

EFFLUENTS

# Radioactive Effluents from Nuclear Power Plants

Annual Report 2008



Office of Nuclear Reactor Regulation  
U.S. Nuclear Regulatory Commission  
Washington, DC 20555-0001



This page intentionally left blank

---

# **Radioactive Effluents From Nuclear Power Plants**

Annual Report 2008

---



Prepared By:

N. Daugherty, Oak Ridge Institute for Science and Education

R. Conatser, U.S. Nuclear Regulatory Commission

Prepared for

Office of Nuclear Reactor Regulation

U.S. Nuclear Regulatory Commission

Washington, DC 20555-0001

This page intentionally left blank

## ABSTRACT

---

This report describes radioactive effluents from commercial nuclear power plants (NPPs) in the United States. This information was reported by the licensees for radioactive discharges that occurred in 2008. The report provides information relevant to the potential impact of NPPs on the environment and on public health. The report includes information on:

- radionuclides in liquid and gaseous effluents from NPPs and
- radiation doses to the public from NPP effluents.

This report is a summary of the effluent data reported by the NPPs. To view all the information contained in the Annual Radioactive Effluent Release Reports from each NPP, visit the Nuclear Regulatory Commission (NRC) Web site at <http://www.nrc.gov/about-nrc/radiation.html>.

The radionuclide and radiation dose data in this report are intended to provide the reader with a means to quickly characterize the effluents from any NPP. The data presented are considered by the NRC to be particularly relevant to the potential impact of NPPs on public health and the environment. The radionuclides selected for inclusion are either the most predominant in radioactive effluents or are particularly useful indicators of overall releases. The radiation doses in the report are those most directly associated with potential public health impact.

For purposes of comparison, the data also include the median (midpoint) radionuclide concentrations, as well as the applicable NRC dose limits and design objectives. Finally, the results of the National Council on Radiation Protection's assessment of radiation exposure to the U.S. population also are included so the reader can compare the dose from NPP effluents relative to natural background and other sources of radiation exposure.

This page intentionally left blank

# TABLE OF CONTENTS

---

<b>ABSTRACT</b> .....	i
<b>TABLE OF CONTENTS</b> .....	iii
<b>LIST OF TABLES AND FIGURES</b> .....	iv
<b>ABBREVIATIONS</b> .....	vi
<b>1 INTRODUCTION</b> .....	1-1
1.1 Purpose.....	1-1
1.2 Scope.....	1-1
1.3 Source of Data.....	1-6
1.4 Limitations of the Data.....	1-6
<b>2 DESCRIPTION OF THE DATA</b> .....	2-1
2.1 Airborne and Liquid Effluents.....	2-1
2.2 Radiation Dose to the Public.....	2-3
2.3 Other Sources of Radiation Dose to the U.S. Population.....	2-4
<b>3 SUMMARY</b> .....	3-1
<b>4 TABLES AND GRAPHS</b> .....	4-1
4.1 Effluent Data.....	4-1
4.2 Radiation Dose.....	4-35
<b>5 REFERENCES</b> .....	5-1
<b>6 GLOSSARY</b> .....	6-1

# LIST OF TABLES AND FIGURES

---

## TABLES

1.1	Nuclear Power Plants, 2008 .....	1-2
1.2	Reactors for Which the NRC Has Normalized Data on a Unit-specific Basis .....	1-8
2.1	Radionuclides in Gaseous Effluents, 2008 .....	2-2
2.2	Radionuclides in Liquid Effluents, 2008 .....	2-3
4.1	BWR Gaseous Releases — Selected Fission and Activation Gases, 2008 .....	4-1
4.2	BWR Gaseous Releases — Iodine, 2008 .....	4-2
4.3	BWR Gaseous Releases — Selected Particulates, 2008 .....	4-3
4.4	BWR Gaseous Releases — Tritium, 2008 .....	4-5
4.5	PWR Gaseous Releases — Selected Fission and Activation Gases, 2008 .....	4-6
4.6	PWR Gaseous Releases — Iodine, 2008 .....	4-8
4.7	PWR Gaseous Releases — Selected Particulates, 2008 .....	4-9
4.8	PWR Gaseous Releases — Tritium, 2008 .....	4-11
4.9	BWR Liquid Releases — Selected Fission and Activation Products, 2008 .....	4-12
4.10	BWR Liquid Releases — Tritium, 2008 .....	4-13
4.11	PWR Liquid Releases — Selected Fission and Activation Products, 2008 .....	4-14
4.12	PWR Liquid Releases — Tritium, 2008 .....	4-16
4.13	BWR Gaseous Effluents — Maximum Annual Organ Dose, 2008 .....	4-35
4.14	PWR Gaseous Effluents — Maximum Annual Organ Dose, 2008 .....	4-36
4.15	BWR Liquid Effluents — Maximum Annual Total Body and Organ Dose, 2008 .....	4-37
4.16	PWR Liquid Effluents — Maximum Annual Total Body and Organ Dose, 2008 .....	4-38



## FIGURES

2.1	Sources of Radiation Exposure to the U.S. Population.....	2-6
4.1	BWR Gaseous Releases — Selected Fission and Activation Gases.....	4-17
4.2	BWR Gaseous Releases — Iodine .....	4-18
4.3	BWR Gaseous Releases — Selected Particulates.....	4-19
4.4	BWR Gaseous Releases — Tritium .....	4-20
4.5	PWR Gaseous Releases — Selected Fission and Activation Gases.....	4-21
4.6	PWR Gaseous Releases — Iodine .....	4-23
4.7	PWR Gaseous Releases — Selected Particulates.....	4-25
4.8	PWR Gaseous Releases — Tritium .....	4-27
4.9	BWR Liquid Releases — Selected Fission and Activation Products.....	4-29
4.10	BWR Liquid Releases — Tritium.....	4-30
4.11	PWR Liquid Releases — Selected Fission and Activation Products.....	4-31
4.12	PWR Liquid Releases — Tritium.....	4-33
4.13	BWR Gaseous Effluents — Maximum Annual Organ Dose.....	4-39
4.14	PWR Gaseous Effluents — Maximum Annual Organ Dose.....	4-40
4.15	BWR Liquid Effluents — Maximum Annual Total Body and Organ Dose.....	4-42
4.16	PWR Liquid Effluents — Maximum Annual Total Body and Organ Dose.....	4-43

## ABBREVIATIONS

---

ALARA	as low as is reasonably achievable
ARERR	Annual Radioactive Effluent Release Report
BWR	boiling water reactor
CFR	Code of Federal Regulations
NCRP	National Council on Radiation Protection and Measurements
NPP	nuclear power plant
NRR	U.S. NRC, Office of Nuclear Reactor Regulation
ODCM	Offsite Dose Calculation Manual
PWR	pressurized water reactor
(U.S.) EPA	United States Environmental Protection Agency
(U.S.) NRC	United States Nuclear Regulatory Commission

# **Section 1**

## **INTRODUCTION**

---

### **1.1 PURPOSE**

This report describes radioactive effluents from commercial nuclear power plants (NPPs) in the United States during calendar year 2008. It is based on an extensive amount of information submitted to the Nuclear Regulatory Commission (NRC) by all U.S. NPP licensees. The original information was submitted by the NPPs in their Annual Radioactive Effluent Release Reports (ARERRs) and comprises several thousand pages of data. These reports may be viewed in their entirety on the NRC Web site (<http://www.nrc.gov/about-nrc/radiation.html>).

For the years between 1972 and 1993, this type of annual information was condensed in a tabular format and published as a large volume of raw information (Ref. 1-22). An evaluation of the practice of generating annual reports revealed the need for a more concise summary report that presented the information in a more intuitive, graphic format (Ref. 23).

The purpose of this report is to condense an extremely large volume of technical information into a few graphs and tables from which the reader can quickly, if broadly, characterize the effluents from any U.S. NPP. These graphs and tables are designed to provide easily understandable information for the public at large, while also providing experienced professionals with enough information to evaluate trends in industry performance and to identify potential performance issues for individual power plants. Those users wanting more extensive and detailed information are encouraged to retrieve the original ARERRs from the NRC Web site.

### **1.2 SCOPE**

This report summarizes data from all NPPs that were in commercial operation between January 1, 2008 and December 31, 2008. A list of NPPs for which information is included in this report is provided in *Table 1.1*.

**TABLE 1.1**  
Nuclear Power Plants, 2008

<b>Plant Name</b>	<b>Type</b>	<b>Full Plant Name</b>	<b>Location</b>
Arkansas 1 & 2	PWR	Arkansas Nuclear One (ANO), Units 1 & 2	Russellville, AR
Beaver Valley 1 & 2	PWR	Beaver Valley, Units 1 & 2	Shippingport, PA
Braidwood 1 & 2	PWR	Braidwood Generating Station, Units 1 & 2	Braceville, IL
Browns Ferry 1, 2, & 3	BWR	Browns Ferry Nuclear Plant, Units 1, 2, & 3	Decatur, AL
Brunswick 1 & 2	BWR	Brunswick Steam Electric Plant, Units 1 & 2	Southport, NC
Byron 1 & 2	PWR	Byron Generating Station, Units 1 & 2	Byron, IL
Callaway	PWR	Callaway Plant, Unit 1	Callaway, MO
Calvert Cliffs 1, 2	PWR	Calvert Cliffs Nuclear Power Plant, Units 1 & 2	Lusby, MD
Catawba 1, 2	PWR	Catawba Nuclear Station, Units 1 & 2	York, SC
Clinton	BWR	Clinton Power Station	Clinton, IL
Columbia Generating	BWR	Columbia Generating Station	Richland, WA
Comanche Peak 1, 2	PWR	Comanche Peak Steam Electric Station, Units 1 & 2	Glen Rose, TX
Cook 1, 2	PWR	Donald C. Cook Nuclear Plant, Units 1 & 2	Bridgman, MI
Cooper Station	BWR	Cooper Nuclear Station	Brownville, NE
Crystal River 3	PWR	Crystal River, Unit 3	Crystal River, FL
Davis-Besse	PWR	Davis-Besse Nuclear Power Station, Unit 1	Oak Harbor, OH
Diablo Canyon 1, 2	PWR	Diablo Canyon, Units 1 & 2	Avila Beach, CA
Dresden 2, 3	BWR	Dresden Generating Station, Units 2 & 3	Morris, IL
Duane Arnold	BWR	Duane Arnold Energy Center	Palo, IA
Farley 1 & 2	PWR	Joseph M. Farley Nuclear Plant, Units 1 & 2	Ashford, AL
Fermi 2	BWR	Fermi 2 Nuclear Power Plant	Newport, MI

**TABLE 1.1 (continued)**  
Nuclear Power Plants, 2008

<b>Plant Name</b>	<b>Type</b>	<b>Full Plant Name</b>	<b>Location</b>
Fitzpatrick	BWR	James A. FitzPatrick Nuclear Power Plant	Lycoming, NY
Fort Calhoun	PWR	Fort Calhoun Station, Unit 1	Fort Calhoun, NE
Ginna	PWR	R.E. Ginna Nuclear Power Plant, Unit 1	Ontario, NY
Grand Gulf	BWR	Grand Gulf Nuclear Station, Unit 1	Port Gibson, MS
Harris	PWR	Shearon Harris Nuclear Power Plant, Unit 1	New Hill, NC
Hatch 1, 2	BWR	Edwin I. Hatch Nuclear Plant, Units 1 & 2	Baxley, GA
Hope Creek	BWR	Hope Creek Generating Station, Unit 1	Hancocks Bridge, NJ
Indian Point 2, 3	PWR	Indian Point Energy Center, Units 2 & 3	Buchanan, NY
Kewaunee	PWR	Kewaunee Power Station	Kewaunee, WI
LaSalle 1, 2	BWR	LaSalle County Generating Station, Units 1 & 2	Marseilles, IL
Limerick 1, 2	BWR	Limerick Generating Station, Units 1 & 2	Saratoga, PA
McGuire 1, 2	PWR	McGuire Nuclear Station, Units 1 & 2	Huntersville, NC
Millstone 2, 3	PWR	Millstone Power Station, Units 2 & 3	Waterford, CT
Monticello	BWR	Monticello Nuclear Generating Plant	Monticello, MN
Nine Mile Point 1, 2	BWR	Nine Mile Point Nuclear Station, Units 1 & 2	Lycoming, NY
North Anna 1, 2	PWR	North Anna Power Station, Units 1 & 2	Mineral, VA
Oconee 1, 2, 3	PWR	Oconee Nuclear Station, Units 1, 2, & 3	Seneca, SC

**TABLE 1.1 (continued)**  
Nuclear Power Plants, 2008

<b>Plant Name</b>	<b>Type</b>	<b>Full Plant Name</b>	<b>Location</b>
Oyster Creek	BWR	Oyster Creek Nuclear Generating Station	Forked River, NJ
Palisades	PWR	Palisades Nuclear Plant	Covert, MI
Palo Verde 1, 2, 3	PWR	Palo Verde Nuclear Generating Station, Units 1, 2, & 3	Phoenix, AZ
Peach Bottom 2, 3	BWR	Peach Bottom Atomic Power Station, Units 2 & 3	Delta, PA
Perry	BWR	Perry Nuclear Power Plant, Unit 1	Perry, OH
Pilgrim	BWR	Pilgrim Nuclear Power Station, Unit 1	Plymouth, MA
Point Beach 1, 2	PWR	Point Beach Nuclear Plant, Units 1 & 2	Two Rivers, WI
Prairie Island 1, 2	PWR	Prairie Island Nuclear Generating Plant, Units 1 & 2	Welch, MN
Quad Cities 1, 2	BWR	Quad Cities Generating Station, Units 1 & 2	Cordova, IL
River Bend	BWR	River Bend Station, Unit 1	St. Francisville, LA
Robinson 2	PWR	H. B. Robinson Steam Electric Plant, Unit 2	Hartsville, SC
Salem 1, 2	PWR	Salem Nuclear Generating Station, Units 1 & 2	Hancocks Bridge, NJ
San Onofre 2, 3	PWR	San Onofre Nuclear Generating Station, Units 2 & 3	San Clemente, CA
Seabrook	PWR	Seabrook Station, Unit 1	Seabrook, NH
Sequoyah 1, 2	PWR	Sequoyah Nuclear Plant, Units 1 & 2	Soddy-Daisy, TN
South Texas 1, 2	PWR	South Texas Project Electric Generating Station, Units 1 & 2	Wadsworth, TX
St. Lucie 1, 2	PWR	St. Lucie Nuclear Plant, Units 1 & 2	Ft. Pierce, FL
Summer	PWR	Virgil C. Summer Nuclear Station, Unit 1	Jenkinsville, SC
Surry 1, 2	PWR	Surry Power Station, Units 1 & 2	Surry, VA
Susquehanna 1, 2	BWR	Susquehanna Steam Electric Station, Units 1 & 2	Berwick, PA

**TABLE 1.1 (continued)**  
Nuclear Power Plants, 2008

<b>Plant Name</b>	<b>Type</b>	<b>Full Plant Name</b>	<b>Location</b>
Three Mile Island 1	PWR	Three Mile Island Generating Station, Unit 1	Harrisburg, PA
Turkey Point 3, 4	PWR	Turkey Point Nuclear Plant, Units 3 & 4	Princeton, FL
Vermont Yankee	BWR	Vermont Yankee Nuclear Plant, Unit 1	Vernon, VT
Vogtle 1, 2	PWR	Vogtle Electric Generating Plant, Units 1 & 2	Waynesboro, GA
Waterford 3	PWR	Waterford Steam Electric Station, Unit 3	Killona, LA
Watts Bar	PWR	Watts Bar Nuclear Plant, Unit 1	Spring City, TN
Wolf Creek	PWR	Wolf Creek Generating Station, Unit 1	Burlington, KS
<b>Reactors No Longer In Commercial Operation</b>			
Big Rock Point	BWR	Big Rock Point Restoration Project	Charlevoix, MI
Dresden 1	BWR	Dresden Generating Station, Unit 1	Morris, IL
Haddam Neck	PWR	Haddam Neck Nuclear Plant Site	Haddam Neck, CT
Humboldt Bay	BWR	Humboldt Bay Power Plant, Unit 3	Eureka, CA
Indian Point 1	PWR	Indian Point Energy Center, Unit 1	Buchanan, NY
Lacrosse	BWR	LaCrosse Boiling Water Reactor	Genoa, WI
Maine Yankee	PWR	Maine Yankee	Bath, ME
Millstone 1	PWR	Millstone Power Station, Unit 1	Waterford, CT
Rancho Seco	PWR	Rancho Seco, Unit 1	Herald, CA
San Onofre 1	PWR	San Onofre Nuclear Generating Station, Unit 1	San Clemente, CA
Three Mile Island 2	PWR	Three Mile Island Nuclear Station, Unit 2	Middletown, PA
Trojan	PWR	Trojan Nuclear Plant, Unit 1	Portland, OR
Yankee-Rowe	PWR	Yankee Nuclear Power Station	Franklin Co., MA
Zion 1, 2	PWR	Zion Generating Station, Units 1 & 2	Warrenville, IL

The NRC uses the information on radioactive releases to ensure NPPs are operated within regulatory requirements and consistent with the objective of maintaining radiation doses as low as is reasonably achievable (ALARA). For this summary report, only information submitted with regard to NRC reporting requirements and guidance is included.

The Big Rock Point, Haddam Neck, Humboldt Bay, Lacrosse, Maine Yankee, Rancho Seco, Trojan, Yankee-Rowe and Zion 1 and 2 reactor sites are shutdown and are not collocated with an operating reactor. The data from these shutdown reactors are not included in the tables in this report. The Dresden 1, Millstone 1, and Three Mile Island 2 reactors are shutdown and are collocated with one of more operating reactors. For these shutdown reactors, the licensee reports data for the shutdown unit separately from the operating units, and the results from these shutdown reactors are not included in this report. For the Indian Point 1 and San Onofre 1 reactor sites, which are shutdown and collocated beside two operating units, the licensee reports the sum of the effluents from the shutdown unit with one (or both) of the operating units. For these shutdown reactors, the effluent data are included with (and attributed to) one or more of the operating units in this report.

### **1.3 SOURCE OF DATA**

Each commercial nuclear power plant in the United States is authorized by the NRC to release small amounts of radioactive materials to the environment as specified in the licensing documents for the plant. NRC regulations require each NPP to establish and maintain a program for monitoring radioactive effluents (10 CFR 50.36 and 10 CFR 50, Appendix I, Section IV.B) and to report these effluents in an Annual Radioactive Effluent Release Report (10 CFR 50.36a) (Ref. 24). Licensees submit their reports to the NRC with content and format in accordance with Regulatory Guide 1.21 (Ref. 25).

The information included in this document was obtained from the licensees' ARERRs. Individual licensee reports are available in the NRC Public Document Room, One White Flint North, 11555 Rockville Pike (first floor), Rockville, Maryland 20852, phone 1-800-397-4209 or 301-415-4737; in local Public Document Rooms located near each licensed facility; and on the Internet as posted on the NRC's public Web site at <http://www.nrc.gov/about-nrc/radiation.html>.

The data from these reports are entered into a database that is maintained by the NRC. The public may access this database through an NRC Web site (<http://www.reirs.com/effluent/>). The data are entered into the database as they are reported by each site.

### **1.4 LIMITATIONS OF THE DATA**

Some NPPs have more than one reactor unit located at a site. If the licensee reports data separately for each reactor unit, those data are reflected in this report as reported by the licensee. Because some licensees are allowed to operate multi-unit sites with a common radioactive waste processing system, the NRC allows these licensees to report total effluents



from the site instead of reporting the totals from each reactor unit. This complicates the task of presenting the effluent information in a manner that allows both (1) a direct comparison of one reactor unit to another, and (2) a direct comparison of each reactor unit to NRC limits and regulations.

For purposes of presentation in this report, the data are normalized on a per-unit basis. For multi-unit sites where the effluents are from a common radioactive waste system, the effluents are divided equally between the units in operation during that year. For example, Calvert Cliffs has two units (1 and 2) with a common radioactive waste processing system. For this report, the total effluents for Calvert Cliffs were split equally between Unit 1 and Unit 2. In the case of Beaver Valley, the licensee reports gaseous effluents from four sources: Unit 1, Unit 2, a common plant vent, and a common building vent. In this case, the releases from the common vents are split equally between Unit 1 and Unit 2, and the totals for each unit then are calculated. In those cases where the licensee does not report unit-specific data, the NRC has – for purposes of presentation in this report – split the data on a unit-specific basis. This may affect either the radionuclide data or the dose data (or both). The affected NPPs and the type of data affected are listed in table 1-2.

Although there are other methods of normalizing effluent data (e.g., on the basis of thermal or electrical power generation), the unit-based method selected (1) is most intuitive, (2) is most directly comparable with the NRC required design objectives, and (3) is easily derived from the effluent data supplied by the licensee. This approach satisfies a primary objective for this report: to allow the reader to quickly formulate reasonable comparisons between reactors and with the regulatory limits. It should be noted, however, that the actual unit contributions to a common multi-unit release might be different than the equal distribution calculated with this approach.

Care has been taken to assure that the information contained in this report accurately reflects the information provided by the licensees. The report includes licensees' corrections submitted to the NRC up to the time of publication. However, if licensees submit amendments to the data in accordance with NRC regulatory guidance, the NRC reserves the right to update the data in future reports. For the most current data, the reader should use the most recent versions of the NPPs' ARERRs and the NRC's annual summary report, which are available on the NRC Web site.

**TABLE 1.2**

Reactors for Which the NRC Has Normalized Data on a Unit-specific Basis

<b>Boiling Water Reactors (BWRs)</b>	<b>Pressurized Water Reactors (PWRs)</b>
Browns Ferry 1, 2 & 3 (R, D)	Beaver Valley 1 & 2 (R)
Brunswick 1 & 2 (R, D)	Calvert Cliffs 1 & 2 (R, D)
Dresden 2 & 3 (R)	Catawba 1 & 2 (R, D)
LaSalle 1 & 2 (R, D)	Comanche Peak 1 & 2 (R, D)
Limerick 1 & 2 (R, D)	Cook 1 & 2 (R, D)
Nine Mile Point 1 & 2 (D)	Diablo Canyon 1 & 2 (R, D)
Peach Bottom 2 & 3 (R, D)	Indian Point 1 & 2 (R, D)
Quad Cities 1 & 2 (R, D)	McGuire 1 & 2 (R, D)
Susquehanna 1 & 2 (R)	North Anna 1 & 2 (R, D)
	Oconee 1, 2 & 3 (R, D)
	Point Beach 1 & 2 (R, D)
	Prairie Island 1 & 2 (R, D)
	San Onofre 2 & 3 (R, D)
	Sequoyah 1 & 2 (R, D)
	Surry 1 & 2 (D)

*Notes:**R = Radionuclide Data, D = Dose Data*

## **Section 2**

# **DESCRIPTION OF THE DATA**

---

### **2.1 AIRBORNE AND LIQUID EFFLUENTS**

The effluent data are presented in Section 4 as tables and graphs. *Tables 4.1* through *4.12* list the total measured activities of selected radionuclides in gaseous and liquid effluents during 2008. These data are illustrated in *Figures 4.1* through *4.12*. If there is no value listed in a particular cell in a table, it is because the licensee indicated the radionuclide was not detected at that NPP. In those cases, the corresponding graph will not contain information on that radionuclide at that NPP.

For comparison purposes, median values are included on some tables and graphs. The median is a statistical estimate of the midpoint of the data. It is a method of estimating a central or typical value while avoiding bias caused by extremely high or low values in the data set. All sites are included when calculating the medians, even those sites for which no measurable release of a particular radionuclide is reported. If the majority of reactors did not detect a nuclide, the median will be blank.

The tables and graphs are organized by reactor type: boiling water reactors (BWRs) and pressurized water reactors (PWRs). The tables and graphs are further subdivided into liquid and gaseous effluents. Finally, the data are subdivided into effluent radionuclide categories.

In order to present the airborne and liquid effluent data in a manner that is both useful and concise, only selected radionuclides are included in the tables and graphs of this report. The radionuclides included are listed by effluent category in *Tables 2.1* and *2.2*.

The unit used for calculating and reporting effluent activity is the curie (Ci), a traditional unit for reporting radioactivity in the United States. Other countries report radionuclide activity in units of becquerels (Bq). One curie equals  $3.7\text{E}+10$  ( $3.7 \times 10^{10}$ ) becquerels.

**TABLE 2.1**  
Radionuclides in Gaseous Effluents, 2008

<b>Gaseous Effluent Categories</b>	<b>Some Common Radionuclides in this Category</b>	<b>Radionuclides Included in this Report</b>
Fission and Activation Gases	Krypton (85, 85m, 87, 88) Xenon (131, 131m, 133, 133m, 135, 135m) Argon (41)	Kr-85 Xe-133 Xe-135
Iodines/Halogens	Iodine (131, 132, 133, 134, 135) Bromine (82)	I-131
Particulates	Cobalt (58, 60) Cesium (134, 137) Chromium (51) Manganese (54) Niobium (95)	Co-58 Co-60 Cs-134 Cs-137
Tritium	Hydrogen (3)	H-3
Gross Alpha	Total alpha activity from all alpha emitters	Not Presented in this Report

The radionuclides highlighted in this report are good indicators of total radioactive releases from the site, and they can provide additional information about operational practices at the site. For example, although there are more than 11 radionuclides in the category of “fission and activation gases,” only 3 (Kr-85, Xe-133, and Xe-135) were selected for inclusion in this report. These three were chosen because as their activity increases, the activity of other fission and activation gases typically increases as well. Conversely, if the activity of these three radionuclides is very low, the activity of other fission and activation gases tends to be low also.

In addition, the ratios of the activities of selected radionuclides can provide insights into fuel performance, radioactive waste system operation, and general radioactive waste handling practices at a site. The interested reader wanting to see all radionuclides released from NPPs is encouraged to review the detailed, site-specific ARERs on the NRC Web site.

**TABLE 2.2**  
Radionuclides in Liquid Effluents, 2008

<b>Liquid Effluent Categories</b>	<b>Some Common Radionuclides in this Category</b>	<b>Radionuclides Included in this Report</b>
Mixed Fission and Activation Products	Iron (55) Cobalt (58, 60) Cesium (134, 137) Chromium (51) Manganese (54) Zirconium (95) Niobium (95) Iodine (131, 133, 135)	Fe-55 Co-58 Co-60 Cs-134 Cs-137 I-131
Tritium	Hydrogen (3)	H-3
Dissolved and Entrained Noble Gases	Krypton (85, 85m, 87, 88) Xenon (131, 133, 133m, 135, 135m)	Not Presented in this Report
Alpha	Total alpha activity from all alpha emitters	Not Presented in this Report

## 2.2 RADIATION DOSE TO THE PUBLIC

Each licensee calculates radiation doses from radioactive effluents in accordance with requirements of 10 CFR 50, Appendix I, (Ref. 24) based on:

1. actual measurements of the radioactive materials released to the environment,
2. models of how radionuclides are dispersed and diluted in the environment,
3. models of how radionuclides are incorporated into animals, plants, and soil, and
4. biokinetic models of human uptake and metabolism of radioactive materials.

These models are designed to calculate the doses to the individuals closest to the NPP or the individuals who may be exposed to the highest concentrations of radioactive materials from radioactive effluents. This is often referred to as the maximum exposed individual. The parameters and assumptions used in these calculations typically include conservative assumptions that tend to overestimate the calculated exposures. As a result, the actual doses received by real individuals are often much less than those calculated. Guidance for these

calculations is provided in NRC Regulatory Guide 1.109, and licensees have incorporated this guidance into their Offsite Dose Calculation Manuals (ODCM) (Ref. 26). ODCMs are available in the NRC Public Document Room and in local Public Document Rooms (e.g., public libraries) located near each NPP. The interested reader may refer to these documents for additional information about dose calculations.

The traditional unit for reporting radiation dose in the United States is the millirem (mrem). Other countries report radiation dose in units of sieverts (Sv). One millirem equals 0.00001 sievert. The number 0.00001 is often represented in scientific notation as  $1 \times 10^{-5}$  or 1E-05.

Once the doses are calculated as described in the preceding paragraphs, the calculated doses are compared to the operating limits for a NPP. Licensees have established operating limits for plant systems to control the amounts of radioactive materials released from NPPs. The NRC requires these operating limits to be established in accordance with the design objectives in 10 CFR 50, Appendix I (Ref. 24). These operating limits are designed to ensure radioactive effluents from NPPs are kept as low as is reasonably achievable (ALARA). It should be understood that these are *operating* limits for plant systems and are not *safety* limits. If a licensee would exceed one of these operating limits, they are required to take corrective actions to ensure the plant systems are functioning as designed. Maintaining the design functions of plant systems is critical to ensure radioactive releases do not exceed the dose limits in 10 CFR 20 (which are federal *safety* limits) (Ref. 27). For purposes of comparison, the operating limits are set to a small fraction (typically about 3%) of the federal safety limits. Licensees have incorporated several different operating limits into their ODCMs as required by their Technical Specifications to satisfy NRC regulatory requirements.

Radiation doses from plant effluents are summarized in Section 4 (*Tables 4.13 through 4.16 and Figures 4.13 through 4.16*). These graphs and figures contain the annual organ doses (for gaseous and liquid effluents), the annual total body doses (for liquid effluents), and the corresponding operating limits. These doses are measures of the potential impact of NPP effluents on public health and the environment. For multi-unit sites, the operating limits are established on a per-unit basis. If there is no value listed in a particular cell of a table, it is because the value was not reported by the licensee. In such cases, the corresponding graph will not contain dose information for that NPP. Although only the annual organ doses and the annual total body doses are included in this report, other doses calculated by the NPPs are included in the individual NPP ARERRs, available on the NRC Web site.

## **2.3 OTHER SOURCES OF RADIATION DOSE TO THE U.S. POPULATION**

For comparison with NPP effluents, this section provides a perspective on the doses that Americans typically receive on average from natural and background radiation.

In March 2009, the National Council on Radiation Protection and Measurements (NCRP) published Report No. 160 as an update to the 1987 NCRP Report No. 93, *Ionizing Radiation*

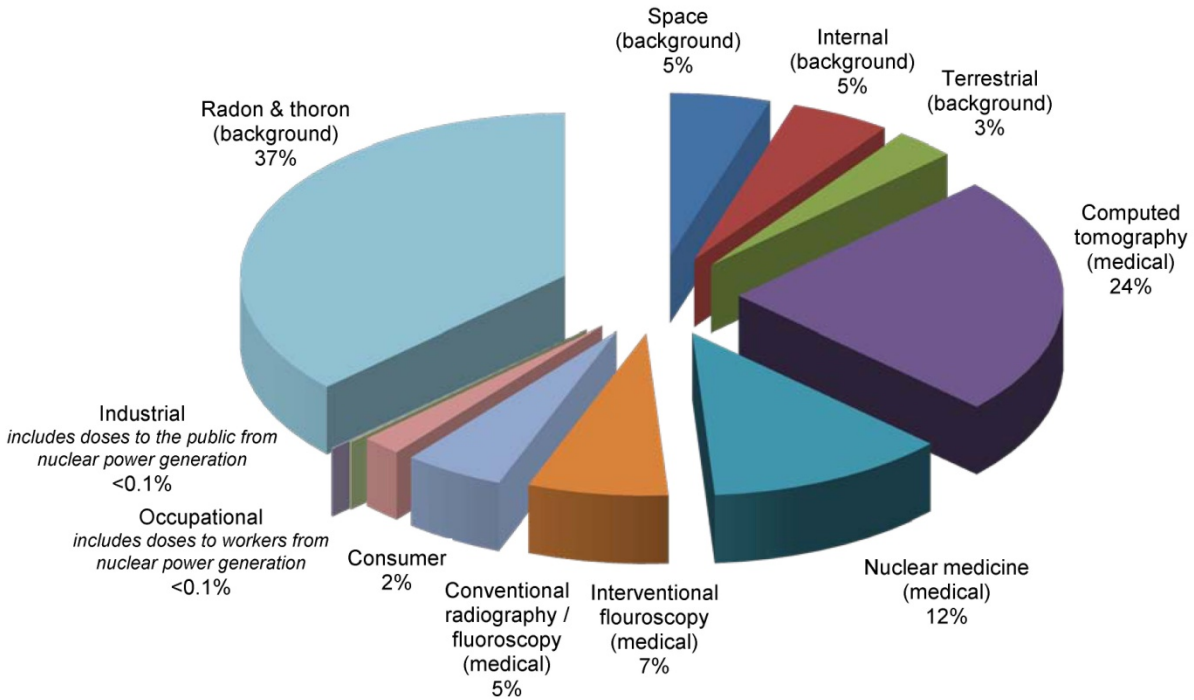
*Exposure of the Population of the United States* (Refs. 28, 29). Report No. 160 describes the doses to the U.S. population from all sources of ionizing radiation for 2006, the most recent data available at the time the report was written. The report also includes information on the variability of those doses from one individual to another. The NCRP estimated that the average person in the United States receives the equivalent of about 620 mrem of radiation dose each year. NCRP Report No. 160 describes each of the sources of radiation that contribute to this dose, including:

1. naturally-occurring sources (natural background) such as cosmic radiation from space, terrestrial radiation from radioactive materials in the earth, and naturally occurring radioactive materials in food people eat and air people breathe;
2. medical sources from diagnosis and treatment of health disorders using radioactive pharmaceuticals and radiation-producing equipment;
3. consumer products;
4. industrial processes, security devices, educational tools, and research activities;
5. exposures of workers that result from their occupations.

*Figure 2.1* is a pie chart showing the relative contributions of these sources to radiation dose to the U.S. population. Larger relative contributors to dose are represented by proportionally larger slices of the pie. Doses to the public from nuclear power generation are included in the industrial category; doses to workers from nuclear power generation are included in the category of occupational dose.

Doses to the public due to effluents from NPPs are less than 0.1% of what the average person receives each year from all sources of radiation. Doses to workers from occupational exposures, including those received from work at NPPs, also are less than 0.1% of the average dose to a member of the public from all sources.

**FIGURE 2.1**  
Sources of Radiation Exposure to the U.S. Population



Percent contribution of various sources of exposure to the total collective effective dose and the total effective dose per individual in the U.S. population for 2006. Percent values have been rounded to the nearest 1%, except for those <math><1\%</math> [less than 1%]. *Credit: Modification to image courtesy of National Council on Radiation Protection and Measurements.*



## **Section 3**

### **SUMMARY**

---

The effluent data from 2008 have been compiled and reported in the following section. The information contained in this report characterizes liquid and gaseous effluents from all United States nuclear power plants (NPPs) in commercial operation for calendar year 2008. Although all NPPs released some amount of radioactive materials in 2008, none of the effluents from any NPP exceeded any NRC limit, any NRC design objective, or any of the licensees' operating limits for radioactive effluents.

The effluent data provided in this report are considered by the NRC to be particularly relevant to the potential impact of the NPPs on public health and the environment. The radionuclides highlighted in this report are good indicators of the total radioactive releases from the site and they provide additional information about operational practices at a site. The radiation doses in this report are those most directly associated with potential public health impact from radioactive effluents.

The statistical medians of the effluent values, the corresponding operating limits, and the results of NCRP's assessment of radiation exposure to the U.S. population are provided for comparison to the effluent data. Comparisons between NPPs should be approached with caution because differences in fuel conditions, fuel cycle length, radwaste processing equipment, reactor types, reactor ages, electrical outputs, and operating conditions can have an effect on radioactive effluents.

More complete and detailed information, including copies of the NPP Annual Radioactive Effluent Release Reports, is available to the public on the NRC Web site.

This page intentionally left blank

## Section 4

### TABLES AND GRAPHS

#### 4.1 EFFLUENT DATA

**TABLE 4.1**  
BWR Gaseous Releases — Selected Fission and Activation Gases, 2008

BWR Facility	Kr-85 (Ci)	Xe-133 (Ci)	Xe-135 (Ci)	BWR Facility	Kr-85 (Ci)	Xe-133 (Ci)	Xe-135 (Ci)
Browns Ferry 1				Columbia Generating			8.80E+00
Browns Ferry 2				Quad Cities 1		8.91E+00	1.36E+00
Browns Ferry 3				Quad Cities 2		8.91E+00	1.36E+00
Hatch 1				Dresden 2		2.94E+00	1.77E+01
Hatch 2				Dresden 3		2.94E+00	1.77E+01
Susquehanna 1				Pilgrim		1.22E+01	1.77E+01
Susquehanna 2				Limerick 1	4.10E-01	2.25E+01	1.33E+01
Vermont Yankee				Nine Mile Point 2		4.31E+01	6.86E+00
Clinton	1.10E-03			Brunswick 1		2.00E+01	6.18E+01
Nine Mile Point 1		3.29E-01	3.41E-05	Brunswick 2		2.00E+01	6.18E+01
Fermi 2			3.60E-01	Fitzpatrick		6.61E+01	1.70E+01
Hope Creek		9.91E-02	1.08E+00	River Bend		1.13E+01	8.84E+01
Perry		2.28E-02	2.29E+00	Peach Bottom 2		1.04E+02	7.62E+00
Cooper Station		1.85E-01	2.25E+00	Peach Bottom 3		1.04E+02	7.62E+00
Duane Arnold			3.00E+00	Grand Gulf	9.91E-02	9.58E+01	4.18E+01
Limerick 2	4.10E-01	7.99E-01	1.90E+00	LaSalle 1		2.21E+02	1.39E+00
Oyster Creek			7.55E+00	LaSalle 2		2.21E+02	1.39E+00
<b>BWR Median Release</b>		<b>7.99E-01</b>	<b>2.25E+00</b>	Monticello		2.83E+02	6.68E+01

**TABLE 4.2**  
BWR Gaseous Releases — Iodine, 2008

<b>BWR Facility</b>	<b>I-131 (Ci)</b>
Limerick 1	
Limerick 2	
Perry	
Susquehanna 1	
Susquehanna 2	
Clinton	3.53E-05
Vermont Yankee	4.20E-05
Hatch 1	8.33E-05
Hatch 2	1.15E-04
Cooper Station	1.29E-04
Duane Arnold	1.30E-04
Columbia Generating	3.95E-04
Oyster Creek	4.25E-04
Nine Mile Point 1	4.36E-04
Browns Ferry 1	6.92E-04
Browns Ferry 2	6.92E-04
Browns Ferry 3	6.92E-04
<b>BWR Median Release</b>	<b>7.27E-04</b>

<b>BWR Facility</b>	<b>I-131 (Ci)</b>
Dresden 2	7.27E-04
Dresden 3	7.27E-04
Quad Cities 1	8.33E-04
Quad Cities 2	8.33E-04
Fitzpatrick	9.57E-04
Peach Bottom 2	3.28E-03
Peach Bottom 3	3.28E-03
Fermi 2	3.90E-03
Nine Mile Point 2	4.19E-03
River Bend	5.13E-03
Hope Creek	7.24E-03
Pilgrim	8.31E-03
Grand Gulf	1.18E-02
Monticello	1.23E-02
LaSalle 1	2.32E-02
LaSalle 2	2.32E-02
Brunswick 1	5.91E-02
Brunswick 2	5.91E-02

**TABLE 4.3**  
BWR Gaseous Releases — Selected Particulates, 2008

<b>BWR Facility</b>	<b>Co-58 (Ci)</b>	<b>Co-60 (Ci)</b>	<b>Cs-134 (Ci)</b>	<b>Cs-137 (Ci)</b>
Perry				
Vermont Yankee				
Hatch 2		3.76E-07		
Oyster Creek		7.17E-06		
Duane Arnold	3.89E-06	9.67E-06		3.47E-07
Grand Gulf	4.81E-06	1.02E-05		1.26E-06
Hatch 1	5.94E-06	1.33E-05		
Susquehanna 1		2.03E-05		
Susquehanna 2		2.03E-05		
Limerick 2	8.00E-07	2.19E-05		
Pilgrim		1.69E-05		1.04E-05
Limerick 1	8.00E-07	2.96E-05		
Fitzpatrick	3.68E-06	2.72E-05		
Peach Bottom 2	1.52E-07	3.07E-05		9.21E-06
Peach Bottom 3	1.52E-07	3.07E-05		9.21E-06
River Bend	1.66E-06	4.29E-05		
Clinton		5.61E-05		
<b>BWR Median Release</b>	<b>8.00E-07</b>	<b>5.92E-05</b>		<b>1.90E-06</b>

**TABLE 4.3 (continued)**  
**BWR Gaseous Releases — Selected Particulates, 2008**

<b>BWR Facility</b>	<b>Co-58 (Ci)</b>	<b>Co-60 (Ci)</b>	<b>Cs-134 (Ci)</b>	<b>Cs-137 (Ci)</b>
Fermi 2	1.45E-05	6.29E-05		
Hope Creek		8.30E-05		
Browns Ferry 1	5.91E-06	5.92E-05	2.69E-06	2.81E-05
Browns Ferry 2	5.91E-06	5.92E-05	2.69E-06	2.81E-05
Browns Ferry 3	5.91E-06	5.92E-05	2.69E-06	2.81E-05
Nine Mile Point 2		1.36E-04		2.20E-06
Dresden 2	9.75E-07	1.44E-04		6.87E-06
Dresden 3	9.75E-07	1.44E-04		6.87E-06
Columbia Generating	1.91E-05	2.51E-04		
LaSalle 1		3.05E-04		3.09E-05
LaSalle 2		3.05E-04		3.09E-05
Brunswick 1	6.01E-05	2.92E-04		3.70E-06
Brunswick 2	6.01E-05	2.92E-04		3.70E-06
Cooper Station	2.36E-05	4.50E-04		1.90E-06
Monticello	8.13E-08	2.87E-04		1.89E-04
Quad Cities 1	2.96E-06	6.54E-04		2.98E-05
Quad Cities 2	2.96E-06	6.54E-04		2.98E-05
Nine Mile Point 1		1.03E-03		1.47E-05

**TABLE 4.4**  
BWR Gaseous Releases — Tritium, 2008

<b>BWR Facility</b>	<b>H-3 (Ci)</b>
Perry	
Hope Creek	3.59E-03
Vermont Yankee	5.51E+00
Dresden 2	1.02E+01
Dresden 3	1.02E+01
Grand Gulf	1.03E+01
Limerick 1	1.08E+01
Limerick 2	1.08E+01
Fitzpatrick	1.50E+01
Cooper Station	1.75E+01
River Bend	1.79E+01
Peach Bottom 2	2.16E+01
Peach Bottom 3	2.16E+01
Oyster Creek	2.76E+01
Hatch 1	2.89E+01
LaSalle 1	2.92E+01
LaSalle 2	2.92E+01
<b>BWR Median Release</b>	<b>2.99E+01</b>

<b>BWR Facility</b>	<b>H-3 (Ci)</b>
Susquehanna 1	2.99E+01
Susquehanna 2	2.99E+01
Monticello	3.13E+01
Nine Mile Point 1	3.20E+01
Columbia Generating	3.48E+01
Hatch 2	3.67E+01
Clinton	3.77E+01
Quad Cities 1	5.10E+01
Quad Cities 2	5.10E+01
Duane Arnold	5.93E+01
Browns Ferry 1	6.13E+01
Browns Ferry 2	6.13E+01
Browns Ferry 3	6.13E+01
Pilgrim	7.23E+01
Fermi 2	7.91E+01
Nine Mile Point 2	9.14E+01
Brunswick 1	1.48E+02
Brunswick 2	1.48E+02

**TABLE 4.5**  
PWR Gaseous Releases — Selected Fission and Activation Gases, 2008

<b>PWR Facility</b>	<b>Kr-85 (Ci)</b>	<b>Xe-133 (Ci)</b>	<b>Xe-135 (Ci)</b>
Palo Verde 3			
Indian Point 3		3.17E-03	
Farley 2		8.82E-03	
Farley 1		2.68E-02	
Seabrook	2.56E-02	6.69E-03	4.81E-04
Beaver Valley 1		3.87E-02	1.62E-05
McGuire 1	4.00E-02	2.23E-02	2.39E-03
McGuire 2	4.00E-02	2.23E-02	2.39E-03
Beaver Valley 2		5.29E-02	2.01E-02
Kewaunee		7.65E-02	4.61E-03
Wolf Creek	3.18E-03	2.31E-01	
Vogtle 1	2.56E-02	2.14E-01	
Prairie Island 1	2.66E-01	2.63E-04	
Prairie Island 2	2.66E-01	2.63E-04	
Harris		2.64E-01	1.29E-02
St. Lucie 2		2.82E-01	1.74E-03
Catawba 1	7.45E-03	2.65E-01	1.26E-02
Catawba 2	7.45E-03	2.65E-01	1.26E-02
Point Beach 1	6.85E-04	1.51E-01	1.39E-01
Point Beach 2	6.85E-04	1.51E-01	1.39E-01
Salem 1		2.71E-01	2.39E-02
St. Lucie 1		6.79E-02	2.99E-01
Three Mile Island 1	2.08E-01	1.59E-01	2.43E-03
Palo Verde 1		4.35E-01	5.37E-03
Surry 1	4.00E-01	1.15E-01	1.51E-02
Surry 2	4.00E-01	1.15E-01	1.51E-02
Sequoyah 1	1.85E-01	4.60E-01	2.93E-02
Sequoyah 2	1.85E-01	4.60E-01	2.93E-02
Salem 2		6.29E-01	4.98E-02
North Anna 1	3.75E-01	3.00E-01	1.62E-02
North Anna 2	3.75E-01	3.00E-01	1.62E-02
Summer		7.56E-01	5.34E-01
Byron 1		1.42E+00	2.52E-03
Byron 2		2.08E+00	2.12E-03
Fort Calhoun	2.59E-03	3.01E+00	8.81E-02
<b>PWR Median Release</b>	<b>2.08E-01</b>	<b>2.08E+00</b>	<b>2.39E-02</b>



**TABLE 4.5 (continued)**  
PWR Gaseous Releases — Selected Fission and Activation Gases, 2008

<b>PWR Facility</b>	<b>Kr-85 (Ci)</b>	<b>Xe-133 (Ci)</b>	<b>Xe-135 (Ci)</b>
Watts Bar	5.27E-02	3.01E+00	5.12E-02
Crystal River 3	5.71E-01	2.58E+00	1.20E-01
Ginna		2.99E+00	4.68E-01
Oconee 1	2.07E+00	3.61E+00	8.66E-02
Oconee 2	2.07E+00	3.61E+00	8.66E-02
Oconee 3	2.07E+00	3.61E+00	8.66E-02
South Texas 1		7.19E+00	
Palisades	5.28E-02	1.17E+01	2.57E-01
Cook 1	7.69E+00	6.33E+00	1.68E-01
Cook 2	7.69E+00	6.33E+00	1.68E-01
Millstone 2	6.24E+00	1.22E+01	6.68E-02
South Texas 2	7.81E-02	1.89E+01	8.07E-04
Arkansas 1	8.93E-01	2.10E+01	
Diablo Canyon 1	5.90E-01	2.57E+01	9.56E-05
Diablo Canyon 2	5.90E-01	2.57E+01	9.56E-05
Davis-Besse	1.87E+00	2.51E+01	
Braidwood 1	3.20E+00	2.53E+01	1.12E+00
San Onofre 2	1.47E+00	3.66E+01	
San Onofre 3	1.47E+00	3.66E+01	
Indian Point 2	4.56E+01	1.43E+00	7.98E-02
Turkey Point 4	2.24E-01	4.35E+01	6.85E+00
Turkey Point 3	2.24E-01	5.06E+01	6.85E+00
Millstone 3	6.03E+00	5.34E+01	1.64E+00
Arkansas 2	2.41E+00	6.97E+01	1.94E+00
Callaway	2.60E+00	1.04E+02	1.20E+00
Palo Verde 2	1.93E+00	1.25E+02	2.00E+00
Robinson 2	5.41E+00	1.47E+02	9.44E-01
Braidwood 2	3.21E+00	2.75E+02	3.55E+00
Calvert Cliffs 1	5.24E+01	2.68E+02	6.67E+00
Calvert Cliffs 2	5.24E+01	2.68E+02	6.67E+00
Comanche Peak 1	4.53E-01	4.85E+02	6.00E+00
Comanche Peak 2	4.53E-01	4.85E+02	6.00E+00
Waterford 3	1.26E+00	5.09E+02	1.25E+01
Vogtle 2	2.01E-01	6.23E+02	5.53E+00

**TABLE 4.6**  
PWR Gaseous Releases — Iodine, 2008

<b>PWR Facility</b>	<b>I-131 (Ci)</b>
Catawba 1	
Catawba 2	
Harris	
Indian Point 2	
Indian Point 3	
Kewaunee	
Prairie Island 1	
Prairie Island 2	
Sequoyah 1	
Sequoyah 2	
Wolf Creek	
Seabrook	5.85E-10
North Anna 1	1.65E-08
North Anna 2	1.65E-08
Farley 2	3.11E-08
Ginna	3.44E-08
Beaver Valley 1	5.85E-08
Beaver Valley 2	5.85E-08
Surry 1	1.27E-07
Surry 2	1.27E-07
Crystal River 3	1.02E-06
South Texas 1	1.18E-06
Point Beach 1	1.71E-06
Point Beach 2	1.71E-06
McGuire 1	2.65E-06
McGuire 2	2.65E-06
Vogtle 2	4.16E-06
Three Mile Island 1	5.85E-06
Salem 1	6.16E-06
Palo Verde 3	8.62E-06
St. Lucie 1	1.20E-05
Farley 1	1.55E-05
Fort Calhoun	1.82E-05
Salem 2	1.84E-05
Vogtle 1	1.88E-05

<b>PWR Facility</b>	<b>I-131 (Ci)</b>
<b>PWR Median</b>	<b>1.88E-05</b>
Summer	2.01E-05
Byron 1	2.14E-05
Callaway	3.75E-05
Oconee 1	3.96E-05
Oconee 2	3.96E-05
Oconee 3	3.96E-05
Palo Verde 1	6.56E-05
Comanche Peak 1	7.02E-05
Comanche Peak 2	7.02E-05
Turkey Point 3	8.94E-05
Turkey Point 4	8.94E-05
St. Lucie 2	9.11E-05
Byron 2	9.94E-05
Arkansas 1	1.31E-04
Davis-Besse	1.44E-04
Waterford 3	1.50E-04
Watts Bar	1.53E-04
Cook 1	1.97E-04
Cook 2	1.97E-04
Palisades	3.65E-04
San Onofre 2	6.22E-04
San Onofre 3	6.22E-04
Arkansas 2	7.45E-04
Braidwood 1	1.18E-03
Braidwood 2	1.32E-03
Millstone 2	1.34E-03
South Texas 2	1.75E-03
Diablo Canyon 1	2.36E-03
Diablo Canyon 2	2.36E-03
Robinson 2	2.46E-03
Millstone 3	4.60E-03
Palo Verde 2	8.13E-03
Calvert Cliffs 1	8.64E-03
Calvert Cliffs 2	8.64E-03

**TABLE 4.7**  
PWR Gaseous Releases — Selected Particulates, 2008

<b>PWR Facility</b>	<b>Co-58 (Ci)</b>	<b>Co-60 (Ci)</b>	<b>Cs-134 (Ci)</b>	<b>Cs-137 (Ci)</b>
Arkansas 1				
Braidwood 1				
Braidwood 2				
Catawba 1				
Catawba 2				
Davis-Besse				
Farley 1				
Fort Calhoun				
Indian Point 3				
Palo Verde 3				
Sequoyah 1				
Sequoyah 2				
Summer				
Three Mile Island 1				
Turkey Point 3				
Vogtle 1				
Wolf Creek				
Farley 2		2.47E-08		
Turkey Point 4	4.39E-08			
Ginna	1.34E-07			
Watts Bar			5.52E-08	8.95E-08
Prairie Island 1	1.51E-07			2.66E-08
Prairie Island 2	1.51E-07			2.66E-08
Palisades	6.72E-07			
Arkansas 2	1.02E-06			
Crystal River 3	6.99E-07			3.82E-07
Cook 1	1.31E-06			
Cook 2	1.31E-06			
Robinson 2	1.04E-06	2.09E-07		1.33E-07
Oconee 1	4.70E-07			9.96E-07
Oconee 2	4.70E-07			9.96E-07
Oconee 3	4.70E-07			9.96E-07
Kewaunee	1.22E-06	2.46E-07		1.52E-07
Seabrook	2.32E-06	1.43E-08		
Surry 1	2.37E-06			7.45E-08
<b>PWR Median Release</b>	<b>1.02E-06</b>			

**TABLE 4.7 (continued)**  
PWR Gaseous Releases — Selected Particulates, 2008

<b>PWR Facility</b>	<b>Co-58 (Ci)</b>	<b>Co-60 (Ci)</b>	<b>Cs-134 (Ci)</b>	<b>Cs-137 (Ci)</b>
Surry 2	2.37E-06			7.45E-08
Byron 2	3.88E-06			
Waterford 3	2.94E-06	7.95E-07		8.43E-07
Byron 1	4.80E-06			
St. Lucie 2	9.27E-08			5.07E-06
Calvert Cliffs 1			3.29E-06	3.07E-06
Calvert Cliffs 2			3.29E-06	3.07E-06
Point Beach 1	2.77E-06	4.32E-06		6.65E-08
Point Beach 2	2.77E-06	4.32E-06		6.65E-08
Millstone 2	6.06E-06	2.06E-06		1.41E-06
North Anna 1	2.42E-06	8.92E-06		8.70E-07
North Anna 2	2.42E-06	8.92E-06		8.70E-07
Diablo Canyon 1	2.06E-05			
Diablo Canyon 2	2.06E-05			
Salem 1	2.55E-05			
Vogtle 2	2.72E-05			
McGuire 1	3.16E-05			
McGuire 2	3.16E-05			
Beaver Valley 1	3.24E-05			
Comanche Peak 1	3.61E-05		6.16E-06	
Comanche Peak 2	3.61E-05		6.16E-06	
Callaway	5.06E-07	4.38E-05		3.19E-07
Harris		5.17E-05		
Beaver Valley 2	5.96E-05	9.17E-07		9.17E-07
Indian Point 2				1.28E-04
Salem 2	1.50E-04			
South Texas 1	1.33E-04	3.17E-05		
Palo Verde 1	2.15E-04	2.53E-05		2.05E-06
St. Lucie 1	1.19E-05	2.38E-04		9.63E-06
Millstone 3	2.81E-04	7.81E-05	1.52E-05	9.54E-06
South Texas 2	4.15E-04	7.51E-05		
San Onofre 2	2.82E-04	2.82E-04		1.33E-05
San Onofre 3	2.82E-04	2.82E-04		1.33E-05
Palo Verde 2	9.88E-04	1.06E-04		3.54E-06

**TABLE 4.8**  
PWR Gaseous Releases — Tritium, 2008

<b>PWR Facility</b>	<b>H-3 (Ci)</b>	<b>PWR Facility</b>	<b>H-3 (Ci)</b>
Calvert Cliffs 1	2.64E+00	<b>PWR Median Release</b>	<b>3.06E+01</b>
Calvert Cliffs 2	2.64E+00	Point Beach 1	3.21E+01
Fort Calhoun	3.13E+00	Point Beach 2	3.21E+01
Summer	3.41E+00	San Onofre 2	3.37E+01
Prairie Island 1	5.20E+00	San Onofre 3	3.37E+01
Prairie Island 2	5.20E+00	Braidwood 1	3.42E+01
Vogtle 2	6.72E+00	Wolf Creek	3.71E+01
Beaver Valley 1	8.00E+00	Palisades	3.80E+01
Beaver Valley 2	8.00E+00	St. Lucie 1	4.00E+01
Robinson 2	8.42E+00	Watts Bar	4.20E+01
Indian Point 2	9.86E+00	South Texas 2	4.27E+01
Farley 1	1.07E+01	South Texas 1	4.83E+01
Millstone 2	1.15E+01	Callaway	4.94E+01
Indian Point 3	1.20E+01	Byron 2	5.38E+01
North Anna 1	1.35E+01	GINNA	5.43E+01
North Anna 2	1.35E+01	Salem 2	6.06E+01
Turkey Point 4	1.43E+01	Davis-Besse	6.63E+01
Vogtle 1	1.52E+01	Waterford 3	6.79E+01
Crystal River 3	1.56E+01	Three Mile Island 1	7.20E+01
St. Lucie 2	1.59E+01	Millstone 3	7.48E+01
Oconee 1	1.65E+01	Diablo Canyon 1	7.98E+01
Oconee 2	1.65E+01	Diablo Canyon 2	7.98E+01
Oconee 3	1.65E+01	Braidwood 2	9.14E+01
Turkey Point 3	1.69E+01	Seabrook	9.60E+01
Surry 1	2.36E+01	McGuire 1	1.13E+02
Surry 2	2.36E+01	McGuire 2	1.13E+02
Arkansas 2	2.59E+01	Cook 1	1.21E+02
Arkansas 1	2.62E+01	Cook 2	1.21E+02
Kewaunee	2.62E+01	Catawba 1	1.29E+02
Byron 1	2.86E+01	Catawba 2	1.29E+02
Farley 2	2.88E+01	Salem 1	2.18E+02
Sequoyah 1	2.99E+01	Harris	2.60E+02
Sequoyah 2	2.99E+01	Palo Verde 2	3.50E+02
Comanche Peak 1	3.06E+01	Palo Verde 3	4.96E+02
Comanche Peak 2	3.06E+01	Palo Verde 1	8.69E+02

**TABLE 4.9**  
BWR Liquid Releases — Selected Fission and Activation Products, 2008

<b>BWR Facility</b>	<b>Co-58 (Ci)</b>	<b>Co-60 (Ci)</b>	<b>Cs-134 (Ci)</b>	<b>Cs-137 (Ci)</b>	<b>Fe-55 (Ci)</b>	<b>I-131 (Ci)</b>
Vermont Yankee						
Clinton						
Columbia Generating						
Duane Arnold						
Fermi 2						
Fitzpatrick						
LaSalle 1						
LaSalle 2						
Limerick 1						
Limerick 2						
Monticello						
Nine Mile Point 1						
Oyster Creek						
Pilgrim						
Dresden 2		3.35E-05		1.91E-06		
Dresden 3		3.35E-05		1.91E-06		
Susquehanna 1	1.24E-04	3.92E-04				
<b>BWR Median Release</b>		<b>1.94E-04</b>				
Susquehanna 2	1.24E-04	3.92E-04				
Quad Cities 1		1.94E-04		6.75E-04		
Quad Cities 2		1.94E-04		6.75E-04		
Nine Mile Point 2	2.00E-05	1.30E-03				
Brunswick 1	1.91E-05	5.82E-04	2.19E-05	1.10E-04		1.10E-03
Brunswick 2	1.91E-05	5.82E-04	2.19E-05	1.10E-04		1.10E-03
Cooper Station		1.18E-03	7.26E-05	1.43E-03	2.12E-04	
Browns Ferry 1	1.51E-05	1.03E-03	3.01E-04	1.95E-03	5.00E-05	
Browns Ferry 2	1.51E-05	1.03E-03	3.01E-04	1.95E-03	5.00E-05	
Browns Ferry 3	1.51E-05	1.03E-03	3.01E-04	1.95E-03	5.00E-05	
Hatch 2	2.96E-05	5.94E-04		1.39E-04	6.42E-03	1.02E-06
River Bend	1.84E-05	6.34E-03			1.01E-03	
Perry		1.30E-02				
Hope Creek	2.02E-05	1.82E-03	3.37E-04	5.02E-04	1.25E-02	6.63E-06
Hatch 1	4.07E-05	2.41E-03	3.80E-06	8.56E-04	1.86E-02	
Peach Bottom 2	2.93E-03	7.66E-02	6.05E-05	5.22E-04	3.61E-03	8.99E-06
Peach Bottom 3	2.93E-03	7.66E-02	6.05E-05	5.22E-04	3.61E-03	8.99E-06
Grand Gulf	6.97E-03	2.13E-02		9.36E-05	9.07E-02	3.73E-04

**TABLE 4.10**  
BWR Liquid Releases — Tritium, 2008

<b>BWR Facility</b>	<b>H-3 (Ci)</b>	<b>BWR Facility</b>	<b>H-3 (Ci)</b>
Clinton		Browns Ferry 2	2.45E+00
Columbia Generating		Browns Ferry 3	2.45E+00
Fermi 2		Quad Cities 1	2.83E+00
LaSalle 1		Quad Cities 2	2.83E+00
LaSalle 2		Fitzpatrick	3.81E+00
Monticello		Hope Creek	6.47E+00
Nine Mile Point 1		Nine Mile Point 2	7.26E+00
Oyster Creek		Hatch 2	1.44E+01
Pilgrim		Susquehanna 1	1.65E+01
Vermont Yankee		Susquehanna 2	1.65E+01
Duane Arnold	1.13E-03	Limerick 1	2.06E+01
Dresden 2	4.09E-02	Limerick 2	2.06E+01
Dresden 3	4.09E-02	Perry	2.07E+01
Cooper Station	8.74E-01	Hatch 1	2.98E+01
Peach Bottom 2	1.40E+00	River Bend	7.72E+01
Peach Bottom 3	1.40E+00	Grand Gulf	9.89E+01
Browns Ferry 1	2.45E+00	Brunswick 1	1.27E+02
<b>BWR Median Release</b>	<b>2.45E+00</b>	Brunswick 2	1.27E+02

**TABLE 4.11**  
PWR Liquid Releases — Selected Fission and Activation Products, 2008

<b>PWR Facility</b>	<b>Co-58 (Ci)</b>	<b>Co-60 (Ci)</b>	<b>Cs-134 (Ci)</b>	<b>Cs-137 (Ci)</b>	<b>Fe-55 (Ci)</b>	<b>I-131 (Ci)</b>
Palo Verde 1						
Palo Verde 2						
Palo Verde 3						
Three Mile Island 1				1.90E-04		
Cook 1	1.93E-03	3.53E-04	2.02E-05	2.31E-05	6.95E-04	1.04E-05
Cook 2	1.93E-03	3.53E-04	2.02E-05	2.31E-05	6.95E-04	1.04E-05
Oconee 1	2.89E-03	2.08E-04		7.55E-05		
Oconee 2	2.89E-03	2.08E-04		7.55E-05		
Oconee 3	2.89E-03	2.08E-04		7.55E-05		
Fort Calhoun	1.23E-03	1.17E-03	6.17E-05	8.65E-04		1.38E-03
GINNA	4.59E-03	4.24E-04				
Crystal River 3	1.50E-03	3.09E-03		1.49E-04	8.39E-04	
Catawba 1	4.83E-03	1.93E-03		1.42E-05		3.45E-06
Catawba 2	4.83E-03	1.93E-03		1.42E-05		3.45E-06
Indian Point 3	6.51E-05	4.21E-03	1.98E-04	5.40E-04	1.87E-03	
South Texas 1	1.87E-03	3.81E-03	5.37E-05	5.12E-04	1.05E-03	
Comanche Peak 1	5.97E-03	5.01E-04			8.39E-04	
Comanche Peak 2	5.97E-03	5.01E-04			8.39E-04	
Farley 1	1.96E-03	4.21E-03	1.62E-06	1.49E-04	1.48E-03	
Diablo Canyon 1	2.50E-03	1.56E-03	1.18E-06	1.13E-06	3.91E-03	3.72E-05
Diablo Canyon 2	2.50E-03	1.56E-03	1.18E-06	1.13E-06	3.91E-03	3.72E-05
Byron 1	6.59E-03	1.60E-03	6.45E-06			2.98E-05
Byron 2	6.59E-03	1.60E-03	6.45E-06			2.98E-05
South Texas 2	8.51E-04	4.84E-03	3.45E-05	2.34E-04	2.00E-03	4.51E-04
Robinson 2	3.57E-03	2.84E-03	4.45E-06	6.59E-05	1.87E-03	1.75E-04
Salem 2	8.29E-03	9.18E-04	7.00E-08	2.41E-05		
Surry 1	5.09E-03	2.99E-03		1.37E-03		2.02E-06
Surry 2	5.09E-03	2.99E-03		1.37E-03		2.02E-06
St. Lucie 1	3.64E-03	1.56E-03	2.36E-06	3.58E-05	5.55E-03	
St. Lucie 2	3.64E-03	1.56E-03	2.36E-06	3.58E-05	5.55E-03	
Davis-Besse	2.82E-03	1.11E-04	2.10E-05	8.94E-05	7.89E-03	2.13E-04
Harris	8.03E-03	3.19E-03			1.49E-03	
San Onofre 2	5.98E-03	3.71E-03	5.13E-05	2.80E-04	4.08E-03	
San Onofre 3	5.98E-03	3.71E-03	5.13E-05	2.80E-04	4.08E-03	
Summer	1.53E-03	4.54E-03	4.48E-04	8.62E-04	6.93E-03	3.18E-06
<b>PWR Median Release</b>	<b>5.97E-03</b>	<b>3.09E-03</b>	<b>1.26E-05</b>	<b>2.18E-04</b>	<b>2.75E-03</b>	<b>2.02E-06</b>



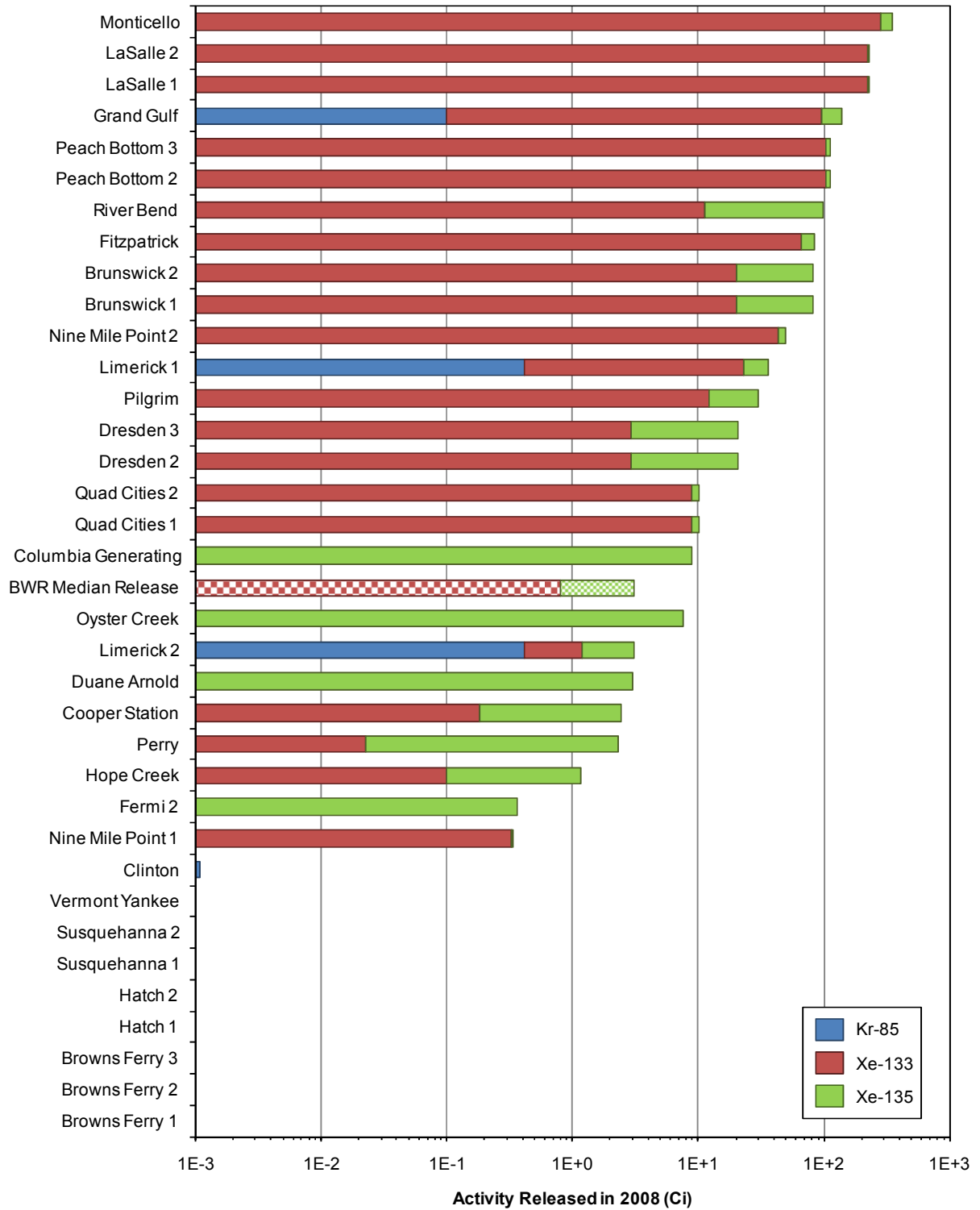
**TABLE 4.11 (continued)**  
PWR Liquid Releases — Selected Fission and Activation Products, 2008

<b>PWR Facility</b>	<b>Co-58 (Ci)</b>	<b>Co-60 (Ci)</b>	<b>Cs-134 (Ci)</b>	<b>Cs-137 (Ci)</b>	<b>Fe-55 (Ci)</b>	<b>I-131 (Ci)</b>
Palisades	1.20E-02	3.31E-03		3.05E-05		6.39E-06
Farley 2	2.57E-03	1.02E-02		6.08E-04	3.84E-03	
Kewaunee	4.83E-03	2.00E-03		9.99E-07	1.17E-02	
Waterford 3	4.70E-03	2.23E-03	3.27E-05	3.59E-05	1.16E-02	4.12E-05
Salem 1	1.20E-02	3.10E-03	6.15E-05	3.65E-03		
Vogtle 1	4.84E-03	4.46E-03	3.33E-05	7.42E-04	8.77E-03	1.34E-05
McGuire 1	1.03E-02	4.20E-03	1.01E-03	4.11E-03		
McGuire 2	1.03E-02	4.20E-03	1.01E-03	4.11E-03		
Indian Point 2	3.68E-03	2.04E-03	5.16E-04	1.35E-02		
Seabrook	6.22E-03	1.36E-03			1.34E-02	
Calvert Cliffs 1	5.43E-03	3.58E-03	2.27E-03	3.58E-03	9.15E-03	2.21E-03
Calvert Cliffs 2	5.43E-03	3.58E-03	2.27E-03	3.58E-03	9.15E-03	2.21E-03
Point Beach 1	1.89E-02	5.49E-03		4.68E-05	2.75E-03	4.66E-07
Point Beach 2	1.89E-02	5.49E-03		4.68E-05	2.75E-03	4.66E-07
Sequoyah 1	9.32E-03	5.75E-03	1.26E-05	2.18E-04	1.30E-02	8.95E-06
Sequoyah 2	9.32E-03	5.75E-03	1.26E-05	2.18E-04	1.30E-02	8.95E-06
Braidwood 1	1.61E-02	6.17E-03	1.23E-03	1.02E-03	4.07E-03	4.40E-04
Braidwood 2	1.61E-02	6.17E-03	1.23E-03	1.04E-03	4.07E-03	4.40E-04
Vogtle 2	1.33E-02	8.50E-03	1.70E-04	1.29E-03	6.64E-03	6.29E-05
North Anna 1	9.93E-03	2.00E-02	1.61E-04	9.94E-04	3.73E-03	
North Anna 2	9.93E-03	2.00E-02	1.61E-04	9.94E-04	3.73E-03	
Millstone 3	1.34E-02	1.12E-02	5.60E-04	6.25E-04	1.02E-02	1.10E-03
Arkansas 1	1.61E-02	1.59E-03	4.50E-03	7.86E-03	6.82E-03	1.03E-03
Turkey Point 4	1.85E-02	8.55E-03	4.06E-04	5.05E-04	1.17E-02	4.01E-05
Turkey Point 3	1.85E-02	8.55E-03	4.21E-04	5.19E-04	1.17E-02	1.23E-04
Watts Bar	8.36E-03	2.19E-03	3.92E-04	4.51E-04	2.85E-02	1.30E-04
Arkansas 2	7.05E-03	1.24E-03	8.24E-04	1.63E-03	2.94E-02	3.85E-05
Millstone 2	9.91E-03	2.28E-02	8.87E-05	6.82E-04	3.06E-02	
Wolf Creek	7.82E-02	2.91E-03	2.76E-06	1.17E-02	8.73E-04	1.17E-04
Prairie Island 1	6.45E-02	5.29E-03	1.23E-06	3.74E-06	7.68E-02	1.54E-05
Prairie Island 2	6.45E-02	5.29E-03	1.23E-06	3.74E-06	7.68E-02	1.54E-05
Beaver Valley 1	5.05E-02	1.49E-02	2.68E-05	8.08E-04	8.14E-02	
Beaver Valley 2	5.05E-02	1.49E-02	2.68E-05	8.08E-04	8.14E-02	
Callaway	1.31E-01	2.74E-02	1.13E-03	2.93E-03	8.61E-03	1.86E-03

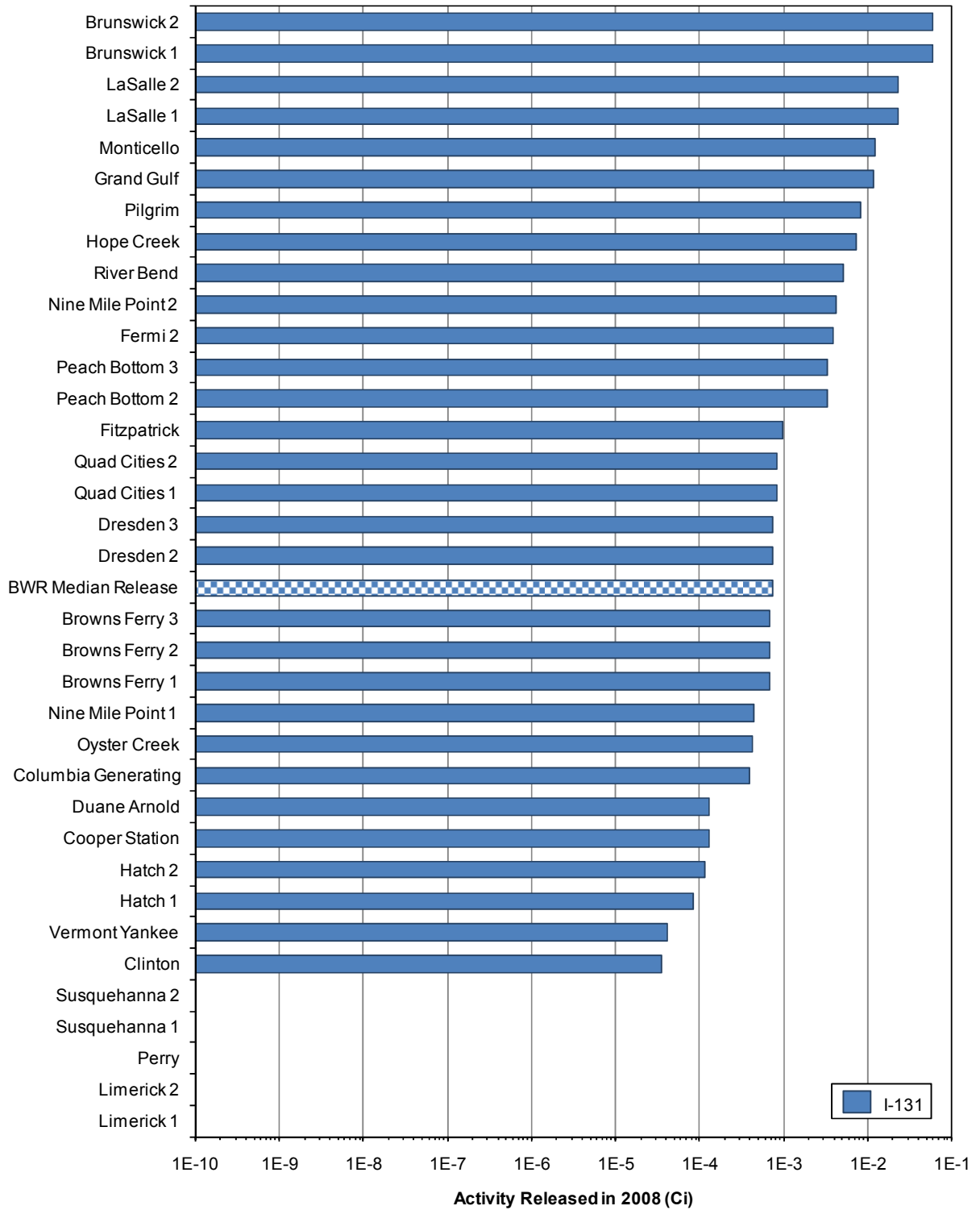
**TABLE 4.12**  
PWR Liquid Releases — Tritium, 2008

<b>PWR Facility</b>	<b>H-3 (Ci)</b>	<b>PWR Facility</b>	<b>H-3 (Ci)</b>
Palo Verde 1		<b>PWR Median Release</b>	<b>5.26E+02</b>
Palo Verde 2		Vogtle 1	5.85E+02
Palo Verde 3		Robinson 2	5.96E+02
Kewaunee	1.59E+02	Calvert Cliffs 1	6.01E+02
Three Mile Island 1	1.67E+02	Calvert Cliffs 2	6.01E+02
St. Lucie 1	1.70E+02	Farley 2	6.13E+02
St. Lucie 2	1.70E+02	Sequoyah 1	6.35E+02
Fort Calhoun	1.77E+02	Sequoyah 2	6.35E+02
Indian Point 2	2.10E+02	North Anna 1	6.47E+02
Prairie Island 1	2.19E+02	North Anna 2	6.47E+02
Prairie Island 2	2.19E+02	Arkansas 1	6.61E+02
Seabrook	2.21E+02	Indian Point 3	6.67E+02
Oconee 1	2.52E+02	Millstone 3	6.95E+02
Oconee 2	2.52E+02	Braidwood 1	7.05E+02
Oconee 3	2.52E+02	Braidwood 2	7.05E+02
Davis-Besse	2.58E+02	South Texas 1	7.17E+02
Point Beach 1	2.67E+02	Wolf Creek	7.29E+02
Point Beach 2	2.67E+02	Palisades	7.38E+02
Salem 2	2.67E+02	Beaver Valley 1	7.52E+02
Surry 1	3.01E+02	Beaver Valley 2	7.52E+02
Surry 2	3.01E+02	Vogtle 2	7.78E+02
Harris	3.26E+02	McGuire 1	8.15E+02
Turkey Point 3	3.27E+02	McGuire 2	8.15E+02
Turkey Point 4	3.27E+02	Summer	8.45E+02
Ginna	3.30E+02	Cook 1	1.01E+03
Catawba 1	3.35E+02	Cook 2	1.01E+03
Catawba 2	3.35E+02	Diablo Canyon 1	1.20E+03
Crystal River 3	3.48E+02	Diablo Canyon 2	1.20E+03
Salem 1	4.24E+02	Comanche Peak 1	1.21E+03
Waterford 3	4.45E+02	Comanche Peak 2	1.21E+03
Millstone 2	4.77E+02	South Texas 2	1.39E+03
San Onofre 2	5.22E+02	Byron 1	1.50E+03
San Onofre 3	5.22E+02	Byron 2	1.50E+03
Arkansas 2	5.26E+02	Watts Bar	1.64E+03
Farley 1	5.62E+02	Callaway	1.66E+03

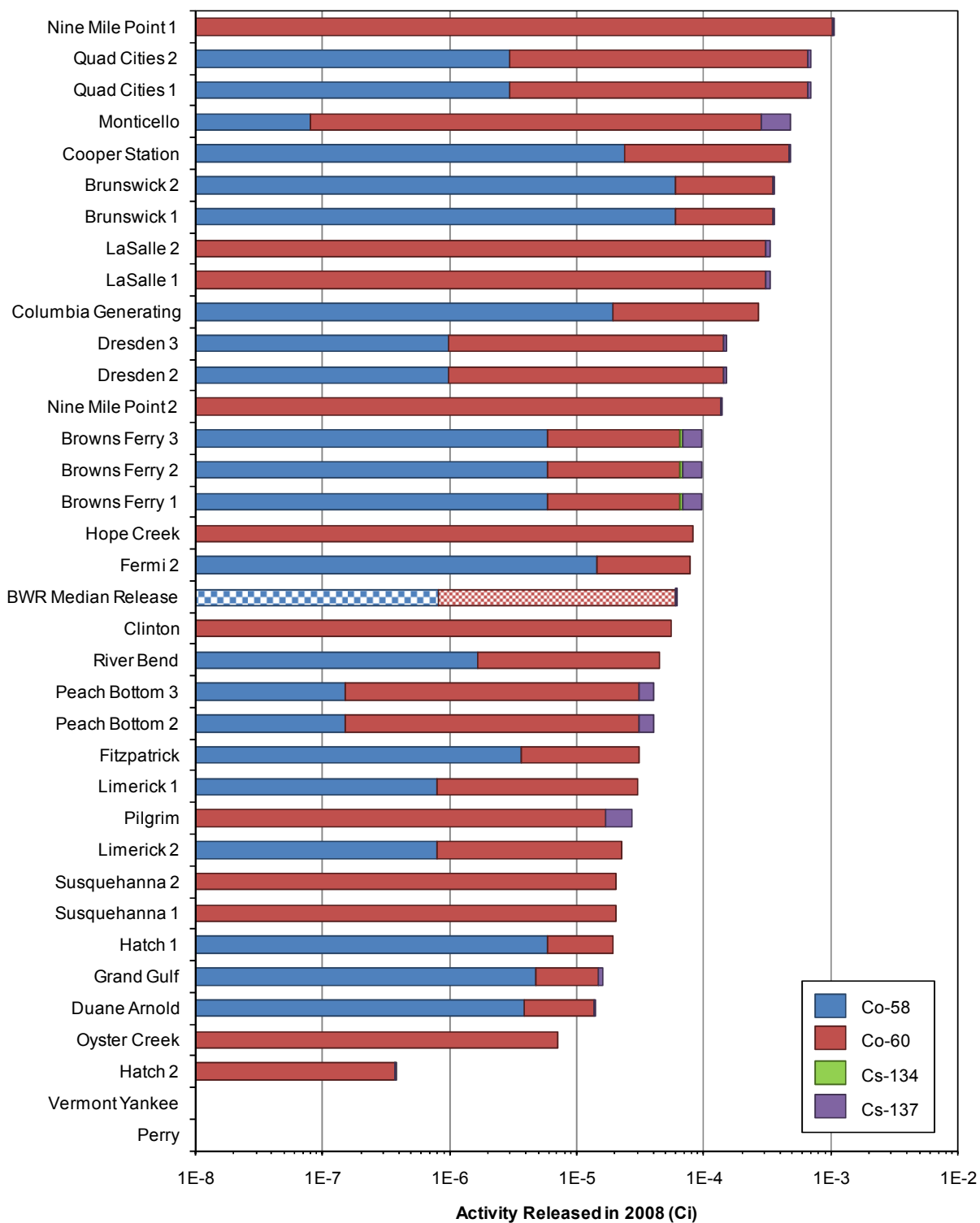
**FIGURE 4.1**  
**BWR Gaseous Releases — Selected Fission and Activation Gases**



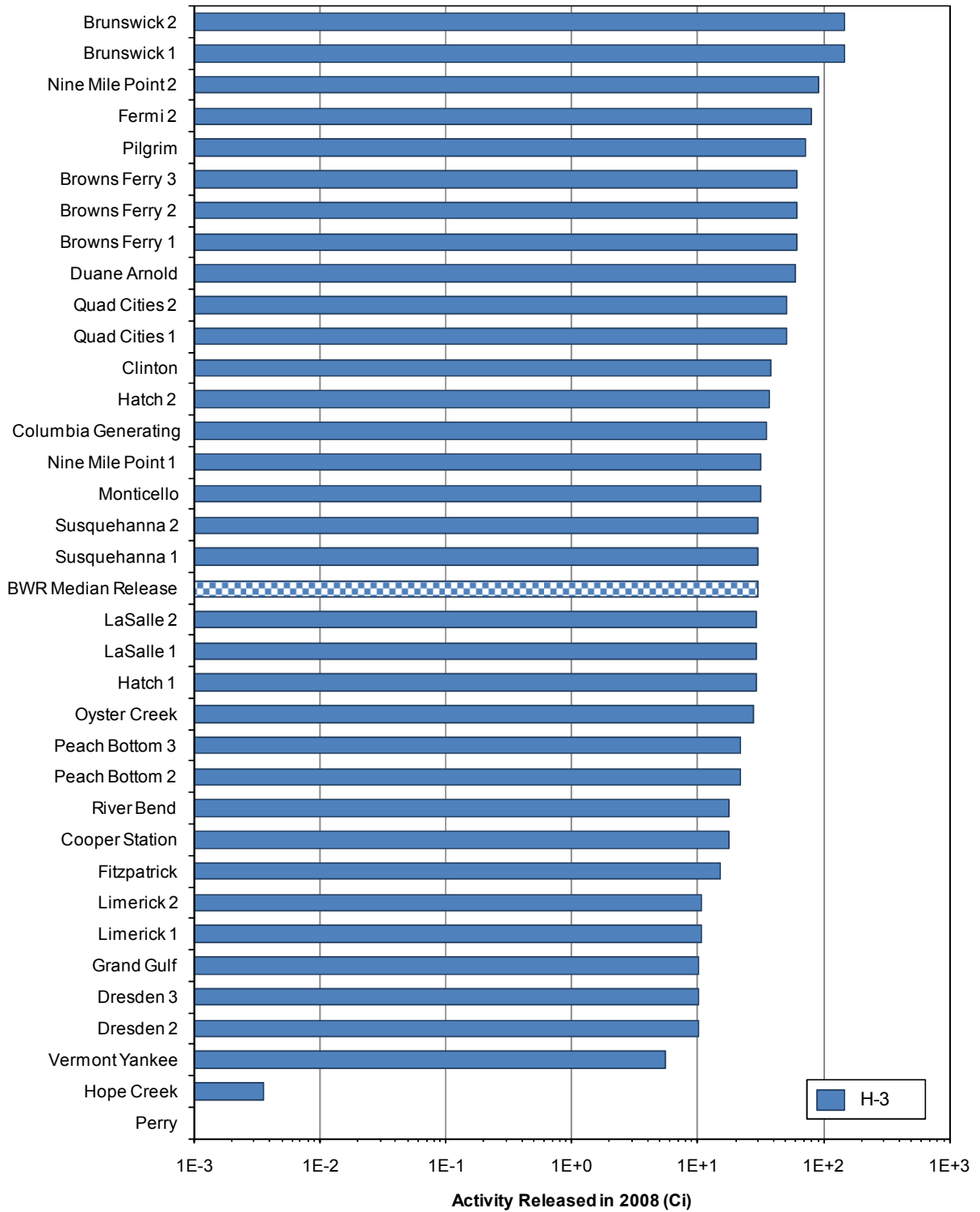
**FIGURE 4.2**  
BWR Gaseous Releases — Iodine



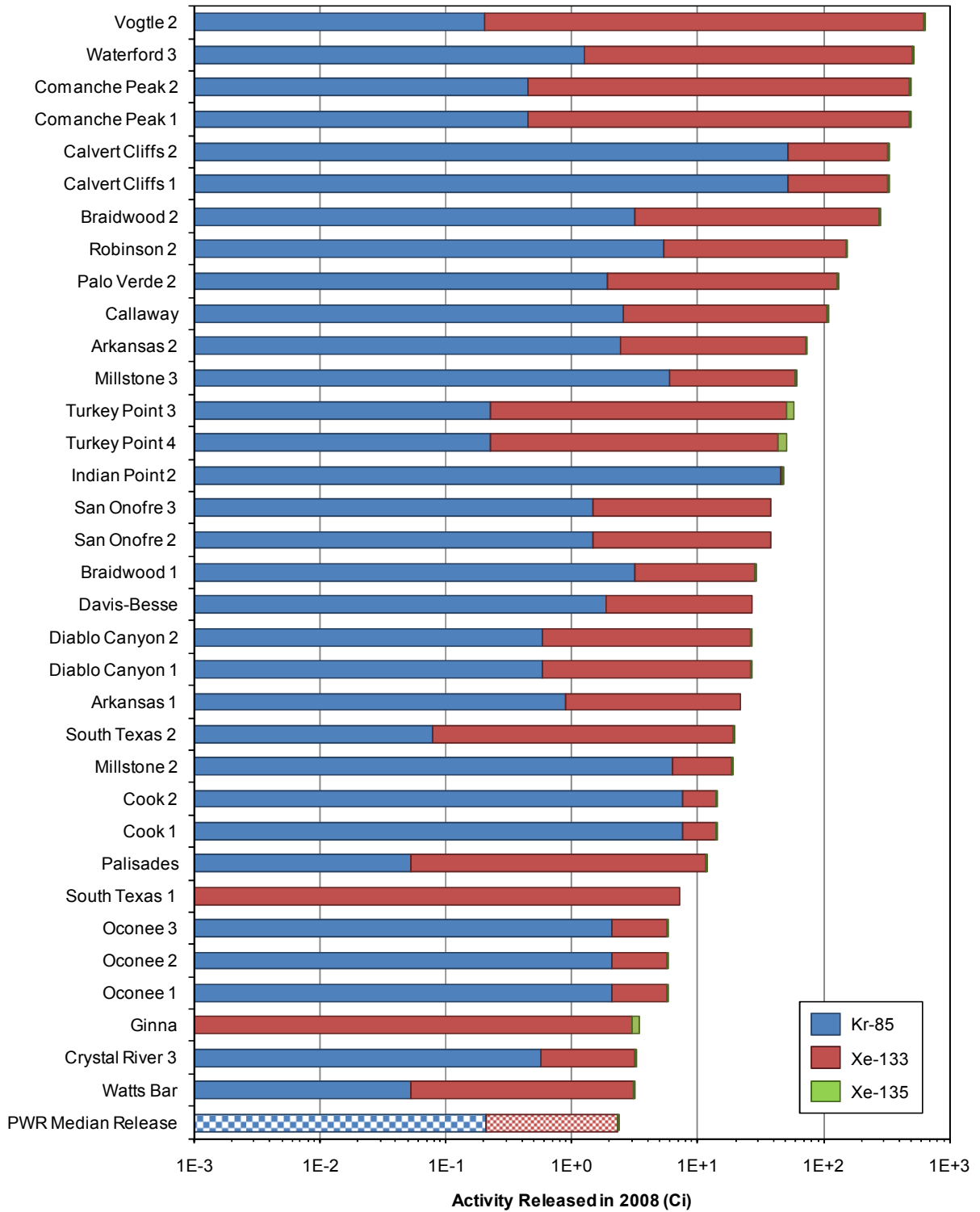
**FIGURE 4.3**  
BWR Gaseous Releases — Selected Particulates



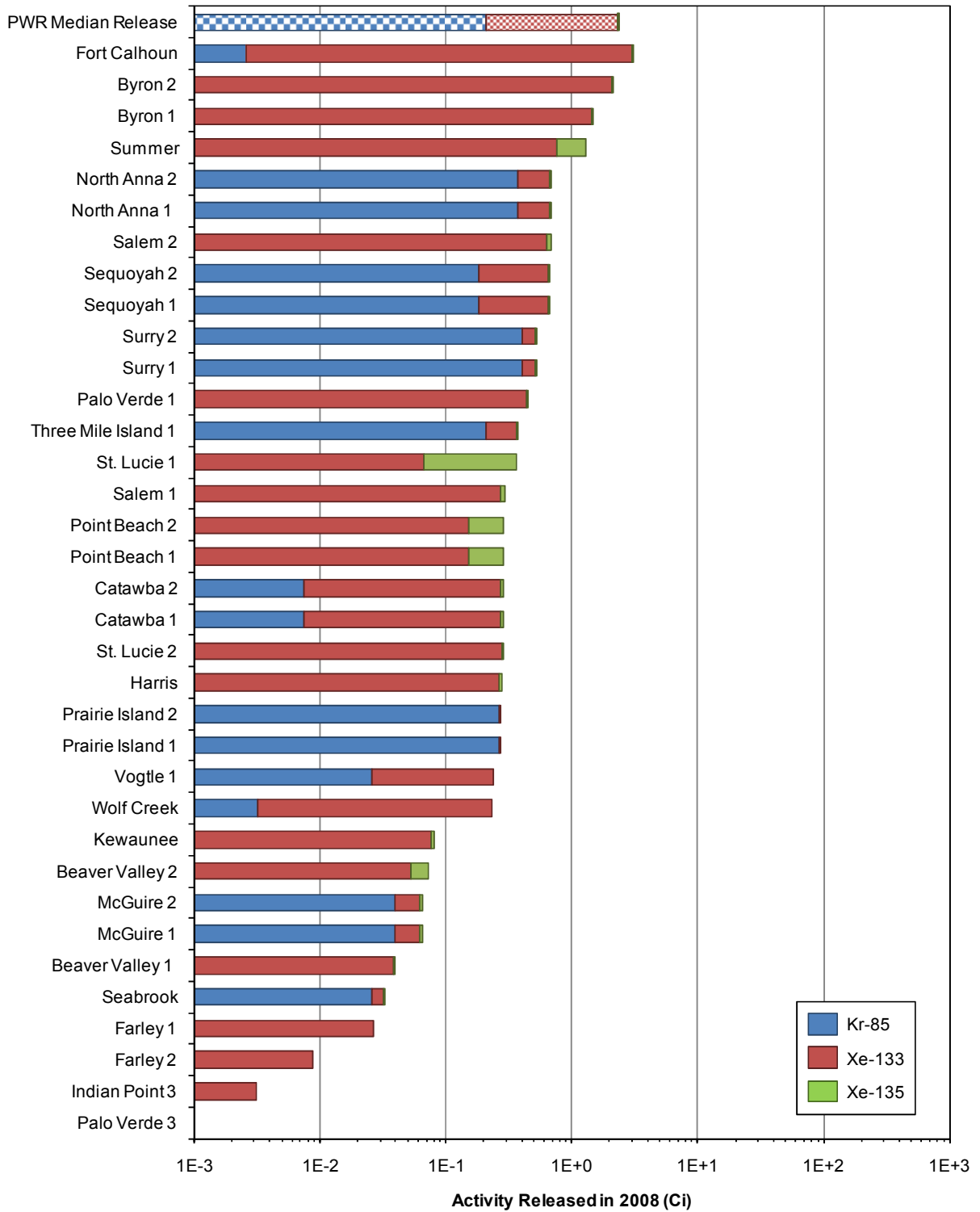
**FIGURE 4.4**  
BWR Gaseous Releases — Tritium



**FIGURE 4.5**  
PWR Gaseous Releases — Selected Fission and Activation Gases

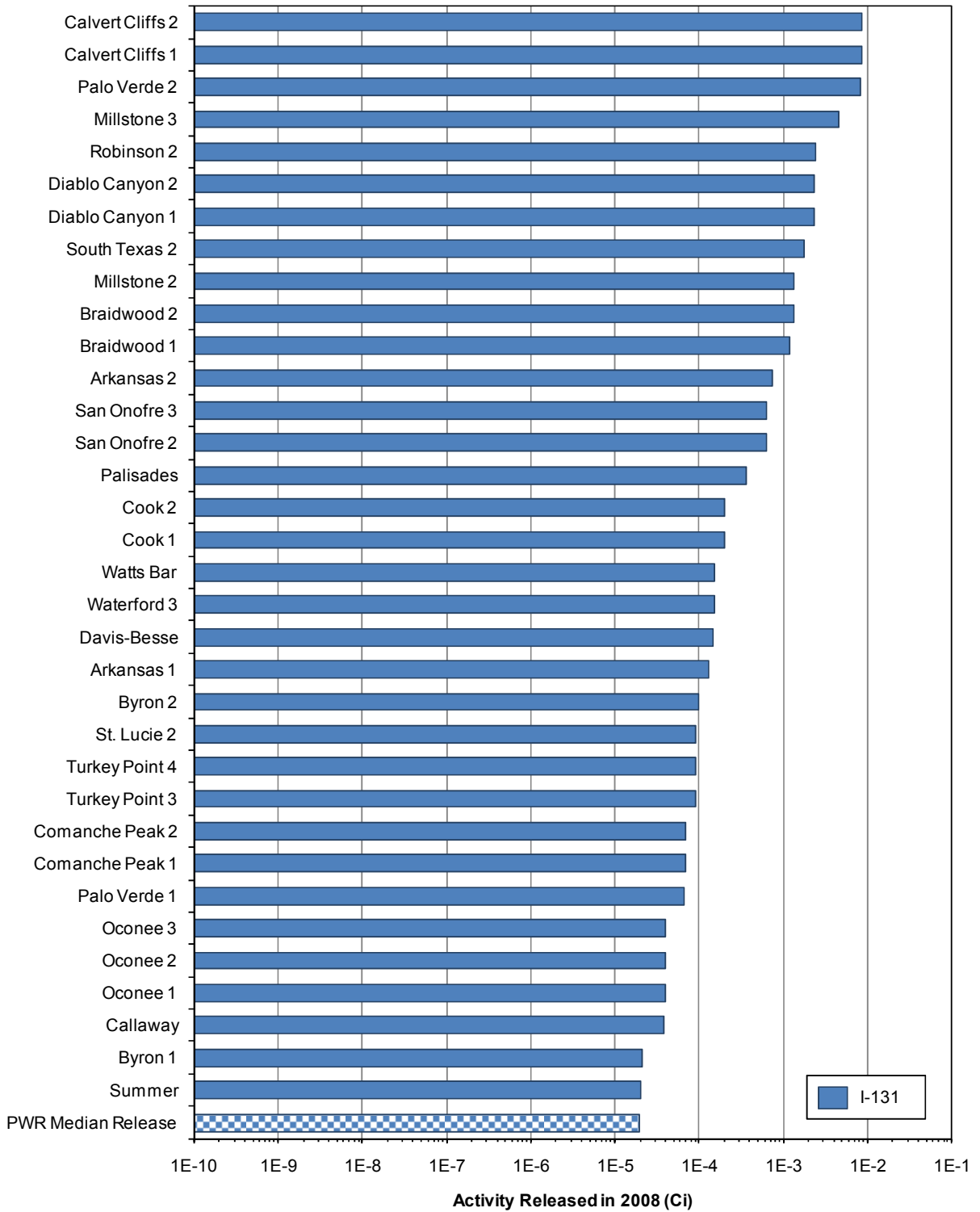


**FIGURE 4.5 (continued)**  
**PWR Gaseous Releases — Selected Fission and Activation Gases**

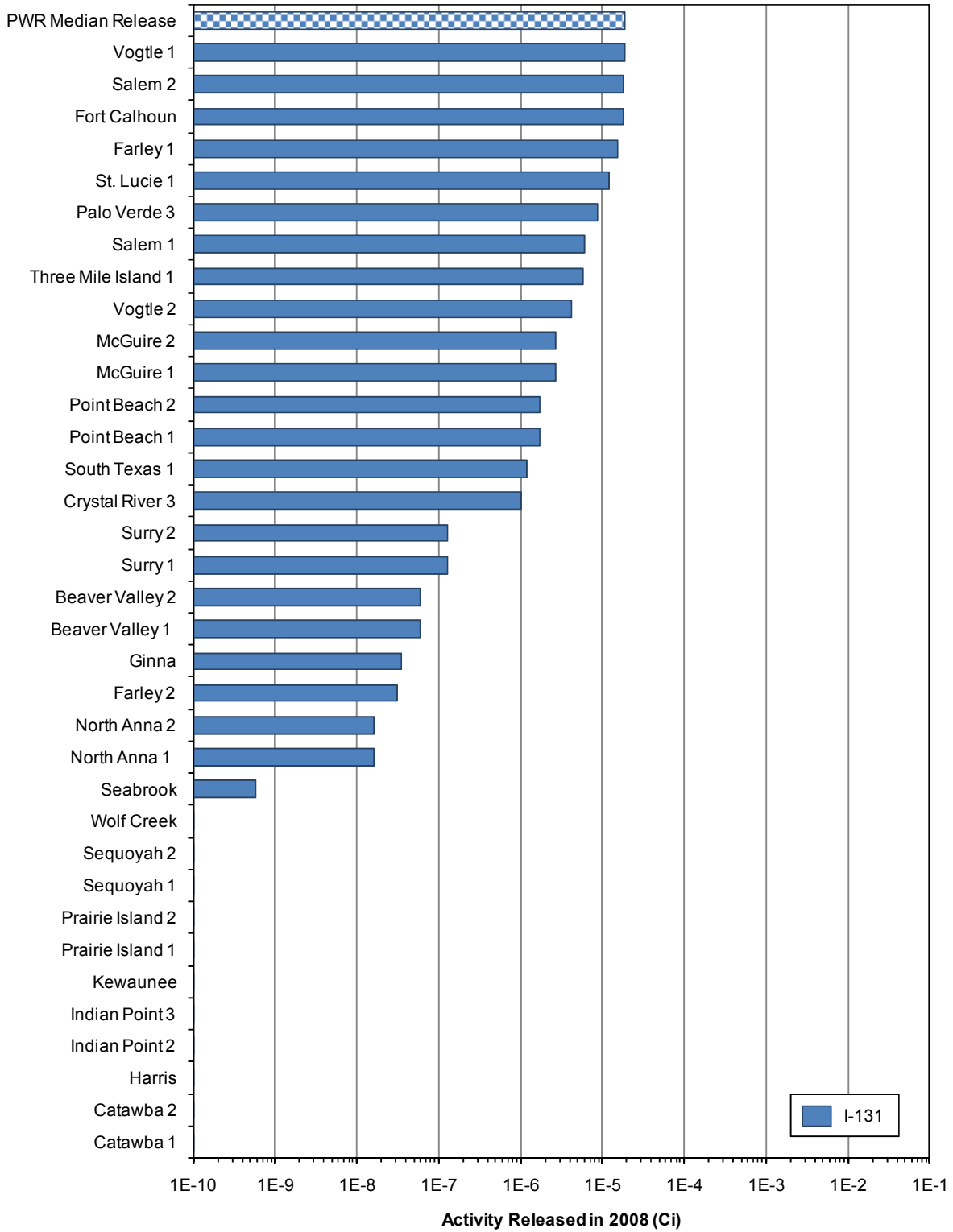




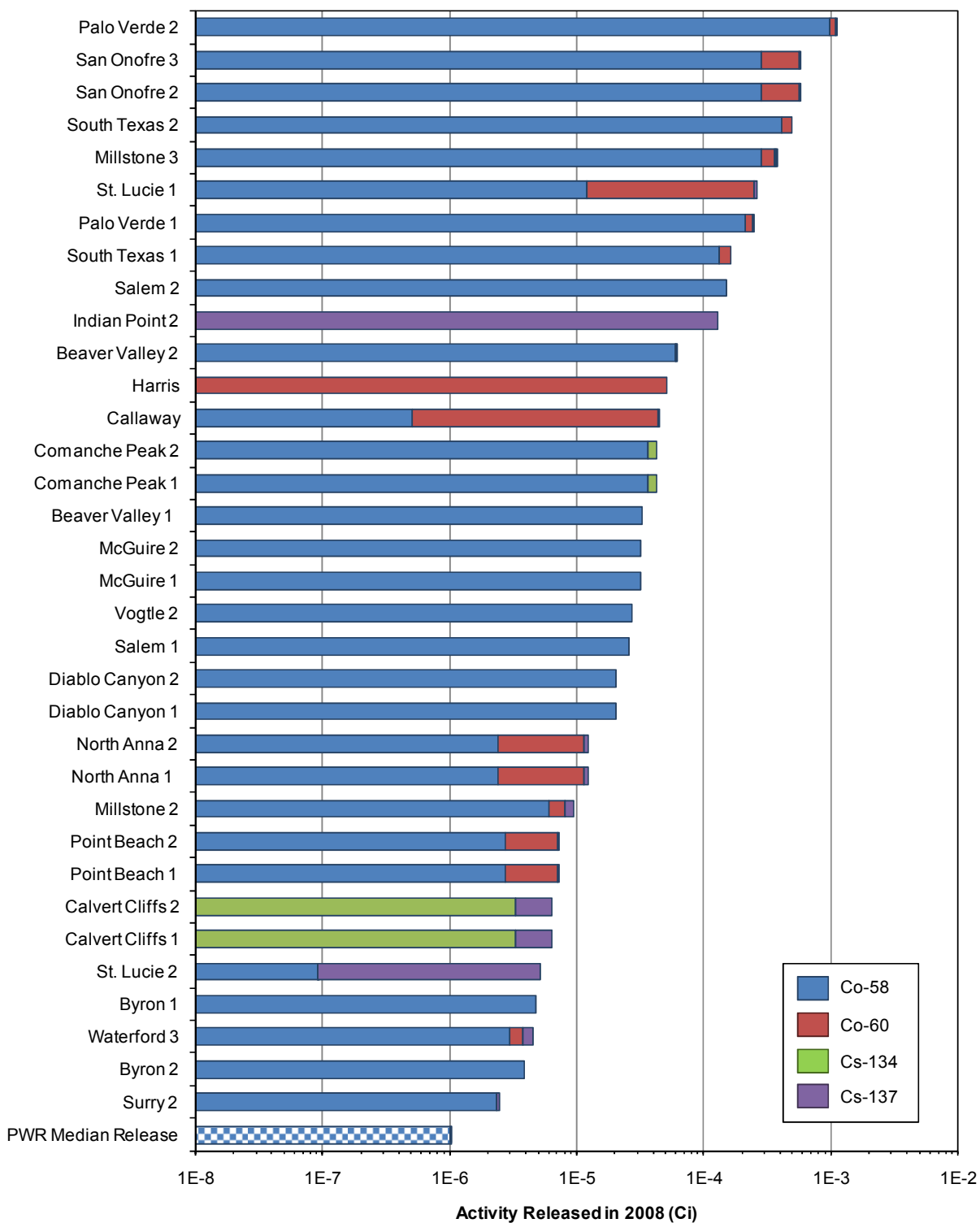
**FIGURE 4.6**  
PWR Gaseous Releases — Iodine



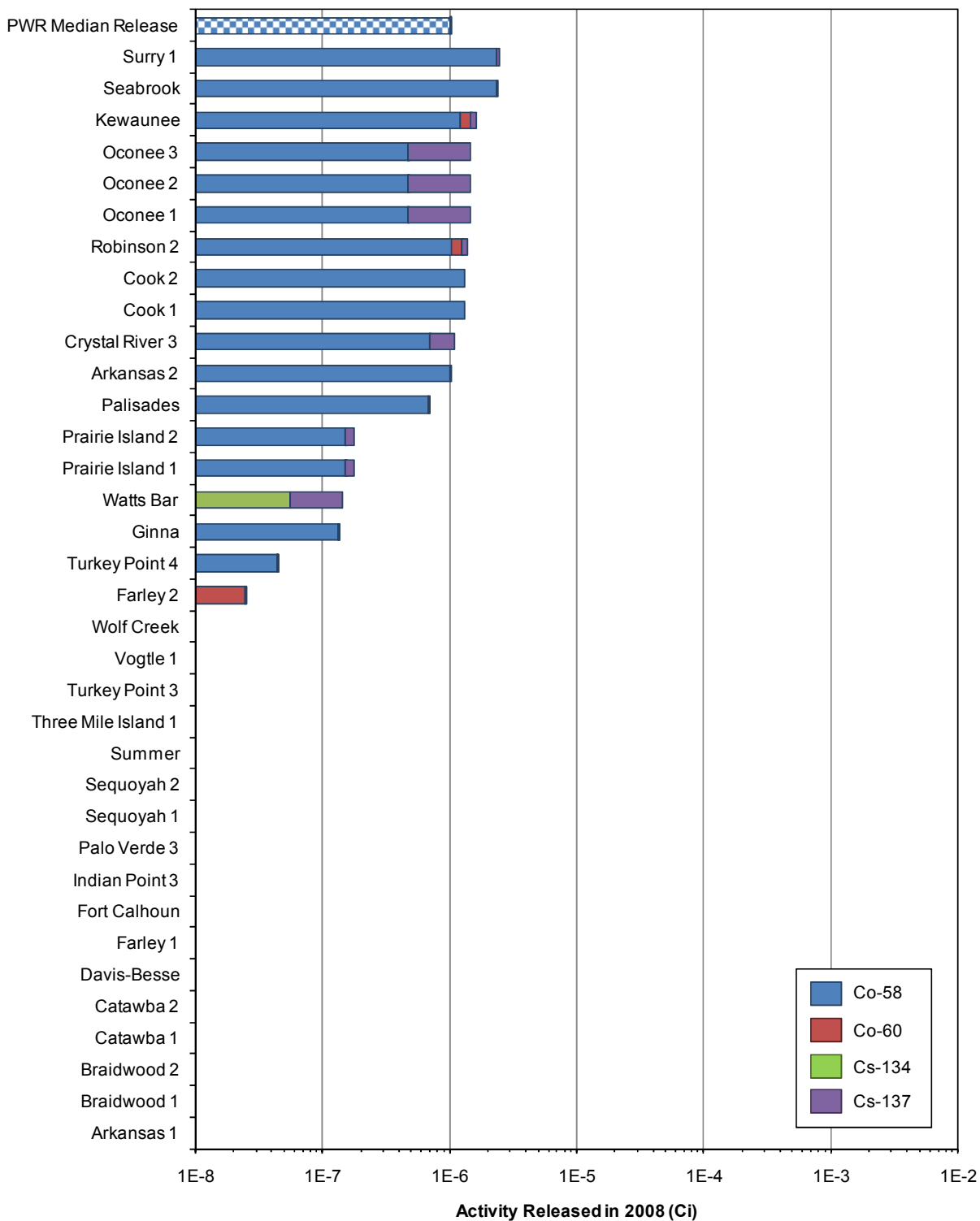
**FIGURE 4.6 (continued)**  
**PWR Gaseous Releases — Iodine**



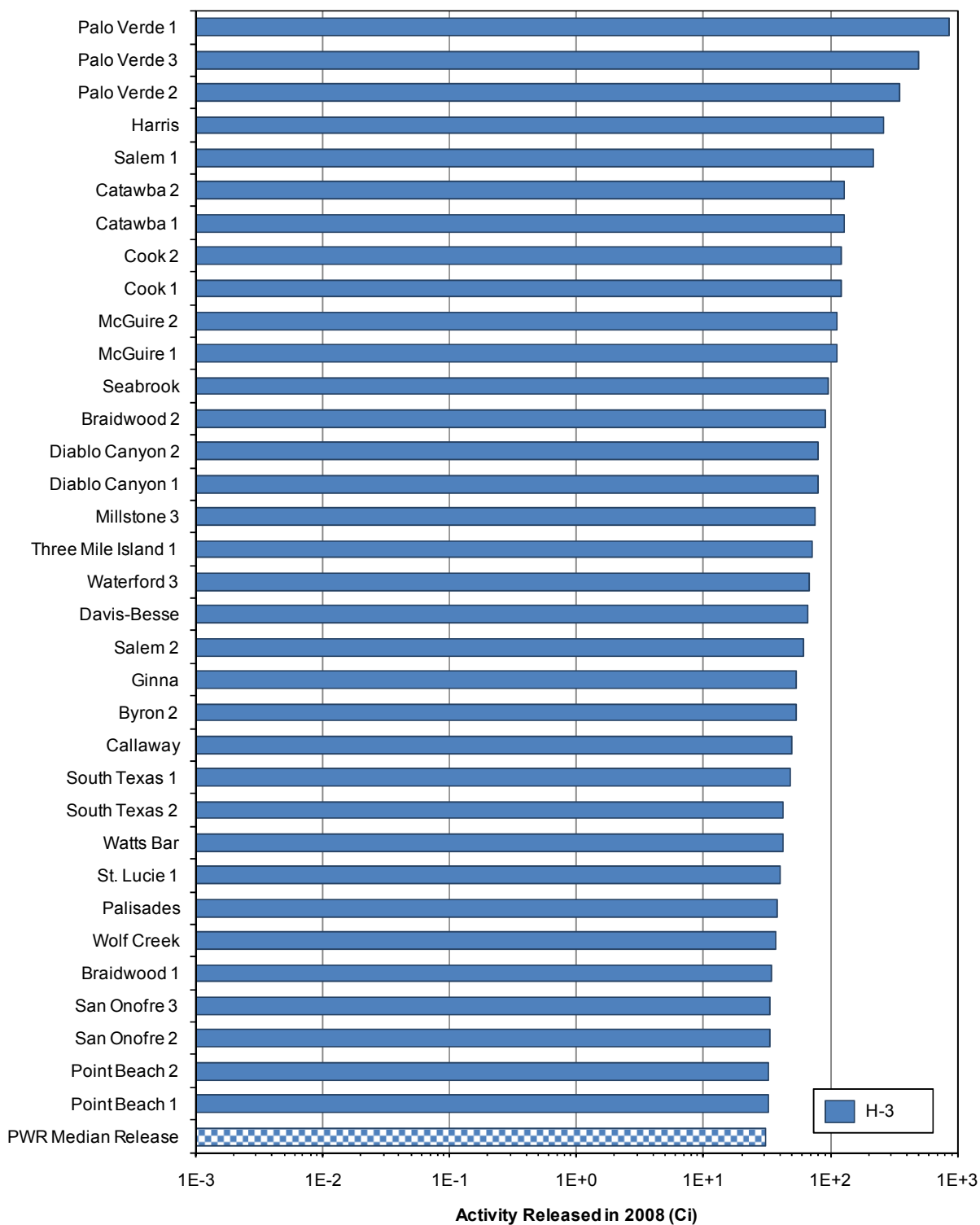
**FIGURE 4.7**  
PWR Gaseous Releases — Selected Particulates



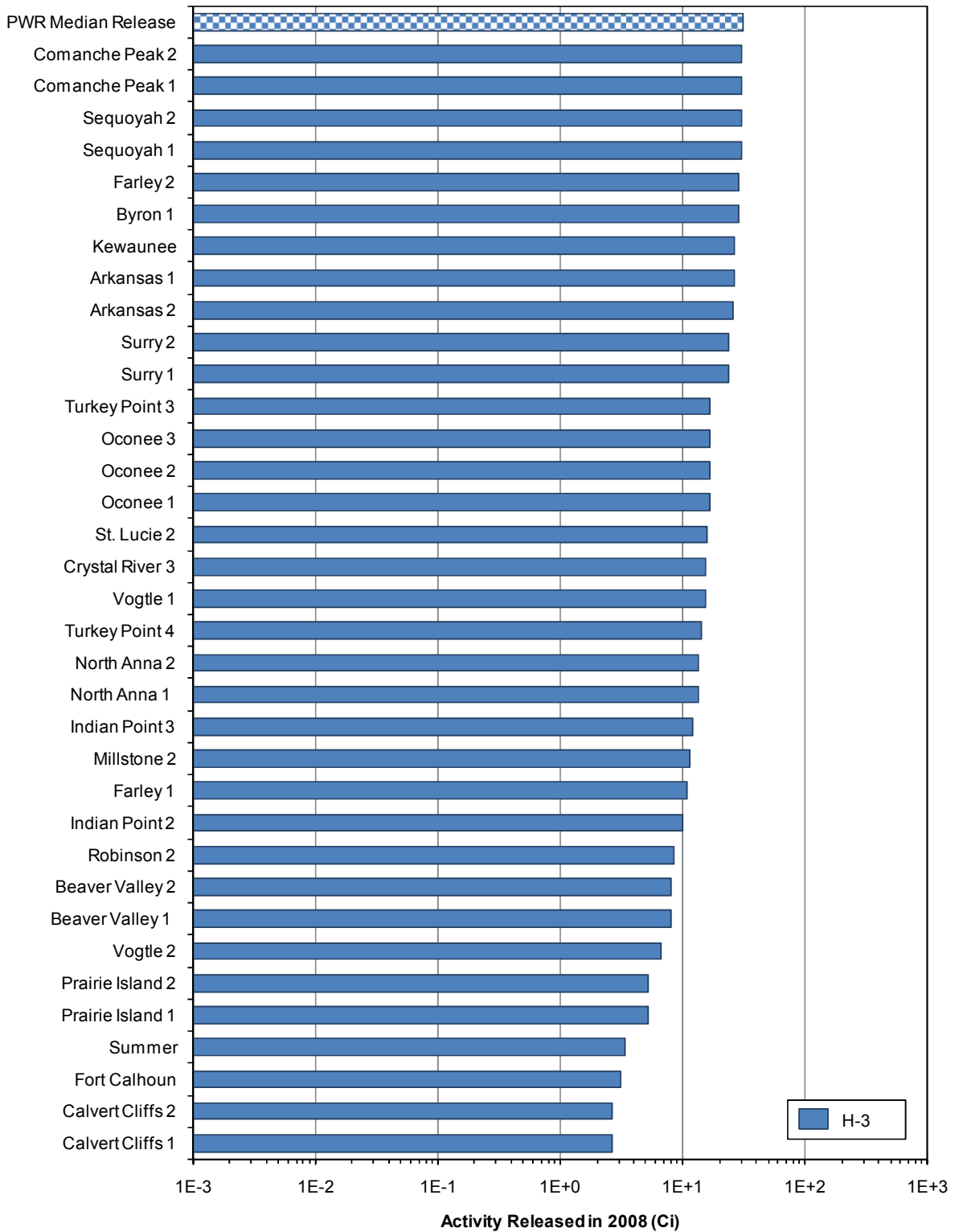
**FIGURE 4.7 (continued)**  
**PWR Gaseous Releases — Selected Particulates**



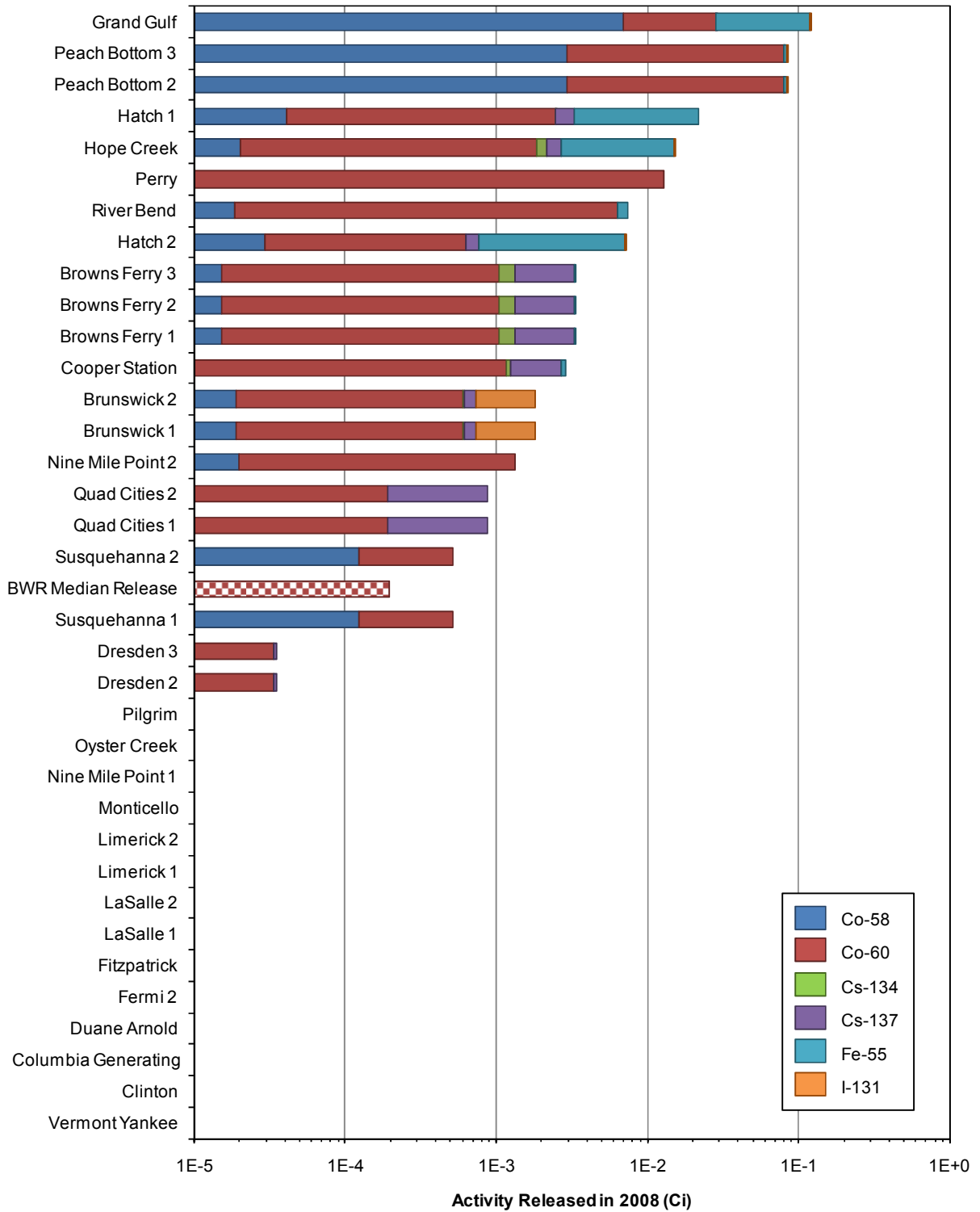
**FIGURE 4.8**  
PWR Gaseous Releases — Tritium



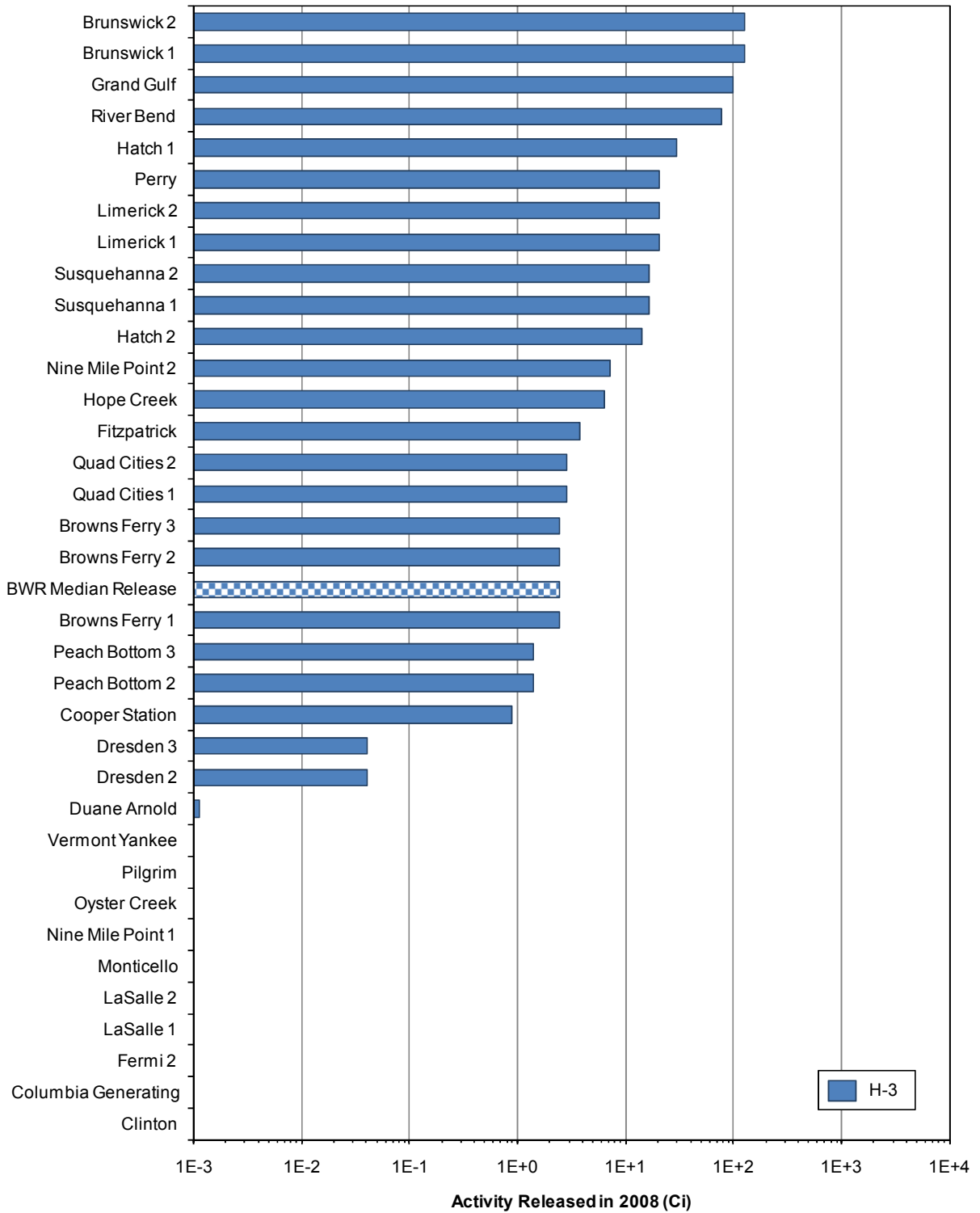
**FIGURE 4.8 (continued)**  
**PWR Gaseous Releases — Tritium**



**FIGURE 4.9**  
**BWR Liquid Releases — Selected Fission and Activation Products**

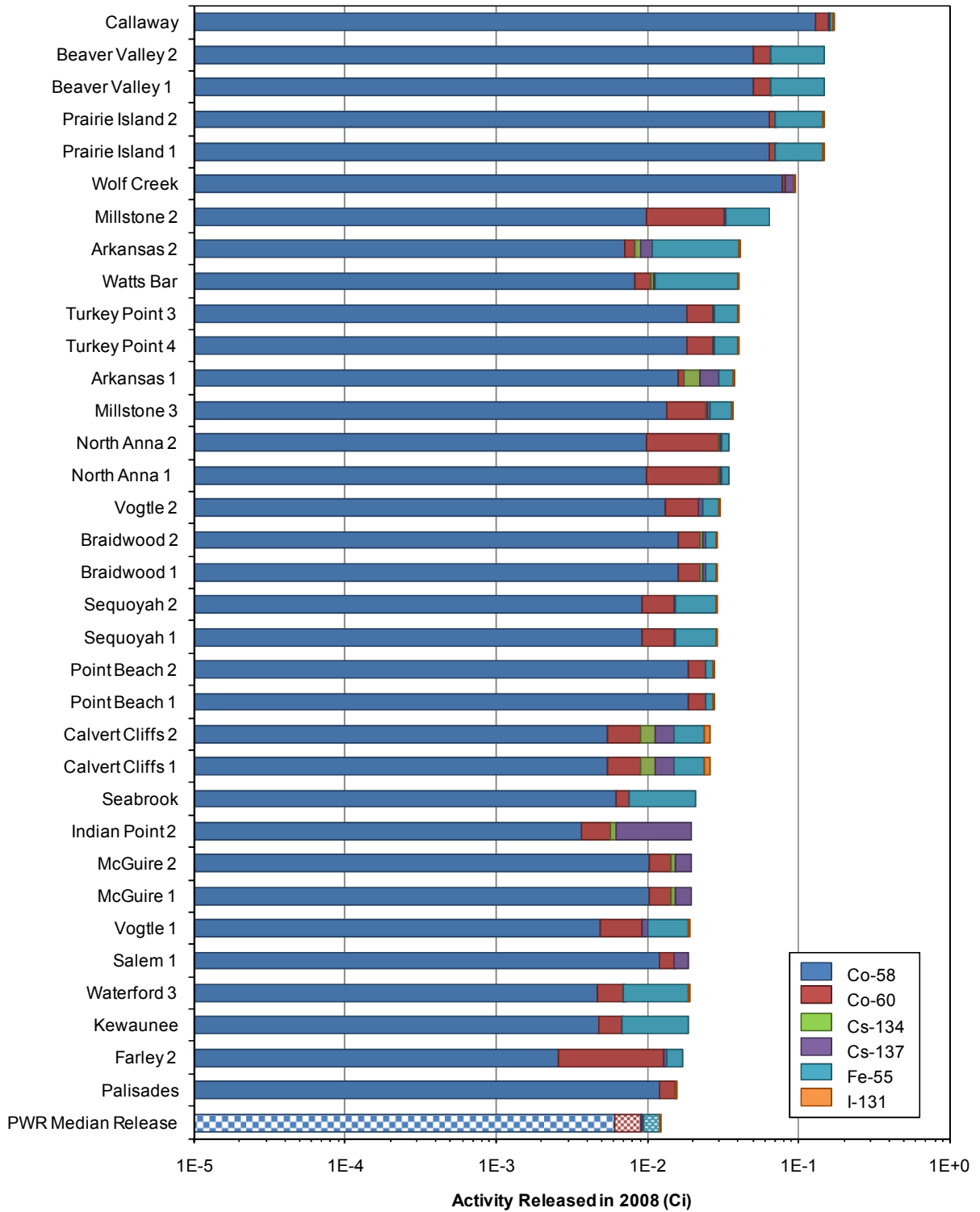


**FIGURE 4.10**  
**BWR Liquid Releases — Tritium**

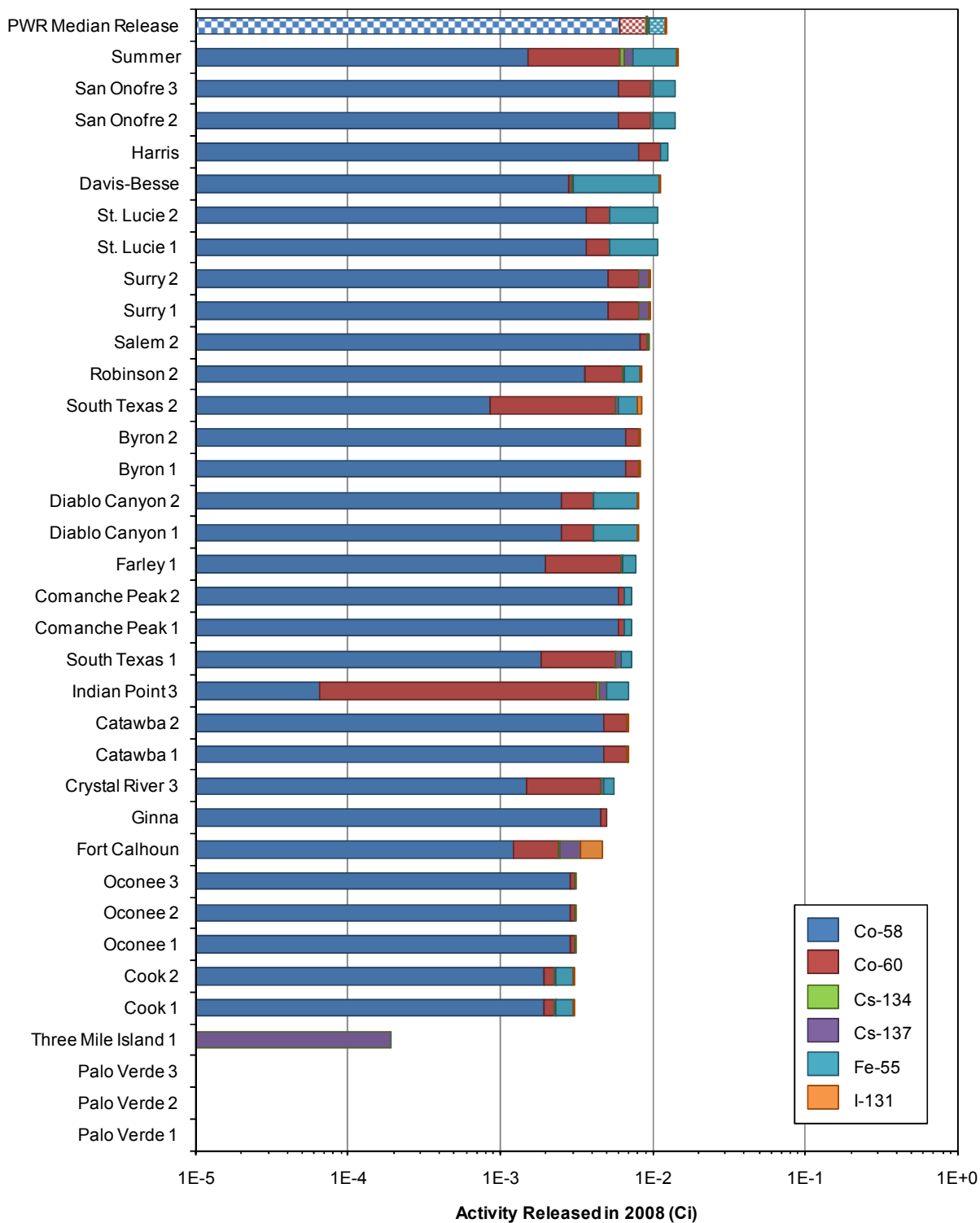




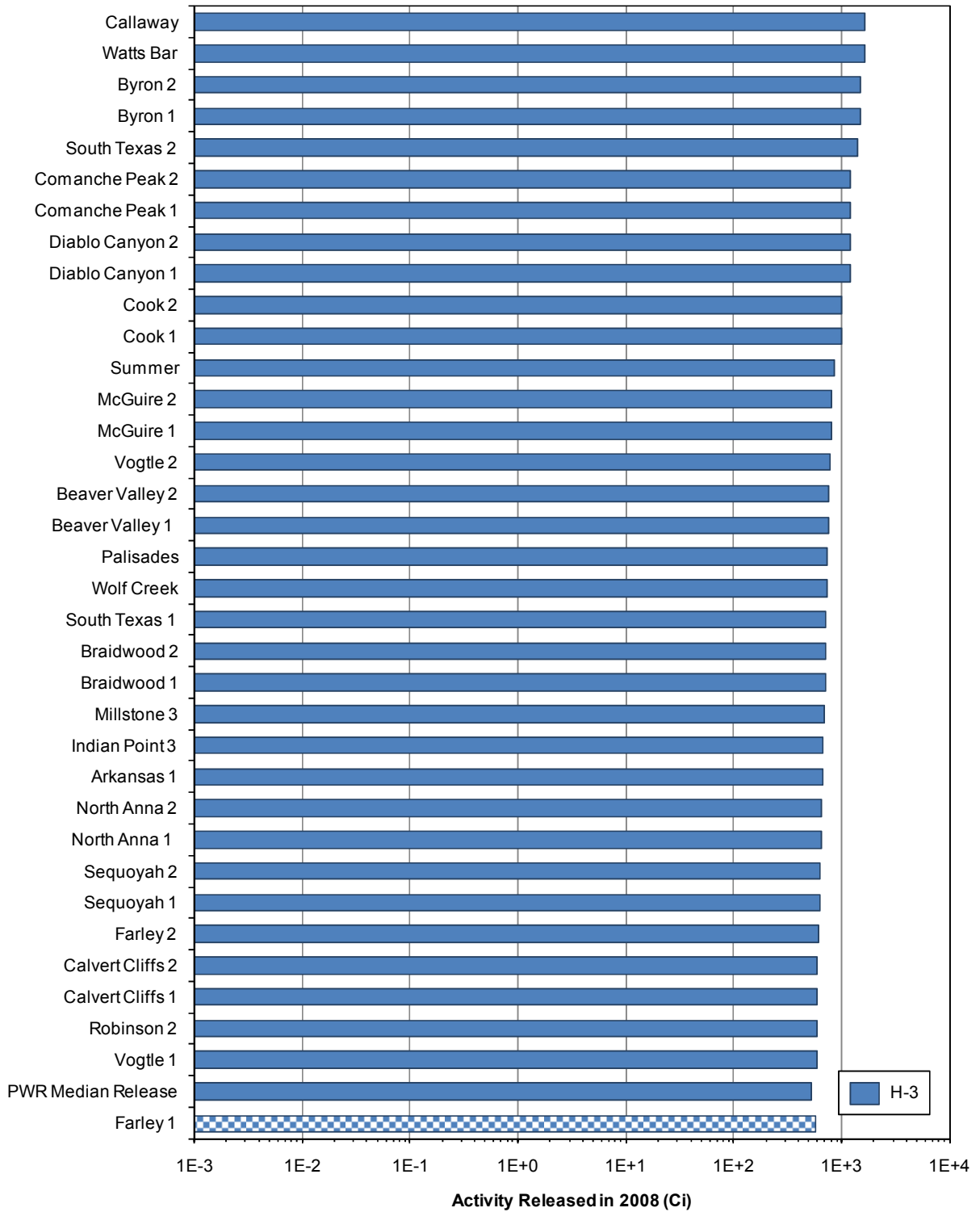
**FIGURE 4.11**  
**PWR Liquid Releases — Selected Fission and Activation Products**



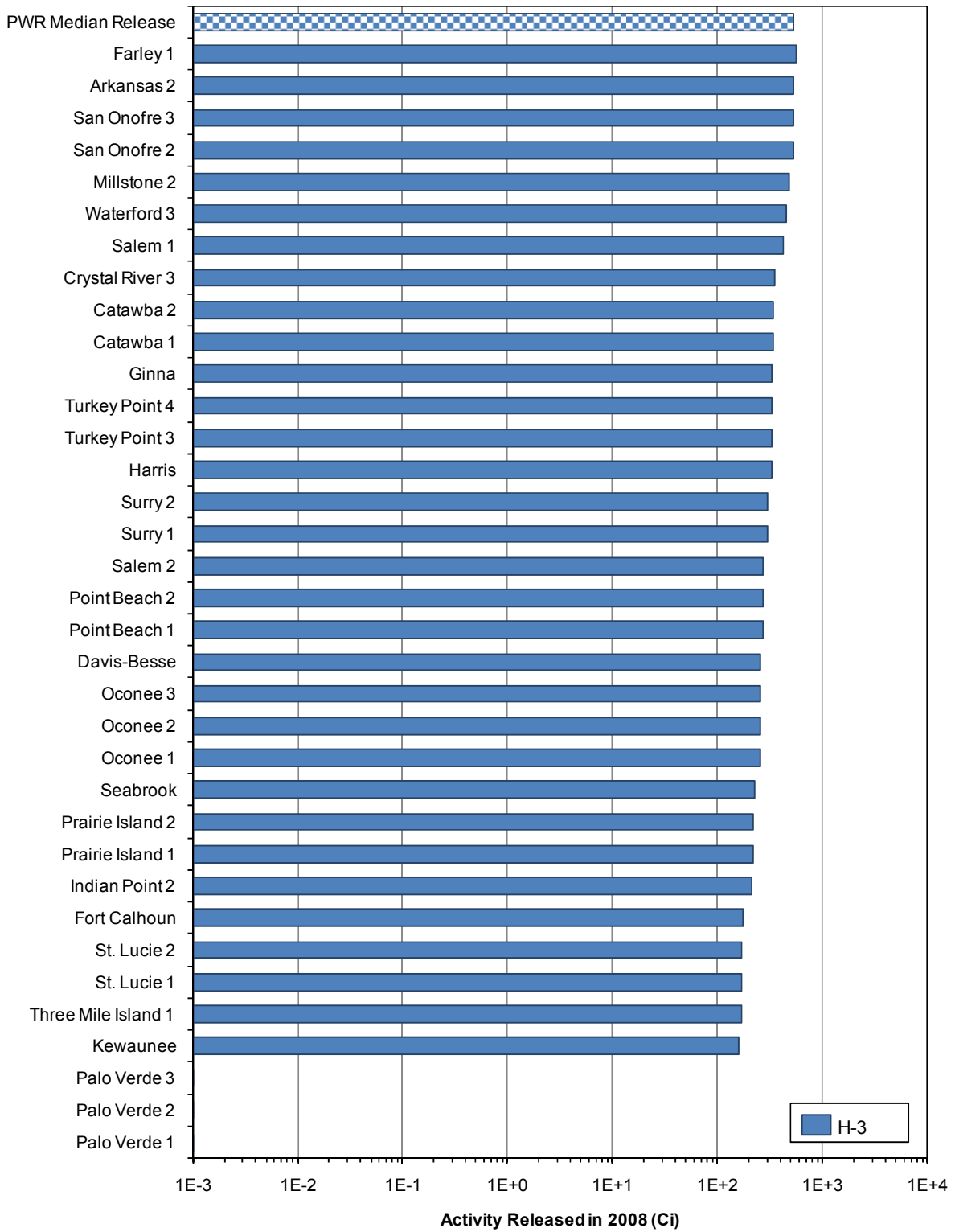
**FIGURE 4.11 (continued)**  
**PWR Liquid Releases — Selected Fission and Activation Products**



**FIGURE 4.12**  
**PWR Liquid Releases — Tritium**



**FIGURE 4.12 (continued)**  
**PWR Liquid Releases — Tritium**



## 4.2 RADIATION DOSE

**TABLE 4.13**  
BWR Gaseous Effluents — Maximum Annual Organ Dose, 2008

<b>BWR Facility</b>	<b>Annual Organ Dose (mrem)</b>
Perry	5.26E-05
Hope Creek	5.03E-04
Clinton	7.45E-04
Vermont Yankee	1.94E-03
Dresden 2	2.33E-03
Limerick 1	2.94E-03
Limerick 2	2.94E-03
Oyster Creek	3.58E-03
Dresden 3	1.01E-02
Duane Arnold	1.13E-02
Browns Ferry 1	1.22E-02
Browns Ferry 2	1.22E-02
Browns Ferry 3	1.22E-02
Fitzpatrick	1.29E-02
Hatch 1	1.37E-02
Columbia Generating	1.44E-02
Nine Mile Point 1	1.63E-02
Hatch 2	1.77E-02
Cooper Station	1.97E-02
LaSalle 1	3.39E-02
LaSalle 2	3.39E-02
Nine Mile Point 2	7.87E-02
Monticello	8.40E-02
Susquehanna 1	8.94E-02
Pilgrim	1.07E-01
Quad Cities 1	1.19E-01
Quad Cities 2	1.19E-01
Fermi 2	1.25E-01
Grand Gulf	2.18E-01
River Bend	2.38E-01
Susquehanna 2	4.21E-01
Brunswick 1	5.00E-01
Brunswick 2	5.00E-01
Peach Bottom 2	6.83E-01
Peach Bottom 3	6.83E-01
<b>Gaseous Effluent Operational Limit</b>	<b>1.50E+01</b>

**TABLE 4.14**  
PWR Gaseous Effluents — Maximum Annual Organ Dose, 2008

<b>PWR Facility</b>	<b>Annual Organ Dose (mrem)</b>	<b>PWR Facility</b>	<b>Annual Organ Dose (mrem)</b>
Ginna	3.45E-06	Fort Calhoun	1.74E-02
Salem 2	3.03E-05	Sequoyah 1	1.95E-02
Salem 1	9.32E-05	Sequoyah 2	1.95E-02
Vogtle 2	1.30E-04	Prairie Island 1	2.18E-02
Vogtle 1	2.04E-04	Prairie Island 2	2.18E-02
Kewaunee	5.55E-04	Wolf Creek	2.62E-02
Diablo Canyon 1	1.11E-03	Byron 2	3.10E-02
Farley 1	1.50E-03	Arkansas 1	4.46E-02
St. Lucie 2	1.56E-03	Watts Bar	4.74E-02
Turkey Point 4	1.64E-03	Surry 1	5.70E-02
Turkey Point 3	1.67E-03	Surry 2	5.70E-02
Crystal River 3	1.79E-03	Millstone 2	6.60E-02
South Texas 1	1.95E-03	Millstone 3	9.34E-02
Indian Point 3	1.99E-03	Waterford 3	1.18E-01
St. Lucie 1	2.10E-03	Cook 1	1.24E-01
Summer	2.17E-03	Cook 2	1.24E-01
Davis-Besse	2.21E-03	McGuire 1	1.35E-01
Indian Point 2	2.67E-03	McGuire 2	1.35E-01
Farley 2	3.85E-03	Arkansas 2	1.77E-01
Palisades	5.44E-03	Palo Verde 3	1.78E-01
South Texas 2	5.50E-03	Beaver Valley 1	1.79E-01
Oconee 1	5.87E-03	Comanche Peak 1	2.07E-01
Oconee 2	5.87E-03	Comanche Peak 2	2.07E-01
Oconee 3	5.87E-03	Palo Verde 2	2.26E-01
North Anna 1	6.65E-03	Palo Verde 1	3.13E-01
North Anna 2	6.65E-03	Calvert Cliffs 1	3.35E-01
Three Mile Island 1	6.96E-03	Calvert Cliffs 2	3.35E-01
Byron 1	8.02E-03	Harris	3.51E-01
San Onofre 2	9.89E-03	Catawba 1	4.64E-01
San Onofre 3	9.89E-03	Catawba 2	4.64E-01
Beaver Valley 2	1.01E-02	Robinson 2	5.60E-01
Diablo Canyon 2	1.08E-02	Braidwood 1	1.44E+00
Callaway	1.20E-02	Braidwood 2	1.60E+00
Point Beach 1	1.27E-02	<b>Gaseous Effluent Operational Limit</b>	<b>1.50E+01</b>
Point Beach 2	1.27E-02		
Seabrook	1.28E-02		

**TABLE 4.15**

BWR Liquid Effluents — Maximum Annual Total Body and Organ Dose, 2008

<b>BWR Facility</b>	<b>Annual Total Body Dose (mrem)</b>	<b>Annual Organ Dose (mrem)</b>
Clinton		
Columbia Generating		
Fermi 2		
LaSalle 1		
LaSalle 2		
Monticello		
Nine Mile Point 1		
Nine Mile Point 2		
Oyster Creek		
Pilgrim		
Vermont Yankee		
Dresden 3	5.22E-07	5.35E-07
Dresden 2	2.20E-06	4.11E-06
Fitzpatrick	1.63E-05	1.63E-05
Duane Arnold	3.23E-05	3.23E-05
Hope Creek	1.51E-05	5.57E-05
River Bend	1.00E-04	1.15E-03
Susquehanna 1	5.80E-04	8.95E-04
Susquehanna 2	5.80E-04	8.95E-04
Hatch 2	6.26E-04	8.77E-04
Browns Ferry 1	1.28E-03	1.80E-03
Browns Ferry 2	1.28E-03	1.80E-03
Browns Ferry 3	1.28E-03	1.80E-03
Perry	2.21E-03	3.15E-03
Brunswick 1	2.54E-03	3.26E-03
Brunswick 2	2.54E-03	3.26E-03
Peach Bottom 2	2.15E-03	4.86E-03
Peach Bottom 3	2.15E-03	4.86E-03
Limerick 1	3.56E-03	5.10E-03
Limerick 2	3.56E-03	5.10E-03
Quad Cities 1	6.75E-03	1.07E-02
Quad Cities 2	6.75E-03	1.07E-02
Hatch 1	7.79E-03	3.67E-02
Grand Gulf	2.19E-01	4.57E-01
Cooper Station	3.18E-01	6.27E-01
<b>Liquid Effluent Operational Limit</b>	<b>3.00E+00</b>	<b>1.00E+01</b>

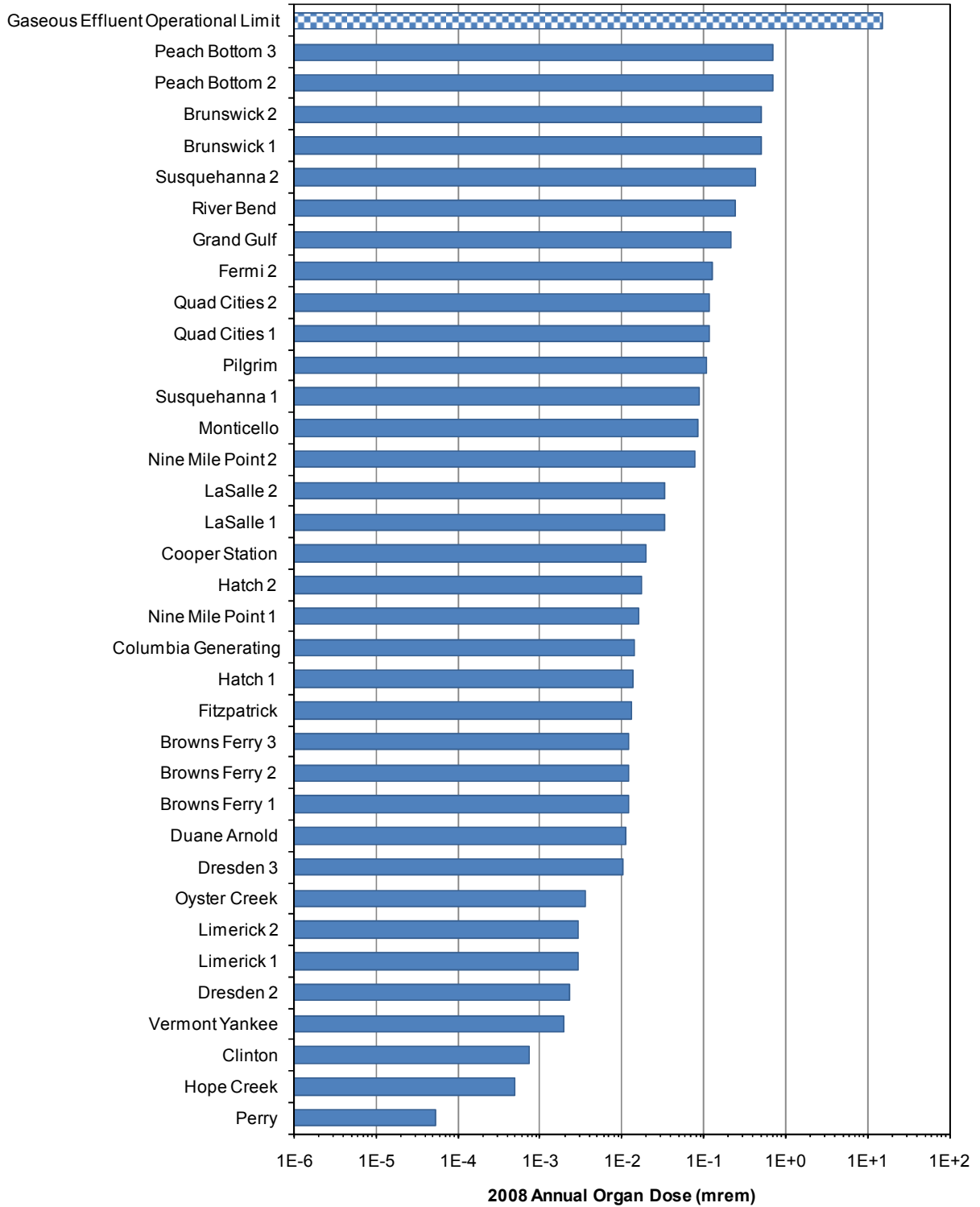
**TABLE 4.16**

PWR Liquid Effluents — Maximum Annual Total Body and Organ Dose, 2008

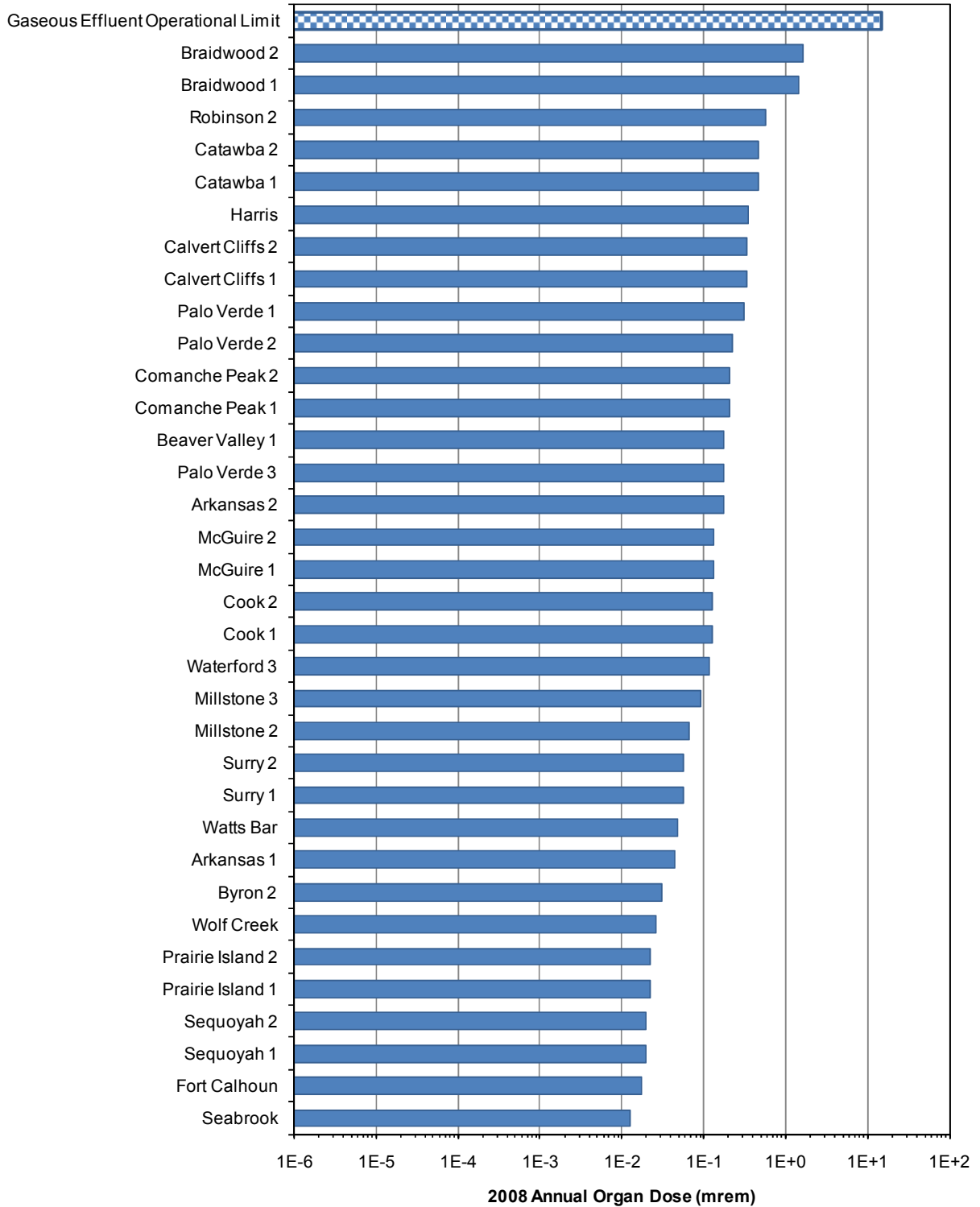
PWR Facility	Annual Total Body Dose (mrem)	Annual Organ Dose (mrem)	PWR Facility	Annual Total Body Dose (mrem)	Annual Organ Dose (mrem)
Palo Verde 1			Harris	7.63E-03	1.15E-02
Palo Verde 2			Millstone 2	1.03E-03	1.82E-02
Palo Verde 3			Arkansas 1	8.70E-03	1.16E-02
Ginna	3.64E-06	3.66E-06	Farley 1	6.64E-03	1.57E-02
Salem 2	1.15E-05	2.49E-05	Farley 2	6.64E-03	1.57E-02
Crystal River 3	2.08E-05	6.76E-05	Watts Bar	1.43E-02	1.68E-02
Salem 1	4.03E-05	7.76E-05	Catawba 1	1.85E-02	1.89E-02
Surry 1	7.50E-05	1.82E-04	Catawba 2	1.85E-02	1.89E-02
Surry 2	7.50E-05	1.82E-04	Callaway	1.65E-02	2.19E-02
Turkey Point 4	4.02E-04		Three Mile Island 1	1.88E-02	2.12E-02
Turkey Point 3	4.04E-04		Oconee 1	2.03E-02	2.24E-02
Indian Point 3	1.56E-04	2.83E-04	Oconee 2	2.03E-02	2.24E-02
Diablo Canyon 1	2.18E-04	3.80E-04	Oconee 3	2.03E-02	2.24E-02
Diablo Canyon 2	2.18E-04	3.80E-04	Vogtle 1	1.95E-02	2.36E-02
Robinson 2	3.39E-04	4.72E-04	Cook 1	2.84E-02	2.85E-02
Waterford 3	6.03E-04	7.04E-04	Cook 2	2.84E-02	2.85E-02
Indian Point 2	6.11E-04	1.47E-03	Fort Calhoun	2.39E-02	3.50E-02
Palisades	1.98E-03	2.29E-03	Vogtle 2	2.69E-02	3.28E-02
Prairie Island 1	8.20E-04	3.68E-03	Beaver Valley 1	4.60E-02	7.01E-02
Prairie Island 2	8.20E-04	3.68E-03	Beaver Valley 2	4.60E-02	7.01E-02
Seabrook	7.69E-04	3.77E-03	Comanche Peak 1	6.36E-02	6.38E-02
Kewaunee	1.04E-03	4.19E-03	Comanche Peak 2	6.36E-02	6.38E-02
Arkansas 2	2.30E-03	3.00E-03	Byron 1	7.52E-02	8.42E-02
Davis-Besse	2.60E-03	3.42E-03	Byron 2	7.52E-02	8.42E-02
Millstone 3	6.65E-04	5.52E-03	Braidwood 1	6.60E-02	1.09E-01
Calvert Cliffs 1	1.10E-03	5.30E-03	Braidwood 2	6.60E-02	1.09E-01
Calvert Cliffs 2	1.10E-03	5.30E-03	McGuire 1	1.02E-01	1.25E-01
San Onofre 2	1.31E-03	5.62E-03	McGuire 2	1.02E-01	1.25E-01
San Onofre 3	1.31E-03	5.62E-03	North Anna 1	1.91E-01	2.55E-01
South Texas 1	4.12E-03	4.17E-03	North Anna 2	1.91E-01	2.55E-01
Point Beach 1	3.25E-03	5.80E-03	Wolf Creek	2.26E-01	2.43E-01
Point Beach 2	3.25E-03	5.80E-03	St. Lucie 1	2.20E+00	8.99E+00
Sequoyah 1	7.55E-03	7.70E-03	St. Lucie 2	2.20E+00	8.99E+00
Sequoyah 2	7.55E-03	7.70E-03	<b>Liquid Effluent Operational Limit</b>	<b>3.00E+00</b>	<b>1.00E+01</b>
Summer	7.58E-03	7.76E-03			
South Texas 2	7.97E-03	8.02E-03			



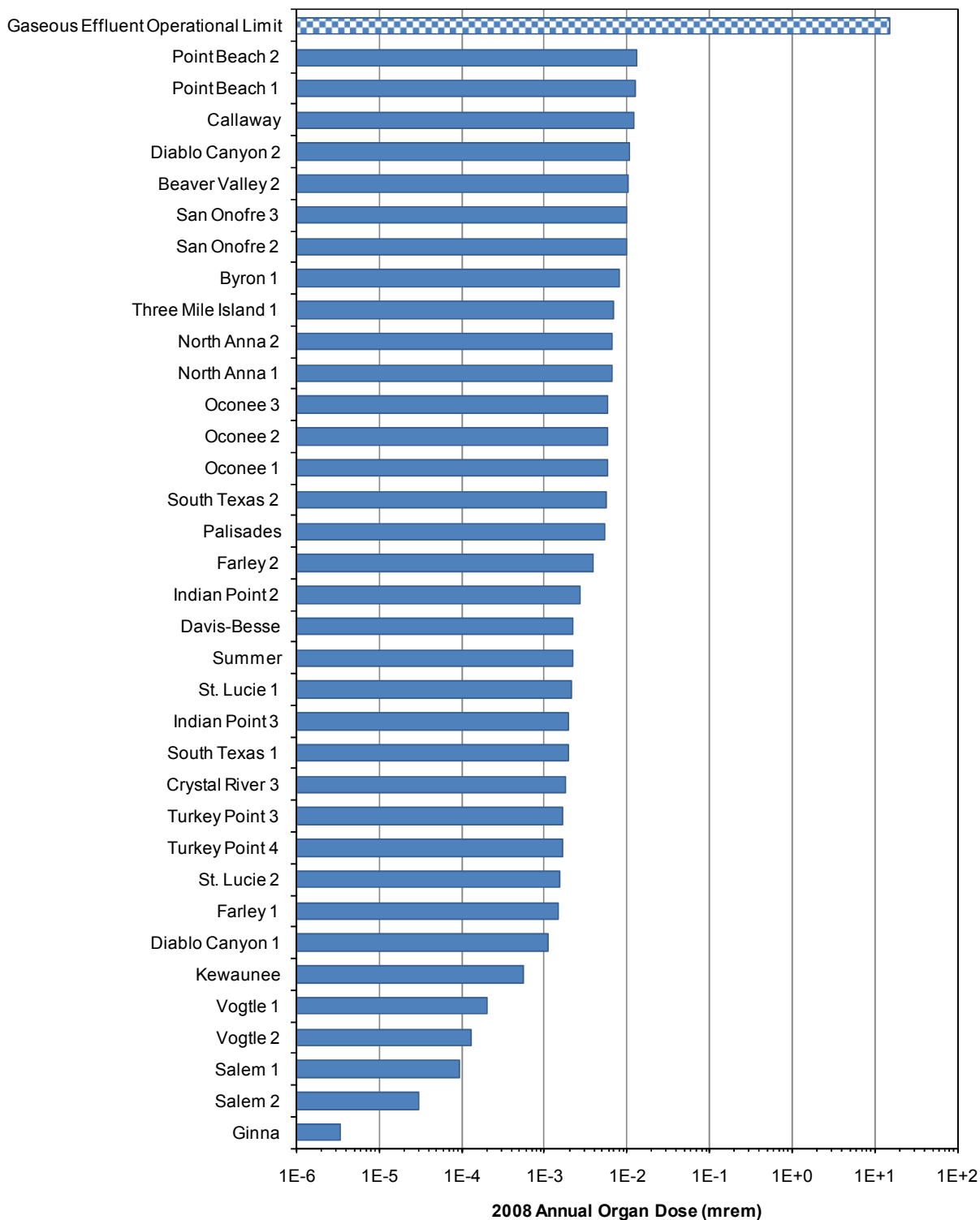
**FIGURE 4.13**  
**BWR Gaseous Effluents — Maximum Annual Organ Dose**



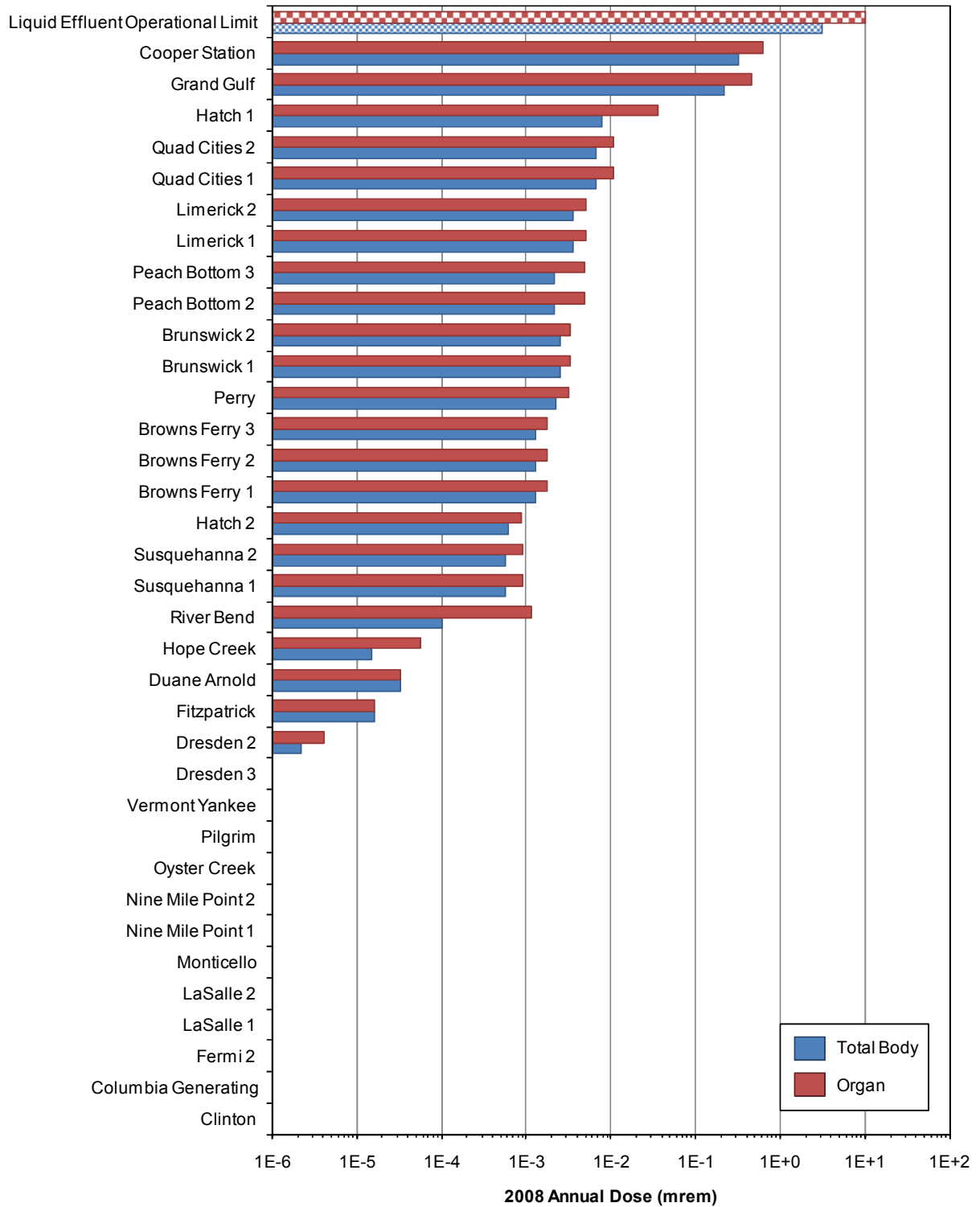
**FIGURE 4.14**  
**PWR Gaseous Effluents — Maximum Annual Organ Dose**



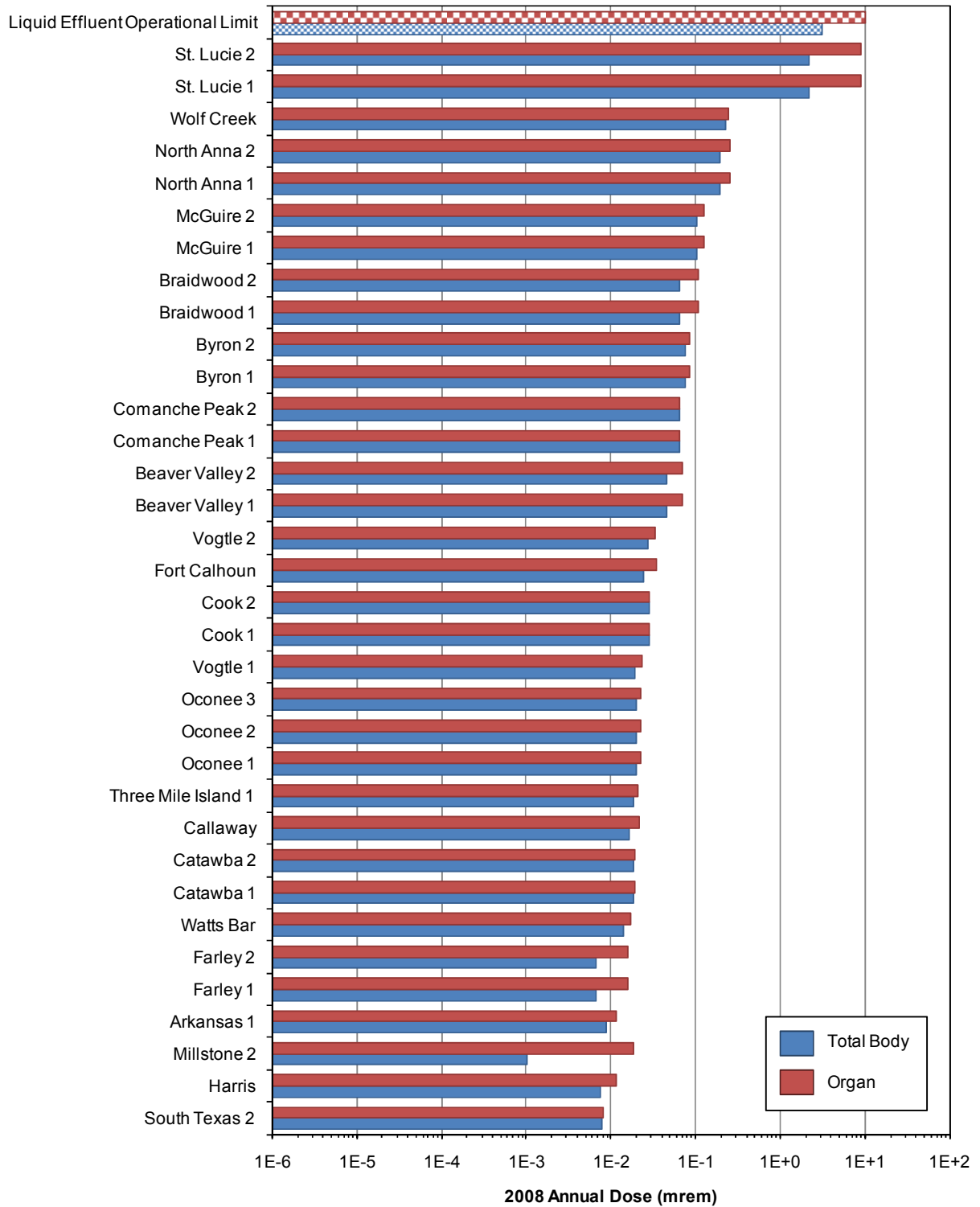
**FIGURE 4.14 (continued)**  
**PWR Gaseous Effluents — Maximum Annual Organ Dose**



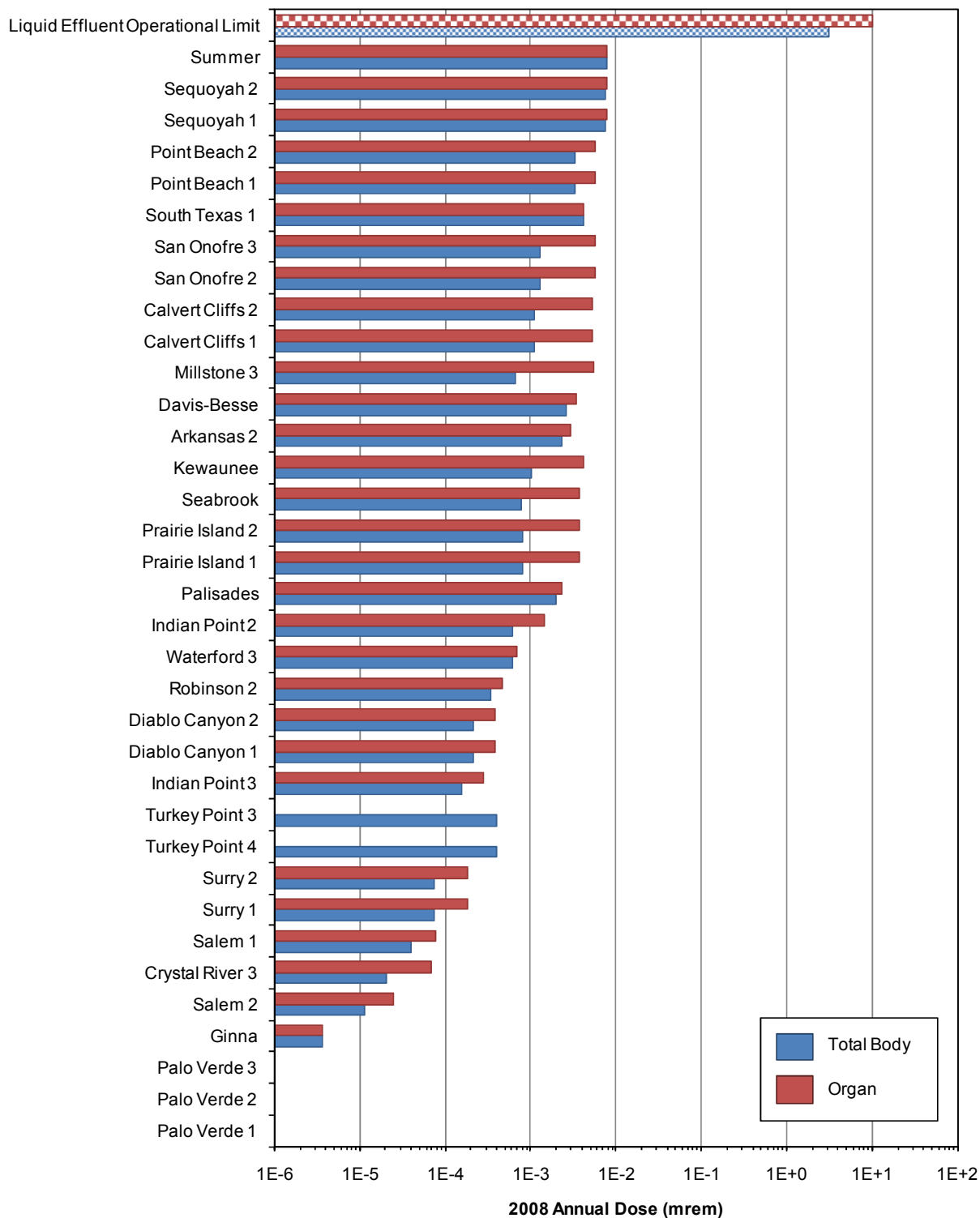
**FIGURE 4.15**  
**BWR Liquid Effluents — Maximum Annual Total Body and Organ Dose**



**FIGURE 4.16**  
**PWR Liquid Effluents — Maximum Annual Total Body and Organ Dose**



**FIGURE 4.16 (continued)**  
**PWR Liquid Effluents — Maximum Annual Total Body and Organ Dose**



## **Section 5**

### **REFERENCES**

---

1. "Report on Releases of Radioactivity in Effluents and Solid Wastes from Nuclear Power Plants for 1972," Directorate of Regulatory Operations, August 1973.
2. "Summary of Radioactivity Releases in Effluents from Nuclear Power Plants During 1973," NUREG-75/001, January 1975.
3. "Radioactive Materials Released from Nuclear Power Plants, 1974," NUREG-0077, June 1976.
4. "Radioactive Materials Released from Nuclear Power Plants, 1975," NUREG-0218, March 1977.
5. "Radioactive Materials Released from Nuclear Power Plants, 1976," NUREG-0367, March 1978.
6. "Radioactive Materials Released from Nuclear Power Plants, 1977," NUREG-0521, January 1979.
7. "Radioactive Materials Released from Nuclear Power Plants, 1978," NUREG/CR-1497, BNL-NUREG-51192, March 1981.
8. "Radioactive Materials Released from Nuclear Power Plants, 1979," NUREG/CR-2227, BNL-NUREG-51416, November 1981.
9. "Radioactive Materials Released from Nuclear Power Plants, 1980," NUREG/CR-2907, BNL-NUREG-51581, Vol. 1, January 1983.
10. "Radioactive Materials Released from Nuclear Power Plants, 1981," NUREG/CR-2907, BNL-NUREG-51581, Vol. 2, June 1984.
11. "Radioactive Materials Released from Nuclear Power Plants, 1982," NUREG/CR-2907, BNL-NUREG-51581, Vol. 3, February 1986.
12. "Radioactive Materials Released from Nuclear Power Plants, 1983," NUREG/CR-2907, BNL-NUREG-51581, Vol. 4, August 1986.
13. "Radioactive Materials Released from Nuclear Power Plants, 1984," NUREG/CR-2907, BNL-NUREG-51581, Vol. 5, August 1987.
14. "Radioactive Materials Released from Nuclear Power Plants, 1985," NUREG/CR-2907, BNL-NUREG-51581, Vol. 6, January 1988.
15. "Radioactive Materials Released from Nuclear Power Plants, 1986," NUREG/CR-2907, BNL-NUREG-51581, Vol. 7, November 1988.
16. "Radioactive Materials Released from Nuclear Power Plants, 1987," NUREG/CR-2907, BNL-NUREG-51581, Vol. 8, October 1989.

17. "Radioactive Materials Released from Nuclear Power Plants, 1988," NUREG/CR-2907, BNL-NUREG-51581, Vol. 9, July 1991.
18. "Radioactive Materials Released from Nuclear Power Plants, 1989," NUREG/CR-2907, BNL-NUREG-51581, Vol. 10, September 1992.
19. "Radioactive Materials Released from Nuclear Power Plants, 1990," NUREG/CR-2907, BNL-NUREG-51581, Vol. 11, October 1993.
20. "Radioactive Materials Released from Nuclear Power Plants, 1991," NUREG/CR-2907, BNL-NUREG-51581, Vol. 12, May 1994.
21. "Radioactive Materials Released from Nuclear Power Plants, 1992," NUREG/CR-2907, BNL-NUREG-51581, Vol. 13, August 1995.
22. "Radioactive Materials Released from Nuclear Power Plants, 1993," NUREG/CR-2907, BNL-NUREG-51581, Vol. 14, August 1995.
23. SECY-06-0212, Preparation of Annual Reports on Radioactive Materials Released in Gaseous and Liquid Effluents and in Solid Wastes Shipped for Disposal by Commercial Nuclear Power Plants, U.S. Nuclear Regulatory Commission, Washington, DC, October 17, 2006.
24. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. Nuclear Regulatory Commission, Washington, DC.
25. Regulatory Guide 1.21, "Measuring, Evaluating, and Reporting Radioactive Material in Liquid and Gaseous Effluents and Solid Waste," Revision 2, U.S. Nuclear Regulatory Commission, Washington, DC, June 2009.
26. Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Demonstrating Compliance with 10 CFR Part 50, Appendix I," U.S. Nuclear Regulatory Commission, Washington, DC, October 1977.
27. 10 CFR Part 20, "Standards for Protection Against Radiation," U.S. Nuclear Regulatory Commission, Washington, DC.
28. NCRP Publication No. 160, "Ionizing Radiation Exposure of the Population of the United States, National Council on Radiation Protection and Measurements", Bethesda, MD, March 3, 2009.
29. NCRP Publication No. 93, "Ionizing Radiation Exposure of the Population of the United States, National Council on Radiation Protection and Measurements", Bethesda, MD, September 1987.



**AVAILABILITY OF REFERENCE MATERIALS  
IN NRC PUBLICATIONS**

**NRC Reference Material**

As of November 1999, you may electronically access NUREG-series publications and other NRC records at NRC's Public Electronic Reading Room at [www.nrc.gov/reading-rm/adams.html](http://www.nrc.gov/reading-rm/adams.html) . Publicly released records include, to name a few, NUREG-series publications; *Federal Register* notices; applicant, licensee, and vendor documents and correspondence; NRC correspondence and internal memoranda; bulletins and information notices; inspection and investigative reports; licensee event reports; and Commission papers and their attachments.

NRC publications in the NUREG series, NRC regulations, and *Title 10, Energy, in the Code of Federal Regulations* may also be purchased from one of these two sources.

1. The Superintendent of Documents  
U.S. Government Printing Office  
P. O. Box 37082 Washington, DC 20402-9328  
<http://www.gpoaccess.gov/index.html>  
202-512-1800
2. The National Technical Information Service  
Springfield, VA 22161-0002  
<http://www.ntis.gov/> .  
1-800-533-6847 or, locally, 703-805-6000

A single copy of each NRC draft report for comment is available free, to the extent of supply, upon written request as follows:

Address: Office of the Chief Information Officer,  
Reproduction and Distribution  
Services Section  
U.S. Nuclear Regulatory Commission  
Washington, DC 20555-0001  
E-mail: [DISTRIBUTION@nrc.gov](mailto:DISTRIBUTION@nrc.gov)  
Facsimile: 301-415-2289

Some publications in the NUREG series that are posted at NRC's Web site address <http://www.nrc.gov/reading-rm/doc-collections/nuregs/> are updated periodically and may differ from the last printed version. Although references to material found on a Web site bear the date the material was accessed, the material available on the date cited may subsequently be removed from the site.

**Non-NRC Reference Material**

Documents available from public and special technical libraries include all open literature items, such as books, journal articles, and transactions, *Federal Register* notices, Federal and State legislation, and congressional reports. Such documents as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings may be purchased from their sponsoring organization.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at—

The NRC Technical Library  
Two White Flint North  
11545 Rockville Pike  
Rockville, MD 20852-2738

These standards are available in the library for reference use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from—

American National Standards Institute  
11 West 42nd Street  
New York, NY 10036-8002  
<http://www.ansi.org/>  
212-642-4900

The NUREG series comprises (1) technical and administrative reports and books prepared by the staff (NUREG-XXXX) or agency contractors (NUREG/CR-XXXX), (2) proceedings of conferences (NUREG/CP-XXXX), (3) reports resulting from international agreements (NUREG/IA-XXXX), (4) brochures (NUREG/BR-XXXX), and (5) compilations of legal decisions and orders of the Commission and Atomic and Safety Licensing Boards and of Directors' decisions under Section 2.206 of NRC's regulations (NUREG-0750).

This page intentionally left blank

## **Section 6**

### **GLOSSARY**

---

*Activity or radioactivity:* The rate of radioactive decay of a radionuclide, measured in the traditional unit of the curie (Ci) or the international standard unit of the becquerel (Bq).

*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 and from past nuclear accidents such as Chernobyl that contribute to background radiation and are not under the control of the licensee. Background radiation does not include radiation from source, byproduct, or special nuclear materials regulated by the Nuclear Regulatory Commission.

*Effluent discharge, radioactive discharge:* The portion of an effluent release that reaches an unrestricted area.

*Effluent release, radioactive release:* The emission of an effluent.

*Exposure pathway:* A mechanism by which radioactive material is transferred from the (local) environment to humans. There are three commonly recognized exposure pathways: inhalation, ingestion, and direct radiation.

*Fission and activation gases:* The noble (chemically non-reactive) gases formed from the splitting (fission) of the uranium-235 isotope in a nuclear reactor or the creation of radioactive atoms from non-radioactive atoms (activation) by the capture of neutrons or gamma rays that were released during the fission process.

*Gaseous effluents:* Airborne effluents.

*Iodines/Halogens:* The measured radioactive isotopes of iodine or of other non-metal elements in group 17 of the Periodic Table of Elements. Licensees might report any combination of the iodine isotopes I-131, I-132, I-133, I-134, and I-135, as well as other halogens such as bromine-82 (Br-82).

*Maximum exposed individual:* Individuals characterized as maximum with regard to food consumption, occupancy, and other usage of the region in the vicinity of the plant site. As such, they represent individuals with habits that are considered to be maximum reasonable deviations from the average for the population in general. Additionally, in physiological or metabolic respects, the maximum exposure individuals are assumed to have those characteristics that represent the averages for their corresponding age group in the general population.

*Member of the public (10 CFR 20):* Any individual except when that individual is receiving an occupational dose.

*Monitoring:* The measurement of radiation levels, concentrations, surface area concentrations or quantities of radioactive material and the use of results of these measurements to evaluate potential exposures and doses.

*Noble gas:* One of six noble gases (helium, neon, argon, krypton, xenon and radon) with an oxidation number of 0 that prevents it from forming compounds readily. All noble gases have the maximum number of electrons possible in their outer shell (2 for Helium, 8 for all others), making them stable.

*Particulates:* Radioactive materials entrained in the gaseous effluent that are not included in any other effluent category.

*Site boundary:* That line beyond which the land is neither owned, nor leased, nor otherwise controlled by the licensee.

*Tritium:* The radioactive isotope of hydrogen (H-3).