenance and enhancement of long-term productivity (Section 4.14.2), and the irreversible and irretrievable commitment of resources (Section 4.14.3) that would be associated with the proposed action (license renewal). Potential unavoidable adverse environmental impacts and irreversible and irretrievable resource commitments that would be associated with alternatives to the proposed action are also discussed.

4.14.1 Unavoidable Adverse Environmental Impacts

Unavoidable adverse environmental impacts are impacts that would occur after implementation of all feasible mitigation measures. Continued nuclear power plant operations and the implementation of any of the replacement power alternatives considered in this GEIS would result in some unavoidable adverse environmental impacts.

The impacts of continued nuclear power plant operations that are anticipated to occur are discussed for each resource area in Sections 4.1 through 4.11. Some of these impacts cannot be avoided because they are inherently associated with nuclear power plant operations and cannot be fully mitigated. Minor unavoidable adverse impacts on air quality would occur due to emission and release of various chemical and radiological constituents into the environment from plant operations. Nonradiological emissions are expected to comply with EPA emissions standards, though the alternative of operating a fossil-fueled power plant in some areas may worsen existing air quality attainment issues. Routine chemical and radiological emissions would not exceed the National Emission Standards for Hazardous Air Pollutants. Other unavoidable adverse impacts (depending on the plant) include the impact on land use and visual resources, some minor noise effects, surface water and groundwater use, thermal effluents emitted to the environment from the power conversion equipment, and entrainment and impingement of aquatic organisms in the cooling water system.

During nuclear power plant operations, workers and members of the public would face unavoidable exposure to radiation and hazardous and toxic chemicals, but releases would be controlled and the resulting exposures would not exceed any standards or regulatory limits. Workers would be exposed to radiation and chemicals associated with routine plant operations and the handling of nuclear fuel and waste material. Workers would have a higher risk of exposure than members of the public, but doses would be administratively controlled and would not exceed any standards or administrative control limits. Construction and operation of alternative replacement power energy generating facilities would also result in unavoidable exposure to hazardous and toxic chemicals to workers and the general public.

Also unavoidable would be the generation of spent nuclear fuel and waste material, including LLW, hazardous waste, and nonhazardous waste. Hazardous and nonhazardous wastes would also be generated at non-nuclear power generating facilities. Wastes generated during plant operations would be collected, stored, and shipped for suitable treatment, recycling, or disposal in accordance with applicable Federal and State regulations. Due to the costs of handling these materials, power plant operators would be expected to conduct all activities and optimize all operations in a way that generates the smallest amount of waste practical. Although pollution prevention and waste minimization efforts are intended to prevent emissions to the environment and prevent and/or minimize the quantities of waste generated, some waste and emissions cannot be entirely eliminated due to current technology.

Many of these unavoidable impacts are being mitigated by incorporating safety features and/or applying operational procedures at the plants and are monitored by the plant owners and State agencies. Thermal, entrainment, and impingement impacts at plants with once-through cooling water systems are unavoidable. However, these impacts could be reduced by modifying the once-through cooling system or by converting to a closed-cycle cooling system. Although closed-cycle cooling water systems can reduce thermal, entrainment, and impingement impacts, they increase water consumption (through cooling tower evaporation), fogging, icing, and salt drift.

Nuclear power plants being considered for license renewal already exist and have been operating for decades. The environmental impacts considered for license renewal are those associated with continued nuclear power plant operation and refurbishment. Replacement power and other alternatives to license renewal generally involve major construction impacts.

Therefore, unavoidable adverse impacts of a replacement power alternative could be greater than those associated with the continued operation of an existing nuclear power plant.

Unavoidable adverse impacts would vary among the nuclear power plants, and the scale of the impact would depend on the specific characteristics of each power plant and its interaction with the environment. These unavoidable adverse impacts are evaluated in plant-specific SEISs.

4.14.2 Relationship between Short-Term Use of the Environment and Long-Term Productivity

The operation of power generating facilities would result in short-term uses of the environment as described earlier in this Chapter. "Short term" is the period of time during which continued power generating activities would take place.

Power plant operations would necessitate short-term use of the environment and commitments of resources and would also commit certain resources (e.g., land and energy) indefinitely or permanently. Certain short-term resource commitments would be substantially greater under most energy alternatives, including license renewal, than under the no-action alternative due to the continued generation of electrical power as well as continued use of generating sites and associated infrastructure. During operations, all energy alternatives would entail similar relationships between local short-term uses of the environment and the maintenance and enhancement of long-term productivity.

Short-term use of the environment can affect long-term productivity of the ecosystem if that use alters the ability of the ecosystem to reestablish an equilibrium that is comparable to that of its original condition. An initial commitment regarding the trade-off between short-term use and long-term productivity at a nuclear power plant was made when the power plant was first constructed decades ago. Renewal of the operating license and the continued operation of the nuclear power plant would not alter any existing effects on long-term productivity, but they might postpone the availability of the power plant site for other uses. The no-action alternative would lead to a cessation of operations and shutdown of the power plant (an eventuality regardless of whether or not a license is renewed).

Air emissions from power plant operations would introduce small amounts of radiological and nonradiological constituents to the region around the plant site. Over time, these emissions could result in increased concentrations and exposure but are not expected to impact air quality or radiation exposure to the extent that public health and long-term productivity of the environment would be impaired.

Continued employment, expenditures, and tax revenues generated during power plant operations would directly benefit local, regional, and State economies over the short term.

Local governments investing project-generated tax revenues into infrastructure and other required services could enhance economic productivity over the long term.

The management and disposal of spent nuclear fuel, LLW, hazardous waste, and nonhazardous waste would require an increase in energy and would consume space at treatment, storage, or disposal facilities. Regardless of the location, the use of land to meet waste disposal needs would reduce the long-term productivity of the land.

Power plant facilities would be committed to electricity production over the short term. After decommissioning these facilities and restoring the power plant site, the land would become available for other productive uses.

The nature of the relationship between short-term use of the environment and long-term productivity would vary among plants and would depend on the specific characteristics of each plant and its interaction with the environment. This relationship is evaluated in plant-specific SEISs.

4.14.3 Irreversible and Irretrievable Commitment of Resources

Irreversible and irretrievable commitment of resources for electrical power generation would include the commitment of land, water, energy, raw materials, and other natural and manmade resources required for power plant operations during the license renewal term and any refurbishment activities that might be carried out that would not otherwise have taken place if the operating licenses had not been renewed. This section describes the irreversible and irretrievable commitments of resources that have been identified in this GEIS. A commitment of resources is irreversible when primary or secondary impacts limit the future options for a resource. An irretrievable commitment refers to the use or consumption of resources neither renewable nor recoverable for future use. In general, the commitment of capital, energy, labor, and material resources would also be irreversible.

Resources include materials and equipment required for nuclear power plant maintenance and operation, energy and water needed to run the plants, the nuclear fuel used by the reactors to generate electricity, and the land required to permanently dispose of the radioactive and nonradioactive wastes. Some of these resources could be retrieved and reused at the end of the license renewal term. For example, some reactor equipment can be used at other reactors or can be decontaminated and released for recycling or restricted or unrestricted use by others. However, some of the equipment and irradiated components that might be replaced during the license renewal term might not be reused or recycled and therefore need to be permanently disposed of. In addition, the fossil fuels used by power plants would be permanently lost. Most of the water used by power plants relying on once-through cooling is returned to the surface water bodies that supply the cooling water. The relatively small portion of the water that evaporates to the air would be lost to the local water bodies and the region but would be returned to the environment as part of the hydrologic cycle, potentially within another watershed. For closed-cycle cooling systems, a much larger percent of the water used for cooling would be lost to evaporation, but that, too, would be returned as part of the hydrologic cycle.

The most significant irreversible and irretrievable commitment of resources related to nuclear power plant operations during the license renewal term would be the nuclear fuel used to generate electricity and the land used to dispose and store wastes, including spent nuclear fuel generated during the license renewal term. The treatment, storage, and disposal of LLW, hazardous waste, and nonhazardous waste would require the irretrievable commitment of energy and fuel and could result in the irreversible commitment of space in disposal facilities. Some of the land used for the disposal of LLW may be available for other uses in a few hundred years because of the nearly complete decay of short-lived radionuclides in LLW, but most of the land used for the disposal of some mixed or hazardous wastes could be permanently lost to other users.

The irreversible and irretrievable commitment of resources would not be the same for all nuclear power plants and would depend on the specific characteristics of the power plant and its resource needs. This commitment is evaluated in plant-specific SEISs.

The implementation of any of the replacement power alternatives would entail the irreversible and irretrievable commitment of energy, water, chemicals, and, in some cases, fossil fuels. These resources would be committed over the entire life cycle of the power plant from construction, operation, and decommissioning, and would essentially be unrecoverable.

Energy expended would be in the form of fuel for equipment, vehicles, and power plant operations and electricity for power plant construction and facility operations. Electricity and fuels would be purchased from offsite commercial sources. Water would be obtained from existing water supply systems. These resources are generally available, and the amounts required are not expected to deplete available supplies or exceed available system capacities.

The irreversible and irretrievable commitment of material resources are the materials that cannot be recovered or recycled, materials that are rendered radioactive and/or cannot be decontaminated, and materials consumed or reduced to unrecoverable forms of waste. However, none of the resources used by these alternative replacement power generating facilities is in short supply, and, for the most part, readily available.

Various materials and chemicals, including acids and caustics, would be required to support operations activities. These materials would be derived from commercial vendors, and their consumption is not expected to affect local, regional, or national supplies.

4.15 References

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The overall responsibility for the preparation of this Generic Environmental Impact Statement revision was assigned to the U.S. Nuclear Regulatory Commission (NRC), Office of Nuclear Reactor Regulation. The revision was prepared by members of the Office of Nuclear Reactor Regulation with assistance from other NRC organizations, Argonne National Laboratory, and Information Systems Laboratories, Inc.

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(a) Argonne National Laboratory is operated for the U.S. Department of Energy by UChicago Argonne, LLC.
(b) Information Systems Laboratories, Inc., is located in Rockville, Maryland.

6 Distribution List

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David Agnew	Cape Cod Downwinders
Jack Alexander	Entergy Nuclear
Ralph Andersen	Nuclear Energy Institute
Rita Arditti	Women's Community Center Cancer Project
Kathryn Barnes	Don't Waste Michigan
Craig Beauchamp	Coalition for Responsible and Ethical Environmental Decisions
Rochelle Becker	Alliance for Nuclear Responsibility
Tama Becker-Varano	San Luis Obispo Mothers for Peace
Pamela Blockey-O'Brien	Private Citizen
Dorothy Boberg	United Nations Association of the San Fernando Valley
James Boyd	California Energy Commission
Rodger Boyd	Private Citizen
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7 Glossary

Absorbed dose: The energy imparted by ionizing radiation per unit mass of tissue. The units of absorbed dose are the rad and the gray (Gy).

Acid: A solution with a pH measurement less than 7

Acid rain: Also called acid precipitation or acid deposition, acid rain is precipitation containing harmful amounts of nitric and sulfuric acids formed from the smokestacks of coal and oil burning power plants and from nitrogen oxides emitted by motor vehicles. It can be wet precipitation (rain, snow, or fog) or dry precipitation (absorbed gaseous and particulate matter, aerosol particles, or dust). The term pH is a measure of acidity or alkalinity and ranges from 0 to 14. A pH measurement of 7 is regarded as neutral. Normal rain has a pH of about 5.6, which is slightly acidic. Acid rain has a pH below 5.6.

Activation products: Radionuclides produced from the interaction of radiation with matter. Generally it is the neutrons that interact with stable atoms and make them radioactive.

Activity: The rate of disintegration (transformation) or decay of radioactive material. The units of radioactivity are the curie (Ci) and the Becquerel (Bq).

Acute effects: Effects resulting from short-term exposure to relatively high levels of a stressing factor (e.g., contaminant, disease, electromagnetic field, noise, and radionuclides) over long periods.

Acute radiation exposure: A single accidental exposure to high doses of radiation for a short period of time, which may produce biological effects within a short time after exposure.

Adverse environmental impacts: Impacts that are determined to be harmful to the environment.

Advisory Council on Historic Preservation (ACHP): Established by the National Historic Preservation Act of 1966, the Advisory Council on Historic Preservation is an independent Federal agency that promotes the preservation, enhancement, and productive use of the nation's historic resources *and advises the President and the Congress on national historic preservation policy*. The agency provides guidance on the application of Federal law concerning cultural resources and serves as an arbiter when disputes arise.

Aerobic: Requiring the presence of oxygen to support life.

Air quality: Assessment of the health-related and visual characteristics of the air often derived from quantitative measurements of the concentrations of specific injurious or contaminating substances. Air quality standards are the prescribed levels of substances in the outside air that cannot be exceeded during a specific time in a specified area.

ALARA: Acronym for “as low as (is) reasonably achievable.” This means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest (see 10 CFR 20.1003).

Alkaline or basic: A solution with a pH measurement above 7.0.

Alkalinity: The capacity of water to neutralize acids; a property imparted by the water's content of carbonate, bicarbonate, hydroxide, and on occasion borate, silicate, and phosphate.

Alluvial: Refers to soil or unconsolidated sediment that has been deposited by running water, as in a riverbed, floodplain, or delta.

Alluvial aquifer: An aquifer composed of alluvial sediments, generally located in a river valley.

Alpha particle: Positively charged highly energetic ionizing radiation that consists of two protons and two neutrons.

Alternatives to the proposed action considered in the GEIS: (1) Not renewing the operating licenses of commercial nuclear power plants (no-action alternative). This is the only alternative to the proposed action that is within the NRC’s decision-making authority; (2) replacing existing nuclear generating capacity with other energy sources (including fossil energy generation, new nuclear generation, and renewable energy); (3) compensating for lost nuclear generation capacity by using demand-side management (conservation) or purchasing power.

Ambient air: The surrounding atmosphere as it exists around people, plants, and structures.

Ambient noise level: The level of acoustic noise at a given location, such as in a room or outdoors, that is representative of typical conditions unaffected by human activities.

Ambient water temperature: The water temperature in a water body that is representative of typical conditions unaffected by human activities (e.g., the temperature of the surface water body away from the thermal effluent).

Anadromous: Pertaining to fish that spend a part of their life cycle in the sea and return to freshwater streams to spawn; for example, salmon, steelhead, and shad.

Annual dose: Dose received in one year.

Anoxic: Absence of oxygen. Usually used in reference to an aquatic habitat when the water becomes completely depleted of oxygen and results in the death of any organism that requires oxygen for survival.

Anthracite coal: A hard, black coal averaging 86–97 percent carbon, but with a slightly lower heating value than bituminous coal. Anthracite coal deposits are rare in the United States and account for less than 1 percent of annual production. Its limited availability confines its use to specialty applications such as residential and industrial space heating.

Anthropogenic: Made or generated by a human or caused by human activity.

Aquatic biota: Consisting of, relating to, or being in water; living or growing in, or near the water. An organism that lives in, on, or near the water.

Aquifer: An underground layer of permeable, unconsolidated sediments or porous or fractured bedrock that yields usable quantities of water to a well or spring.

Archaeological Resources Protection Act of 1979: Requires Federal permitting for excavation or removal of archaeological resources from public or Native American lands.

Area of Potential Effect (APE): The geographic area or areas within which an undertaking may directly or indirectly cause alterations in the character or use of historic properties, if any such properties exist. The APE for a license renewal action is the area at the power plant site and its immediate environs and viewshed that may be impacted by post-license renewal land-disturbing operations or possible refurbishment activities associated with the proposed action. The APE may extend beyond the immediate environs in those instances where post-license renewal land-disturbing operations or projected refurbishment activities specifically related to license renewal may potentially have an effect on known or proposed historic sites. This determination is made irrespective of ownership or control of the lands of interest (see also 36 FR 800.16(d)).

Atom: The smallest particle of an element that cannot be divided or broken up by chemical means. It consists of a central core of protons and neutrons, called the nucleus. Electrons revolve in orbits in the region surrounding the nucleus.

Atomic Energy Act: The Atomic Energy Act of 1954 is a United States Federal law that is, according to the Nuclear Regulatory Commission, “the fundamental U.S. law on both the civilian and the military uses of nuclear materials.” It covers the laws for the “development and the regulation of the uses of nuclear materials and facilities in the United States.” It was an amendment to the Atomic Energy Act of 1946 and substantially refined certain aspects of the law, including increased support for the possibility of a civilian nuclear industry.

Attainment: An area is deemed in attainment by the U.S. Environmental Protection Agency (EPA) when the air quality is monitored and the resultant concentrations are found to be consistently below the National Ambient Air Quality Standards (NAAQS). Areas can be in attainment for some pollutants, while designated as nonattainment for others. Some areas are designated as “maintenance” areas. These are regions that were initially designated as attainment or unclassifiable and have since attained compliance with the NAAQS.

Attenuation: The reduction or lessening in amount, such as in the concentration or effects of a pollutant.

Auxiliary buildings: Auxiliary buildings house support systems, such as the ventilation system, emergency core cooling system, laundry facilities, water treatment system, and waste treatment system. An auxiliary building may also contain the emergency diesel generators and, in some pressurized water reactors, the fuel storage facility. The facility’s control room is often located in the auxiliary building.

Avian: Of, relating to, or characteristic of birds.

Barrel: A unit of volume equal to 42 U.S. gallons.

Background radiation: Radiation from cosmic sources; naturally occurring radioactive material, including radon (except as a decay product of source or special nuclear material); and global fallout as it exists in the environment from the testing of nuclear explosive devices or from past nuclear accidents such as Chernobyl and are not under the control of the licensee. Background radiation does not include radiation from sources, by-products, or special nuclear materials regulated by the Commission.

Baseline: A quantitative expression of conditions, costs, schedule, or technical progress that constitutes the standard against which to measure the performance of an effort. For National Environmental Policy Act evaluations, baseline is defined as the existing environmental conditions against which impacts of the proposed action and its alternatives can be compared. The environmental baseline is the site environmental conditions as they exist or are estimated to exist in the absence of the proposed action.

Becquerel: The unit of radioactive decay equal to 1 disintegration per second. 37 billion (3.7×10^{10}) becquerels = 1 curie (Ci).

BEIR reports: Series of reports issued by the National Research Council to advise the Federal government on the relationship between exposure to ionizing radiation and human health. BEIR stands for Biological Effects of Ionizing Radiation.

Benthic: Of, relating to, or occurring at the bottom of a body of water.

Best Available Control Technology (BACT): A pollution control standard created by the U.S. Environmental Protection Agency that is used to determine what air pollution control technology will be used to control a specific pollutant to a specified limit.

Best management practices (BMPs): A practice or combination of pollution control techniques that aim to reduce pollution.

Beta particle: An electron that is ejected from the nucleus of a radioactive atom. It is much lighter than an alpha particle and can travel a longer distance in air compared to an alpha particle, but can still be stopped by a thin sheet of aluminum foil.

Bioamplification: Also known as biological magnification and bioconcentration, is the progressive increase in the concentration of chemical contaminants (e.g., DDT, PCBs, methyl mercury) from the bottom of the food chain (e.g., bacteria, phytoplankton, zooplankton) to the top of the food chain (e.g., fishing-eating birds such as a bald eagle).

Bioavailability: The degree to which chemicals can be taken up by organisms.

Biocide: A chemical agent, such as a pesticide, that is used to kill and control living organisms.

Biological Assessments: Information prepared by or under the direction of the Federal agency concerning listed and proposed species and designated and proposed critical habitat that may be present in the action area and the evaluation of potential effects of the action on such species and habitat.

Biomass: Organic nonfossil material of biological origin constituting a renewable energy source.

Biota: The combined flora and fauna of a region.

Bituminous coal: A dense black or brown coal that has, on average 45–86 percent carbon by weight and a heating value as much as five times greater than lignite coal. U.S. deposits are 100–300 million years old and are found primarily in the states of West Virginia, Kentucky, and Pennsylvania, with lesser amounts in the Midwest. Bituminous coal is the most abundant rank of coal in the United States. It is used primarily to produce electricity, and in the industrial sector, to produce heat and process steam and as a starting material for the production of coke, an intensely hot-burning derivative fuel used in the steel industry.

Blast furnace: A furnace in which solid fuel (coke) is burned with an air blast to smelt ore.

Blowdown: Continual or periodic purging of a circulating working fluid to prevent buildup of impurities in the fluid.

Boiler: A device for generating steam for power, processing, or heating purposes; or hot water for heating purposes or hot water supply. Heat from an external combustion source is transmitted to a fluid contained within the tubes found in the boiler shell. This fluid is delivered to an end-use at a desired pressure, temperature, and quality.

Boiling water reactor (BWR): A reactor in which water, used as both coolant and moderator, boils in the core to produce steam, which drives a turbine connected to an electrical generator, thereby producing electricity.

Brownfield site: Abandoned, idled, or under-used industrial and commercial facilities in which expansion or redevelopment is sometimes complicated by real or perceived environmental contaminations. (See also greenfield site).

Btu: British thermal unit. A measure of the energy required to raise the temperature of one pound of water by one degree Fahrenheit.

Burnup spent fuel: See spent fuel burnup.

Cap and trade: An environmental policy instrument used by governments to limit the amount of pollutants emitted to the environment. The total emissions are capped at a specified level but polluters can trade the emission allowances among themselves as long as the total amount is not exceeded.

Capacity: See generator capacity.

Capacity factor: The actual energy output of an electricity-generating device divided by the energy output that would be produced if it operated at its rated power output for the entire year. Generally expressed as percentage.

Capacity rating: See rated power.

Carbon: A naturally abundant nonmetallic element that occurs in many inorganic and in all organic compounds, which exists freely as graphite and diamond and as a constituent of coal, limestone, and petroleum. Carbon is capable of chemical self-bonding to form an enormous number of chemically, biologically, and commercially important molecules. Carbon's atomic number is 6.

Carbon capture and storage: Refers to the capture of carbon dioxide generated at fossil-fueled power plants and the storing of carbon dioxide so it is not released into the air. Underground storage media are being investigated for this feasibility (e.g., abandoned mines, depleted oil or natural gas fields, and other types of geologic media).

Carbon monoxide (CO): A colorless, odorless gas formed when carbon in fuel is not burned completely. Motor vehicle exhaust is a major contributor to nationwide CO emissions, followed by other engines and vehicles. CO interferes with the blood's ability to carry oxygen to the body's tissues and results in numerous adverse health effects. CO is listed as a criteria air pollutant under Title I of the Clean Air Act.

Carbonaceous: Consisting of, containing, relating to, or yielding carbon.

Carbon sequestration: See carbon capture and storage.

Carcinogenesis: The process by which normal cells are transformed into cancer cells.

Cask: A heavily shielded container used to store and/or ship radioactive materials. Lead and steel are common materials used in the manufacture of casks.

Category 1 issue: Environmental impact issues that meet all of the following criteria: (1) the environmental impacts associated with the issue have been determined to apply either to all nuclear plants or, for some issues, to nuclear plants that have a specific type of cooling system or other specified plant or site characteristics; (2) a single significance level (i.e., small, moderate, or large) has been assigned to the impacts (except for collective offsite radiological impacts from the fuel cycle and from high-level waste and spent fuel disposal); (3) mitigation of adverse impacts associated with the issue has been considered in the analysis, and it has been determined that additional plant-specific mitigation measures are likely not to be sufficiently beneficial to warrant implementation. For issues that meet the three Category 1 criteria, no additional plant-specific analysis is required in future supplemental environmental impact statements (SEISs) unless new and significant information is identified.

Category 2 issue: Environmental impact issues that do not meet one or more of the criteria of Category 1, and, therefore, additional plant-specific review for these issues is required.

Cesium: A metal that may be stable (nonradioactive) or unstable (radioactive). The most common radioactive form of cesium is cesium-137. Another fairly common radioisotope is cesium-134.

Chain reaction: A reaction that initiates its own repetition. In a fission chain reaction, a fissionable nucleus absorbs a neutron and fissions spontaneously, releasing additional neutrons. These, in turn, can be absorbed by other fissionable nuclei, releasing more neutrons. A fission chain reaction is self-sustaining when the number of neutrons released in a given time equals or exceeds the number of neutrons lost by absorption in nonfissionable material or by escape from the system.

Chlorinated hydrocarbons: Organic compounds made up of atoms of carbon, hydrogen, and chlorine. All chlorinated hydrocarbons have a carbon-chlorine bond. Sometimes hydrogen is not present at all, as in carbon tetrachloride (CCl_4). Examples of chlorinated hydrocarbons include dichloro-diphenyl-trichloroethane (DDT) and polychlorinated biphenyls (PCBs). Chlorinated hydrocarbons tend to be very long-lived and persistent in the environment; they tend to be toxic; and they tend to accumulate in the food web and undergo bioamplification.

Chronic effects: Effects resulting from exposure to low levels of a stressing factor (e.g., contaminant, disease, electromagnetic field, noise, and radionuclides) over long periods.

Chronic radiation exposure: Long-term, low-level overexposure to radiation or radioactive materials.

Cladding: The thin-walled metal tube that forms the outer jacket of a nuclear fuel rod. It prevents corrosion of the fuel by the coolant and the release of fission products into the coolant. Aluminum, stainless steel, and zirconium alloys are common cladding materials.

Class I areas (Clean Air Act): Class I areas are Federally owned properties for which air quality-related values are highly prized and for which no diminution of air quality, including visibility, can be tolerated. Class I areas fall under the stewardship of four Federal agencies: the U.S. Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, and the U.S. Forest Service. Air quality impacts in Class I areas are strictly limited, while restrictions in Class II areas are less strict.

Class II areas (Clean Air Act): See Class I areas.

Class 2B carcinogenic: Agents (e.g., electromagnetic fields [EMFs]) or substances that are possibly carcinogenic to humans.

Clean Air Act (CAA): Establishes national ambient air quality standards and requires facilities to comply with emission limits or reduction limits stipulated in State Implementation Plans (SIPs). Under this act, construction and operating permits, as well as reviews of new stationary sources and major modifications to existing sources, are required. The Act also prohibits the Federal government from approving actions that do not conform to SIPs.

Clean coal technologies: Technologies that would allow the continued use of coal (or coal-derived synthetic fuels) for electricity production, while at the same time, mitigating the potential adverse impacts to air quality and guaranteeing compliance with regulatory requirements. Clean coal initiatives include coal-cleaning processes to remove constituents that would ultimately be converted to problematic pollutants during combustion, synthesis of clean derivative fuels through coal gasification technologies, improved combustion technologies, and improved devices, and ancillary support systems for capturing and sequestering pollutants.

Clean Water Act (CWA): Act requiring National Pollutant Discharge Elimination System (NPDES) permits for discharges of effluents to surface waters, permits for stormwater discharges related to industrial activity, permits for discharges to or dredging of wetlands, notification of oil discharges to navigable waters of the United States, and water quality certification from the State in which the discharge will occur.

Climatology: The meteorological study of climates and their phenomena.

Closed-cycle cooling: In this type of cooling water system, the cooling water is recirculated through the condenser after the waste heat is removed by dissipation to the atmosphere, usually by circulating the water through large cooling towers constructed for that purpose.

Coal: A readily combustible black or brownish-black rock whose composition, including inherent moisture, consists of more than 50 percent by weight and more than 70 percent by volume of carbonaceous material. It is formed from plant remains that have been compacted, hardened, chemically altered, and metamorphosed by heat and pressure over geologic time.

Coal bed methane: Methane is generated during coal formation and is contained in the coal microstructure. Typical recovery entails pumping water out of the coal to allow the gas to escape. Methane is the principal component of natural gas. Coal bed methane can be added to natural gas pipelines without any special treatment.

Coal combustion wastes: Wastes produced from the combustion of coal, which contains concentrated levels of numerous contaminants, particularly metals like arsenic, mercury, lead, chromium, cadmium, and radioactive elements found naturally in coal.

Coal gasification: The process of converting coal into gas. The basic process involves crushing coal to a powder, which is then heated in the presence of steam and oxygen to produce a gas. The gas is then refined to reduce sulfur and other impurities. The gas can be used as a fuel or processed further and concentrated into chemical or liquid fuel.

Coal-producing regions: *Appalachian Region*: Alabama, Georgia, eastern Kentucky, Maryland, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia; *Interior Region (with Gulf Coast)*: Arkansas, Illinois, Indiana, Iowa, Kansas, Louisiana, Michigan, Mississippi, Missouri, Oklahoma, Texas, and western Kentucky; *Western Region*: Alaska, Arizona, Colorado, Montana, New Mexico, North Dakota, Utah, Washington, and Wyoming. *Note:* Some States discontinue producing coal as reserves are depleted or as production becomes uneconomical.

Coal rank: The classification of coals according to their degree of progressive alteration from lignite to anthracite. In the United States, the standard ranks of coal include lignite, sub-bituminous coal, bituminous coal, and anthracite, and are based on fixed carbon, volatile matter, heating value, and agglomerating (or caking) properties.

Coal seam: A deposit of coal.

Coal synfuel: Any liquid fuel obtained from coal.

Coal washing: The process of removing noncombustible materials, sulfur, mercury, and other contaminants from coal. Coal washing involves grinding the coal into smaller pieces and separating materials according to density. One coal-washing technique involves feeding the coal into barrels that contain a fluid with a density that causes the coal to float, while unwanted material sinks and is removed from the fuel mix.

***Code of Federal Regulations* (CFR):** The codification of the general and permanent rules published in the *Federal Register* by the executive departments and agencies of the Federal government. It is divided into 50 titles that represent broad areas subject to Federal regulation. Each volume of the CFR is updated once each calendar year and is issued on a quarterly basis.

Co-firing: The process of burning natural gas in conjunction with another fuel to reduce air pollutants.

Coke: A solid carbonaceous residue derived from low-ash, low-sulfur bituminous coal from which the volatile constituents are driven off by baking in an oven at temperatures as high as 2000°F so that the fixed carbon and residual ash are fused together. Coke is used as a fuel and as a reducing agent in smelting iron ore in a blast furnace. Coke from coal is gray, hard, and porous and has a heating value of 24.8 million Btu per ton.

Cold shutdown: The term used to define a reactor coolant system at atmospheric pressure and at a temperature below 200°F following a reactor cooldown.

Collective dose: The sum of the individual doses received in a given period by a specified population from exposure to a specified source of radiation.

Combined cycle: A technology through which electricity is produced from otherwise lost waste heat exiting from one or more gas (combustion) turbines. The exiting heat is routed to a conventional boiler or to a heat recovery steam generator for utilization by a steam turbine in the production of electricity. This process increases the efficiency of the electric generating unit.

Combustion: Chemical oxidation accompanied by the generation of energy, typically in the form of light and heat.

Committed dose equivalent: The dose equivalent to organs or tissues of reference that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

Compact: A group of two or more States formed to dispose of low-level radioactive waste on a regional basis. The Low-Level Radioactive Waste Policy Act of 1980 encouraged States to form compacts to ensure continuing low-level waste disposal capacity. As of December 2000, 44 States have formed 10 compacts. No compact has successfully sited and constructed a disposal facility.

Condenser: A large heat exchanger designed to cool exhaust steam from a turbine below the boiling point so that it can be returned to the heat source as water. In a pressurized water reactor, the water is returned to the steam generator. In a boiling water reactor, it returns to the reactor core. The heat removed from the steam by the condenser is transferred to a circulating water system and is exhausted to the environment, either through a cooling tower or directly into a body of water.

Coniferous: Of or relating to or part of trees or shrubs bearing cones and evergreen leaves.

Containment or reactor building: The containment or reactor building in a pressurized water reactor (PWR) is a massive concrete or steel structure that houses the reactor vessel, reactor coolant piping and pumps, steam generators, pressurizer, pumps, and associated piping. The reactor building structure of a BWR generally includes a containment structure and a shield building. The BWR containment reactor building is a massive concrete or steel structure that houses the reactor vessel, the reactor coolant piping and pumps, and the suppression pool. It is located inside a somewhat less substantive structure called the shield building. The shield building for a BWR also generally contains the spent fuel pool and the new fuel pool. The reactor building for both PWRs and BWRs is designed to withstand natural disasters, such as hurricanes and earthquakes. The containment's ability to withstand such events and to contain the effects of accidents initiated by system failures constitutes the principal protection against releasing radioactive material to the environment.

Cooling pond: A natural or man-made body of water that is used for dissipating waste heat from power plants.

Cooling tower: Structures designed to remove excess heat from the condenser without dumping the heated cooling water directly into water bodies, such as lakes or rivers. There are two principal types of cooling towers: mechanical draft towers and natural draft towers. Most nuclear plants that have once-through cooling do not rely on cooling towers. However, five facilities with once-through cooling also have cooling towers.

Cooling tower drift: Water lost from a cooling tower in the form of liquid droplets entrained in the exhaust air. Drift is independent of water lost through evaporation. Units may be in lb/hr or a percentage of circulating water flow. Drift eliminators control this loss from the tower.

Cooling-water intake structure: The structure and any associated constructed waterways used to withdraw cooling water from water bodies. The cooling water intake structure extends from the point at which water is withdrawn from the surface water source to the first intake pump or series of pumps.

Corona discharge: The electrical breakdown of air into charged particles that results in the creation of ions or charged particles in air due to electric field discharge near transmission lines, most noticeable during thunder or rain storms. Corona is a phenomenon associated with all energized transmission lines. It is the electrical breakdown of air into charged particles. The phenomenon appears as a bluish-purple glow on the surface of and adjacent to a conductor when the voltage gradient exceeds a certain critical value, thereby producing light, audible noise (described as crackling or hissing), and ozone.

Council on Environmental Quality (CEQ): Established by the National Environmental Policy Act (NEPA). Council on Environmental Quality regulations (40 CFR Parts 1500–1508) describe the process for implementing NEPA, including preparation of environmental assessments and environmental impact statements, and the timing and extent of public participation.

Criteria pollutants: A group of very common air pollutants whose presence in the environment is regulated by the EPA on the basis of certain criteria (information on health and/or environmental effects of pollution). Criteria air pollutants are widely distributed all over the United States. There are six common air pollutants for which National Ambient Air Quality Standards have been established by the EPA under Title I of the Clean Air Act: sulfur dioxide, nitrogen oxides, carbon monoxide, ozone, particulate matter ($PM_{2.5}$ and PM_{10}), and lead. Standards were developed for these pollutants on the basis of scientific knowledge about their health and environmental effects.

Critical habitat: Specific geographic areas, whether occupied by a listed species or not, that are essential for its conservation and that have been formally designated by rules published in the *Federal Register*.

Criticality: A term used in reactor physics to describe the state when the number of neutrons released by fission is exactly balanced by the neutrons being absorbed (by the fuel and poisons) and escaping the reactor core. A reactor is said to be “critical” when it achieves a self-sustaining nuclear chain reaction, as when the reactor is operating.

Crude oil: A mixture of hydrocarbons that exists in liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities. Depending upon the characteristics of the crude stream, it may also include: (1) small amounts of hydrocarbons that exist in the gaseous phase in natural underground reservoirs but are liquid at atmospheric pressure; (2) small amounts of nonhydrocarbons produced with the oil, such as sulfur and various metals, and (3) drip gases and liquid hydrocarbons produced from tar sands, oil sands, gilsonite, and oil shale.

Cultural resources: The remains of past human activities that have historic or cultural meaning. They include archaeological sites (e.g., prehistoric campsites and villages), historic-era resources (e.g., farmsteads, forts, and canals), and traditional cultural properties (e.g., resource collection areas and sacred areas). Culture is understood to mean the traditions, beliefs, practices, lifeways, arts, crafts, and social institutions of any community, be it an Indian tribe, a local ethnic group, or the people of the nation as a whole (see also National Park Service Bulletin #38).

Cumulative dose: The total dose resulting from repeated or prolonged exposures to ionizing radiation over time.

Cumulative impacts: The impacts on the environment that result from the incremental impacts of an action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency (Federal or nonfederal) or person undertakes such other actions.

Cumulative risk: The risk of a common toxic effect associated with concurrent exposure by all relevant pathways and routes of exposure to a group of chemicals that share a common mechanism of toxicity.

Curie (Ci): The basic unit used to describe the intensity of radioactivity in a sample of material. The curie is equal to 37 billion (3.7×10^{10}) disintegrations per second, which is approximately the activity of 1 gram of radium. A curie is also a quantity of any radionuclide that decays at a rate of 37 billion disintegrations per second. It is named for Marie and Pierre Curie, who discovered radium in 1898.

Decibel, A-weighted (dBA): A standard unit for the measure of the relative loudness or intensity of sound. The relative intensity is the ratio of the intensity of a sound wave to a reference intensity. In general, a sound doubles in loudness with every increase of 10 dB. By convention, the intensity level of sound at the threshold of hearing for a young healthy individual is 0 dB.

Deciduous: Trees and shrubs that shed their leaves on an annual cycle.

Decommissioning: The process of closing down a facility followed by reducing residual radioactivity to a level that permits the release of the property for unrestricted use or restricted use (see 10 CFR 20.1003).

DECON: A method of decommissioning in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed and safety buried in a low-level radioactive waste landfill or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations.

Decontamination: Removal of unwanted radioactive or hazardous contamination by a chemical or mechanical process.

Deep-dose equivalent: The dose equivalent at a tissue depth of 1 cm; applies to external whole-body exposure.

Demand-side management (DSM): The planning, implementation, and monitoring of utility activities designed to encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand. It only refers to energy and load-shape modifying activities that are undertaken in response to utility-administered programs. It does not refer to energy and load-shaped changes arising from the normal operation of the marketplace or from government-mandated energy-efficiency standards. DSM covers the complete range of load-shape objectives, including strategic conservation and load management, as well as strategic load growth.

Demographics: A term used to describe specific population characteristics such as age, gender, education, and income level.

Densitometer: An apparatus for measuring the optical density of a material, such as a photographic negative.

Depleted uranium: Uranium having a percentage of uranium-235 smaller than the 0.7 percent found in natural uranium. It results from uranium isotope enrichment operations.

Deposition: The laying down of matter by a natural process (e.g., the settling of particulate matter out of air or water onto soil or sediment surfaces).

Design-basis accident: A postulated accident that a nuclear facility must be designed and built to withstand without loss to the systems, structures, and components necessary to ensure public health and safety.

Desquamation: To shed, peel, or come off in scales.

Detritus: Dead, decaying plant material.

Dewatering: To remove or drain water from an area.

Dielectric: A nonconductor of electricity.

Diesel generator: An electric generator that runs on diesel fuel.

Diffusion: A process in which substances are transported from one area to another due to differences in the concentration of that material or in temperature.

Disposal: The act of placing unwanted materials in an area with the intent of not recovering in the future.

Dissolved gas: Gas dissolved in water or in other liquid without change in its chemical structure.

Dissolved oxygen: Oxygen dissolved in water. Dissolved oxygen is necessary for the life of fish and most other aquatic organisms, and is one of the most important indicators of the condition of a water body.

DNA (deoxyribonucleic acid): One of two types of molecules that encode genetic information (the other is ribonucleic acid [RNA]). In humans, DNA is the genetic material, and RNA is transcribed from it. In some other organisms, RNA is the genetic material and, in reverse fashion, the DNA is transcribed from it.

Dose: The absorbed dose, given in rads (or in SI units, grays), that represents the energy absorbed from the radiation in a gram of any material. The biological dose or dose equivalent, given in rem or sieverts, is a measure of the biological damage to living tissue from radiation exposure.

Dose equivalent: The product of the absorbed dose in tissue, quality factor, and all other modifying factors at the location of interest. The units of dose equivalent are the rem and sievert (Sv).

Dose rates: The ionizing radiation dose delivered per unit of time (e.g., rem or sieverts per hour).

Dosimeter: A small, portable instrument (such as a film badge or thermoluminescent or pocket dosimeter) for measuring and recording the total accumulated personal dose of ionizing radiation.

Dredging: Removing accumulated sediments from a water body to increase depth or remove contaminants.

Dry cask: Large, rugged container made of steel or steel-reinforced concrete, 18 or more inches thick. A cask uses materials like steel, concrete and lead—instead of water—as a radiation shield.

Dry cask storage: A method for storing spent nuclear fuel (see dry cask).

Dry steam: Geothermal plants that use the steam from the geothermal reservoir as it comes from wells, and route it directly through turbine/generator units to produce electricity.

Dual-fired unit: A generating unit that can produce electricity using two or more input fuels. In some of these units, only the primary fuel can be used continuously; the alternate fuel(s) can be used only as a start-up fuel or in emergencies.

Earthquake: A sudden ground motion or vibration of the Earth. It can be produced by a rapid release of stored-up energy along an active fault in the Earth's crust.

Ecoregion: A geographically distinct area of land that is characterized by a distinctive climate, ecological features, and plant and animal communities.

Ecosystem: A group of organisms and their physical environment interacting and functioning as a unit.

Effective dose equivalent: The sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to each of the body organs or tissues that are irradiated.

Effluent: Wastewater (treated or untreated) that flows out of a treatment plant, sewer, or industrial outfall. This term generally refers to wastes discharged into surface waters.

Electric power: The rate at which electric energy is transferred. Electric power is measured by capacity and is commonly expressed in megawatts (MW).

Electric power grid: A system of synchronized power providers and consumers connected by transmission and distribution lines and operated by one or more control centers. In the continental United States, the electric power grid consists of three systems: the Eastern Interconnect, the Western Interconnect, and the Texas Interconnect. In Alaska and Hawaii, several systems encompass areas smaller than the State (e.g., the interconnect serving Anchorage, Fairbanks, and the Kenai Peninsula).

Electricity: A form of energy characterized by the presence and motion of elementary charged particles generated by friction, induction, or chemical change.

Electricity generation: The process of producing electric energy or the amount of electric energy produced by transforming other forms of energy, commonly expressed in kilowatt hours (kWh) or megawatt hours (MWh).

Electromagnetic fields: The field of energy resulting from the movement of alternating electric current (AC) along the path of a conductor, composed of both electrical and magnetic components and existing in the immediate vicinity of, and surrounding, the electric conductor. Electromagnetic fields exist in both high-voltage electric transmission power lines and in low-voltage electric conductors in homes and appliances.

Electromagnetic radiation: A traveling wave motion resulting from changing electric or magnetic fields. Familiar electromagnetic radiation ranges from x-rays (and gamma rays) of short wavelength, through the ultraviolet, visible, and infrared regions, to radar and radio waves of relatively long wavelength.

Endangered species: Any species, plant or animal, that is in danger of extinction throughout all or a significant part of its range. Requirements for declaring a species endangered are found in the Endangered Species Act.

Endangered Species Act of 1973 (ESA): Requires consultation with the U.S. Fish and Wildlife Service and/or the National Marine Fisheries Service to determine whether endangered or threatened species or their habitats will be affected by a proposed activity and what, if any, mitigation measures are needed to address the impacts.

Energy: The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks. Electrical energy is usually measured in kilowatt hours, while heat energy is usually measured in British thermal units (Btu).

Energy demand: The energy needed by consumers at any point in time for household, business, or industrial purposes.

Energy Information Administration (EIA): An independent agency within the U.S. Department of Energy (DOE) that develops surveys, collects energy data, and analyzes and models energy issues. The EIA must meet (1) the requests of Congress, other elements within the DOE, Federal Energy Regulatory Commission, and Executive Branch; (2) its own independent needs; and (3) assist the general public or other interest groups, without taking a policy position.

Energy supply: Energy made available for use. Supply can be considered and measured from the point of view of the energy provider or the receiver.

ENTOMB: A method of decommissioning nuclear facilities in which radioactive contaminants are encased in a structurally long-lived material, such as concrete. The entombment structure is appropriately maintained and continued surveillance is carried out until the radioactivity decays to a level permitting unrestricted release of the property.

Entrainment: The incorporation of all life stages of fish and shellfish with intake water-flow entering and passing through a cooling water intake structure and into a cooling water system.

Environmental assessment (EA): A concise public document that a Federal agency prepares under the National Environmental Policy Act to provide sufficient evidence and analysis to determine whether a proposed action requires preparation of an environmental impact statement or whether a Finding of No Significant Impact can be issued. An EA must include brief discussions on the need for the proposed action and the environmental impacts of the proposed action and the no action alternative.

Environmental impact statement (EIS): A document required of Federal agencies by the National Environmental Policy Act for major proposals or legislation that will or could significantly affect the environment.

Environmental justice: The fair treatment of people of all races, cultures, incomes, and educational levels with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

Erosion: The process where wind, water, ice, and other mechanical and chemical forces wear away materials such as rocks and soil, breaking up particles and moving them from one place to another.

Erythema: Superficial reddening of the skin due to the dilatation of blood vessels. Erythema is often a sign of infection or inflammation.

Essential fish habitat (EFH): Those waters and substrates necessary to fish for spawning, breeding, feeding or growth to maturity. EFH is protected under the Magnuson-Stevens Fishery Conservation and Management Act of 1976.

Estuary: A transitional zone along the coastline where ocean saltwater mixes with freshwater from the land, subject to tidal influences. Estuaries are often semi-enclosed by land, but their currents always have access to the open ocean.

Eutrophication: A condition in an aquatic ecosystem where high nutrient concentrations stimulate blooms of algae (e.g., phytoplankton). Algal decomposition may lower dissolved oxygen concentrations. Although eutrophication is a natural process in the aging of lakes and some estuaries, it can be accelerated by both point and nonpoint sources of nutrients.

Exceedance probability: The average frequency with which an event (e.g., flood, earthquake) of a particular magnitude will be exceeded during a certain length of time. Expressed as the probability that a level will be exceeded in any year (the annual exceedance probability) or as the average recurrence interval (e.g., a 100-year flood).

Exposure: Being exposed to ionizing radiation, radioactive material, or other contaminants.

External dose: That portion of the dose equivalent received from radiation sources outside the body.

Farmland Protection Policy Act: An Act whose purpose is to reduce the conversion of farmland to nonagricultural uses as a result of Federal projects and programs. The Act requires that Federal agencies comply to the fullest extent possible with state and local government policies to preserve farmland. It includes a recommendation that evaluations and analyses of prospective farmland conversion impacts be made early in the planning process—before a site or design is selected—and that, where possible, agencies make such evaluations and analyses part of the National Environmental Policy Act process.

Fault (geology): A fracture or a zone of fractures within a rock formation along which vertical, horizontal, or transverse slippage has occurred. A normal fault occurs when the hanging wall has been depressed in relation to the footwall. A reverse fault occurs when the hanging wall has been raised in relation to the footwall. A strike-slip fault occurs where two geologic plates are sliding past each other and stress builds up between them.

Fecundity: Number of eggs an animal produces during each reproductive cycle; the potential reproductive capacity of an organism or population.

Federal Energy Regulatory Commission (FERC): Independent Federal agency with jurisdiction over interstate electricity sales, wholesale electric rates, hydroelectric licensing, natural gas pricing, and oil pipeline rates.

***Federal Register*:** The official daily publication for rules, proposed rules, and notices of Federal agencies and organizations, as well as Executive Orders and other presidential documents.

Film badge: Photographic film used to measure ionizing radiation exposure for personnel monitoring purposes. The film badge may contain two or three films of differing sensitivities, and it may also contain a filter that shields part of the film from certain types of radiation.

Fission: The splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy. Two or three neutrons are usually released during this type of transformation.

Fission products: The radioactive isotopes formed by the fission of heavy elements.

Floodplain: Lowlands and relatively flat areas adjoining the channel of a river, stream, or other watercourse; or ocean, lake, or other body of water, which have been or may be inundated by flood water, and those other areas subject to flooding. Floodplains include, at a minimum, that area with at least a 1.0 percent chance of being inundated by a flood in any given year.

Flue gas: The air coming out of a chimney after combustion in the burner it is venting. It can include nitrogen oxides, carbon oxides, water vapor, sulfur oxides, particles, and many chemical pollutants.

Flue gas desulfurization: Equipment (also referred to as scrubbers) used to remove sulfur oxides from the combustion gases of a boiler plant before discharge to the atmosphere. Chemicals such as lime are used as scrubbing media.

Fluidized-bed combustion: A method of burning particulate fuel, such as coal, in which the amount of air required for combustion far exceeds that found in conventional burners. The fuel particles are continually fed into a bed of mineral ash in the proportions of 1 part fuel to 200 parts ash, while a flow of air passes up through the bed, causing it to act like a turbulent fluid.

Fossil fuel: Fuel derived from ancient organic remains such as peat, coal, crude oil, and natural gas.

Fossil fuel plant: A plant using coal, petroleum, or gas as its source of energy.

Fossil-fuel electric (power) generation: Electric generation in which the prime mover is a turbine rotated by high-pressure steam produced in a boiler by heat from burning fossil fuels.

Fuel: Any material substance that can be consumed to supply heat or power. Includes petroleum, coal, and natural gas (the fossil fuels), and other consumable materials, such as uranium, biomass, and hydrogen.

Fuel assembly: A cluster of fuel rods (or plates) that are also called fuel pins or fuel elements. Many fuel assemblies make up a reactor core.

Fuel cladding: See cladding.

Fuel cycle: The entire set of sequential processes or stages involved in the utilization of fuel, including extraction, transformation, transportation, and combustion. Emissions generally occur at each stage of the fuel cycle.

Fuel oil: A liquid petroleum product less volatile than gasoline, used as an energy source. Fuel oil includes distillate fuel oil (No. 1, No. 2, and No. 4), and residual fuel oil (No. 5 and No. 6).

Fuel pellets: As used in pressurized water reactors and boiling water reactors, a pellet is a small cylinder approximately 3/8-in. in diameter and 5/8-inch in length, consisting of uranium fuel in a ceramic form—uranium dioxide (UO_2). Typical fuel pellet enrichments in nuclear power reactors range from 2.0 percent to 3.5 percent uranium-235.

Fuel rod: A long, slender tube that holds fissionable material (fuel) for nuclear reactor use. Fuel rods are assembled into bundles called fuel elements or fuel assemblies, which are loaded individually into the reactor core.

Fugitive dust: Particulate air pollution released to the ambient air from ground-disturbing activities related to construction, manufacturing, or transportation (i.e., the discharges are not released through a confined stream such as a stack, chimney, vent, or other functionally equivalent opening). Specific activities that generate fugitive dust include, but are not limited to, land-clearing operations, travel of vehicles on disturbed land or unpaved access roads, or onsite roads.

Fugitive emissions: Unintended leaks of gas from vessels, pipes, valves, or fittings used in the processing, transmission, and/or transportation of liquids or gases. These emissions can include the release of volatile vapors from a diesel fuel, natural gas, or solvent leak.

Fujita scale: Classifies tornadoes based on wind damage. The scale ranges from F0 for the weakest to F5 for the strongest tornadoes.

Gamma rays: High-energy, short wavelength, electromagnetic radiation emitted from the nucleus of an atom. Gamma radiation frequently accompanies alpha and beta emissions and always accompanies fission. Gamma rays are very penetrating and are best stopped or shielded by dense materials, such as lead or depleted uranium. Gamma rays are similar to x-rays. See also x-rays and gamma rays.

Gas bubble disease: A condition that occurs when aquatic organisms are exposed to water with high partial pressures of certain gases (usually nitrogen) and then subsequently are exposed to water with lower partial pressures of the same gases. Dissolved gas (especially nitrogen) within the tissues comes out of solution and forms embolisms (bubbles) within the affected tissues, most noticeably the eyes and fins.

Gas supersaturation: Concentrations of dissolved gases in water that are above the normal saturation limit.

Gas turbine: A gas turbine consists typically of an axial-flow air compressor and one or more combustion chambers where liquid or gaseous fuel is burned and the hot gases are passed to the turbine, and where the hot gases expand, drive the generator, and are then used to run the compressor.

Gasification: A method for converting coal, petroleum, biomass, wastes, or other carbon-containing materials into a gas that can be (1) burned to generate power or (2) processed into chemicals and fuels.

Generator capacity: The maximum output, commonly expressed in megawatts (MW), that generating equipment can supply to system load, adjusted for ambient conditions.

Generic environmental impact statement (GEIS): A GEIS assesses the scope and impact of environmental effects that would be associated with an action at numerous sites.

Geologic repository: A deep underground engineered facility used to permanently isolate used nuclear fuel or high-level nuclear waste while its radioactivity decays safely.

Geology: The science that deals with the study of the Earth: its materials, processes, environments, and its history, including rocks and their formations and structures.

Geothermal energy: Hot water or steam extracted from geothermal reservoirs in the earth's crust. Water or steam extracted from geothermal reservoirs can be used for geothermal heat pumps, water heating, or electricity generation.

Geothermal plant: A plant in which the prime mover is a steam turbine driven either by steam produced from hot water or by natural steam that derives its energy from heat found in rock.

Global climate change: Changes in the Earth's surface temperature thought to be caused by the greenhouse effect and responsible for changes in global climate patterns. The greenhouse effect is the trapping and buildup of heat in the atmosphere (troposphere) near the Earth's surface. Some of the heat flowing back toward space from the Earth's surface is absorbed by water vapor, carbon dioxide, ozone, and certain other gases in the atmosphere and then reradiated back toward the Earth's surface.

Global warming: An increase in the near-surface temperature of the earth. Global warming has occurred in the distant past as the result of natural influences, but the term is today most often used to refer to the warming many scientists predict will occur as a result of increased anthropogenic emissions of greenhouse gases.

Global warming potential (GWP): An index used to compare the relative radiative forcing per unit molecule or unit mass change for varied greenhouse gases of different gases without directly calculating the changes in atmospheric concentrations. The GWPs of a particular greenhouse gas are calculated as a time-integrated ratio of the radiative or climate forcing that would result from the emission of one kilogram of that greenhouse gas to that resulting from the emission of one kilogram of carbon dioxide over a fixed period of time, such as 100 years.

Gonads: Male and female sex organs (testes and ovaries).

Graphite: Pure carbon in mineral form. Technically, graphite at 100 percent carbon is the highest rank of coal. However, its relatively limited availability and physical characteristics and chemical characteristics have limited its use as an energy source. Instead, it is used primarily in lubricants.

Gray: The international system (SI) unit of absorbed dose. One gray is equal to an absorbed dose of 1 Joule/kilogram (one gray equals 100 rads) (see 10 CFR 20.1004).

Greater-than-Class C Waste (GTCC): GTCC waste means low-level radioactive waste that exceeds the concentration limits of radionuclides established for Class C waste in 10 CFR 61.55.

Greenfield site: Vacant land that has never been developed or was formerly occupied by farms or low-density development that left the land free of environmental contamination. Greenfield sites are typically located in suburban or ex-urban areas and can be less costly to develop than the brownfield sites that are often located in urban areas.

Greenhouse gases: Those gases, such as carbon dioxide, nitrous oxide, methane, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride, that are transparent to solar (short-wave) radiation but opaque to long-wave (infrared) radiation, thus preventing long-wave radiant energy from leaving the earth's atmosphere. The net effect is a trapping of absorbed radiation and a tendency to warm the planet's surface. While also a product of industrial activities, carbon dioxide, nitrous oxide, methane, ozone, and water vapor are naturally occurring greenhouse gases.

Grid: See electric power grid.

Gross generation: The total amount of electric energy produced by generating units and measured at the generating terminal in kilowatt hours (kWh) or megawatt hours (MWh).

Groundwater: The water found beneath the earth's surface, usually in porous rock formations (aquifers) or in a zone of saturation, which may supply wells and springs, as well as base flow to major streams and rivers. Generally, it refers to all water contained in the ground.

Habitat: The place, including physical and biotic conditions, where a population or community of organisms, both plants and animals, lives.

Half-life: The time in which one-half of the atoms of a particular radioactive substance disintegrate into another nuclear form. Measured half-lives vary from millionths of a second to billions of years. Also called physical or radiological half-life.

Hazardous air pollutants (HAPs): Air pollutants that are not covered by ambient air quality standards but which, as defined in the Clean Air Act, may present a threat of adverse human health effects or adverse environmental effects. Such pollutants include asbestos, beryllium, mercury, benzene, coke oven emissions, radionuclides, and vinyl chloride.

Hazardous waste: A solid waste or combination of solid wastes that, because of its quantity, concentration, or physical, chemical, or infectious characteristics, may (1) cause or significantly contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness or (2) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed (as defined in the Resource Conservation and Recovery Act, as amended, Public Law 94-580).

Heat sink: Anything that absorbs heat. It is usually part of the environment, such as the air, a river, or a lake.

Heavy metals: Metallic elements with higher atomic weights, many of which are toxic at higher concentrations. Examples are mercury, chromium, cadmium, and lead.

High-level waste (HLW): The highly radioactive materials produced as a byproduct of the reactions that occur inside nuclear reactors. High-level wastes take one of two forms, (1) Spent (used) reactor fuel when it is accepted for disposal, or (2) Waste materials remaining after spent fuel is reprocessed.

Historic property: Any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the *National Register of Historic Places* maintained by the Secretary of the Interior. This term includes artifacts, records, and remains that are related to and located within such properties. The term can also include properties of traditional religious and cultural importance that meet the *National Register* criteria (see also 36 CFR 800.16(l)(1)).

Horizontal axis wind turbine: The most common type of wind turbine, in which the axis of rotation is oriented horizontally.

Hydrocarbons: Any compound or mix of compounds, solids, liquids, or gases, composed of carbon and hydrogen (e.g., coal, crude oil, and natural gas).

Hydrochlorofluorocarbons (HCFCs): Chemicals composed of one or more carbon atoms and varying numbers of hydrogen, chlorine, and fluorine atoms.

Hydroelectric power: The use of flowing water to produce electrical energy.

Hydrofluorocarbons (HFCs): A group of man-made chemicals composed of one or two carbon atoms and varying numbers of hydrogen and fluorine atoms. Most HFCs have 100-year Global Warming Potentials in the thousands.

Hydrology: The study of water that considers its occurrence, properties distribution, circulation, and transport and includes groundwater, surface water, and rainfall.

IGCC: See integrated gasification combined cycle technology.

Impacting factors: The mechanisms by which an action affects a given resource or receptor.

Impingement: The entrapment of all life stages of fish and shellfish on the outer part of an intake structure or against a screening device during periods of intake water withdrawal.

Impulse turbine: A turbine that is driven by high-velocity jets of water or steam from a nozzle directed onto vanes or buckets attached to a wheel.

Independent spent fuel storage installation (ISFSI): An ISFSI is designed and constructed for the interim storage of spent nuclear fuel and other radioactive materials associated with spent fuel storage. ISFSIs may be located at the site of a nuclear power plant or at another location. The most common design for an ISFSI, at this time, is a concrete pad with dry casks containing spent fuel bundles. ISFSIs are used by operating plants that require increased spent fuel storage capability because their spent fuel pools have reached capacity.

In situ: In its original place.

Integrated gasification combined cycle (IGCC) technology: An energy generation technology in which coal, water, and oxygen are fed to a gasifier, which produces syngas. This medium-Btu gas is cleaned (particulates and sulfur compounds removed) and fed to a gas turbine. The hot exhaust of the gas turbine and heat recovered from the gasification process is routed through a heat-recovery generator to produce steam, which drives a steam turbine to produce electricity.

Internal dose: That portion of the dose equivalent received from radioactive material taken into the body.

Ionizing radiation: Any radiation capable of displacing electrons from atoms or molecules, thereby producing ions. Some examples are alpha, beta, gamma, x-rays, neutrons, and ultraviolet light. High doses of ionizing radiation may produce severe skin or tissue damage.

Isotopic enrichment: A process by which the relative abundance of the isotopes of a given element is altered, thus producing a form of the element that has been enriched in one particular isotope and depleted in its other isotopic forms.

Landfill gas: Gas that is generated by decomposition of organic material at landfill disposal sites. The average composition of landfill gas is approximately 50 percent methane and 50 percent carbon dioxide and water vapor by volume. The methane percentage, however, can vary from 40 to 60 percent, depending on several factors including waste composition (e.g., carbohydrate and cellulose content). The methane in landfill gas may be vented, flared, or combusted to generate electricity or heat, or injected into a pipeline for combustion elsewhere.

Leachate: The liquid that has percolated through the soil or other medium.

License renewal: Renewal of the operating license of a nuclear power plant.

License renewal term: That period of time past the original or current license term for which the renewed license is in force. Although the length of license renewal terms can vary, they cannot exceed 20 years.

Licensee: The entity (usually an energy company) that holds the license to operate a nuclear power plant.

Light water reactors (LWRs): Reactors that use ordinary water as coolant, including BWRs and PWRs, the most common types used in the United States.

Lignite coal: Also referred to as brown coal, it is the youngest and lowest rank coal with respect to its value as an energy source. Lignite coal deposits are relatively young and have not experienced extremes of heat and pressure as have higher ranks of coal. On average, lignite coals contain 25–35 percent by weight carbon. They represent about 7 percent of the U.S. annual coal production and are used primarily to produce electricity.

Load shape: A method of describing peak load demand and the relationship of power supplied to the time of occurrence.

Lower limit of detection (LLD): The lowest limit that a detector can measure.

Lowest observed effects level (LOEL): The lowest exposure level at which there are statistically or biologically significant increases in frequency or severity of an effect between the exposed population and its appropriate control group.

Low-income populations: Persons whose average family income is below the poverty line. The poverty line takes into account family size and age of individuals in the family. In 1999, the poverty line for a family of five with three children below the age of 18 was $19,882. For any family below the poverty line, all family members are considered to be below the poverty line.

Low-level radioactive waste (LLW): A general term for a wide range of wastes having low levels of radioactivity. Nuclear fuel cycle facilities (e.g., nuclear power reactors and fuel fabrication plants) that use radioactive materials generate low-level wastes as part of their normal operations. These wastes are generated in many physical and chemical forms and levels of contamination (see 10 CFR 61.2). Low-level radioactive wastes containing source, special nuclear, or by-product material are acceptable for disposal in a land disposal facility. For the purposes of this definition, low-level waste has the same meaning as in the Low-Level Radioactive Waste Policy Act, that is, radioactive waste not classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or by-product material as defined in Section 11e.(2) of the Atomic Energy Act (uranium or thorium tailings and waste).

Macroinvertebrates: Nonplanktonic, aquatic invertebrates, including insects, crustaceans, mollusks, and worms, which typically inhabit the bottom sediments of rivers, ponds, lakes, wetlands, or oceans. Their abundance and diversity are often used as an indicator of ecosystem health.

Maintenance areas: Regions that were initially designated as nonattainment or unclassifiable and have since attained compliance with the National Ambient Air Quality Standards. The Clean Air Act outlines several conditions that must be met before an area can be reclassified from nonattainment to an attainment maintenance area, one of which is the development and EPA approval of a maintenance plan.

Man-rem: See person-rem.

Marine: Of or pertaining to ocean environments.

Maximally exposed individual (MEI): A hypothetical individual who, because of proximity, activities, or living habits, could potentially receive the maximum possible dose of radiation or of a hazardous chemical from a given event or process.

Maximum achievable control technology (MACT): The emission standard for sources of air pollution requiring the maximum reduction of hazardous emissions, taking cost and feasibility into account. Under the Clean Air Act Amendments of 1990, the MACT must not be less than the average emission level achieved by controls on the best performing 12 percent of existing sources, by category of industrial and utility sources.

Mechanical draft tower: Cooling tower system that sprays heated cooling water downward, while large fans pull air across the dropping water to remove the heat. As the water drops downward onto the slats in the cooling tower, the drops break up into a finer spray, and, thus, facilitate cooling.

Megawatt: A unit of power equal to 1 million watts. Megawatt-thermal is commonly used to define heat produced, while megawatt-electric defines electricity produced.

Methane: A colorless, flammable, odorless hydrocarbon gas (CH_4), which is the major component of natural gas. Methane is an important source of hydrogen in various industrial processes. Methane is a greenhouse gas.

Methyl tertiary butyl ether (MTBE): A gasoline additive, an oxygenate produced by reacting methanol with isobutylene.

Microorganism: An organism that can be seen only through a microscope. Microorganisms include bacteria, protozoa, algae, and fungi.

Minority populations: Include American Indian or Alaskan Native; Asian; Native Hawaiian or other Pacific Islander; Black races; or people of Hispanic ethnicity. “Other” races and multiracial individuals may be considered as separate minorities.

Mitigation: A method or process by which impacts from actions can be made less injurious to the environment through appropriate protective measures.

Mixed waste: Waste that contains both radioactive and hazardous constituents.

Motile: Moving or having the power to move.

Municipal solid waste (MSW): Residential solid waste and some nonhazardous commercial, institutional, and industrial wastes.

National Ambient Air Quality Standards (NAAQS): Air quality standards established by the Clean Air Act, as amended. The primary NAAQS specify maximum outdoor air concentrations of criteria pollutants that would protect the public health within an adequate margin of safety. The secondary NAAQS specify maximum concentrations that would protect the public welfare from any known or anticipated adverse effects of a pollutant.

National Environmental Policy Act of 1969 (NEPA): Act requiring Federal agencies to prepare a detailed statement on the environmental impacts of their proposed major actions that may significantly affect the quality of the human environment.

National Historic Preservation Act (NHPA) of 1966: Section 106 of the NHPA addresses the impacts of Federal undertakings on historic properties. Undertakings are defined in the NHPA as any project or activity that is funded or under the direct jurisdiction of a Federal agency, or any project or activity that requires a Federal permit, license, or approval (see also 36 CFR 800.16(y)).

National Pollutant Discharge Elimination System (NPDES): A Federal and State permitting system controlling the discharge of effluents to surface water and regulated through the Clean Water Act, as amended.

Native American Graves Protection and Repatriation Act: This Act provides a process for museums and Federal agencies to return certain Native American cultural items—human remains, funerary objects, sacred objects, or objects of cultural patrimony—to lineal descendants and culturally affiliated Indian Tribes and Native Hawaiian organizations. The Act includes provisions for unclaimed and culturally unidentifiable Native American cultural items, intentional and inadvertent discovery of Native American cultural items on Federal and Tribal lands, and penalties for noncompliance and illegal trafficking. The Act also allows the intentional removal from or excavation of Native American cultural items from Federal or Tribal lands only with a permit or upon consultation with the appropriate Tribe.

Natural draft cooling towers: Natural draft cooling towers use the differential pressure between the relatively cold outside air and the hot humid air on the inside of the tower as the driving force to move and cool water without the use of fans.

Natural gas: A gaseous mixture of hydrocarbon compounds, the primary one being methane.

Natural gas combined cycle (NGCC) technology: An advanced power generation technology that improves the fuel efficiency of natural gas. Most new gas power plants in North America and Europe use NGCC technology.

Natural gas liquids (NGL): Those hydrocarbons in natural gas that are separated from the gas as liquids through the process of absorption, condensation, adsorption, or other methods in gas processing or cycling plants. Generally such liquids consist of propane and heavier hydrocarbons and are commonly referred to as lease condensate, natural gasoline, and liquefied petroleum gases. Natural gas liquids include natural gas plant liquids (primarily ethane, propane, butane, and isobutene).

Naturally occurring radioactive materials (NORM): Radioactive materials that are found in nature.

Neutron: An uncharged elementary particle, with a mass slightly greater than that of the proton, found in the nucleus of every atom heavier than hydrogen.

NGCC: See natural gas combined cycle technology.

Nitrogen oxides (NO_x): Nitrogen oxides include various nitrogen compounds, primarily nitrogen dioxide and nitric oxide. They form when fossil fuels are burned at high temperatures and react with volatile organic compounds to form ozone, the main component of urban smog. They are also a precursor pollutant that contributes to the formation of acid rain. Nitrogen oxides are among the six criteria air pollutants specified under Title I of the Clean Air Act.

No-action alternative: For this GEIS, the no-action alternative represents a decision by the Nuclear Regulatory Commission to not allow for continued operation of nuclear power plants beyond the current operating license terms. All plants eventually would be required to shut down and undergo decommissioning. Under the no-action alternative, these eventualities would occur sooner rather than later.

Noble gases: A gaseous chemical element that does not readily enter into chemical combination with other elements. Examples are helium, argon, krypton, xenon, and radon.

Noise: Unwanted sound; a subjective term reflective of societal values regarding what constitutes unwanted or undesirable intrusions of sound.

Nonattainment: Any area that does not meet the national primary or secondary ambient air quality standard established by the Environmental Protection Agency for designated pollutants, such as carbon monoxide and ozone.

Nonradioactive nonhazardous waste: Waste that is neither radioactive nor hazardous.

Nonrenewable fuels: Fuels that cannot be easily made or “renewed,” such as oil, natural gas, and coal.

Nonrenewable waste fuels: Municipal solid wastes from nonbiogenic sources and tire-derived fuels.

Nonstochastic effect: Health effects, the severity of which varies with the dose and for which a threshold is believed to exist. Radiation-induced cataract formation is an example of a nonstochastic effect (also called a deterministic effect).

North American Electric Reliability Council (NERC): A council formed in 1968 by the electric utility industry to promote the reliability and adequacy of bulk power supply in the electric utility systems of North America. NERC consists of regional reliability councils and encompasses essentially all the power regions of the contiguous United States, Canada, and Mexico.

North American Industry Classification System (NAICS): A coding system developed jointly by the United States, Canada, and Mexico to classify businesses and industries according to the type of economic activity in which they are engaged. NAICS replaces the Standard Industrial Classification (SIC) codes.

Nuclear fuel: Fuel that produces energy in a nuclear reactor through the process of nuclear fission.

Nuclear fuel cycle: The series of steps involved in supplying fuel for nuclear power reactors, including mining, milling, isotopic enrichment, fabrication of fuel elements, use in reactors, chemical reprocessing to recover the fissionable material remaining in the spent fuel, re-enrichment of the fuel material re-fabrication into new fuel elements, and waste disposal.

Nuclear power (nuclear electric power): Electricity generated by the use of the thermal energy released from the fission of nuclear fuel in a reactor.

Nuclear power plant: A facility that uses a nuclear reactor to generate electricity.

Nuclear reactor: A device in which nuclear fission may be sustained and controlled in a self-supporting nuclear reaction. There are many types of reactors, but all incorporate certain features, including fissionable material or fuel, a moderating material (unless the reactor is operated on fast neutrons), a reflector to conserve escaping neutrons, provisions of removal of heat, measuring and controlling instruments, and protective devices. The reactor is the heart of a nuclear power plant.

Nuclear Regulatory Commission (NRC): An independent regulatory agency that is responsible for overseeing the civilian use of nuclear materials in the United States. The NRC was established on October 11, 1974, by President Gerald Ford as one of two successor organizations to the Atomic Energy Commission (AEC), which became defunct on that same day. The NRC took over the AEC's responsibility for seeing that civilian nuclear materials and facilities are used safely and affect neither the public health nor the quality of the environment. The Commission's activities focus on the nuclear reactors in the United States that are used to generate electricity on a commercial basis. It licenses the construction of new nuclear reactors and regulates their operation on a continuing basis. It oversees the use, processing, handling, and disposal of nuclear materials and wastes; inspects nuclear power plants and monitors both their safety procedures and their security measures; enforces compliance with established safety standards; and investigates nuclear accidents. The NRC's Commissioners are appointed by the President of the United States and confirmed by the Senate for five-year terms.

Occupational dose: The dose received by an individual in the course of employment in which the individual's assigned duties involve exposure to radiation or to radioactive material. Occupational dose does not include dose received from background radiation, from any medical administration the individual has received, from exposure to individuals administered radioactive materials and released in accordance with 10 CFR 35.75, from voluntary participation in medical research programs, or as a member of the general public.

Occupational exposure: An exposure that occurs during work with sources of ionizing radiation. For example, exposures received from working on a nuclear reactor, in nuclear reprocessing, or by a dental nurse taking x-rays would be classed as occupational.

Occupational Safety and Health Administration (OSHA): Independent Federal agency whose mission is to prevent work-related injuries, illnesses, and deaths. Congress created OSHA under the Occupational Safety and Health Act on December 29, 1970.

Once-through cooling system: In this cooling system, circulating water for condenser cooling is obtained from an adjacent body of water, such as a lake or river, passed through the condenser tubes, and returned directly at a higher temperature to the adjacent body of water.

Organ dose: Dose received as a result of radiation energy absorbed in a specific organ.

Organism: An individual of any form of animal or plant life.

Outer Continental Shelf (OCS): The OCS consists of the submerged lands, subsoil, and seabed, lying between the seaward extent of the States' jurisdiction and the seaward extent of Federal jurisdiction.

Overburden: Any material, consolidated or unconsolidated, that overlies a coal or other rock or mineral deposit.

Ozone (O_3): A strong-smelling, reactive toxic chemical gas consisting of three oxygen atoms chemically attached to each other. It is formed in the atmosphere by chemical reactions involving nitrogen oxide and volatile organic compounds. The reactions are energized by sunlight. Ozone is a criteria air pollutant under the Clean Air Act and is a major constituent of smog.

Parabolic trough: A high-temperature (above 180°F) solar thermal concentrator with the capacity for tracking the sun using one axis of rotation. Also known as a power trough.

Particulate matter: Fine solid or liquid particles, such as dust, smoke, mist, fumes, or smog, found in air or emissions. The size of the particulates is measured in micrometers (μm). One micrometer is 1 millionth of a meter or 0.000039 inch. The U.S. Environmental Protection Agency has set standards for $PM_{2.5}$ and PM_{10} particulates.

Pathway (exposure): The way in which people are exposed to radiation or other contaminants. The three basic pathways are inhalation (contaminants are taken into the lungs), ingestion (contaminants are swallowed), and direct (external) exposure (contaminants cause damage from outside the body).

Peak load: The maximum load during a specified period of time.

Perched aquifer/groundwater: A body of groundwater of small lateral dimensions separated from an underlying body of groundwater by an unsaturated zone.

Perfluorocarbons (PFCs): A group of man-made chemicals composed of one or two carbon atoms and four to six fluorine atoms, containing no chlorine. PFCs have no commercial uses and are emitted as a by-product of aluminum smelting and semiconductor manufacturing. PFCs have very high 100-year Global Warming Potentials and are very long-lived in the atmosphere.

Personal protective equipment (PPE): Clothing and equipment that are worn to reduce exposure to potentially hazardous chemicals and other pollutants.

Person-rem: The sum of the individual radiation dose equivalents received by members of a certain group or population. It may be calculated by multiplying the average dose per person by the number of persons exposed. For example, a thousand people, each exposed to one millirem, would have a collective dose of one person-rem.

Petroleum: A broadly defined class of liquid hydrocarbon mixtures. Includes crude oil, lease condensate, unfinished oils, refined products obtained from the processing of crude oil, and natural gas plant liquids. Volumes of finished petroleum products include nonhydrocarbon compounds, such as additives and detergents, after they have been blended into products.

Photosynthesis: The process in green plants and certain other organisms by which carbohydrates are synthesized from carbon dioxide and water using sunlight as an energy source. Most forms of photosynthesis release oxygen as a by-product. Chlorophyll typically acts as the catalyst in this process.

Photovoltaic and solar thermal energy: Energy radiated by the sun as electromagnetic waves (electromagnetic radiation) that is converted at electric utilities into electricity by means of solar (photovoltaic) cells or concentrating (focusing) collectors.

Photovoltaic cell (PVC): An electronic device consisting of layers of semiconductor materials fabricated to form a junction (adjacent layers of materials with different electronic characteristics) and electrical contacts and being capable of converting incident light directly into electricity (direct current).

Photovoltaic system: A system that converts light into electric current.

Phytoplankton: Small, often single-celled plants that live suspended in bodies of water.

Plutonium: A heavy, man-made, radioactive metallic element. The most important isotope is Pu-239, which has a half-life of more than 20,000 years; it can be used in reactor fuel and is the primary isotope in weapons.

Plume: A visible or measurable emission or discharge of a contaminant from a given point of origin into any medium, such as that formed from a cooling water outfall into a receiving water body or smokestack into the atmosphere.

PM_{10}: Particulate matter with a mean aerodynamic diameter of 10 micrometers (0.0004 in.) or less. Particles less than this diameter are small enough to be deposited in the lungs.

$PM_{2.5}$: Particulate matter with a mean aerodynamic diameter of 2.5 micrometers (0.0001 in.) or less.

Polycyclic aromatic hydrocarbons (PAHs): Aromatic hydrocarbons containing more than one fused benzene ring. PAHs are commonly formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances.

Population dose: Dose received collectively by a population.

Potable water: Water that is fit for humans to drink.

Power: The rate of producing, transferring, or using energy, most commonly associated with electricity. Power is measured in watts and often expressed in kilowatts (kW) or megawatts (MW).

Pressurized water reactor (PWR): A power reactor in which thermal energy is transferred from the core to a heat exchanger by high-temperature water kept under high pressure in the primary system. Steam is generated in the heat exchanger in a secondary circuit.

Prevention of significant deterioration (PSD): A Federal permit program for facilities defined as major sources under the New Source Review program. The intent of the program is to prevent the air quality in an attainment area from deteriorating.

Primary system: A term that refers to the circulating water system in a pressurized water reactor, which removes the energy from the reactor and delivers it to the heat exchanger.

Proposed action: An action proposed by a Federal agency and evaluated in an environmental impact statement or environmental assessment. In this GEIS, the proposed action is to renew commercial nuclear power plant operating licenses.

Proton: A small particle, typically found within an atom's nucleus, that possesses a positive electrical charge. The number of protons is unique for each chemical element.

Proximity: Used sparingly to evaluate the remoteness of areas in which nuclear plants are located. A measure of the distance to larger cities.

Public dose: The dose received by members of the public from exposure to radiation or to radioactive material released by a licensee, or to any other source of radiation under the control of a licensee. Public dose does not include occupational dose or doses received from background radiation, from any medical administration the individual has received, from exposure to individuals administered radioactive materials and released in accordance with 10 CFR 35.75, or from voluntary participation in medical research programs.

Pulverized coal: Coal that has been crushed to a fine dust in a grinding mill. It is blown into the combustion zone of a furnace and burns very rapidly and efficiently.

Pumped-storage hydroelectric plant: A hydropower plant that usually generates electric energy during peak load periods by using water previously pumped into an elevated storage reservoir during off-peak periods when excess generating capacity is available to do so. When additional generating capacity is needed, the water can be released from the reservoir through a conduit to turbine generators located in a power plant at a lower level.

Putrescible: Subject to the biological decomposition of organic matter and associated with anaerobic (no oxygen present) conditions.

Pyrolysis: The thermal decomposition of biomass at high temperatures (greater than 400°F, or 200°C) in the absence of air. The end product of pyrolysis is a mixture of solids (char), liquids (oxygenated oils), and gases (methane, carbon monoxide, and carbon dioxide) with proportions determined by operating temperature, pressure, oxygen content, and other conditions.

Quality factor: The modifying factor that is used to derive dose equivalent from absorbed dose.

Rad: The special unit for radiation absorbed dose, which is the amount of energy from any type of ionizing radiation (e.g., alpha, beta, gamma, neutrons) deposited in any medium (e.g., water, tissue, air). A dose of one rad means the absorption of 100 ergs (a small but measurable amount of energy) per gram of absorbing tissue (100 rad = 1 gray).

Radiation (ionizing radiation): Alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. Radiation, as used in 10 CFR Part 20, does not include nonionizing radiation, such as radiowaves or microwaves, or visible, infrared, or ultraviolet light (see also 10 CFR 20.1003).

Radioactive decay: The decrease in the amount of any radioactive material with the passage of time due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, often accompanied by gamma radiation.

Radioactive waste: Radioactive materials at the end of a useful life cycle or in a product that is no longer useful and should be properly disposed of.

Radioactivity: The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nucleus of an unstable isotope. Also, the rate at which radioactive material emits radiation. Measured in units of becquerels or disintegrations per second.

Radioisotope: An unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation. Approximately 5,000 natural and artificial radioisotopes have been identified.

Radionuclide: A radioisotope of an element.

Raptor: A bird of prey such as a falcon, hawk, or eagle.

Rated power: The design power level of an electrical generating device, which is the maximum power the device is allowed to generate.

Reactor vessel: A device in which nuclear fission may be sustained and controlled in a self-supporting nuclear reaction. It houses the core (made up of fuel rods, control rods, and instruments contained within a reactor vessel) of most types of power reactors.

Receptor: The individual or resource being affected by the impact.

Reference reactor year (RRY): Refers to one year of operation of a 1,000-MW electric capacity nuclear power plant operating at an 80 percent availability factor to produce about 80 MW-yr (0.8 GW-yr) of electricity.

Refurbishment: Repair or replacement of reactor systems, structures, and components, such as turbines, steam generators, pressurizers, and recirculation piping systems.

Region of Influence: Area occupied by affected resources and the distances at which impacts associated with license renewal may occur.

rem (roentgen equivalent man): The acronym for roentgen equivalent man is a standard unit that measures the effects of ionizing radiation on humans. The dose equivalent in rem is equal to the absorbed dose in rads multiplied by the quality factor of the type of radiation (see 10 CFR 20.1004).

Renewable energy resources: Energy resources that are naturally replenishing but flow-limited. They are virtually inexhaustible in duration, but limited in the amount of energy that is available per unit of time. Renewable energy resources include biomass, hydro, geothermal, solar, wind, ocean thermal, wave action, and tidal action.

Renewable portfolio standards (RPSs): State policies that require electricity providers to generate a certain percentage, or, in some cases a certain specified amount, of electrical power through the use of renewable energy sources by a certain date.

Residual fuel oil: A general classification for the heavier oils, known as No. 5 and No. 6 fuel oils, that remain after the distillate fuel oils and lighter hydrocarbons are distilled away in refinery operations.

Resource Conservation and Recovery Act (RCRA): Act that regulates the storage, treatment, and disposal of hazardous and nonhazardous wastes.

Right-of-way: The land and legal right to use and service the land along which a transmission line is located. Transmission line right-of-ways are usually acquired in widths that vary with the kilovolt (kV) size of the line.

Riparian: Relating to, living in, or located on the bank of a river, lake, or tidewater.

Risk: The combined answers to the following questions: (1) What can go wrong? (2) How likely is it? (3) What are the consequences?

Risk coefficient: A coefficient used to convert dose to risk.

roentgen equivalent man (rem): See rem.

Runoff: The portion of rainfall, melted snow, or irrigation water that flows across the ground and that may eventually enter surface waters.

Run-of-river hydroelectric plant: A hydropower plant that uses the flow of a stream as it occurs and has little or no reservoir capacity for storage.

SAFSTOR: A method of decommissioning in which the nuclear facility is placed and maintained in such condition that the nuclear facility can be safely stored and subsequently decontaminated to levels that permit release for restricted or unrestricted use.

Savanna: Grassland with scattered individual trees.

Scouring: The rapid erosion of sediment caused by the movement of water.

Scrubbers: Air pollution control devices that are used to remove particulates and/or gases from industrial or power exhaust streams.

Sediment: Particles of geologic origin that sink to the bottom of a body of water, or materials that are deposited by wind, water, or glaciers.

Seismic: Of, subject to, or caused by an earthquake or earth vibration.

Seismicity: The frequency and distribution of earthquakes.

Service water: Water used to cool heat exchangers or coolers in the power house other than the condenser. Service water may or may not be treated for use.

Shallow-dose equivalent: Applies to external exposure of the skin or an extremity, is taken as the dose equivalent at a tissue depth of 0.007 centimeters averaged over an area of 1 square centimeter.

Sievert (Sv): The international system (SI) unit for dose equivalent equal to 1 Joule/kilogram. 1 sievert = 100 rem. Named for physicist Rolf Sievert.

Sludge: A dense, slushy, liquid-to-semifluid product that accumulates as an end result of an industrial or technological process. Industrial sludges are produced from the processing of energy-related raw materials, chemical products, water, mined ores, sewage, and other natural and man-made products.

Socioeconomics: Social and economic characteristics of a human population. Includes both the social impacts of economic activity and the economic impacts of social activity.

Soils: All unconsolidated materials above bedrock. Natural earthy materials on the Earth's surface, in places modified or even made by human activity, containing living matter, and supporting or capable of supporting plants.

Solar energy: The radiant energy of the sun, which can be converted into other forms of energy, such as heat or electricity.

Solar power tower: A solar energy conversion system that uses a large field of independently adjustable mirrors (heliostats) to focus solar rays on a near single point atop a fixed tower (receiver). The concentrated energy may be used to directly heat the working fluid of a Rankin cycle engine or to heat an intermediary thermal storage medium (such as a molten salt).

Solar radiation: A general term for the visible and near-visible (ultraviolet and near-infrared) electromagnetic radiation that is emitted by the sun. It has a spectral, or wavelength, distribution that corresponds to different energy levels; short wavelength radiation has a higher energy than long-wavelength radiation.

Solar thermal systems or concentrating solar power (CSP): See solar power tower.

Sound intensity: The measure of the amount of energy that is transported over a given area per unit of time. Sound intensity is expressed in units of W/m^2.

Sparseness: Used (with proximity) to evaluate the remoteness of areas in which nuclear plants are located. A measure of population density.

Spawning: Release or deposition of spermatozoa or ova, of which some will fertilize or be fertilized to produce offspring.

Spent fuel burnup: A measure of how much energy is extracted from the nuclear fuel before it is removed from the core. Its units are MW-day per metric tonne of uranium in fresh fuel.

Spent nuclear fuel: Nuclear reactor fuel that has been removed from a nuclear reactor because it can no longer sustain power production for economic or other reasons.

Spent-fuel pool: An underwater storage and cooling facility for spent fuel elements that have been removed from a reactor.

State Historic Preservation Office(r) (SHPO): The State agency (or officer) charged with the identification and protection of prehistoric and historic resources in accordance with the National Historic Preservation Act in the State (see also 36 CFR 800.2(c)(1)).

State implementation plan (SIP): State-specific air quality plan for controlling air pollution emissions at levels that would attain and maintain compliance with the National Ambient Air Quality Standards or State-specific air quality standards. Each State must develop its own regulations to monitor, permit, and control air emissions within its boundaries.

Steam turbine: A device that converts high-pressure steam, produced in a boiler, into mechanical energy that can then be used to produce electricity by forcing blades in a cylinder to rotate and turn a generator shaft.

Stilling basin: An open structure or excavation at the foot of an overfall, chute, drop, or spillway to reduce the energy of the descending stream. A basin constructed to dissipate the energy of fast-flowing water (e.g., from a spillway or bottom outlet) and to protect the stream bed below a dam from erosion.

Stochastic effect: Health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effect.

Store and release dam: Hydropower facilities that store water in a reservoir behind a dam and release the water through turbines as needed to generate electricity.

Stormwater: Stormwater runoff, snowmelt runoff, and surface runoff and drainage.

Stratification: The formation, accumulation, or deposition of materials in layers, such as layers of freshwater overlying higher salinity water (saltwater) in estuaries.

Strip mine: An open cut in which the overburden is removed from a coal bed or other mineral deposit prior to the removal of the desired underlying material.

Sub-bituminous coal: Sub-bituminous coal has a higher heating value than lignite coal, due primarily to its average carbon content of 35–45 percent carbon and lower moisture levels. Sub-bituminous coal deposits in the United States are estimated to be at least 100 million years old. Sub-bituminous coal represents about 42 percent of annual U.S. coal production, with the majority being burned in boilers to produce steam to drive turbines that produce electricity. The major sub-bituminous deposits are in the Western states, primarily Wyoming.

Sulfur: A yellowish nonmetallic element. It is present at various concentrations in many fossil fuels whose combustion releases sulfur compounds that are considered harmful to the environment. Some of the most commonly used fossil fuels are categorized according to their sulfur content, with lower sulfur fuels usually selling at a higher price.

Sulfur dioxide (SO_2): A gas formed from burning fossil fuels. Sulfur dioxide is one of the six criteria air pollutants specified under Title I of the Clean Air Act and contributes to the formation of acid rain.

Sulfur oxides (SO_x): Pungent, colorless gases that are formed primarily by fossil fuel combustion. Sulfur oxides may damage the respiratory tract, as well as plants and trees.

Supercritical and subcritical: Supercritical and subcritical define the thermodynamic state of the water in the steam cycle. In supercritical steam generating units, the pressure at which the steam cycle is maintained is above water's critical point so there is no distinction between water's liquid and gaseous phases and the steam behaves as a homogenous supercritical fluid. The supercritical point for water is 22.1 MPa (approximately 3,207 pounds per square inch [psi]). Supercritical steam generators offer numerous advantages over their subcritical counterparts, including higher thermal efficiencies, greater flexibility in changing loads, and greater combustion efficiencies, resulting in lesser amounts of pollutants per units of power generated. No ultra-supercritical units are operating in the United States.

Supplemental environmental impact statement (SEIS): A SEIS updates or supplements an existing EIS (such as the GEIS). The U.S. Nuclear Regulatory Commission directs the staff to issue site-specific supplements to the GEIS for each license renewal application.

Surface mine (surface mining): A coal-producing mine that is usually within a few hundred feet of the surface. Earth above or around the coal (overburden) is removed to expose the coalbed, which is then mined with surface excavation equipment, such as draglines, power shovels, bulldozers, loaders, and augers. It may also be known as an area, contour, open-pit, strip, or auger mine.

Surface water: Water on the earth's surface that is directly exposed to the atmosphere, as distinguished from water in the ground (groundwater).

Switchyard: A facility used at power plants to increase the electric voltage and feed into the regional power distribution system. Electricity generated at the plant is carried off the site by transmission lines.

Syngas: A gas mixture that contains varying amounts of carbon monoxide and hydrogen generated by the gasification of a carbon-containing fuel.

Tallgrass: Any of various grasses that are tall and that flourish with abundant moisture, typically associated with the prairies of the Midwestern United States.

Terrestrial: Belonging to or living on land.

Thermal: Having to do with heat. Also, a term used to identify a type of electric generating station, capacity, capability, or output in which the source of energy for the prime mover is heat.

Thermal efficiency: A measure of the efficiency of converting the thermal energy generated by the burning of the fossils fuels or the fission of nuclear fuel to electrical energy.

Thermal effluents: Heated discharge from a cooling water system.

Thermal plume: The hot water discharged from a power-generating facility or other industrial plant. When the water at elevated temperature enters a receiving stream or body of water, it is not immediately dispersed and mixed with the cooler waters. The warmer water moves as a single mass (plume) from the discharge point until it cools and gradually mixes with that of the receiving water.

Thermal stratification: The formation of layers of different temperatures in a lake or reservoir.

Thermophilic: Organisms such as bacteria that require a relatively high-temperature environment for normal development.

Threatened species: Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. Requirements for declaring a species threatened are contained in the Endangered Species Act.

Total body dose/Whole-body dose: Sum of the dose received from external exposure to the total body, gonads, active blood-forming organs, head and trunk, or lens of the eye and the dose due to the intake of radionuclides by inhalation and ingestion where a radioisotope is uniformly distributed throughout the body tissues rather than being concentrated in certain parts.

Total effective dose equivalent (TEDE): The sum of the deep-dose equivalent (for external exposure) and the committed effective dose equivalent (for internal exposure).

Transformer: An electrical device for changing the voltage of alternating current.

Transmission: The movement or transfer of electric energy over an interconnected group of lines and associated equipment between points of supply and points at which it is transformed for delivery to consumers or is delivered to other electric systems. Transmission is considered to end when the energy is transformed for distribution to the consumer.

Transmission line: A set of conductors, insulators, supporting structures, and associated equipment used to move large quantities of power at high voltage, usually over long distances between a generating or receiving point and major substations or delivery points.

Transuranic elements: The chemical elements with atomic numbers greater than 92, the atomic number of uranium.

Transuranic waste: Material contaminated with transuranic elements that is produced primarily from reprocessing spent fuel and from use of plutonium in fabrication of nuclear weapons.

Tritium: A radioactive isotope of hydrogen with one proton and two neutrons. It decays by beta emission. It has a radioactive half-life of about 12.5 years.

Turbine: A device in which a stream of water or gas turns a bladed wheel, converting the kinetic energy of the flow into mechanical energy available from the turbine shaft. Turbines are considered the most economical means of turning large electrical generators. They are typically driven by steam, fuel vapor, water, or wind.

U.S. Environmental Protection Agency (EPA): A Federal agency, created for the purpose of promoting human health by protecting the nation's air, water, and soil from harmful pollution by enforcing environmental regulations based on laws passed by Congress. The agency conducts environmental assessment, research, and education. It has the responsibility of maintaining and enforcing national standards under a variety of environmental laws (e.g., Clean Air Act), in consultation with State, Tribal, and local governments. It delegates some permitting, monitoring, and enforcement responsibility to States and Native American Tribes. EPA enforcement powers include fines, sanctions, and other measures. The agency also works with industries and all levels of government in a wide variety of voluntary pollution prevention programs and energy conservation efforts.

Uranium: A radioactive element with the atomic number 92 and, as found in natural ores, an atomic weight of approximately 238. The two principal natural isotopes are uranium-235 (0.7 percent of natural uranium) and uranium-238 (99.3 percent of natural uranium). Natural uranium also includes a minute amount of uranium-234.

Universal waste: A special class of hazardous waste consisting of commonly used and yet hazardous materials: batteries, pesticides, mercury-containing equipment, and lamps.

Vertebrate: Any species having a backbone or spinal column including fish, amphibians, reptiles, birds, and mammals.

Visual impact: The creation of an intrusion or perceptible contrast that affects the scenic quality of a landscape.

Visual resources: Refers to all objects (man-made and natural, moving and stationary) and features such as landforms and water bodies that are visible on a landscape.

Volatile organic compounds (VOCs): A broad range of organic compounds that readily evaporate at normal temperatures and pressures. Sources include certain solvents, degreasers (e.g., benzene), and fuels. Volatile organic compounds react with other substances (primarily nitrogen oxides) to form ozone. They contribute significantly to photochemical smog production and certain health problems.

Waste coal: Usable material that is a by-product of previous coal processing operations. Waste coal may be relatively clean material composed primarily of coal fines, material in which extraneous noncombustible constituents have been partially removed, or mixed coal, soil, and rock (mine waste) burned as is in unconventional boilers, such as fluidized bed units. Examples include fine coal, coal obtained from a refuse bank or slurry dam, anthracite culm, bituminous gob, and lignite waste.

Wastewater: The used water and solids that flow to a treatment plant and/or are discharged to a receiving water body. Stormwater, surface water, and groundwater infiltration also may be included in the wastewater that enters a wastewater treatment plant. Domestic or sanitary wastewater is water originating from human sanitary water use and industrial wastewater is that derived from a variety of industrial processes.

Water table: The boundary between the unsaturated zone and the deeper, saturated zone. The upper surface of an unconfined aquifer.

Water quality: The condition of water with respect to the amount of impurities in it.

Weir: A structure in a waterway or stormwater control device, over which water flows that serves to raise the water level or to direct or regulate flow.

Wetlands: Areas that are inundated or saturated by surface water or groundwater and that typically support vegetation adapted for life in saturated soils. Wetlands generally include swamps, marshes, bogs, and similar areas (e.g., sloughs, potholes, wet meadows, river overflow areas, mudflats, natural ponds).

Wind energy: Kinetic energy present in wind motion that can be converted to mechanical energy for driving pumps, mills, and electric power generators.

Wind farm: One or more wind turbines operating within a contiguous area for the purpose of generating electricity. See also wind power plant.

Wind power plant: Wind turbines interconnected to a common utility system through a system of transformers, distribution lines, and (usually) one substation. Operation, control, and maintenance functions are often centralized through a network of computerized monitoring systems, supplemented by visual inspection.

Wind turbine: Wind energy conversion device that produces electricity; typically three blades rotating about a horizontal axis and positioned upwind of the supporting tower.

X-rays and gamma rays: Waves of pure energy that travel with the speed of light that are very penetrating and require thick concrete or lead shielding to stop them.

Yucca Mountain: The Yucca Mountain, Nevada, site of the U.S. Department of Energy's proposed location for a repository for spent nuclear fuel and high-level radioactive waste. The U.S. Environmental Protection Agency established the public health and environmental radiation protection standards for the facility. However, in March 2010, DOE filed a request with the NRC's Atomic Safety and Licensing Board to withdraw its application for authorization to construct a high-level waste geological repository at Yucca Mountain. The decisions and recommendations concerning the ultimate disposition of spent nuclear fuel are ongoing.

Zooplankton: Small animals that float passively in the water column. Includes eggs and larvae of many fish and invertebrate species.

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10. SUPPLEMENTARY NOTES

11. ABSTRACT (200 words or less)

U.S. Nuclear Regulatory Commission (NRC) regulations allow for the renewal of commercial nuclear power plant operating licenses. To support the license renewal environmental review process, the NRC published the Generic Environmental Impact Statement for License Renewal of Nuclear Plants (GEIS) in 1996. The proposed action considered in the GEIS is the renewal of nuclear power plant operating licenses.

Since publication of the GEIS, approximately 40 plant sites (70 reactor units) have applied for license renewal and undergone environmental reviews, the results of which were published as supplements to the 1996 GEIS. This GEIS revision reviews and reevaluates the issues and findings of the 1996 GEIS. Lessons learned and knowledge gained during previous license renewal reviews provide a significant source of new information for this assessment. In addition, new research, findings, public comments, and other information were considered in evaluating the significance of impacts associated with license renewal.

The intent of the GEIS is to determine which issues would result in the same impact at all nuclear power plants and which issues could result in different levels of impact at different plants and thus require a plant-specific analysis for impact determinations. The GEIS revision identifies 78 environmental impact issues for consideration in license renewal environmental reviews, 59 of which have been determined to be generic to all plant sites. The GEIS also evaluates a full range of alternatives to the proposed action. For most impact areas, the proposed action would have impacts that would be similar to or less than impacts of the alternatives, in large part because most alternatives would require new power plant construction, whereas the proposed action would not.

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