Enclosure 2

R. E. Ginna Nuclear Power Plant
Flood Hazard Reevaluation Report
Revision 1

(133 Pages)

AREVA

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Engineering Information Record

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Constellation Energy Nuclear Group Flood Hazard Reevaluation Report for R. E. Ginna Nuclear Power Plant

Safety Related? ☒ YES ☐ NO

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Record of Revision

Revision No.	Pages/Sections/ Paragraphs Changed	Brief Description / Change Authorization
000	All	Initial Issuance
001	Sections 2.1 and 3	The purpose of this revision is to update results from the Local Intense Precipitation analysis to include runoff from roof areas. This change is due to an error in roof area drainage in the original report identified in AREVA CR 2014-3673. The revised LIP peak flood elevations are generally higher, but do not result in any additional impacts to the Ginna site. No other updates were made to this report. This revision supersedes Revision 000.
001	All	Document template updated to revision 21
001	Section 2.1	Minor editorial changes to improve clarity
001	Section 2.1.2.1.2, Buildings	Description of how buildings were modeled was updated to incorporate changes made to account for AREVA CR 2014-3673. Buildings were previously modeled using Area and Width Reduction Factors and the iRainbuilding function in FLO-2D. Due to the CR, they are now modeled as relatively elevated grid cells.
001	Section 2.1.2.1.2, Channel Outflow Boundaries	Description of channel outflow boundaries was added to add clarity for NRC reviewers.
001	Section 2.1.2.1.4	Results of the LIP evaluation were updated.
001	Section 2.1.3	Results of the LIP evaluation were updated.
001	Section 2.1.4	Reference AREVA, 2013a changed to AREVA, 2014, Revision level changed. Reference AREVA, 2013b changed to AREVA, 2013.
001	Table 2.1-1	Results of LIP simulation changed.
001	Figures 2.1-2 through 2.1-6	Figures replaced due to changes to LIP results.
001	Section 3.1-1	Results of the LIP evaluation were updated.

Overview

This report describes the approach, methods, and results from the reevaluation of flood hazards at the R. E. Ginna Nuclear Power Plant (Ginna). It provides the information, in part, requested by the U.S. Nuclear Regulatory Commission (NRC) to support the evaluation of the NRC staff Recommendation 2.1 for the Near-Term Task Force (NTTF) review of the accident at the Fukushima Daiichi nuclear facility.

Section 1 provides information related to the flood hazard. The section begins with an introduction that includes background information, scope, general method used for the reevaluation, the vertical datum used throughout the report, and a conversion table to determine elevations in other common datums. The section continues by describing detailed Ginna site information, including present-day site layout, topography, and current licensing basis flood protection and mitigation features. The section concludes by identifying relevant changes since license issuance to the local area and watershed as well as flood protections.

Section 2 presents the results of the flood hazard reevaluation. It addresses each of the eight flood-causing mechanisms required by the NRC as well as a combined effect flood. In cases where a mechanism does not apply to the Ginna site, a justification is included. The section also provides a basis for inputs and assumptions, methods, and models used.

Section 3 compares the current and reevaluated flood-causing mechanisms. It provides an assessment of the current licensing and design basis flood elevation to the reevaluated flood elevation for each applicable flood-causing mechanism.

Section 4 (not included in this report) presents an interim evaluation and actions taken, or planned, to address those higher flooding hazards identified in Section 3 relative to the current licensing and design basis. Due to mitigative actions anticipated to be completed prior to the submittal of this report, this section will be prepared at a later date.

The report also contains one appendix. Appendix A describes the software models used in the reevaluation, including the quality assurance criteria and a discussion of validation of model-derived results.

Table of Contents

Table of Contents
(continued)

Table of Contents
(continued)

List of Tables

Page

List of Tables
(continued)

Page

List of Figures

List of Figures
(continued)

Acronyms and Abbreviations

Acronym/Abbreviation	Description
ANS	American Nuclear Society
ANSI	American National Standards Institute
ARC	Antecedent Rainfall Condition
ARF	Area Reduction Factor
CEM	Coastal Engineering Manual
CFR	Code of Federal Regulations
CLB	Current Licensing Basis
CN	Curve Number
COL	Combined Operating License
FEMA	Federal Emergency Management Agency
Ginna	R. E. Ginna Nuclear Power Plant
GLERL	Great Lakes Environmental Research Laboratory
HEC-HMS	Hydrologic Engineering Center Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center River Analysis System
HHA	Hierarchical Hazard Assessment
HMR	Hydrometeorological Report
HURDAT	NOAA National Hurricane Center
IGLD	International Great Lakes Datum
IJC	International Joint Commission
ISLRBC	International Saint Lawrence River Board of Control
LIP	Local Intense Precipitation
MSL	Mean Sea Level
NAVD	North American Vertical Datum
NCDC	National Climatic Data Center
NGDC	National Geophysical Data Center
NGVD	National Geodetic Vertical Datum
NMP3NPP	Nine Mile Point 3 Nuclear Power Plant
NOAA	National Oceanic And Atmospheric Administration
NRC	U.S. Nuclear Regulatory Commission
NRCS	Natural Resources Conservation Service
NTTF	Near Term Task Force
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PMS	Probable Maximum Seiche
PMSS	Probable Maximum Storm Surge
PMWS	Probable Maximum Wind Storm

List of Figures
(continued)

Acronym/Abbreviation	Description
ROC	Rochester Airport
SCS	Soil Conservation Service
SSC	Structures, Systems and Components
SSPP	Great Lakes Storm Surge Planning Program
Tc	Time of Concentration
UFSAR	Updated Final Safety Analysis Report
UH	Unit Hydrograph
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
USLS	United States Lake Survey
WRF	Width Reduction Factor

1.0 INFORMATION RELATED TO THE FLOOD HAZARD

1.1 Introduction

Following the Fukushima Daiichi accident on March 11, 2011, which resulted from an earthquake and subsequent tsunami, the U.S. Nuclear Regulatory Commission (NRC) established the Near-Term Task Force (NTTF) to review the accident. The NTTF subsequently prepared a report with a comprehensive set of recommendations (NRC, 2012).

In response to the NTTF recommendations, and pursuant to Title 10 of the Code of Federal Regulations, Section 50.54 (f), the NRC has requested information from all operating power licensees (NRC, 2012). The purpose of the request is to gather information to re-evaluate seismic and flooding hazards at U.S. operating reactor sites.

The R. E. Ginna Nuclear Power Plant (Ginna), located on Lake Ontario in Ontario, N.Y., is one of the sites required to submit information.

The NRC information request relating to flooding hazards requires licensees to re-evaluate their sites using updated flooding hazard information and present-day regulatory guidance and methodologies and then compare the results against the site's current licensing basis (CLB) for protection and mitigation from external flood events.

1.1.1 Purpose

This report provides, in part, the information requested by the NRC to support the evaluation of the NRC staff recommendations for the NTTF review of the accident at the Fukushima Daiichi nuclear facility.

The report describes the approach, methods, and results from the reevaluation of flood hazards at Ginna.

1.1.2 Scope

This report addresses the eight flood-causing mechanisms and a combined effect flood, identified in Attachment 1 to Enclosure 2 of the NRC information request (NRC, 2012).

Each of these flood causing mechanisms and the potential effects on the Ginna site is described in Section 2 and 3 of this report.

1.1.3 Method

This report follows the Hierarchical Hazard Assessment (HHA) approach, as described in NUREG/CR-7046, "Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America" (NRC, 2011) and its supporting reference documents.

A HHA consists of a series of stepwise, progressively more refined analyses to evaluate the hazard resulting from phenomena at a given nuclear power plant site to safety-related structures, systems, and components (SSC) with the most conservative plausible assumptions consistent with the available data. The HHA starts with the most conservative, simplifying assumptions that maximize the hazards from the maximum probable event. If the assessed hazards result in an adverse effect or exposure to any safety-related SSC, a more site-specific hazard assessment is performed for the probable maximum event.

The HHA approach was carried out for each flood-causing mechanism listed in Section 2 and 3, with the design-basis flood being the event that resulted in the most severe hazard to the safety-related SSC at Ginna. The steps involved to estimate the design-basis flood typically included the following:

1. Identify flood-causing phenomena or mechanisms by reviewing historical data and assessing the geohydrological, geoseismic, and structural failure phenomena in the vicinity of the site and region.

2. For each flood-causing phenomenon, develop a conservative estimate of the flood from the corresponding probable maximum event using conservative simplifying assumptions.
3. If any safety-related SSC is adversely affected by flood hazards, use site-specific data and/or more refined analyses to provide a more realistic condition and flood analysis, while ensuring that these conditions are consistent with those used by Federal agencies in similar design considerations.
4. Repeat Step 2; if all safety-related SSC are unaffected by the estimated flood, or if all site-specific data have been used, specify design bases for each using the most severe hazards from the set of floods corresponding to the flood-causing phenomena.

Section 2 of this report provides additional HHA detail for each of the flood-causing mechanisms evaluated.

1.1.4 Elevation Values

Elevations in the Updated Final Safety Analysis Report (UFSAR) (Ginna, 2011) reference Mean Sea Level (MSL), which for areas distant from tidal fluctuations (i.e., Ginna) are considered to be the same as the NGVD29 vertical datum. MSL is no longer considered an appropriate designation due to established changes in vertical datum identification conventions. MSL is used in this report to maintain consistency with the source references vertical datum identification. Unless otherwise noted, all elevations in this report are in NGVD29 (MSL). For elevations in other datum, use the following conversion table (AREVA, 2013):

Table 1.1-1: Elevation Datum Conversion Table for Ginna

From	To:			
	MSL (ft)	IGLD85 (ft)	NGVD29 (ft)	NAVD88 (ft)
MSL	0	-0.73	0	-0.68
IGLD85	0.73	0	0.7	0.07
NGVD29	0	-0.7	0	-0.69
NAVD88	0.68	-0.07	0.69	0

Where:

MSL = Mean Sea Level
IGLD85 = International Great Lakes Datum of 1985
NGVD29 = National Geodetic Vertical Datum of 1929
NAVD88 = North American Vertical Datum of 1988

1.2 Detailed Site Information

Ginna is a one unit site located on the southern shore of Lake Ontario, in Ontario, NY. The site property consists of approximately 426 acres of partially wooded land. The general site layout is shown in Figure 1.2-1.

1.2.1 Site Layout and Topography

The surface of the land on the southern shore of Lake Ontario, at the site and east and west of it, is either flat or gently rolling. It slopes upward to the south from an elevation of about 255 ft near the edge of the lake; to 440 ft at Ridge Road (New York State Highway 104), 3.5 miles south of the lake.

The confluence of two streams, Deer Creek (which generally flows west to east) and Mill Creek (which generally flows south to north) is located near the southwestern portion of the site. The streams flow along the southern portion of the site into Lake Ontario. For the purposes of this report, the portion of the stream from the confluence point of Mill Creek and Deer Creek to the discharge point into Lake Ontario will also be referred to as

Deer Creek. The contributory drainage area for Deer Creek is about 14.5 square miles. Deer Creek is classified as a perennial stream.

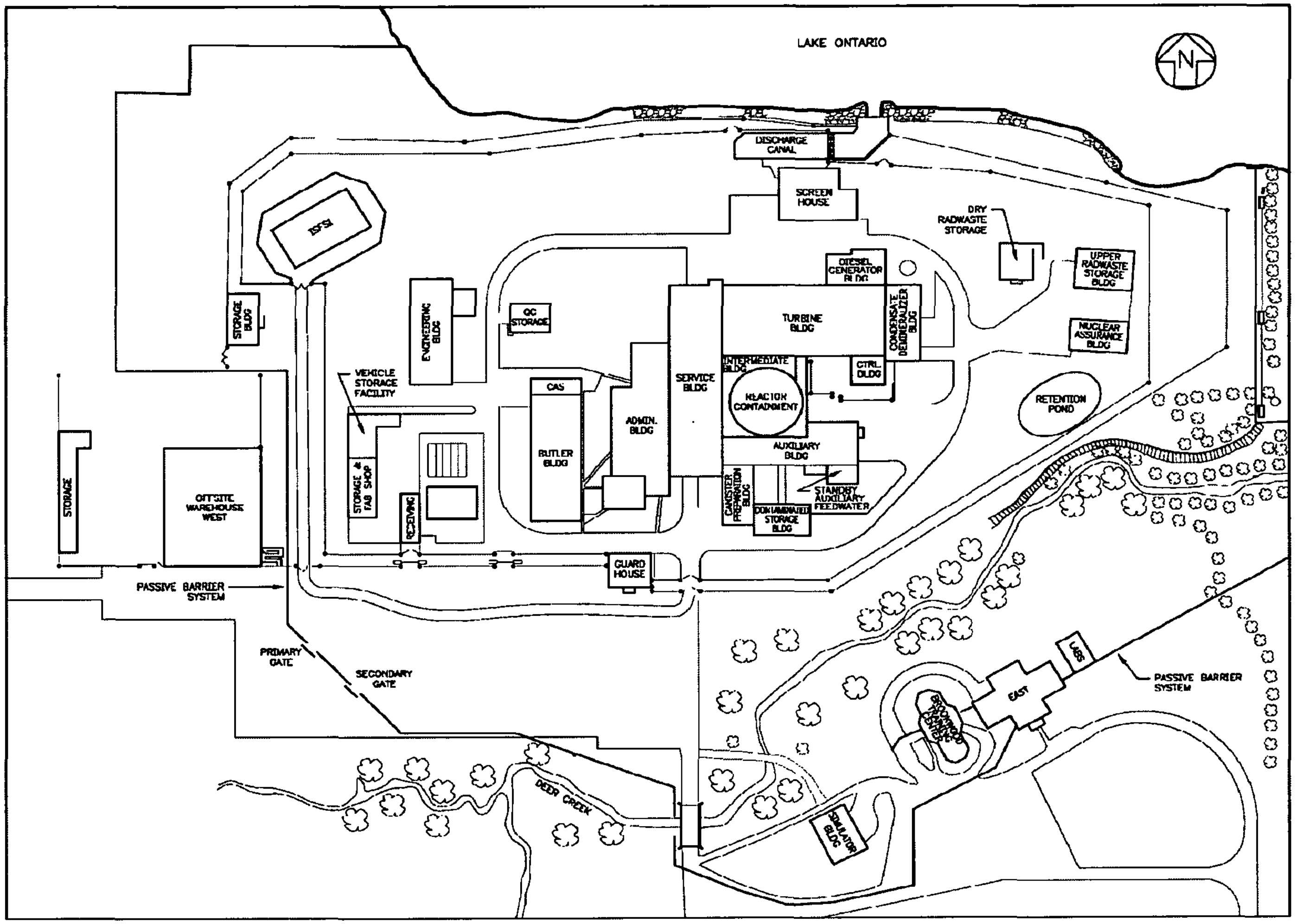
The shoreline of the Ginna site is protected by an armor stone revetment.

1.2.2 Elevation of Safety Structures, Systems and Components

The main plant area and buildings are at grade elevation 270.0 ft. The north side of the turbine building and the screen house are at elevation 253.5 ft. Flooding of the Screen House is not considered to impact safety-related SSC below elevation 254.8 ft (Ginna, 2011, Section 2.4.2.2). The plant grade entrances to the auxiliary building are at elevation 271 ft. The lowest safety-related equipment is in the subbasement of the auxiliary building at elevation 221.5 ft (Ginna, 2011, Section 2.4.7). Additional flood protection measures and resulting protection elevations are discussed in Section 1.4.2.

The plant is protected from lake flooding by a shoreline revetment with a top elevation of 261.0 ft.

Figure 1.2-1: General Site Layout



1.3 Current Design Basis Flood Elevations

The current design basis and related flood elevations for Ginna are described in the Ginna UFSAR (Ginna, 2011, Section 2.4) as well as the recent walkdown report required as part of NRC's 10 CFR 50.54(f) letter (Ginna, 2012). The summary of the design basis below was prepared using these documents.

Deer Creek probable maximum flooding is the bounding design basis flood for Ginna. The Deer Creek discharge flow rate of 26,000 cfs results in flood waters at an elevation of 273.8 feet on the south wall of the Auxiliary Building, 272 feet in the main plant area between the Auxiliary Building and Turbine Building, and an elevation of 256.6 feet in the north yard area between the Screen House and the Turbine Building. (Ginna, 2012, Section 3a)

The probable maximum lake level was determined to be 253.28 feet. This level would result from a Tropical Storm and the associated phenomena. The maximum design basis wave run-up elevation from Lake Ontario was calculated to be 260.94 feet. (Ginna, 2012, Section 3a)

Flood water from local intense precipitation will pond to an elevation of approximately 254.5 ft in the vicinity of the screen house. (Ginna, 2011, Section 2.4.2.2)

1.4 Current Licensing Basis Flood Protection and Mitigation Features

The Ginna licensing basis for flooding protection is described in the Ginna UFSAR (Ginna, 2011, Section 2.4) as well as the recent walkdown report required as part of NRC's 10 CFR 50.54(f) letter (Ginna, 2012).

1.4.1 Flooding Mechanisms

The CLB at Ginna includes a screening for flood mechanisms listed below (Ginna, 2011, Section 2.4.2 through Section 2.4.6):

1. Local Intense Precipitation
2. Flooding in Streams and Rivers
3. Storm Surge
4. Ice Induced Flooding
5. Cooling Water Structures, Canals, Reservoirs

The current controlling flood at Ginna results from the Deer Creek probable maximum flood (PMF).

1.4.2 Durations

A flood duration of approximately 6.5 hours is estimated for the Deer Creek PMF scenario (Ginna, 2012, Section 3a). Duration of flooding is not considered relevant to impacts to safety-related equipment at the site, and is not currently part of the design or licensing basis.

1.4.3 Flood Protection Components

External flood protection requirements in the Current Licensing Basis are as follows (Ginna, 2012, Section 3a).

- A water seal over the 3 inch rattle space between the Containment and the Auxiliary Building walls.
- A portable dam section in front of the two access doors to the Auxiliary Building providing protection to 273.8 ft.
- A portable dam section in front of the rollup door in the Auxiliary providing protection to 273.8 ft.

- Concrete masonry block walls on the south side of the plant designed to withstand the hydrostatic loading.
- Exterior doors to the Diesel Generator Building modified to prevent water ingress. Structural adequacy of the exterior walls designed to resist loads imparted by the floodwater.
- An armor stone revetment along the Lake Ontario shoreline with a top elevation of 261 ft. This feature provides erosion protection as well as prevents lake surge and wave impacts to the site.
- The low roof sections of the Auxiliary Building, Control Building, and Diesel Generator Building have been provided with scuppers designed to ensure that any rainwater resulting from a design-basis storm would not accumulate on the roofs and cause damage. The scuppers are located so that their outflow will not damage any surrounding plant structures or equipment. The flow from the scuppers will not discharge onto equipment or structures required for safe shutdown.

1.4.4 Flood Protection Procedures

Ginna institutes flood protection procedures when Deer Creek reaches the level of the handrails of the Driveway Bridge (approximately 2 ft above the roadway surface elevation of 255.7 ft) over Deer Creek which is significantly below the plant elevation of 271 ft. This provides operators with adequate time to install flood protection equipment prior to site inundation. These technical procedures provide for installation of the flood barriers and for connection of the alternative cooling water supply to the Diesel Generator, assuming Service Water will be lost as a result of flooding of the Screen House. (Ginna, 2012, Section 3a)

1.5 Licensing Basis Flood-Related and Flood Protection Changes

No changes to the licensing basis flood elevations or flood protection have been made.

1.6 Watershed and Local Area Changes

1.6.1 General Site Hydrological Description

The Ginna site is located on the southern shore of Lake Ontario in the Lake Ontario watershed. That hydrologic setting generally provides an overland pathway for runoff directly into the lake with any streams mostly small and intermittent, including Deer Creek.

1.6.2 Watershed Changes

Lake Ontario outflows have been regulated since 1960, primarily through the Moses-Saunders power dam near Cornwall and Massena, New York about 100 miles from the outlet of Lake Ontario (USACE, 2007). Prior to the beginning of flow regulation, the elevation of the lake surface was controlled by a natural rock weir located about 4 mi downstream from Ogdensburg, NY, in the Galop Rapids reach of the St. Lawrence. Long Sault Dam, located near Long Sault, Ontario, acts as a spillway when outflows are larger than the capacity of the Moses-Saunders power dam. A third structure at Iroquois, Ontario, is principally used to help to form a stable ice cover and regulate water levels at the power dam. These facilities are under the authority of the International St. Lawrence River Board of Control (IJC, 2006) and were designed to withstand seismic and flood events.

Prior to regulation, Lake Ontario levels ranged from a maximum of 249.3 ft (IGLD85) in June 1952 to a minimum of 242.6 ft (IGLD85) in November 1934, a range of 6.6 ft. Over the past three decades of regulation, that range has been reduced to 4.3 ft. If not regulated, projected lake levels would have reached approximately 250.2 ft (IGLD85) in July 1986 and 244.73 ft (IGLD85) in February 2000, a range of 5.5 ft. As currently regulated, the mean annual variability is 1.7 ft, with lake levels ranging from 245.0 ft (IGLD85) to 246.7 ft (IGLD85). (USGS, 2007).

Lake Ontario has been regulated by the International Joint Committee (IJC) (formerly the International St. Lawrence River Board of Control, ISLRBC) under Plan 1958-D since 1960. Proposals (Plan Bv7, 2011) to modify the regulated water levels are currently under study and review. Upon the completion of the proposed plan, the discharge of water from Lake Ontario and the flow of water through the International Rapids Section shall be regulated from elevation 243.3 ft (IGLD85) (navigation season) to elevation 247.3 ft (IGLD85). Under regulation, the frequency of occurrences of monthly mean elevations of approximately 246.3 ft (IGLD85) and higher on Lake Ontario shall be less than would have occurred in the past. For the purpose of this evaluation, the proposed maximum and minimum lake levels will be used as appropriate.

1.6.3 Local Area Changes

Local area changes have been minimal since plant operation began at the plant site.

Location and configuration of all current structures were inputs for the Local Intense Precipitation (Section 2.1) and Probable Maximum Flood on Deer Creek calculations as related to the flooding impacts on safety-related SSC.

1.7 Additional Site Details

There are no additional site details.

1.8 References

AREVA, 2013. AREVA Document No. 32-9190267-000, Probable Maximum Storm Surge for Nine Mile Point, Appendix A.

Ginna, 2011. R. E. Ginna Nuclear Power Plant Updated Final Safety Analysis Report (UFSAR) Revision 23, December 6, 2011, See AREVA Document No. 38-9191389-000.

Ginna, 2012. Response to 10 CFR 50.54(f) Request for Information Recommendation 2.3 Flooding, Constellation Nuclear Energy Group, November 27, 2012, NRC Accession No. ML12335A029.

IJC, 2006. Options for Managing Lake Ontario and St. Lawrence River Water Levels and Flows. Final Report by the International Lake Ontario- St. Lawrence River Study Board to the International Joint Commission, March 2006.

NRC, 2011. NUREG/CR-7046: Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America" U.S. Nuclear Regulatory Commission (U.S. NRC). Springfield, VA: National Technical Information Service, 2011.

NRC, 2012. Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(F) Regarding Recommendations 2.1,2.3, And 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident, U.S. Nuclear Regulatory Commission, March 2012.

USACE, 2007. 2007 US Army Corps of Engineers National Coastal Mapping Program (NCMP) Topo/Bathy Lidar: Lake Ontario (NY Shoreline) and Lake Superior (Apostle Islands, WI), 2007.

USGS, 2007. Lake-Level Variability and Water Availability in the Great Lakes, Circular 1311, U.S. Geological Survey, Wilcox, Douglas A., Thompson, Todd A., Booth, Robert K., and Nicholas, J.R., 2007.

2.0 FLOODING HAZARD REEVALUATION

The flooding hazard reevaluation for each of the eight flood causing mechanisms required in Attachment 1 to Enclosure 2 of NRC's March 2012 10 CFR 50.54(f) letter, as well as a combined effect flood, is described in the following subsections. Based on the new evaluations, the controlling flood event for Ginna is a combined effect scenario including a PMF event coincident with a 25-year storm surge and wave runup (See Section 2.9).

2.1 Local Intense Precipitation

This section addresses the potential for flooding at Ginna due to the Local Intense Precipitation (LIP) event. The LIP event is a distinct flooding mechanism that consists of a short-duration, locally heavy rainfall centered upon the plant site itself. Based on NUREG-7046, the LIP is deemed equivalent to the 1-hr, 1-mi^2 PMP (NRC, 2011, Section 3.2). The Local Intense Precipitation calculation for Ginna is documented in full detail in a separate calculation (AREVA, 2014).

2.1.1 Method

2.1.1.1 Local Intense Precipitation

The hierarchical hazard assessment (HHA) approach described in NUREG/CR-7046 (NRC, 2011, Section 2) was used for the evaluation of the LIP and resultant water surface elevation at Ginna.

The HHA approach is consistent with the following standards and guidance documents:

1. NRC Standard Review Plan, NUREG-0800, revised March 2007;
2. NRC Office of Standards Development, Regulatory Guides:
    a. RG 1.102 – Flood Protection for Nuclear Power Plants, Revision 1, dated September 1976;
    b. RG 1.59 – Design Basis Floods for Nuclear Power Plants, Revision 2, dated August 1977; and
3. American National Standard for Determining Design Basis Flooding at Power Reactor Sites (ANSI/ANS 2.8 - 1992)

With respect to LIP, the HHA used the following steps:

1. Define FLO-2D model limits for the LIP analysis.
2. Develop the FLO-2D computer model with site features.
3. Develop LIP/PMP inputs.
4. Perform flood simulations in FLO-2D and to calculate maximum flood depths throughout the Ginna site.

2.1.2 Results

2.1.2.1 Local Intense Precipitation

2.1.2.1.1 FLO-2D Model Limits for LIP Analysis

Due to anticipated unconfined flow characteristics, a two-dimensional hydrodynamic computer model, FLO-2D, was used for the LIP Analysis. FLO-2D is a physical process model that routes flood hydrographs and rainfall-runoff over unconfined flow surfaces or in channels using the dynamic wave approximation to the momentum equation (FLO-2D, 2012). The watershed applicable for the LIP Analysis was computed internally within FLO-2D based on current site topographic data (spot elevations and one-foot contours) input into FLO-2D.

The selected grid element size for the project was 30 feet by 30 feet. Grid elements along the Lake Ontario shoreline were selected as outflow grid elements.

2.1.2.1.2 FLO-2D Computer Model with Site Features

The FLO-2D model developed for the LIP analysis was based on Ginna site features including: topography, buildings, channel segments, and hydraulic structures. Manning's n coefficients which are inputs to the FLO-2D model were assigned based on the various land cover types at Ginna.

Topography: The elevation data used to develop the FLO-2D model consist of surveyed topographic data of the site provided in AutoCAD format (Ginna, 2012).

Manning's Roughness Coefficient: Land use categories were selected based on land cover data (NLCD, 2006 and AREVA, 2014). Manning's n value selected for each land cover category was based on FLO-2D Reference Manual (FLO-2D, 2012).

Buildings: Flow obstructions due to buildings were incorporated into the model as elevated grid elements. The FLO-2D model grid elements representing the buildings were identified based on orthoimagery in ArcMap 10.0.

Grid elements that were completely within the aerial extent of a building were assigned elevations at least 5 feet higher than the surrounding topography. Uniform elevations were assigned to grid elements representing a single building to ensure that runoff from rooftops was uniformly distributed to the surrounding areas. For buildings with different rooftop elevations adjacent to each other, the relative change in rooftop elevations were represented as a 2 foot relative difference in building grid element elevations. This ensures that general flow directions of runoff from rooftops were considered. Representative grid elements for the purpose of reporting results for the Standby Auxiliary Feedwater Building and the proposed Standby Auxiliary Feedwater Building Annex were selected as the elements corresponding to the entrances into these buildings based on information provided by Ginna (Ginna, 2013). Representative grid elements for the purpose of reporting results for all other modeled safety structures at the site were conservatively selected as the elements with the highest water elevation. See Figures 2.2-8 through 2.2-12.

Channel Segments: The model includes three channel segments. The location and cross-sections of the channel segments were based on the surveyed topographic map (Ginna, 2012):

1. The segment representing Deer Creek is approximately 3,430 ft long and extends from the western computational boundary of the model to the confluence point of Deer Creek and Mill Creek. Deer Creek was modeled as a natural channel.
2. The segment representing the Mill Creek is approximately 4,770 ft long and extends from Lake Road to Lake Ontario. Mill Creek was modeled as a natural channel.
3. The Discharge Channel was modeled as a uniform rectangular channel with a depth and width of 15 ft and 40 ft, respectively (Ginna, 2011).

Channel Outflow Boundary: A channel outflow node was assigned to the most downstream channel element to allow all inflows to that element to be discharged into Lake Ontario. The FLO-2D model assigns a flow depth to the channel outflow element based on a weighted average of the upstream flow depths (FLO-2D, 2012). This ensures that normal flow conditions are approximated at the downstream end of the channel. Sensitivity analyses indicated that the elevation of Lake Ontario at its upper regulated limit of 248 feet (Ginna, 2011) do not effect LIP flood elevations due to backwater effects. The normal depth outflow node boundary condition used resulted in a more stable FLO-2D model with lesser conservation of mass error relative to using a set Lake elevation boundary condition.

Hydraulic Structures: The Ginna Access Road Culverts and the Driveway Bridge (Figure 2.2-8) were modeled as completely blocked by debris or otherwise compromised. This was achieved by modifying the channel cross-section elevations at these roads to reflect the top of road elevation. The top of road elevation at the Ginna Access Road is 261.2 ft and the Driveway is at 255.7 ft.

2.1.2.1.3 LIP/PMP inputs

The LIP parameters were defined using National Weather Service Hydrometeorological Reports 51 and 52 (HMR-51 and HMR-52) as prescribed in NUREG/CR-7046 (NRC, 2011, Section 3.2). A front-loaded temporal distribution was used as per NUREG/CR-7046 (NRC, 2011). The total rainfall depth for the 1-hour, 1-mi^2 PMP is 16 inches, with peak intensity of 5.4 inches during the first 5 minutes. The total rainfall depth for the 6-hour probable maximum precipitation (PMP) is 22.4 inches. The 6-hour PMP hyetograph was constructed using the 1-hour PMP for the first hour and equal rainfall increments for the next 5 hours (Figure 2.1-1) (AREVA, 2013). The model conservatively assumes no rainfall losses (initial abstraction or infiltration) during the LIP event.

2.1.2.1.4 LIP Simulation Results

Figure 2.1-2 shows the FLO-2D grid with modeled LIP water surface elevations. Figure 2.1-3 shows the FLO-2D grid with modeled maximum flow depth. Figure 2.1-4 shows the FLO-2D grid with modeled maximum flow velocity vectors, indicating the direction and speed of overland flow. Based on the LIP model simulation, maximum water surface elevations at Ginna safety-related SSC range from 255.8 ft near the Screen House to 270.9 ft at the Reactor Containment and Control Buildings. The results of the Ginna FLO-2D model simulation are presented in Table 2.1-1. Figures 2.1.5 through 2.1.6 are time-series plots of flood elevations for specific cell locations at the Ginna site.

2.1.3 Conclusions

The maximum water surface elevation due to the LIP at Ginna results from a total rainfall depth of 16 inches within one hour and 22.4 inches within 6 hours. In the immediate vicinity of the main buildings at Ginna, predicted maximum water surface elevations resulting from the LIP range from 255.8 ft at the Screen House to approximately 270.9 ft at the Reactor Containment and Control Buildings.

At Ginna, the water elevation resulting from the LIP is not expected to exceed the design basis flood elevation at any of the main structures.

2.1.4 References

AREVA, 2013. AREVA Document No. 32-9190272-000, Probable Maximum Precipitation at R.E. Ginna.

AREVA, 2014. AREVA Document No. 32-9190271-001, Flood Hazard Re-evaluation – Local Intense Precipitation – Generated Flow and Elevations at R.E. Ginna Nuclear Power Plant.

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Ginna, 2013. Ginna Drawing No. 33013-28861 "Standby Auxiliary Feedwater Building Annex", 12/19/12, See AREVA Document No. 38-9202544-000.

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Table 2.1-1: LIP Simulation Results

Structure	Representative Grid Element Number (see Figure 2.2-11)	Design Basis Flood Levels (ft, NGVD29)*	LIP Peak Elevation (ft, NGVD29)**	Maximum Flow Depth (ft)	Maximum Flow Velocity (fps)
Reactor Containment	6193	272.0	270.9	0.7	0.4
Auxiliary Building	6651	272.0 to 273.8	270.7	0.2	0.5
Turbine Building	4364	256.6	255.8	1.8	1.5
Control Building	5740	272.0	270.9	0.5	0.6
All-Volatile-Treatment-Building	5286	272.0	270.8	0.1	0.8
Standby Auxiliary Feedwater Pump Building	6879	273.0	270.2	0.2	0.6
Proposed Standby Auxiliary Feedwater Pump Building Annex	7105	N/A	270.5	0.6	0.8
Screen House	3840	256.6	255.8	2.1	0.7
Diesel Generator Building	4014	256.6	255.8	2.1	3.0

Notes: * - Current design basis flood elevations are approximated from Ginna UFSAR (Ginna, 2011) and are based on flooding from the Deer Creek

** - LIP Peak Elevations are approximate and vary depending on the exact location. Elevations were conservatively rounded up, and peak elevations in the time-series plots are slightly lower that the peak elevations above.

Figure 2.1-1: 6-hour PMP - Incremental Hyetograph

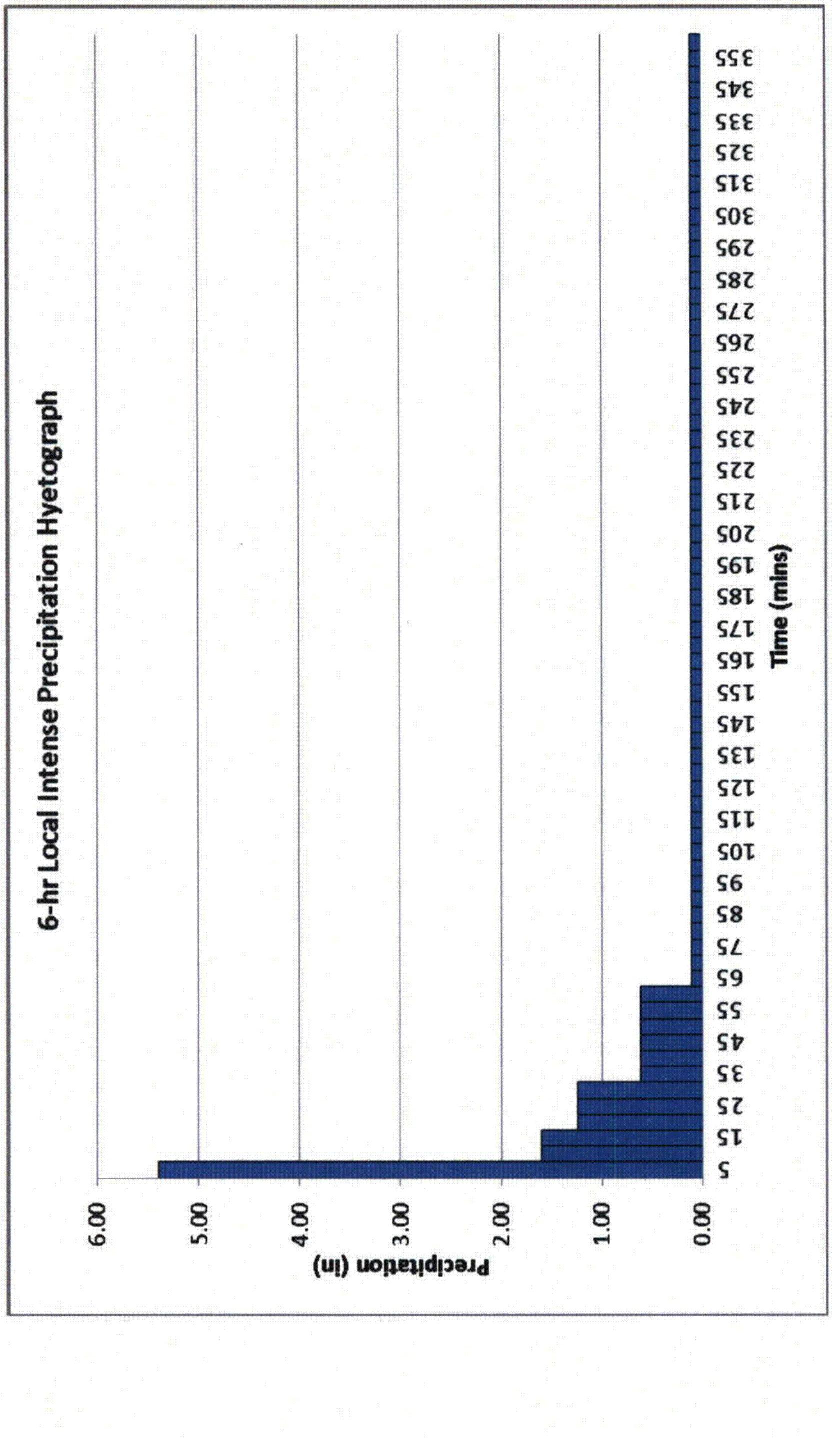


Figure 2.1-2: Grid Element Maximum Water Elevation (ft, NGVD29)

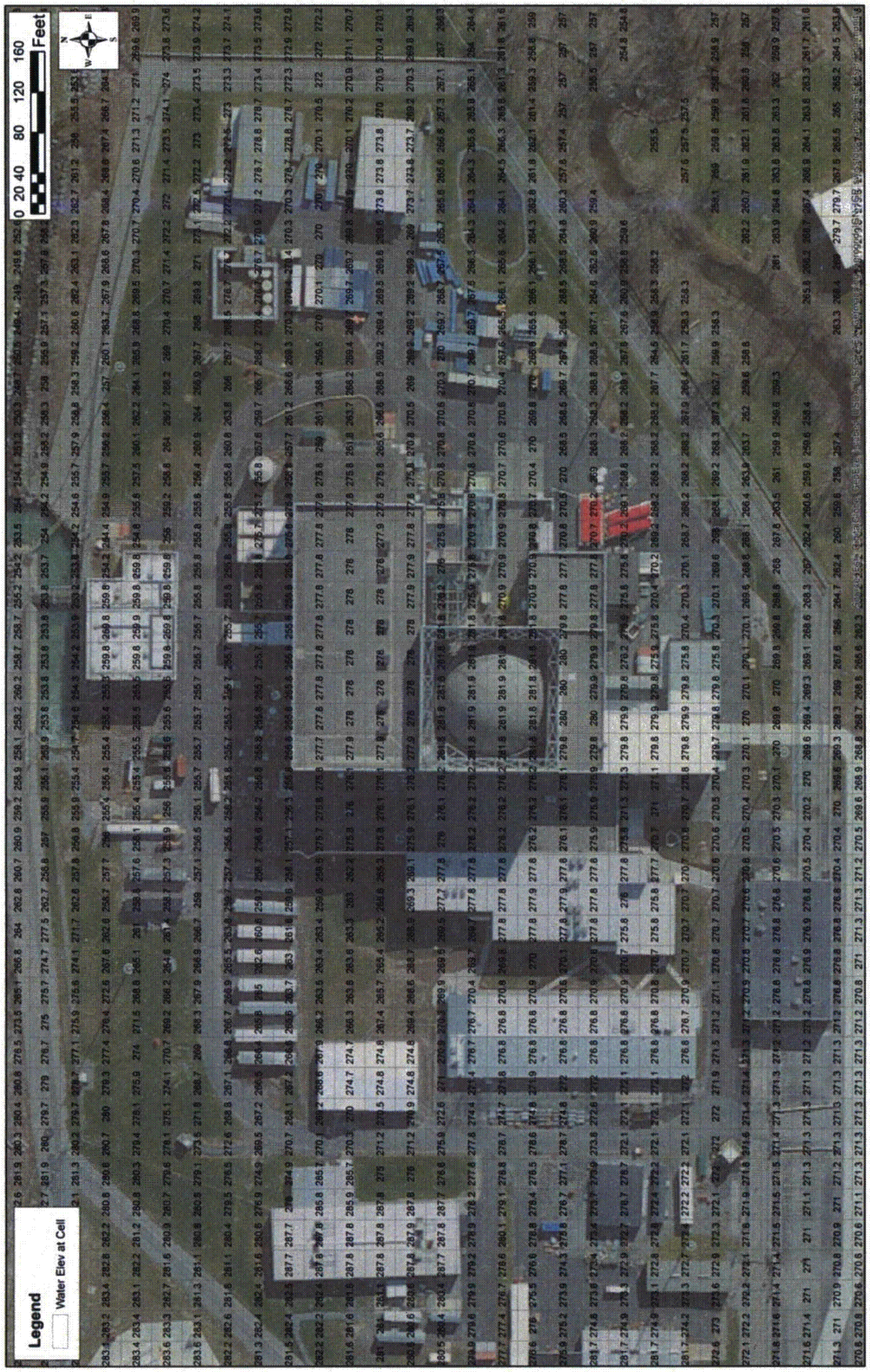


Figure 2.1-3: Grid Element Maximum Flow Depth (ft, NGVD29)

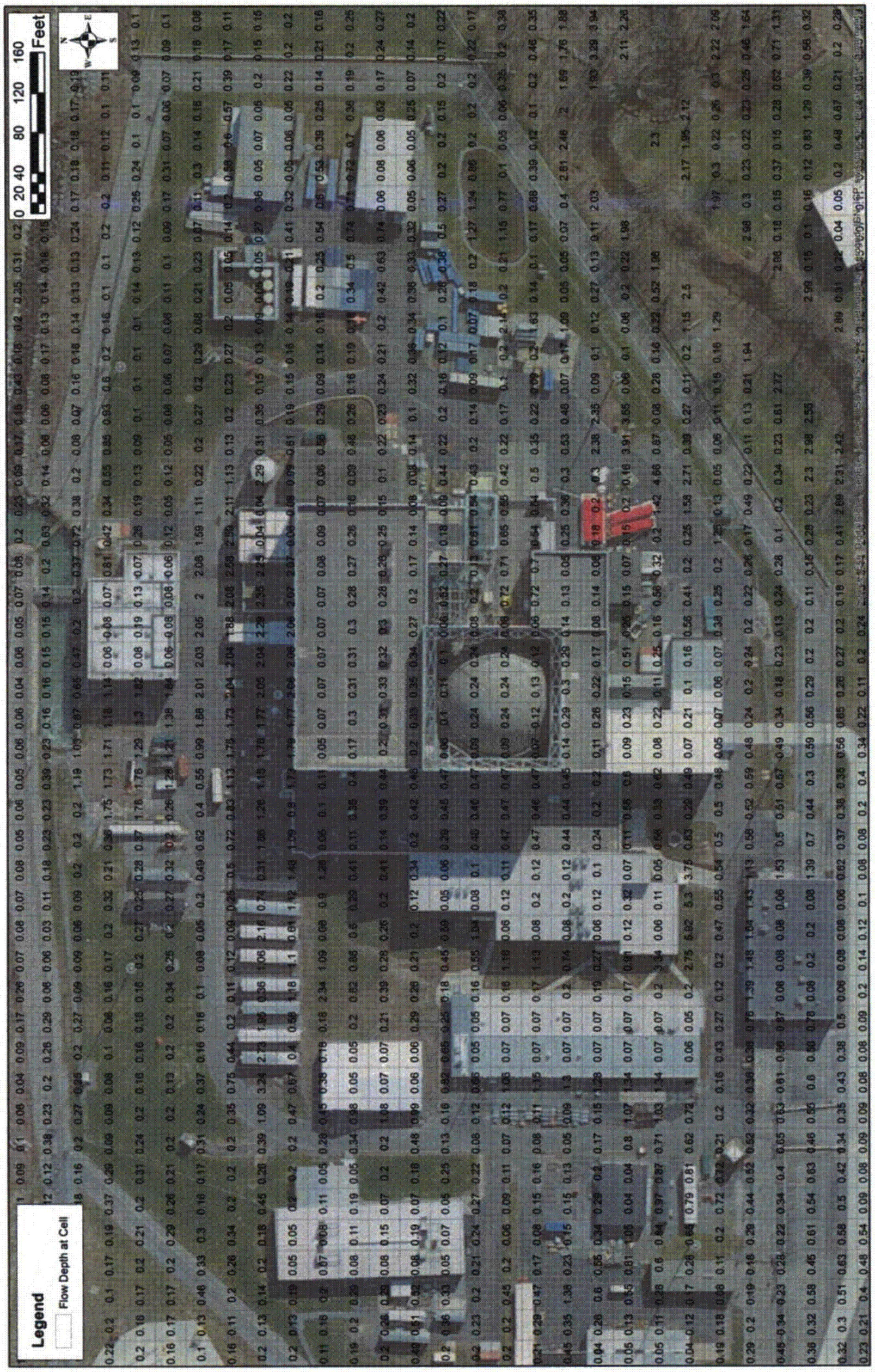


Figure 2.1-4: Grid Element Maximum Velocity Vectors around Ginna

AREVA

Figure 2.1-5: Flood Elevation Timeplot, North of Turbine Building

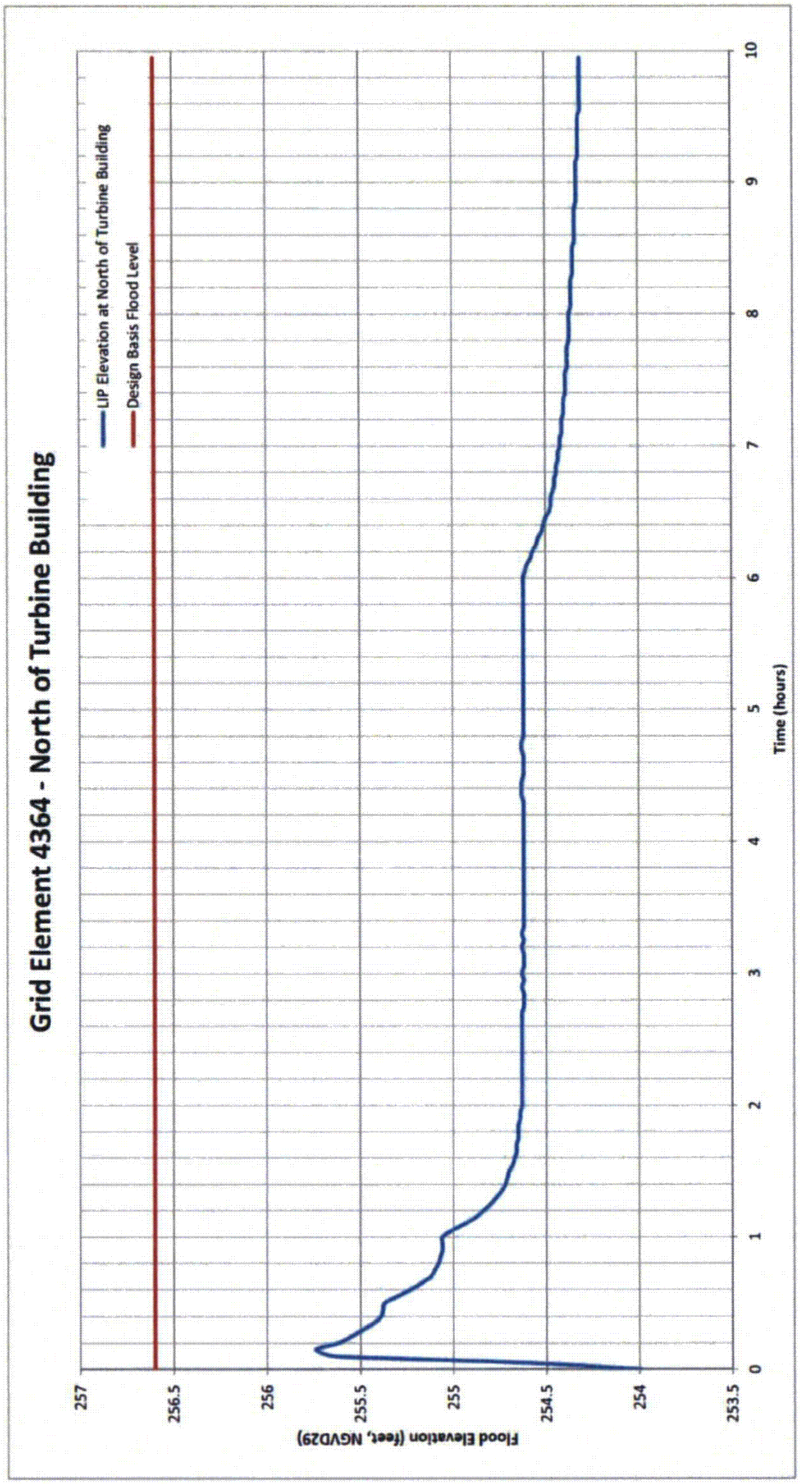
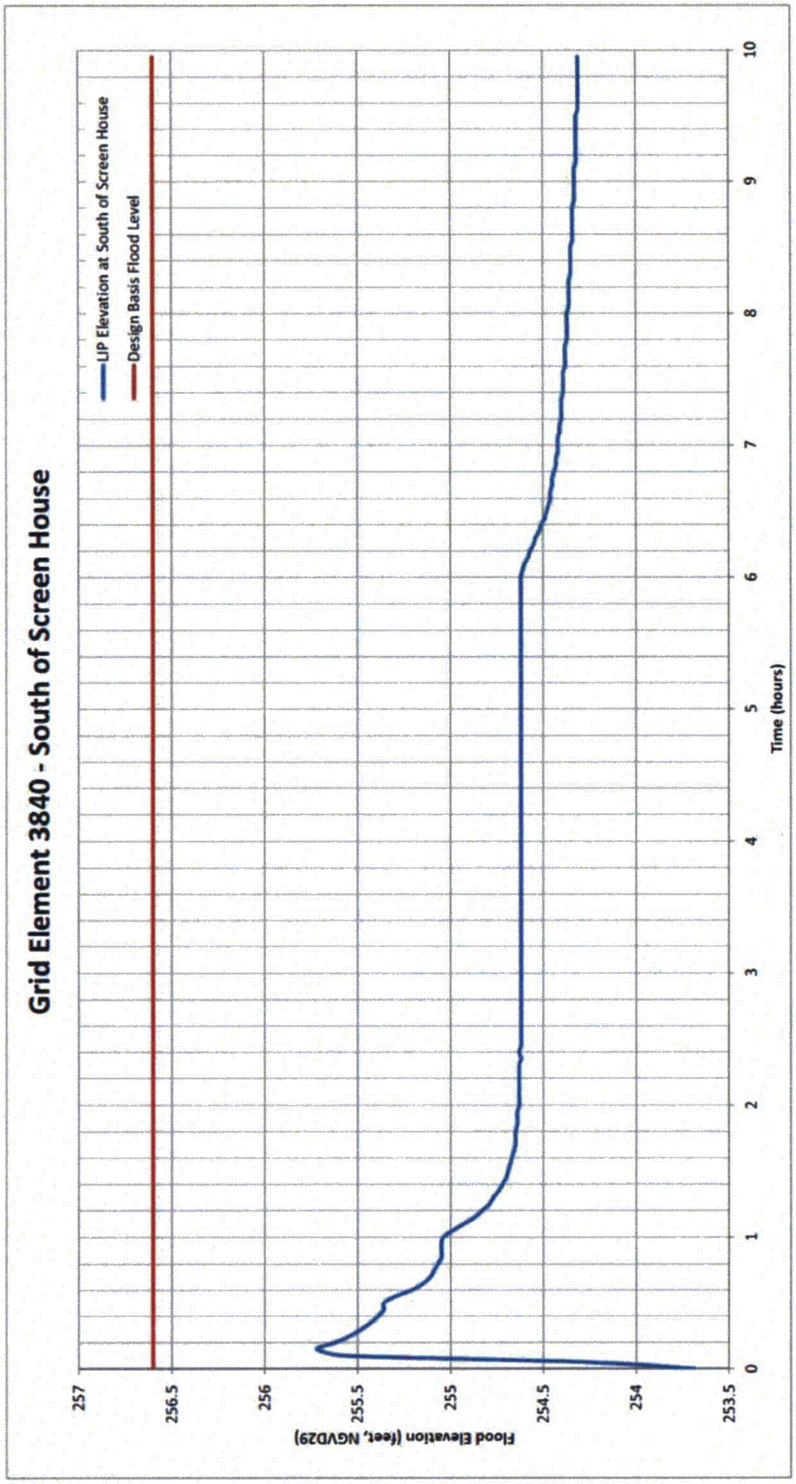


Figure 2.1-6: Flood Elevation Timeplot, South of Screen House



2.2 Probable Maximum Flood in Streams and Rivers

This section addresses the potential for flooding at Ginna due to the Probable Maximum Flood (PMF) in Deer Creek, which traverses the southern portion of the site.

Ginna is located in Ontario, Wayne County, NY along the southern shore of Lake Ontario. The confluence of two streams, Deer Creek (which generally flows west to east) and Mill Creek (which generally flows south to north) is located near the south-western portion of the site. The streams flow along the southern portion of the site into Lake Ontario. For the purposes of this report, the portion of the stream from the confluence point of Mill Creek and Deer Creek to the discharge point into Lake Ontario will also be referred to as Deer Creek. Two crossings (Ginna Access Road and Driveway) cross Deer Creek near Ginna. The Ginna Access Road is located approximately 350 ft downstream from the confluence between the two creeks and about 2,300 ft upstream of the mouth. The Driveway is located approximately 1,400 ft downstream of Ginna Access Road and approximately 900 ft from the mouth. There are five, 5-ft diameter culverts at Ginna Access Road. The Driveway Bridge opening is trapezoidal in shape. The bridge opening is 20 feet wide at the top and 17 feet wide at the bottom. The bridge opening is about 8 feet high. The Ginna Access Road Culverts and the Driveway Bridge have the potential of influencing PMF flood elevations at the site.

Hazard associated with debris transportation coincident with Deer Creek flooding is considered negligible due to the relatively shallow water depth in the vicinity of safety-related SSC coupled with the relatively low flow velocity (less than 5.3 feet per second).

2.2.1 Methodology

The hierarchical-assessment approach (HHA) described in NUREG/CR-7046 (NRC, 2011) was used for the evaluation of the PMF on Deer Creek (AREVA, 2013a) and resultant water surface elevations (AREVA, 2013b).

In particular, the HHA assumptions adopted by the example calculation in Appendix C of NUREG/CR-7046 (NRC, 2011) are:

- Use of conservative Soil Conservation Service (SCS) curve numbers for Antecedent Rainfall Condition (ARC) III;
- Incorporation of an antecedent storm prior to the full PMF; and
- Application of nonlinearity adjustments to SCS Unit Hydrograph (UH).
- Additionally, the two stream crossings near Ginna were assumed to be blocked.

PMP values were computed using methods described in two publications of the NOAA, U.S. Department of Commerce: Hydrometeorological Report No. 51, Probable Maximum Precipitation - United States East of the 105th Meridian (NOAA, 1978) and HMR No. 52, Application of Probable Maximum Precipitation - United States East of the 105th Meridian (NOAA, 1982). The PMP, with a duration of 72 hours, was selected for estimation of the PMF for the combined watersheds of Deer Creek and Mill Creek. An antecedent storm, 40% of the full 72-hour PMP, was modeled. Seasonal variation of the PMP was evaluated based on HMR No. 53 (NOAA, 1980), combined with conservative, potential snowmelt contribution using the energy budget method to rule out the cool-season PMP plus snowmelt as a controlling event.

The SCS (now known as the Natural Resources Conservation Service, NRCS) unit hydrograph method, incorporated in the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) computer model, was used to calculate watershed runoff in this calculation. SCS rainfall-runoff translation parameters, Curve Number (CN) and Lag Time, were calculated. HEC-HMS was used for estimating the PMF hydrograph induced by the 72-hour PMP over the Deer Creek and Mill Creek watersheds (USACE, 2000). As recommended by NUREG/CR-7046 (NRC, 2011), adjustments were made to SCS Unit Hydrograph (UH) to account for nonlinearity runoff response under such a rare and extreme rainfall event. The calculated UH was used within HEC-HMS in place of SCS transform parameters to compute the PMF on the Deer Creek and Mill Creek.

The calculated PMF peak discharges from Deer Creek and Mill Creek were used as input to estimate the PMF flood elevations at Ginna. Due to anticipated significant overbank (floodplain) flow during the PMF, a two-dimensional hydrodynamic computer model, FLO-2D (FLO-2D Pro, 2012), was used in calculating the PMF elevations in lieu of one-dimensional computer models such as USACE Hydrologic Engineering Center River Analysis System (HEC-RAS). FLO-2D is a physical process model that routes flood hydrographs and rainfall-runoff over unconfined flow surfaces or in channels using the dynamic wave approximation to the momentum equation. Overland flood routing in two-dimensions is accomplished through a numerical integration of the equations of motion and the conservation of fluid volume. More information on the FLO-2D software is provided in Appendix A.

2.2.2 Results

2.2.2.1 PMF on Deer Creek

2.2.2.1.1 Rainfall-Runoff Translation Parameters

The contributory drainage area to Deer Creek at its confluence with Lake Ontario is about 14.5 square miles. The two distinct major channels (Deer Creek and Mill Creek), which form the overall watershed area were separately delineated. The Deer Creek sub-watershed is 3.7 square miles and the Mill Creek sub-watershed is 10.8 square miles. The delineated watershed boundaries for Deer Creek and Mill Creek are shown in Figure 2.2-1. The calculated watershed areas are presented in Table 2.2-1.

SCS rainfall-runoff CNs were calculated based on:

- Hydrologic soil groups for Deer Creek and Mill Creek watersheds (NRCS, 2011) as shown in Figure 2.2-2, where Type A indicates the lowest runoff potential and Type D indicates the highest runoff potential;
- Current land use data for the subwatershed areas (NLCD, 2006) as shown in Figure 2.2-3.

Area-weighed composite CNs were calculated. Two ARCs were considered, ARC II (normal conditions) and ARC III (wet conditions). The calculated CNs are summarized in Table 2.2-2.

Lag time is defined as 60 percent of Time of Concentration (Tc). Tc was calculated as the sum of three components: (1) travel time of sheet flow (2) travel time of shallow concentrated flow (3) travel time of open channel flow (NEH, 2010). The estimated flow path for calculation of Tc is shown as Figure 2.2-4. Calculated Tc and lag time are presented in Table 2.2-3.

2.2.2.1.2 PMP Inputs

The PMP calculation was performed in accordance with HMR-51 and HMR-52 (AREVA, 2013c). Total rainfall depth for the 72-hr PMP on the contributory watershed at Ginna was 30.5 inches. An antecedent storm, which is 40% of the 72-hr PMP, was simulated 3 days prior to the start of the full PMP. The final PMP input hyetograph for HEC-HMS simulations is shown in Figure 2.2-5.

Seasonal variation of the PMP was evaluated in combination with snowmelt. The cool-season 72-hour PMP plus maximum daily snowmelt for a 10-square mile watershed at the location of the site is less than the all-season 72-hour PMP for a 10-square mile watershed at the location of the site. It was concluded that the all-season PMP discussed above is the controlling event.

2.2.2.1.3 Nonlinearity Adjustments to UH

The nonlinearity adjustments made to the HEC-HMS calculated SCS UH include (NEH, 2007) a 20% increase in peak discharge of the unit hydrograph, 33% reduction in time to peak of the unit hydrograph and adjustments to the falling limb of the unit hydrograph to conserve the volume under the unit hydrograph as recommended by NUREG/CR-7046 (NRC, 2011). Comparison of the original UH and the nonlinearity-adjusted UHs are presented in Figure 2.2-6.

2.2.2.1.4 Deer Creek PMF Flow

The calculated PMF discharge rates from Deer Creek and Mill Creek for ARC II and ARC III are summarized in Table 2.2-4. The outflow hydrographs from Deer Creek and Mill Creek watersheds are shown in Figure 2.2-7 (with nonlinear adjustments). The peak flow rates in Deer Creek and Mill Creek (20,530 cfs from Mill Creek and 8,140 cfs from Deer Creek) do not occur simultaneously. The combined PMF from Deer Creek and Mill Creek under the 72-hr PMP was determined to be 28,460 cfs, which is rounded to 28,500 cfs for the purpose of this evaluation. This flow incorporates ARC III CN and nonlinearity adjustments.

2.2.2.2 Deer Creek PMF Elevations

2.2.2.2.1 FLO-2D Model Inputs

The FLO-2D computer model was developed based on existing site topography at Ginna and was comprised of 20,109 individual square grid elements; each being 30 feet by 30 feet in size. Grid element elevations are shown in Figures 2.2-9 and 2.2-12. The calculated PMF peak discharge hydrographs from Deer Creek and Mill Creek were used as inflows into the FLO-2D model. Other inputs to the FLO-2D model include:

- Manning's n roughness coefficients based on land cover information (NLCD, 2006). The correlation between the input Manning's n-values and NLCD, 2006 land use categories is presented in Table 2.2-5. Manning's n-values are shown in Figure 2.2-10.
- Channel segments to represent Deer Creek, Mill Creek and the Discharge Canal. The geometries and cross-section data for these segments were based on topographic survey at Ginna (Ginna, 2012) and information contained in the updated FSAR (Ginna, 2011).
- As per NUREG/CR-7046 (NRC, 2011), the Ginna Access Road Culverts and the Driveway Bridge were assumed to be completely blocked by debris or otherwise compromised.
- Area Reduction Factors (ARF) and Width Reduction Factors (WRF) were included to represent buildings that may impede flow at the site.
- Grid elements along the lakeshore were defined as outflow nodes.

An overview of the final FLO-2D model is shown in Figure 2.2-8.

2.2.2.2.2 PMF Elevations at Ginna

Maximum PMF flood elevations at the safety-related SSC generally range from 258.1 ft near the Screen House and Turbine Building to 273.5 ft at the Proposed Standby Auxiliary Feedwater Pump Building Annex. Maximum velocities range from 1.0 feet per second (fps) to 5.3 fps with the highest velocity occurring close to the eastern portion of the All-Volatile-Treatment-Building.

Water from the PMF remains at the SSC for about 5-6 hours with the exception of the southern side of the Screen House, northern portion of Diesel Generator Building, northern portion of the Turbine Building, and the northern portion of the Proposed Standby Auxiliary Feedwater Pump Building Annex, where PMF flow depths exist for about 8 hours.

Maximum PMF elevations north of the Turbine Building, north of the Diesel Generator Building and south of the Screen House exceed their design basis flood elevations for approximately 4 hours. Maximum PMF elevation east of the Control Building and east of the Reactor Building exceed their design basis flood elevations for about 2.5 hours.

The calculated maximum flood elevations due to the 72-hr PMF from the combined contributory watershed of the Deer Creek and Mill Creek are shown in Figure 2.2-13. The maximum flow depths and velocities are shown in Figures 2.2-14 and 2.2-15. The results of this evaluation are summarized in Table 2.2-6.

2.2.3 Conclusions

Based on the PMF calculation for the total contributory drainage area for the Deer Creek and the Mill Creek, the following conclusions can be reached:

- The probable maximum flood elevation on streams results from the All-Season 72-hour PMP depth of 30.5 inches.
- The current design basis peak flood flow in Deer Creek is 26,000 cfs (Ginna, 1983), or about two-thirds of the previous, NRC-calculated PMF peak flow of 38,700 cfs (Ginna, 1982). The flood re-evaluation PMF peak flow in Deer Creek is 28,500 cfs, including adjustments for non-linearity. The re-evaluated PMF peak flow is lower than the previously calculated PMF due principally to refinements in the methodologies used. In particular, the subdivision of the contributory watershed to reflect the separate branches of Deer Creek (i.e., Deer Creek and Mill Creek) results in differences in the timing of the peak flows from each basin, reducing the peak flow at Ginna.
- The peak PMF elevations at the safety-related SSC at Ginna generally range from 258.1 ft to 273.5, corresponding to a PMF peak flow of approximately 28,500 cfs.
- Based on the re-evaluated peak PMF elevations, the Reactor Containment, Turbine Building, Control Building, Screen House and Diesel Generator Building have reduced margins compared to the current design basis flood levels. The Auxiliary Building, All-Volatile-Treatment-Building, Standby Auxiliary Feedwater Pump, and the Proposed Standby Auxiliary Feedwater Pump Building Annex have increased margin compared to the current design basis flood levels.

2.2.4 References

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USACE, 2000. HEC-HMS, Hydrologic Modeling System Technical Reference Manual, CPD-74B, March, 2000.

Table 2.2-1: Watershed Areas

Stream Name	Watershed Area (sq. mi.)	Delineation Point
Deer Creek	3.7	Confluence with Mill Creek (Lat.43°16'33"N; Long. 77°18'39"W)
Mill Creek	10.8	Discharge point at Lake Ontario (Lat.43°16'40"N; Long. 77°18'13"W)

Table 2.2-2: Summary of SCS Curve Numbers

Watershed Name	ARC II (normal)	ARC III (wet)
Deer Creek	83.5	90.4
Mill	81.0	89.4

Table 2.2-3: Time of Concentration (Tc) and Lag (L)

Watershed Name	T_c (hr)	L (hr)	L (min)
Deer Creek	8.1	4.8	291
Mill Creek	10.0	6.0	362

Table 2.2-4: HEC-HMS Calculated Peak Discharge (cfs) - 72-hr PMP

Watershed	ARC	SCS Method w/o Nonlinearity Adjustments	User Specified UHs w/ Nonlinearity Adjustments	Increase (%)
Deer Creek	II (normal)	7,190	8,110	11%
	III (wet)	7,220	8,140	11%
Mill Creek	II (normal)	18,070	20,420	12%
	III (wet)	18,170	20,530	12%
Combined Peak Outflow at Ginna†	II (normal)	24,930	28,330	12%
	III (wet)	25,050	28,500*	12%

†The peak flow rates for Deer Creek and Mill Creek do not occur simultaneously
*Rounded up from the modeled value of 28,460 cfs

Table 2.2-5: Manning's *n* Values and NLCD2006 Land Use Classes

NLCD 2006 CODE	NLCD DEFINITION	MANNING'S N
11	Water	0.025
12	Perennial Ice Snow	0.05
21	Low Intensity Residential	0.1
22	High Intensity Residential	0.08
23	Commercial/Industrial/Transportation	0.06
24	Developed High Intensity	0.05
31	Bare Rock/Sand/Clay	0.08
41	Deciduous Forest	0.4
42	Evergreen Forest	0.6
43	Mixed Forest	0.5
51	Dwarf Scrub	0.35
52	Shrub/Scrub	0.4
71	Grasslands/Herbaceous	0.35
72	Sedge/Herbaceous	0.35
73	Lichens	0.35
74	Moss	0.35
81	Pasture/Hay	0.3
82	Cultivated Crops	0.25
90	Wood Wetlands	0.1
95	Emergent Wetlands	0.1

Table 2.2-6: Summary of PMF Model Results

Structure	Representative Grid Element Number	Design Basis Flood Elevation (ft)*	PMF Peak Elevation (ft)**	Maximum Flow Depth (ft)	Maximum Flow Velocity (fps)
Reactor Containment	6193	272.0	272.4	2.2	1.0
Auxiliary Building	6651	272.0 to 273.8	272.6	2.1	2.8
Turbine Building	4364	256.6	258.1	4.2	3.1
Control Building	5740	272.0	272.4	2.1	2.2
All-Volatile-Treatment-Building	5286	272.0	271.3	0.7	5.3
Standby Auxiliary Feedwater Pump Building	6879	273.0	272.8	2.7	4.0
Proposed Standby Auxiliary Feedwater Pump Building Annex	7105	N/A	273.5	3.6	2.8
Screen House	3840	256.6	258.1	4.4	3.3
Diesel Generator Building	4014	256.6	258.3	4.6	4.3

Notes: * - Current design basis flood elevations are approximated from Ginna UFSAR (Ginna, 2011)

** - PMF Peak Elevations are approximate and vary depending on the exact location

Figure 2.2-1: Watershed Delineation Map

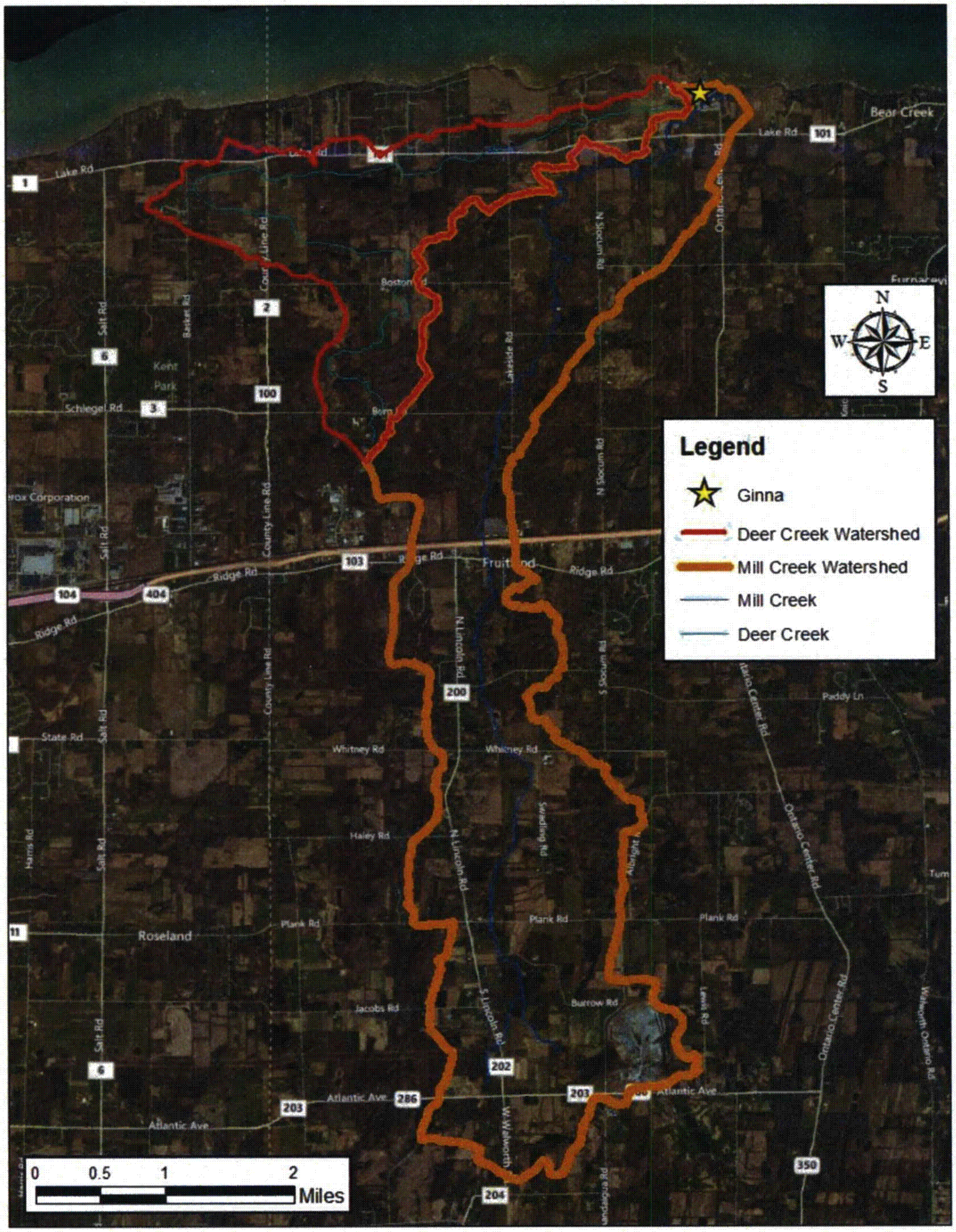


Figure 2.2-2: Hydrologic Soil Groups Map for Watersheds

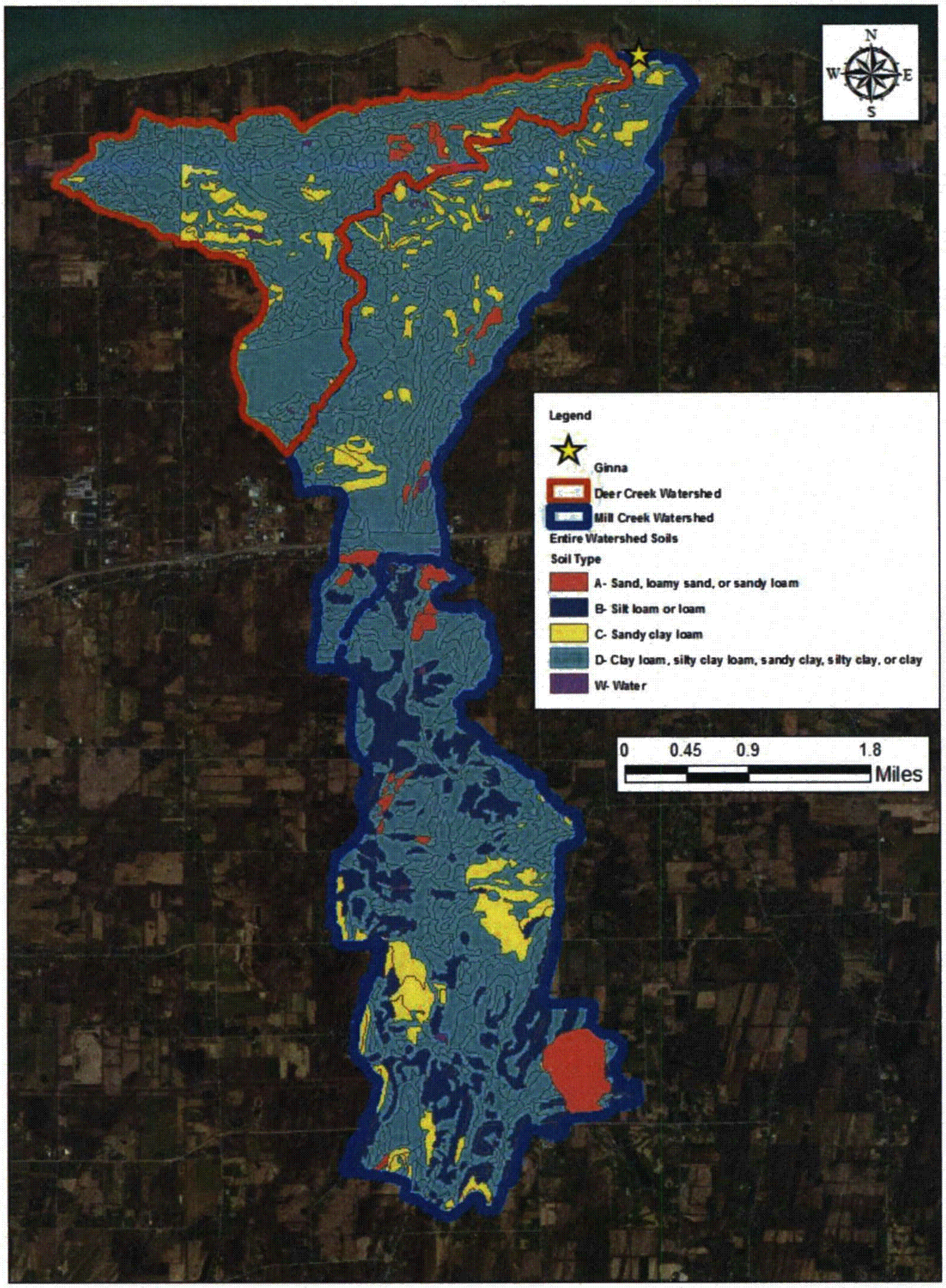


Figure 2.2-3: NLCD 2006 Land Cover Land Use Map for Lakeview Creek Watershed

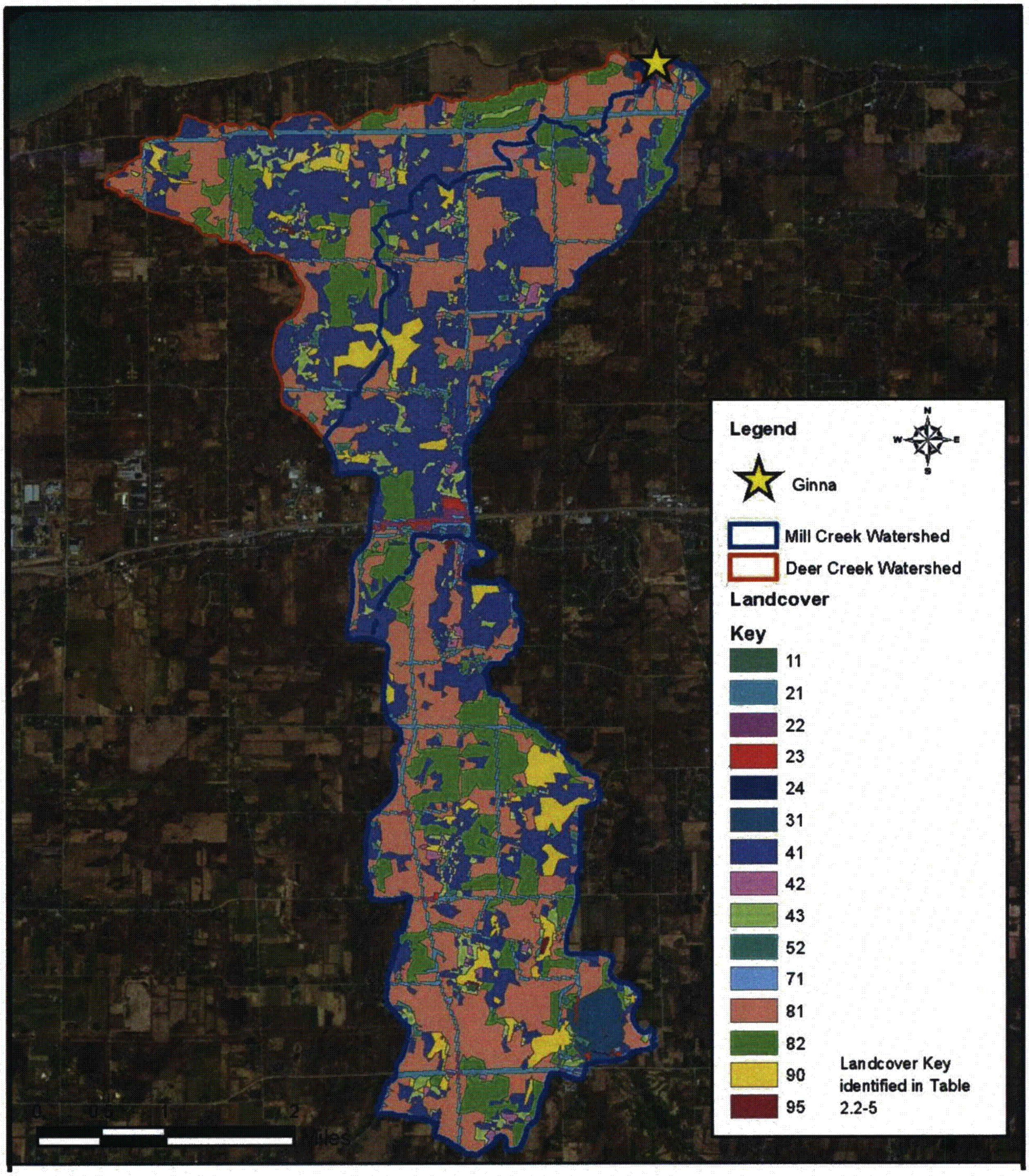


Figure 2.2-4: Flow Path for Time of Concentration for Lakeview Creek Watershed

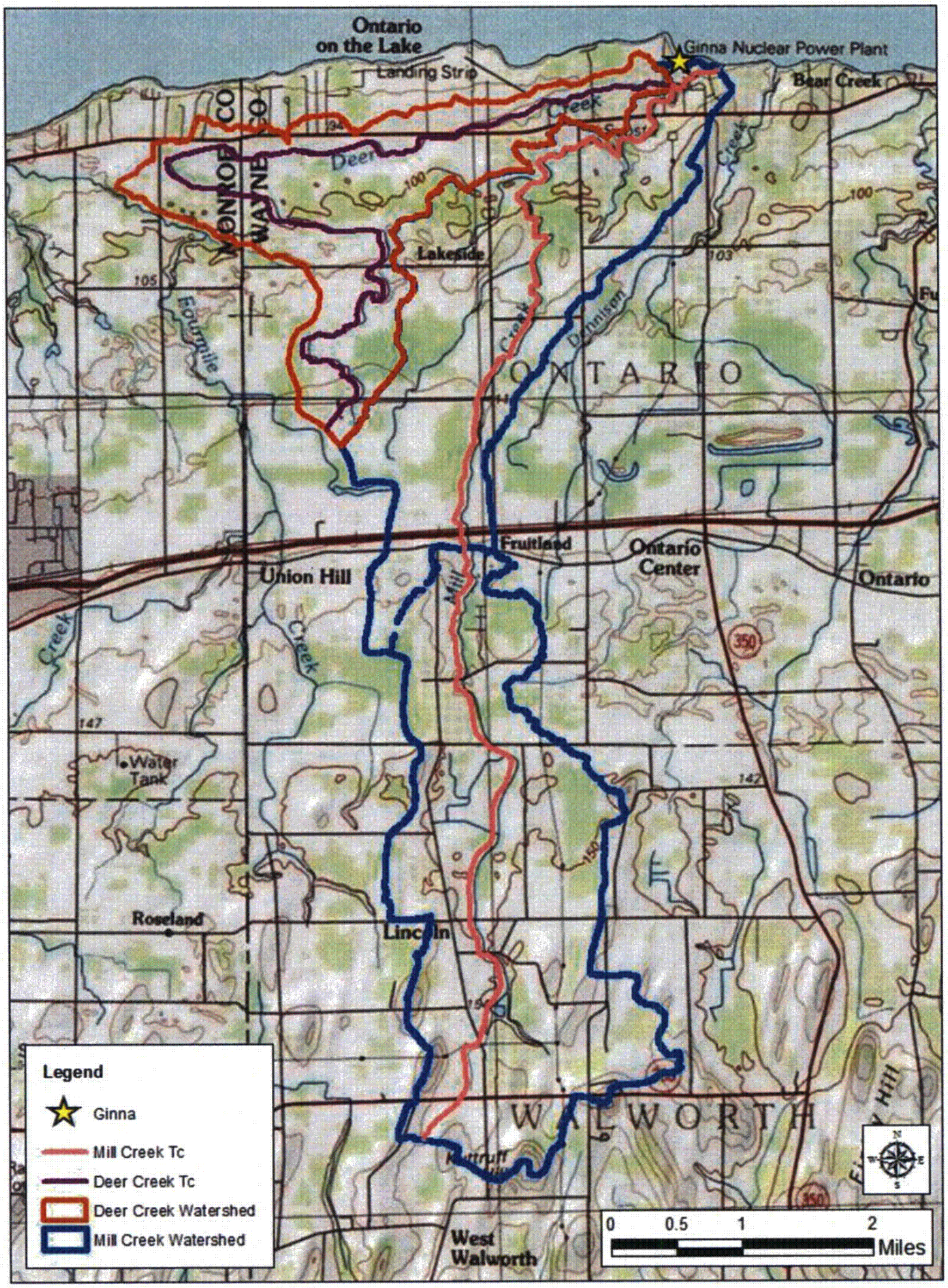


Figure 2.2-5: Input Hyetograph for 72-hr PMP

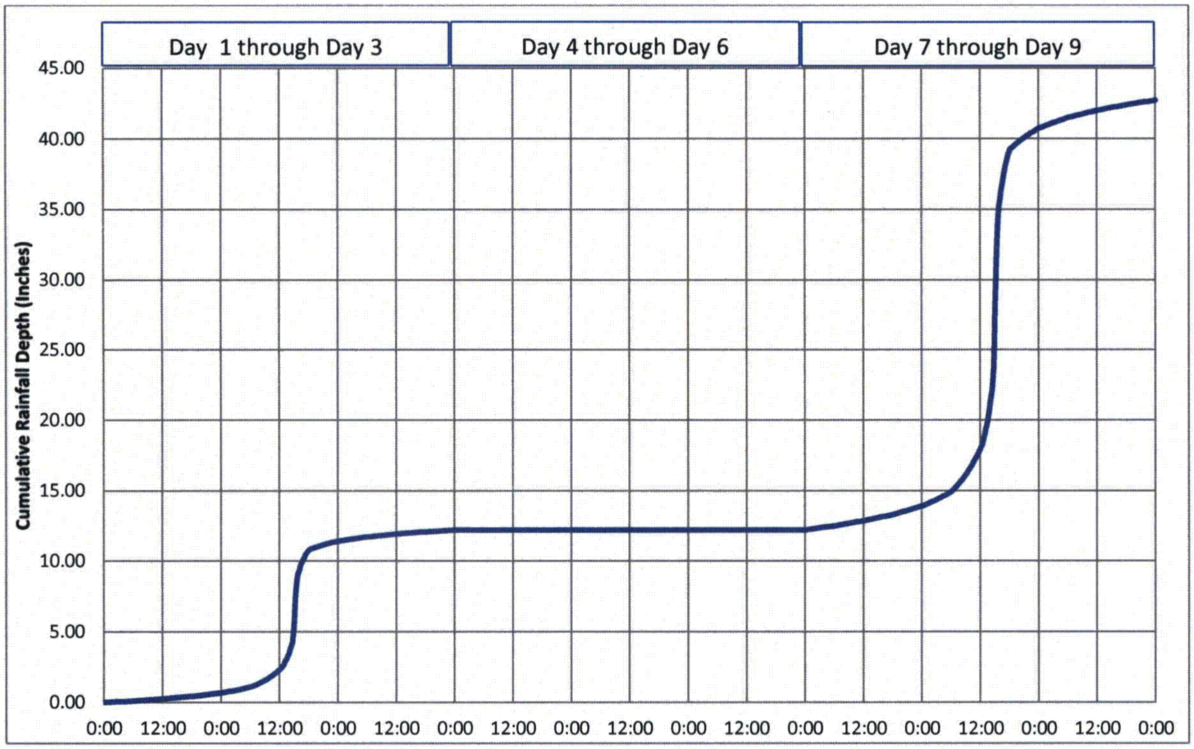


Figure 2.2-6: Unit Hydrograph with Nonlinearity Adjustments

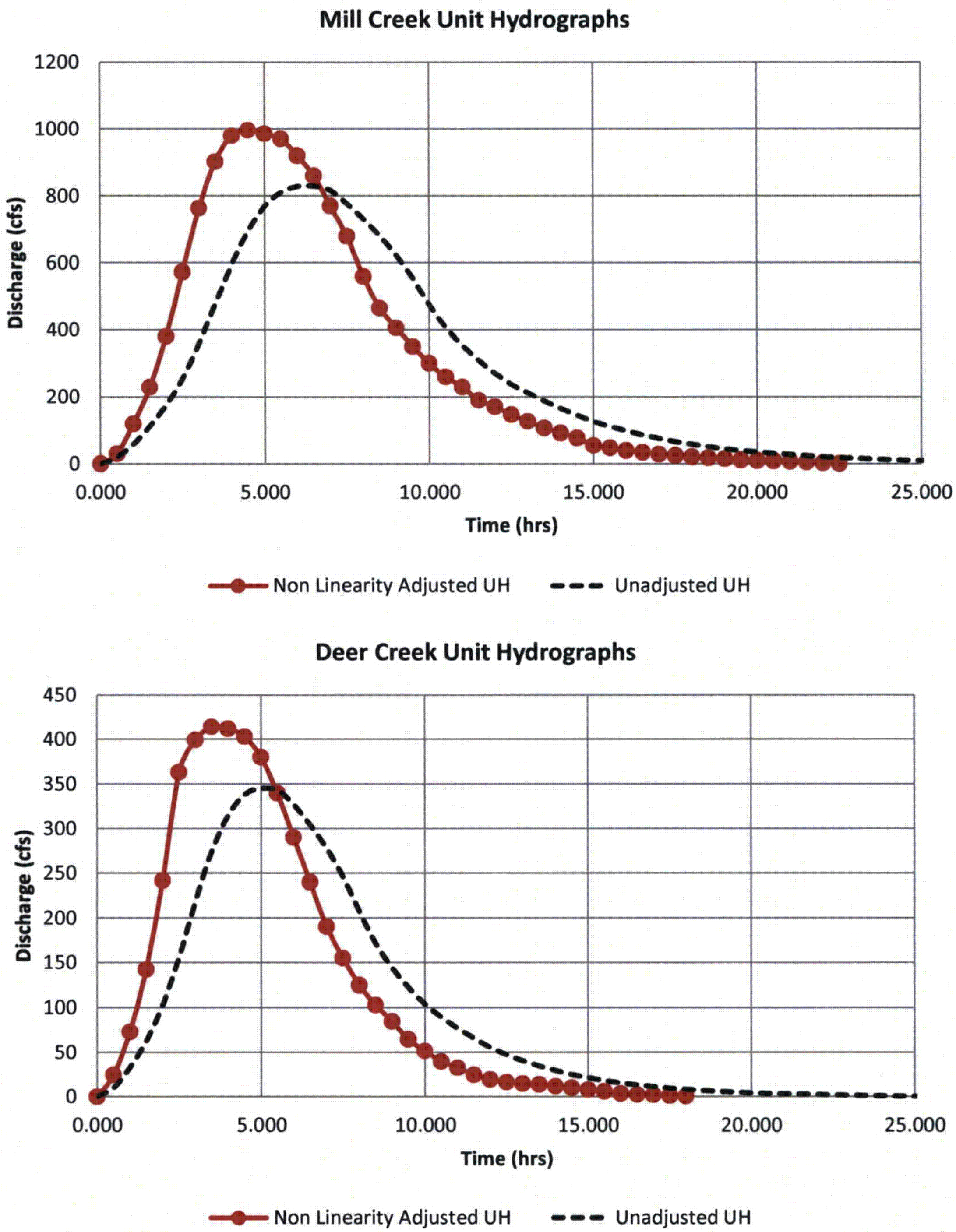
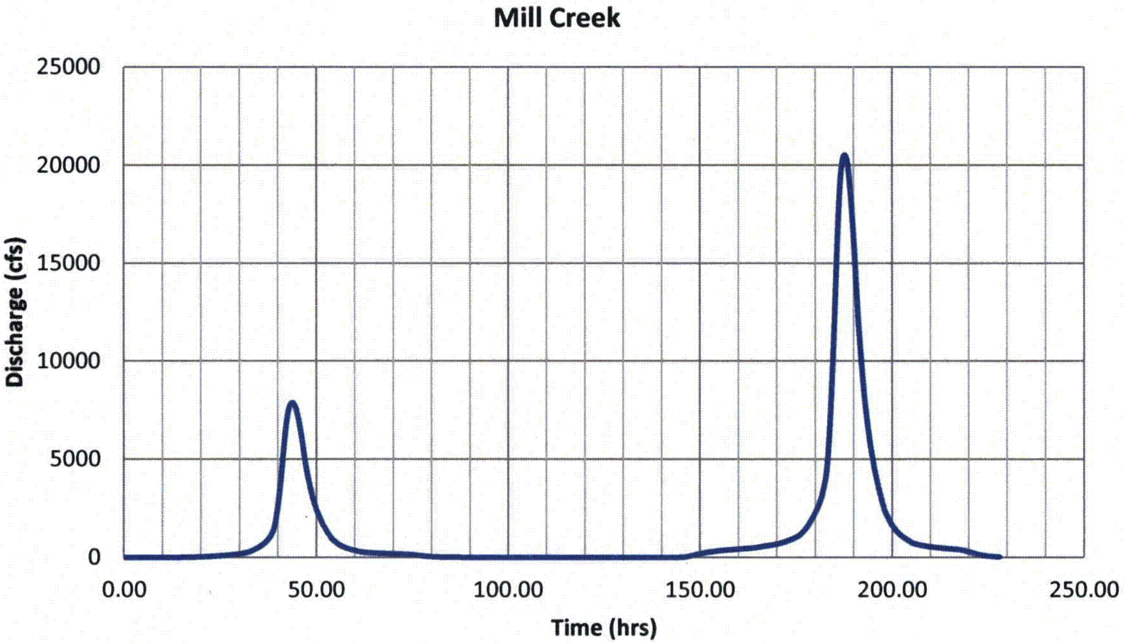


Figure 2.2-7: PMF Outflow Hydrographs



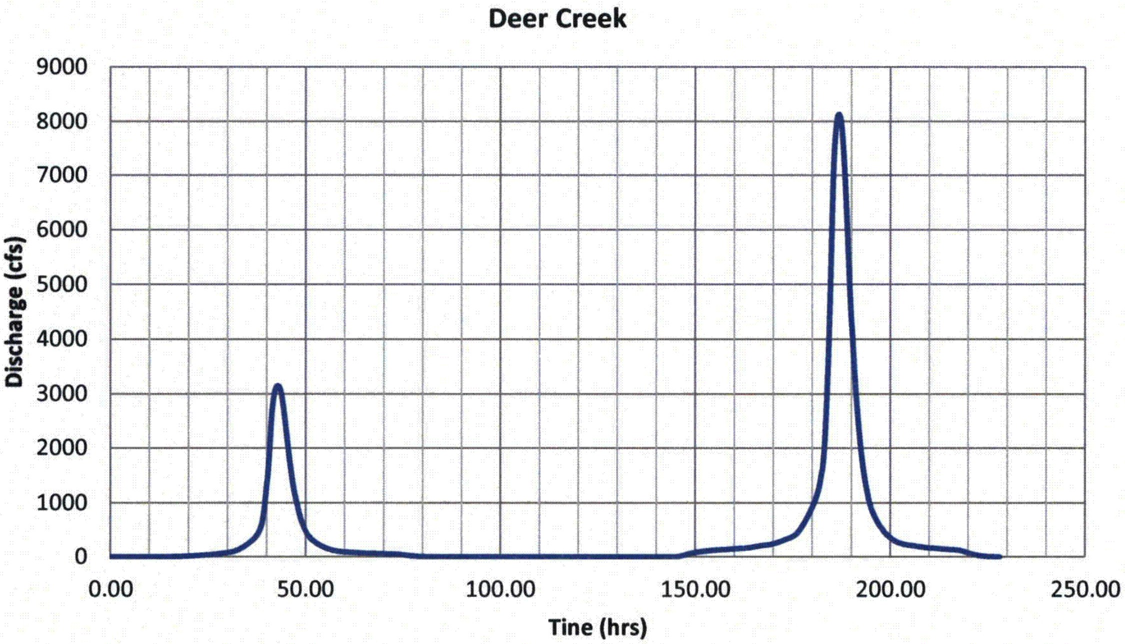


Figure 2.2-8: FLO-2D Model Layout

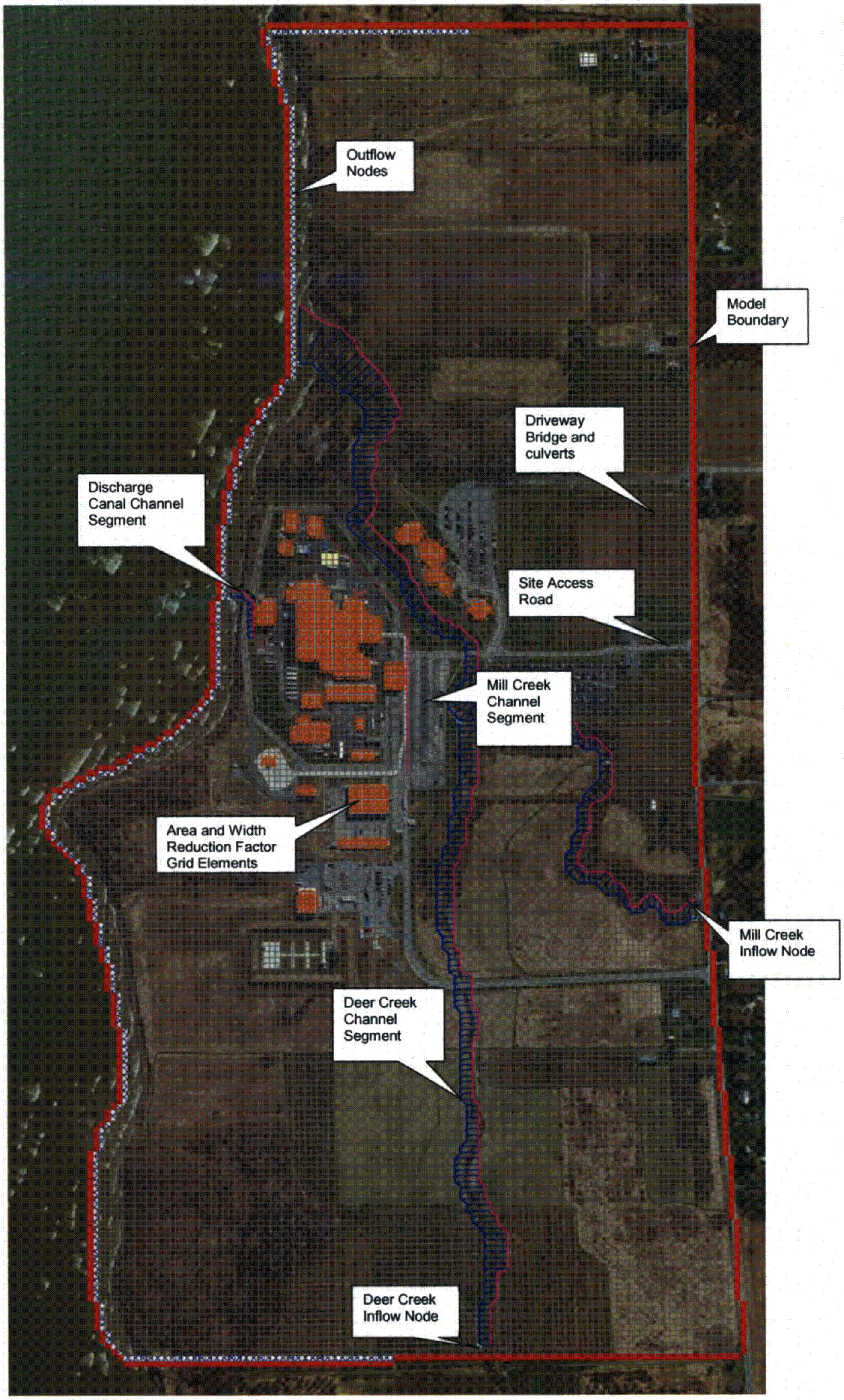


Figure 2.2-9: Grid Element Elevation Rendering (FT, NAVD88)

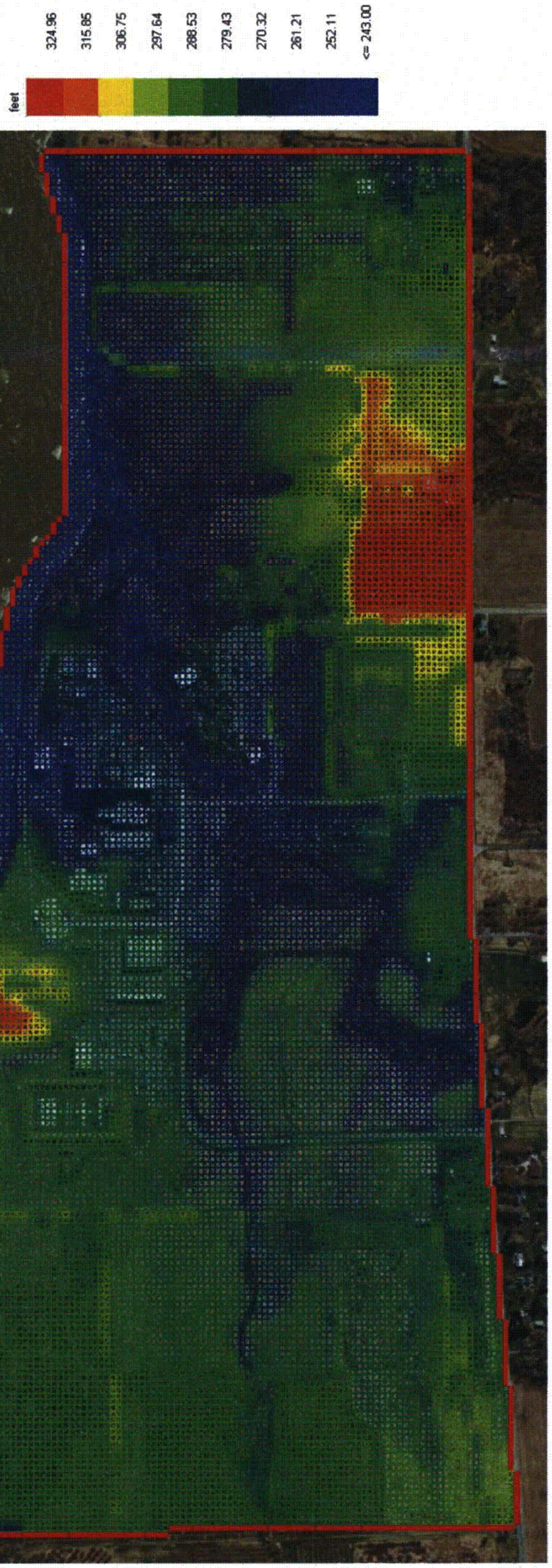


Figure 2.2-10: Grid Element Manning's Coefficient Rendering

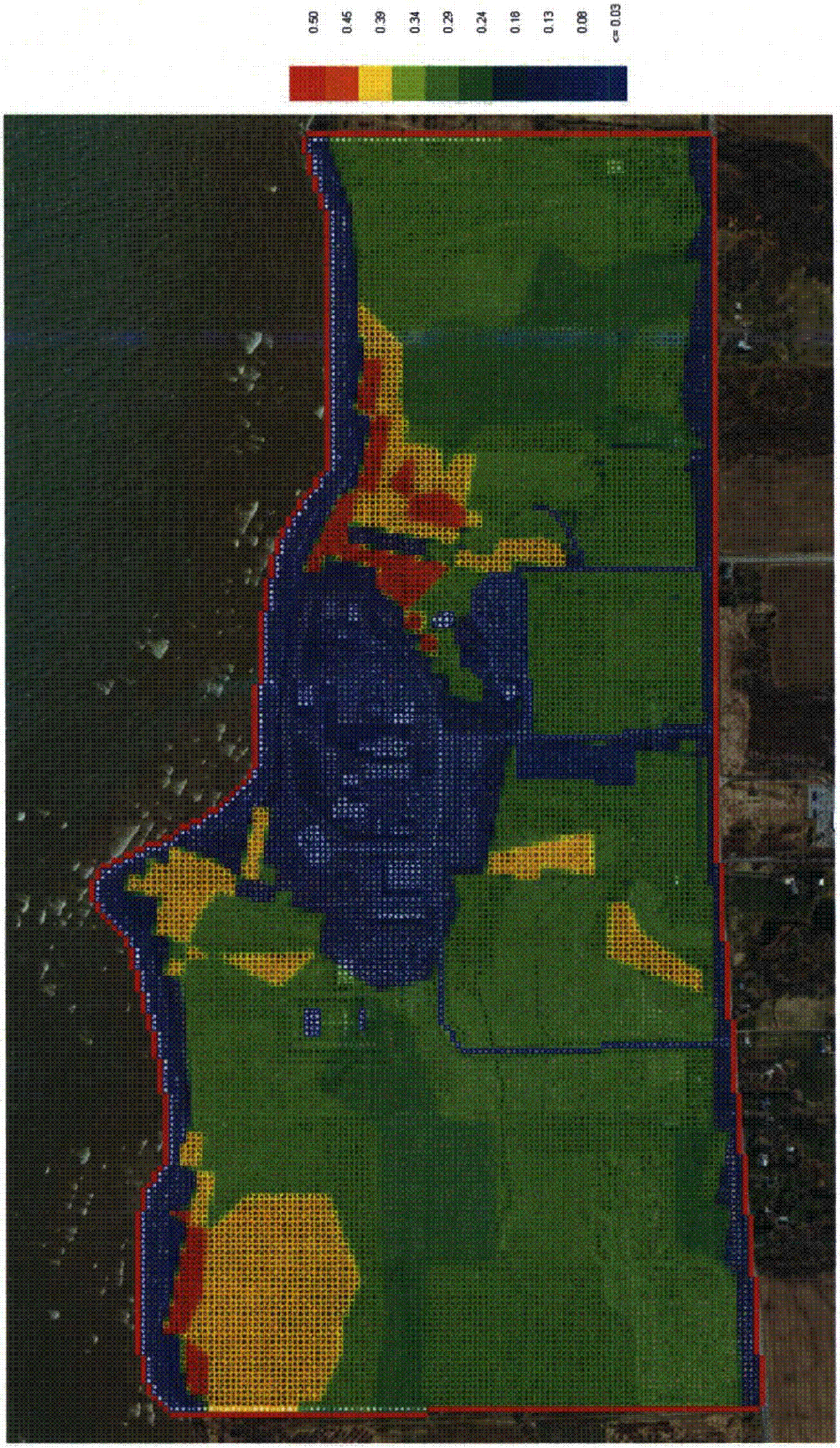


Figure 2.2-11: Grid Element Numbers

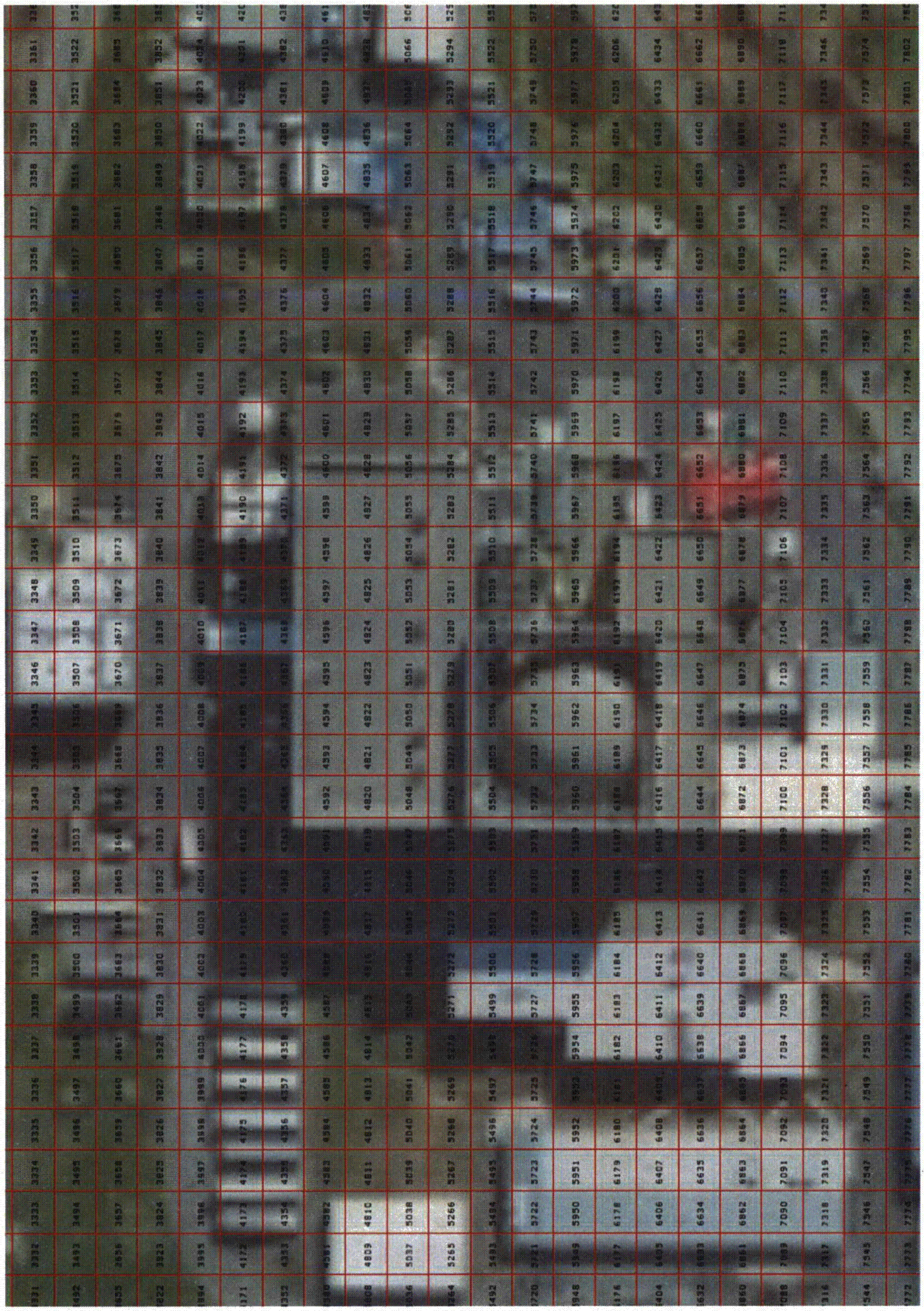


Figure 2.2-12: Grid Elevation at Cell (ft, MSL)

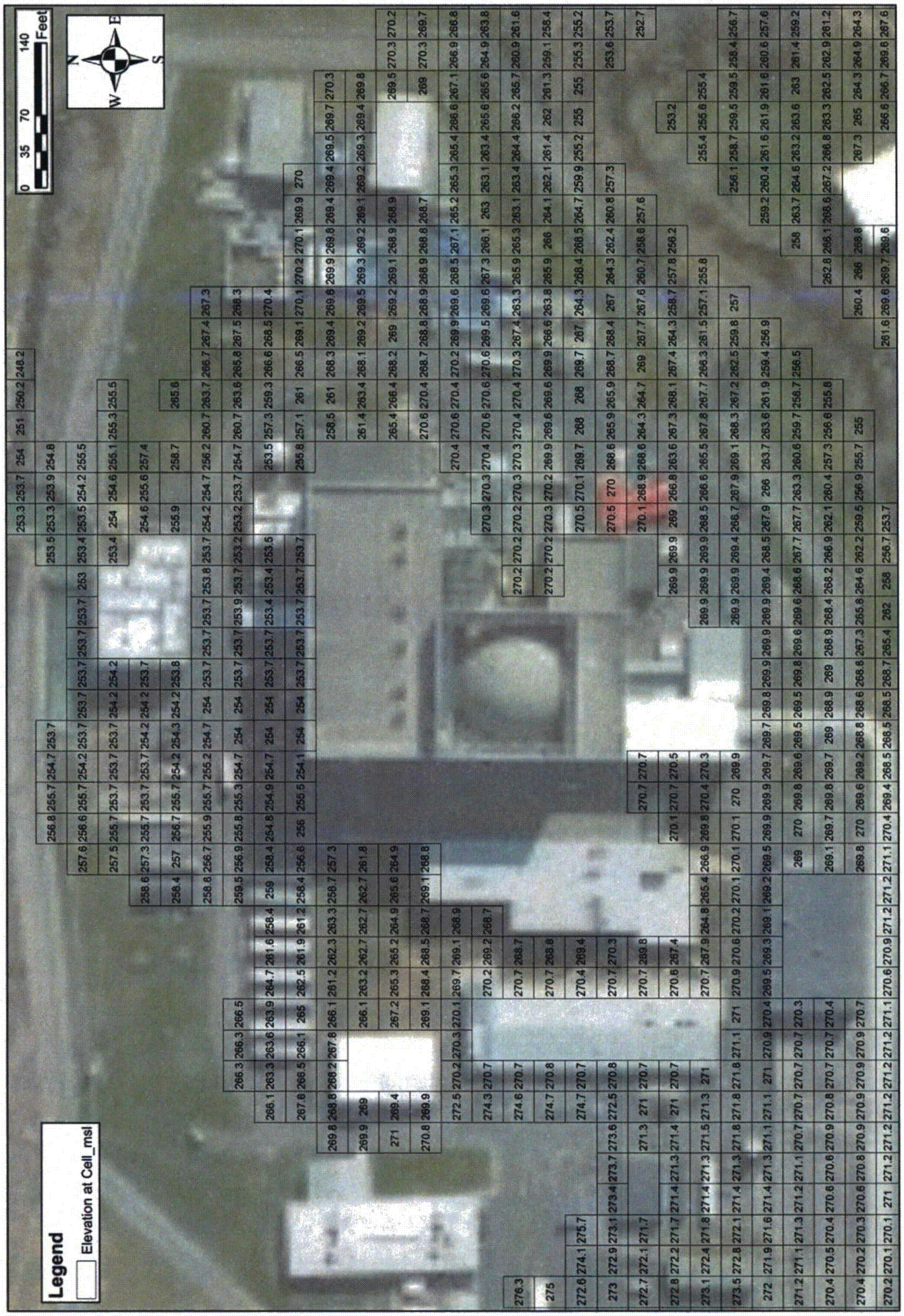


Figure 2.2-13: PMF Maximum Water Surface Elevations (ft, MSL)

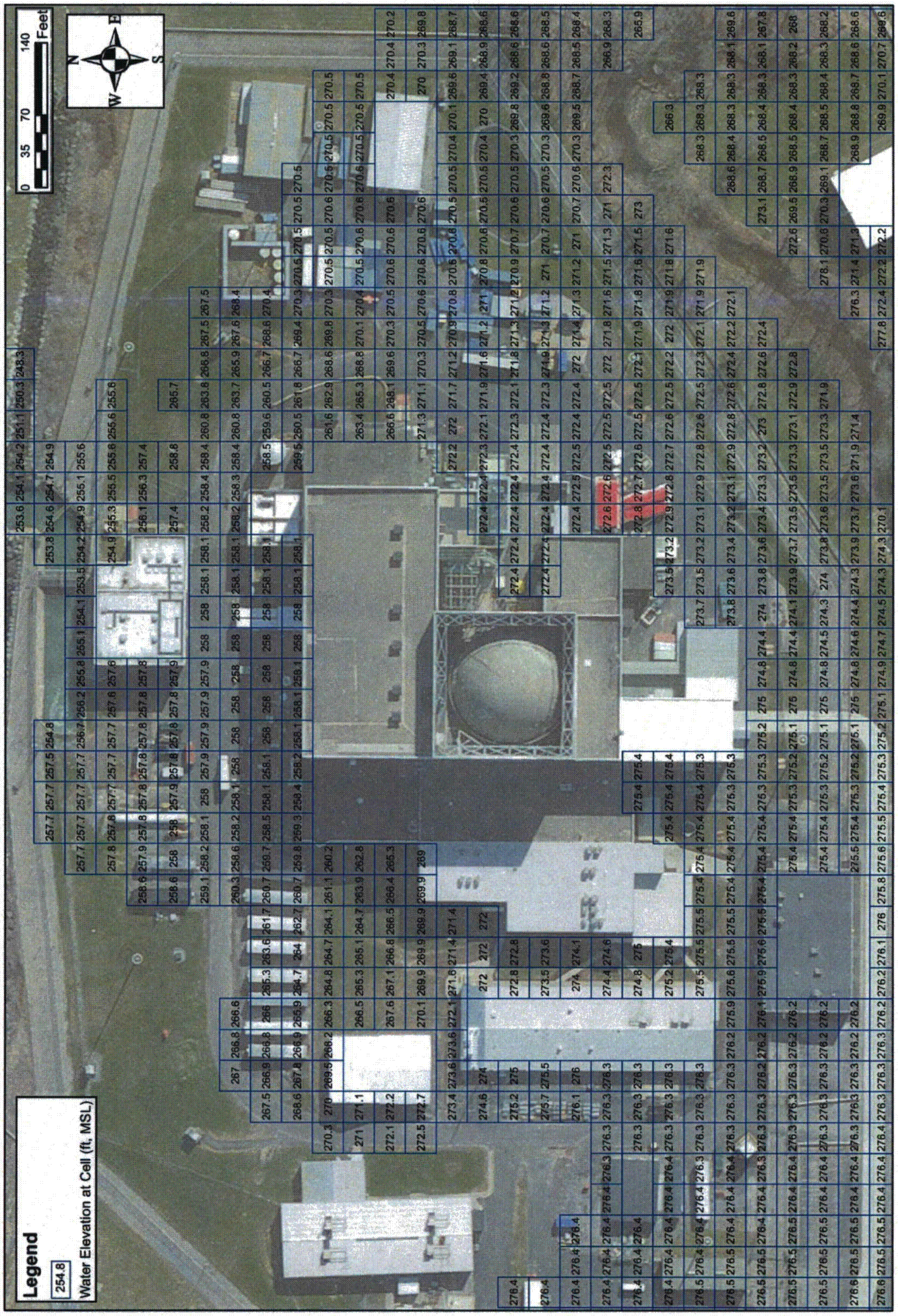


Figure 2.2-14: PMF Maximum Flow Depths (ft)

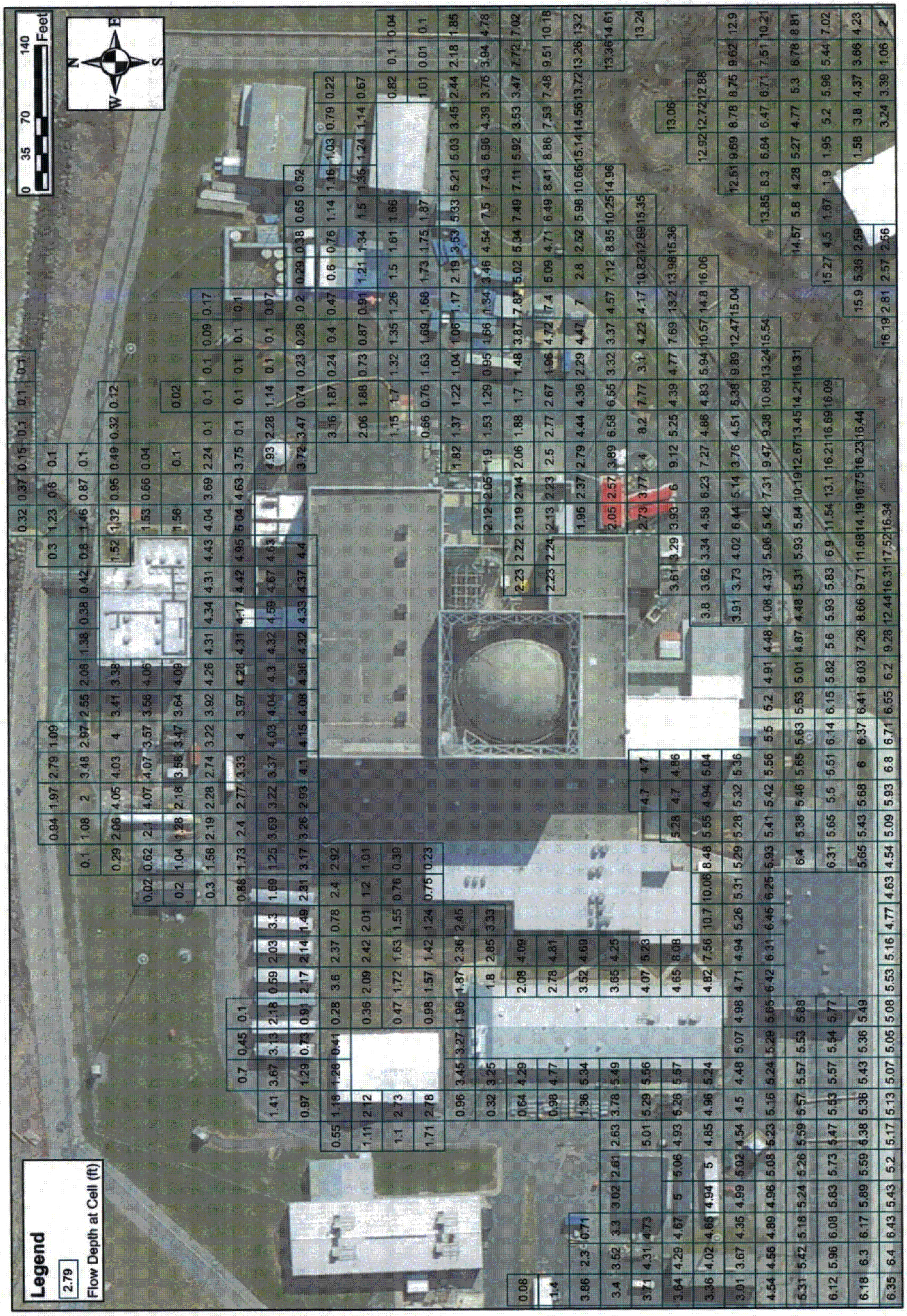
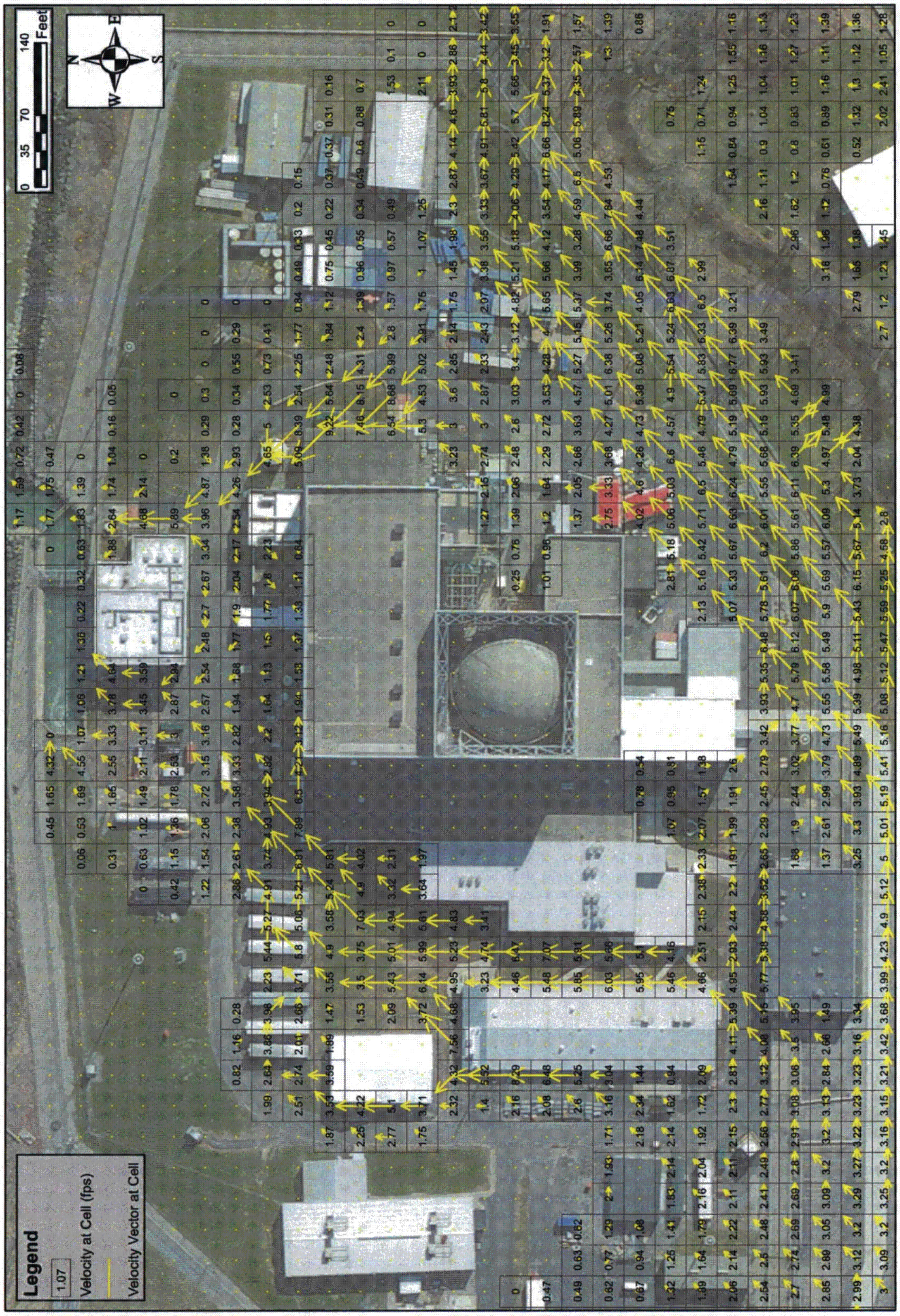


Figure 2.2-15: PMF Maximum Velocities and Vectors (fps)



2.3 Dam Breaches and Failures

Flood waves resulting from severe breaches of upstream dams, including domino-type or cascading dam failures, should be evaluated for the site. Water-storage or water-control structures (such as onsite cooling or auxiliary water reservoirs and onsite levees) that may be located at or above the safety-related site grade should also be evaluated (NRC, 2011, Section 3.4).

2.3.1 Methodology

The HHA approach described in NUREG/CR-7046 (NRC, 2011) was used for Dam Breaches and Failures along with the analyses performed as part of the NMP Unit 3 Nuclear Power Plant (NMP3NPP) Combined License (COL) application (NMP3NPP, 2009). A draft Interim Staff Guidance document regarding estimating flood hazards due to dam failure has been released for public comment (NRC, 2013). Review of this draft document does not indicate any deficiency in this dam failure evaluation.

The proposed NMP3NPP project, located about 50 miles east of the Ginna site, is in the same hydroclimatic setting as the Ginna site. As such, Ginna is characterized by the same regional dam breach or failure induced flooding mechanisms. Therefore, the potential regional dam failure flooding analysis performed at NMP3NPP that may affect Lake Ontario applies to the Ginna site as well. See NMP3NPP, 2009, Section 2.4.4.

In addition, the dam factor and multivariable regression approach in CSU, 2010 was used to estimate the peak outflow from local watershed breached embankment dams. (AREVA, 2013)

2.3.2 Dam Breaches and Failures Results

2.3.2.1 Potential Breaches and Failures

Regionally, the nearest dams to the Ginna site that may affect Lake Ontario are three dams on the Saint Lawrence River, which are used to control the lake level (NMP3NPP, Section 2.4.4.1).

The Saint Lawrence River is used in conjunction with three dams to control the level of Lake Ontario. Since 1960, Lake Ontario outflows have been regulated, primarily through the Moses-Saunders power dam near Cornwall and Massena, New York, about 100 mi from the outlet of Lake Ontario. Long Sault Dam, located near Long Sault, Ontario, acts as a spillway when outflows are larger than the capacity of the Moses-Saunders power dam. A third structure at Iroquois, Ontario, is used principally to help form a stable ice cover and regulate water levels at the power dam. These facilities are under the authority of the International St. Lawrence River Board of Control.

Locally, there are a number of small dams within the general area around the Ginna site (NYDEC, 2012). However, only three of these dams fall within the Ginna site watershed (Figure 2.3-1). The three dams could contribute to flooding of safety-related SSC via a breach or failure.

On site, there are no on-site basins above grade level that could contribute to flooding of safety-related SSC via a breach or failure (Ginna, 2012). A new condensate storage tank will be installed in the proposed Standby Auxiliary Feedwater Building. This tank will contain approximately 160,000 gallons of water. The building is designed to maintain integrity in the event of tank rupture and is not anticipated to impact safety-related SSC at the site outside the Standby Auxiliary Feedwater Building (Ginna, 2013).

2.3.2.2 Effect of Potential Dam Breaches and Failures

St. Lawrence River

The effects resulting from failure of the dams in the St Lawrence River were analyzed in 1968 by the St. Lawrence Study Office of the Canadian Department of Energy, Mines and Resources, as described in the NMP3NPP COL (NMP3NPP, 2009, Section 2.4.4.1). The study showed that the lake level, following the sudden destruction of the dams and the lowest supply sequence on record, would decline gradually from elevation 247.7 ft. (75.5 m) to elevation 240.6 ft. (73.3 m) approximately one year following the assumed failure. The study concluded that once the lake level had declined to about elevation 240.6 ft. (73.3 m), natural control, such as existed before the project, would be reestablished and the lake levels would rise and fall thereafter in accordance with natural inflows delivered to Lake Ontario from the Great Lakes watershed.

Failure of the dams at the outlet of Lake Ontario in the St. Lawrence River, therefore, would result in lower than normal regulated water levels. The lower water levels, however, have been considered in plant design for the Ginna plant.

The minimum allowable lake level for operation is 224.4 ft (Ginna, 2013). The margin, therefore, between the top of the intake and the lowest lake elevation following dam failure is 16.2 ft. (240.6 – 224.4). As a result, sufficient margin exists in the design of the Ginna intake to account for the lower water levels in Lake Ontario produced by the failure of the St. Lawrence River dams.

Local Dams

There are three small dams in the watershed surrounding the Ginna site (Figure 2.3-1). The watershed has two sub-basins, defined by the two major tributaries that form the overall watershed area. To the northwest is Deer Creek, which flows west to east, has a drainage area of 3.7 sq. mi., and includes the MacInnis Marsh Dam. To the south is Mill Creek, which flows south to north, has a drainage area of 10.8 sq. mi., and has two dams, Fruit Mill Dam and William Daly Marsh Dam. Both creeks merge south of the plant into one creek, referred to as Deer Creek.

Failure of the three dams, however, will not affect the Ginna site because of their small storage capacity (AREVA, 2013). As shown in Table 2.3-1, the total peak flow from a breach of the three dam occurring simultaneously and arriving at the site without attenuation is 1,698 cfs. This value is about 12% of the necessary 14,600 cfs flow needed to fill the capacity of the Deer Creek channel (Ginna, 2011, Table 2.4-1). As a result, the Deer Creek will remain below its flood capacity elevation of 270 ft. and not produce flooding at the Ginna site. This scenario represents a sunny day failure. Evaluation of dam failure coincident with other flood mechanisms is discussed in Section 2.9.

2.3.3 Conclusions

Based on previous analyses and the information above, potential dam breaches and failures of the sources upstream of the Ginna site would not affect the safety-related SSC because:

- Regionally, the effects of lower than normal Lake Ontario water levels due to failure of the dams at the outlet of Lake Ontario in the St. Lawrence River have been considered in plant design. A margin of 16.2 ft. exists above the top of the Ginna intake to account for the lowest water level projected.
- Locally, the effects from the simultaneous failure of the three dams in the Ginna watershed would produce a total peak flow much less than the flow needed to fill the capacity of the Deer Creek channel, resulting in the channel water level remaining below the 270 ft. flood elevation of the Ginna site.
- On site, there are no above grade basins that would contribute to the potential flooding at the site.

2.3.4 References

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Table 2.3-1: Local Dam Input Data and Predicted Breach Peak Flow Values

Dam Input Values

Dam	H (ft)	H (m)	A (ac)	A (m^2)	V (ac ft)	V (m^3)
MacInnis	5	1.524	-	-	43	53,040
Fruitland	10	3.048	7.37[b]	29,825	-	90,907
Wm Daly	6	1.8288	-	-	18	22,203

Source: AREVA, 2013, Appendix A

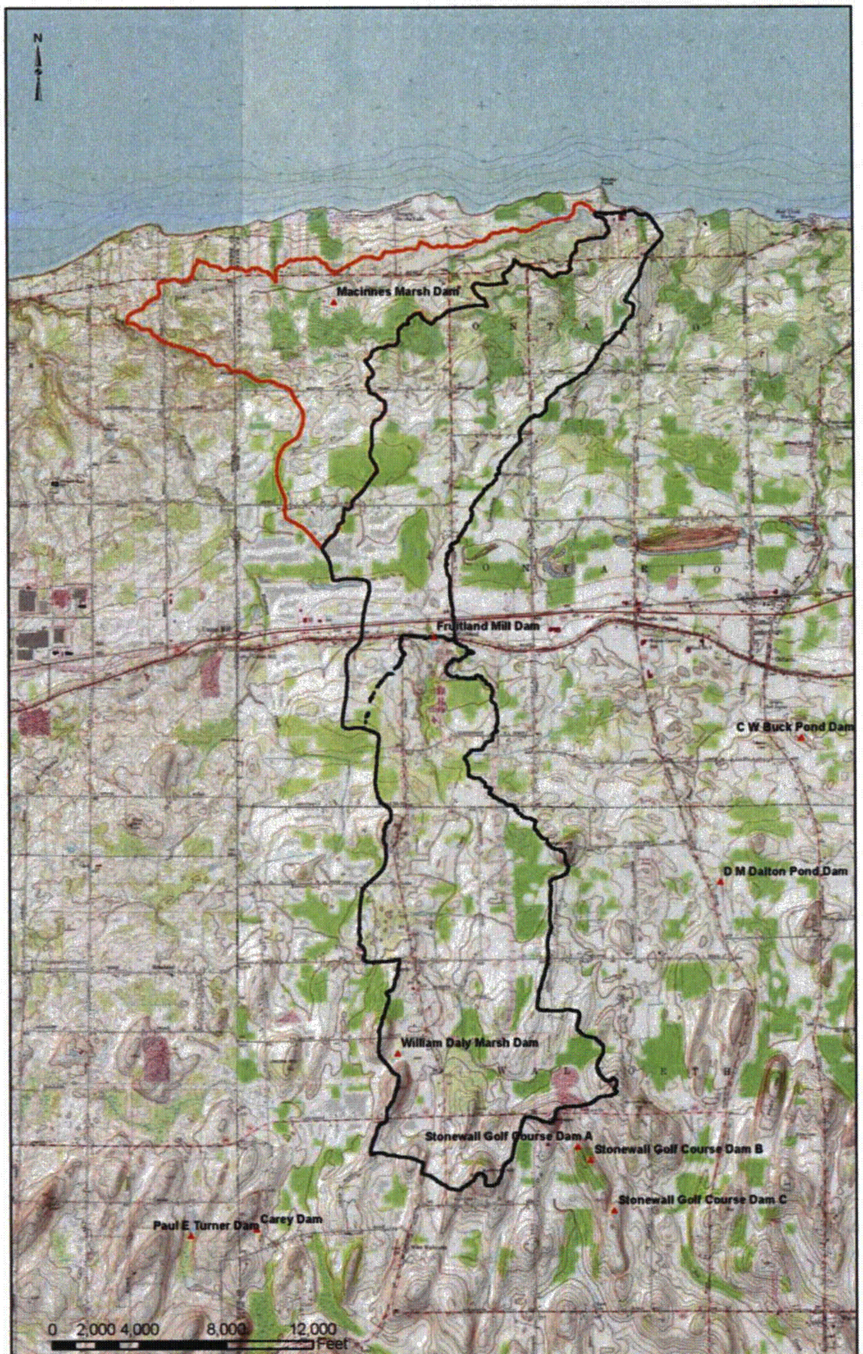
Predicted Breach Peak Flow, Q_p^*

Dam	V (m^3)	H (m)	Q_p (m^3/s)	Q_p (cfs)
MacInnis	53,040	1.52	10.6	373
Fruitland	90,907	3.05	29.0	1,025
Wm Daly	22,203	1.83	8.5	301
		Total	48.1	1,698

* $Q_p = 0.038\ (V^{0.475} \times H^{1.09})$, where
Q_p is the peak outflow through the dam breach in cubic meters per second (m^3/s),
V is the volume behind the dam in cubic meters (m^3), and
H is the height of water behind the dam in meters (m).

Source: AREVA, 2013, Appendix B

Figure 2.3-1: Watershed Delineation and Dam Locations



2.4 Storm Surge

Storm surges are defined as rises in offshore water elevations caused principally by the sheer force of winds acting on the water surfaces, typically associated with hurricanes (NRC, 2011, Section 3.5).

2.4.1 Methodology

The HHA approach described in NUREG/CR-7046 (NRC, 2011) was used to calculate the Probable Maximum Storm Surge (PMSS) at Ginna. In accordance with the HHA approach, this calculation uses the simple Great Lakes Storm Surge Planning Program (SSPP) software program developed by National Oceanic and Atmospheric Administration's (NOAA) Great Lakes Environmental Research Laboratory (GLERL) (Schwab et al., 1987) and the Probable Maximum Wind Storm (PMWS) wind velocity and direction, to conservatively predict the PMSS at Ginna (AREVA, 2013a).

The methodology to determine the design storm surge at Ginna includes the following steps (as defined in ANSI/ANS-2.8-1992, American National Standard for Determining Design Basis Flooding at Nuclear Reactor Sites (ANSI, 1992):

- Selection of the historic design storm by performance of a statistical analysis of NOAA one-hour and six-minute water level data to: a) eliminate long term water level fluctuations; b) identify the short term water level fluctuations; and c) identify the historical storm and storm type resulting in the highest recorded wind speeds and storm surges.
- Development of the PMWS meteorological parameters by modification of the historical storm parameters in accordance with ANSI/ANS-2.8-1992.
- Development of the antecedent water level by comparing the maximum controlled water level elevation on Lake Ontario to the 100-year high water level, and selecting the lesser water elevation per ANSI/ANS-2.8-1992.
- Calculation of the PMSS still water elevation using the SSPP.

2.4.2 Results

2.4.2.1 Selection of the Design Storm

Consistent with NUREG/CR-7046 and ANSI/ANS-2.8-1992, identification of the historic storm for development of the PMWS parameters was based on review and analysis of the NOAA National Climatic Data Center (NCDC) (NOAA, 2012a) water level data from nearby NOAA Tides and Currents stations (NOAA, 2012b) and the NOAA National Hurricane Center (HURDAT) data which has been summarized by Environment Canada (EC, 2012a-d). The storm types evaluated included tropical cyclones (hurricanes), moving squall lines and extra-tropical cyclones.

The physical characteristics of Lake Ontario are illustrated in Figure 2.4-1. Lake Ontario has a length of about 195 miles and an average width of about 53 miles, and is oriented with its long dimension trending in a northeast-southwest direction. The bathymetry of the lake offshore in the vicinity of Ginna is characterized by a deep basin, with a lake bottom depth between approximately 700 and 800 feet. Ginna is located along the southern lake shoreline.

Water-level fluctuations due to storm surges on the Great Lakes are generally caused by one of several types of strong storms, including:

- Tropical systems that move north from the Gulf Region and Mid-Atlantic;

- Non-convective storms (extra-tropical cyclones) that originate in Canada and move to the east through the lakes region (Alberta Low) or originate in the southern and central Rockies (Colorado Low) and move east through the lakes region; and
- Convective storms or thunderstorm frontal passages, including moving squall lines (FEMA, 2012).

The HURDAT was evaluated relative to tropical systems originating in the southern latitudes and moving into the Great Lakes area. The review of historic hurricane activity for Lake Ontario identified eighteen extra-tropical or tropical cyclones that have tracked over or near Lake Ontario (EC, 2012a). The storms are summarized on Table 2.4.1, which presents the storm speed, wind speed (1-minute, 10 meter) and pressure at the storm track latitudes and longitudes near the lake.

Storm tracks were typically in an approximate north-south direction. Storm forward speeds ranged from 6 to 58 miles per hour and averaged 28 miles per hour. Wind speeds ranged from 25 to 70 miles per hour and averaged 42 miles per hour. Sixteen of the eighteen storms had transitioned into extra-tropical storms before reaching Lake Ontario. The other two remained tropical depressions or storms. Six of the storms are of note for Lake Ontario due to observed flooding, wind or rainfall and are discussed below. Hurricane Hazel in 1954 caused widespread rainfall-induced flooding along the western shore of Lake Ontario (EC, 2012b). Hurricane Isabelle, which passed over Lake Erie to the west, in September, 2003 caused large waves in the western portion of the Lake Ontario (EC, 2012c). Hurricane Audrey (July 1957), Hurricane Katrina (August 2005), and Hurricane Frances (September 2004) were reported to have caused extreme rainfall in and around Lake Ontario (EC, 2012c) (EC, 2012d). Rainfall from Hurricane Fran (September 1996) caused flooding in the western portion of the lake, however water level records from the southern and eastern portion of the lake show no significant surges (EC,2012d).

Squall lines are also a consideration in the Great Lakes region, particularly along the shores of Lake Michigan. ANSI/ANS-2.8-1992 states that "A moving squall line should be considered for the locations along Lake Michigan where significant surges have been observed because of such a meteorological event" and notes the possible occurrence of squall lines within the other Great Lakes (ANSI, 1992). Review of the literature indicates that moving squall lines are not the controlling storm event relative to storm surge in Lake Ontario. Specifically:

- Federal Emergency Management Agency (FEMA) publications indicate that while moving squall lines are possible in Lake Ontario, it is generally accepted that these local, fast-moving events can be neglected when assessing extreme water levels as their inclusion has negligible influence on water level statistics (FEMA, 2012).
- Analyses by Nadal-Carballo indicate that, in general, neglecting convective events (i.e., moving squall lines) has minimal influence on external water-level statistics (Nadal-Carballo et al, 2012).

The parameters of moving squall lines have been developed previously at Ginna and in American Nuclear Society (ANS) studies, including:

1. ANS developed probable maximum squall line parameters for the Great Lakes in 1976, which were adopted and included in ANSI/ANS-2.8-1992 (ANSI, 1992). These parameters included a pressure gradient of 8 mb over 11.5 miles and a maximum wind of 75 mph (NMPC, 1976).
2. Design parameters for moving squall lines were previously developed for similar sites on the south shoreline of Lake Ontario (NMPC, 1976). Due to a lack of available historic data, the analysis developed synthetic pressure and wind field utilizing Fujita's squall line model (Fujita, 1955). In the analysis, the wind speed was conservatively increased to 50 mph to account for the lack of local, supporting historical data (NMPC, 1976). Since the ANS standards were not yet official in 1976, the prior study also developed a "severe squall line" in which the historical maximum pressure gradient (from the 1953 Nebraska event) was increased 30 percent from 9 mbars to 12 mbars and the maximum wind speed was

increased 50 percent from 50 mph to 75 mph (NMPC, 1976). Using these three models of moving squall line pressure and wind fields, a two-dimensional storm surge model was applied. The model predicted a storm surge of no more than 1.8 feet for any of the events modeled (NMPC, 1976).

As noted above, most of the strong storms in the Great Lakes are extra-tropical, low-pressure non-convective systems. These non-convective storms typically originate in Canada or the southern or central Rockies and move to the east. The movement of high-pressure systems through the region often precedes or follows the occurrence of the low-pressure system. Low-pressure systems spin counter-clockwise, while high-pressure systems spin the opposite way. Winds on the eastern side or leading edge of a low-pressure system are typically coming from the south, while winds on the eastern side of a high-pressure system are coming from the north. High winds and large atmospheric pressure variations are commonly associated with these storm events, and they can cause elevated water levels, or storm surge, along the lake shoreline (FEMA, 2012). This is consistent with findings of Danard (Danard et al, 2003) who concludes that the occurrence of storm surges on Lake Ontario is mainly due to extra-tropical cyclones. The results of a 2003 joint IJC/USACE Lake Ontario Waves study (IJC, 2003) indicate that waves generated by extra-tropical events are more intense than those generated by convective events (squall lines). The winter season is characterized by the most severe cyclones. The principal storm track of winter storms in the Erie-Ontario region is to the northeast (Angel, 1996).

In accordance with the procedures presented in ANSI/ANS-2.8-1992, an analysis of available data for historic synoptic cyclonic wind storms was performed. Long-term (about 50 years) Lake Ontario wind and water level records were compiled from the NOAA NCDC Storm Events Database (NOAA, 2012a) and the Tides and Currents Great Lakes Water Level Data (NOAA, 2012b). Lake Ontario has four NOAA Tides and Currents Stations: Station 9052076, Olcott, New York; Station 9052058, Rochester, New York Station 9052030, Oswego, New York; and Station 9052000, Cape Vincent, New York. Hourly water level data are available for the period of 1961 to 2012. Six minute water level data were evaluated for the period of about 1994 to 2012 and wind data are available for the period of about 1950 to 2012.

Statistical analyses of the verified six-minute water level data (full record from 1994-2012) from all four NOAA stations (NOAA, 2012b) was performed by processing the data with a frequency domain filter in order to attenuate signals from high frequency events such as lake water level fluctuations associated with the annual hydrologic cycle and to identify water levels associated with major storms. Table 2.4-2 identifies the storms that resulted in the largest surges identified by the statistical analysis of the six-minute water levels. The highest surge identified was 1.74 feet at Cape Vincent, NY on February 17, 2006. This extra-tropical storm also had the highest recorded wind speed (80.6 mph) of the surge-causing events. The recorded setdown and surge heights for the top twenty surge storms at Rochester ranged from minus 1.0 foot to plus 0.1 feet. The preliminary result of storm surge modeling performed by Zuzek indicates surge levels of 0.08 feet at Ginna (Zuzek, 2011).

A second statistical analysis of the available hourly water level data (1961 to 2012) from all four stations (NOAA, 2012b) was performed to get an assessment of longer term high water levels. Table 2.4-3 identifies the storms that resulted in the high water levels identified by the statistical analysis of the hourly water levels. The highest surge identified was 2.06 feet at Cape Vincent, NY on November 13, 1992. Wind data are not available for this storm event because this event is not present in the NOAA Storm Events Database (NOAA, 2012a). The second highest surge identified was 1.88 feet at Cape Vincent, NY on February 17, 2006. This extra-tropical storm also had the highest recorded wind speed (80.6 mph) of the surge-causing events.

To evaluate the correlation between severe storm surge events and extreme wave events the filtered water hourly water level data from 1961 to 2012 for the Rochester gauge (Station 9052058) was compared to the Wave Information Studies wave hindcast data (Station 91045 on Lake Ontario). The data comparison is presented in Table 2.4-4 along with HURDAT storm classification information. Table 2.4-4 indicates that historic storm surge heights are relatively small with the largest surge height being less than 1.5 feet. In addition, there does not appear to be a correlation between the top twenty surge events with wave heights or storm type.

2.4.2.2 Development of the Design Storm Parameters

The February 17, 2006 storm, identified by the statistical analysis presented above to have had the greatest recorded wind speed and the second largest surge elevation, was selected as the model storm and modified per ANSI/ANS-2.8-1992 to develop the PMWS parameters.

Pressure maps for the February 17, 2006 storm were obtained from the NCDC (NOAA, 2006). The 15:00 GMT pressure fields were identified as the most critical based on the observed isobars and resultant pressure gradient. The pressure maps were used to calculate the isobars, distance between isobars, and wind angles affecting the lake and to establish a relationship between the pressure maps and a geographic coordinate system in order to determine storm speed.

PMWS Storm Track and Speed

The February 17, 2006 storm originated in the west and travelled in an approximately southwest to northeast direction, which was used to develop the PMWS storm track. The storm track of the PMWS follows the primary tracks constructed from the historic extra-tropical cyclone climatology for the Fall, Winter, and Spring seasons (Angel, 1996). The PMWS translational speed was conservatively maintained at a constant steady-state speed of 40 mph, corresponding to the lower range of the recorded storm speed. The selected PMWS track is consistent with the tracks of the other representative storms that generated significant surges at the site which have three hour surface pressure maps available. Based on the storm track data, the PMWS track represents a conservative track for the generation of winds on Lake Ontario which is deemed to have a reasonable probability of occurrence.

PMWS Wind Field

Lake Ontario was divided into three zones: Z1–Western, Z2–Central, and Z3–Eastern to develop a spatially varying wind field. The isobar patterns as the storm moved along the storm path were used to calculate the PMWS time varying pressure, wind speed and wind direction at the eastern and western ends of each zone using the methods presented in the U.S. Army Corps of Engineers (USACE) Coastal Engineering Manual (CEM) (Resio et al, 2008). Wind directions were calculated to be at an angle of 10 degrees across the isobars as specified by ANSI/ANS-2.8-1992 for the Great Lakes region.

For the maximum wind speed to reach 100 mph (ANSI, 1992) in each zone, the wind speeds were scaled up. In order for the minimum pressure to reach 950 mbar (ANSI, 1992), the minimum pressure of the storm, 992 mbar, was scaled down to 950 mbar.

The PMWS parameters are presented in Table 2.4-5.

2.4.2.3 Development of the Antecedent Water Level

As defined in Appendix H of NUREG/CR-7046 (NRC, 2011) for enclosed bodies of water, the lesser of the 100-year level or the maximum controlled water level should be used for the evaluation of flood levels from storm surges.

The 100-year Lake Ontario high water level was calculated to be 248.4 ft (IGLD85). Lake Ontario has a regulated maximum level of 247.3 ft (IGLD85) as indicated in the following passage:

"*The regulated monthly mean level of Lake Ontario shall not exceed elevation 75.37 m (247.3 feet) with the supplies of the past as adjusted.*" (IJC, 2012)

Based on this, a starting water level of 247.3 ft (IGLD85) was selected for the PMSS evaluation.

2.4.2.4 GLERL SSPP Storm Surge Model

The SSPP was used to predict the surge elevation due to the PMWS (AREVA, 2013b). Appendix A provides a description of the SSPP program.

A comparison of measured water levels to those predicted using the SSPP was performed in accordance with Section 5.5 of NUREG/CR-7046 (NRC, 2011). The storm surges from nine representative, historic storms were calculated using the SSPP and the results were compared to the measured surge elevations. The historic storms evaluated occurred on February 17, 2006, January 9, 2008, January 18, 2012, December 23, 2004, March 10, 2002, February 1, 2002, September 9, 2008, January 30, 2008 and February 10, 2001. Storm surge elevations at three of the four NOAA Tides and Currents stations along the south shore of Lake Ontario (Olcott, NY, Rochester, NY and Oswego, NY) were extracted from the filtered six-minute water level data. These measured water levels were compared with outputs from the SSPP for model validation purposes. The comparison of the predicted to measured water levels for the nine representative extra-tropical storms show that using the spatially averaged constant wind field over the entire lake as input, the SSPP results reasonably and conservatively predict the surge elevation at Rochester near Ginna when compared to measured water levels during the storm (See Figure 2.4-1).

The SSPP predicts a PMWS flood level increase of 3.2 ft at Ginna caused by an extra-tropical cyclone with sustained maximum winds of 100 mph parallel to the long axis of the lake. This PMSS height corresponds to a flood elevation of 251.1 ft. Results of the SSPP model simulation are presented in Table 2.4-6.

2.4.3 Conclusions

Based on the PMSS calculation for Ginna, the following conclusions are reached:

- The controlling storm type is an extra-tropical storm.
- Per ANSI/ANS-2.8-1992, the antecedent water level is the regulated lake water level, which is 247.3 ft (IGLD85).
- The predicted PMSS height is 3.2 feet.
- The predicted PMSS elevation is 251.1 feet (NGVD29) or 250.5 ft (IGLD85).

Uncertainty and conservatism was considered in the calculation as per Section 5.4 of NUREG/CR-7046, as follows. The PMWS parameters, which are the basis for SSPP model used to calculate the PMSS, were adjusted to provide the most adverse conditions. The adjustments included:

- The PMWS storm track was smoothed and the translation speed of the storm was reduced to 40 mph (which was the minimum recorded storm speed) to increase the effect of the pressure gradients and resulting wind speeds,
- The predicted peak wind speed for the PMWS was increased to reflect a maximum over-water wind speed of 100 mph (as defined in ANSI/ANS-2.8-1992). This resulted in a 21% increase in the calculated peak wind speed determined for the synthetic storm used to evaluate the PMWS,

In analyzing the PMSS, the synthetic storm wind speeds and direction are conservatively assumed to be temporally and spatially constant which maximizes the storm surge. A sensitivity analysis was also performed on the peak wind speed direction by analyzing the surge elevations relative to varying wind directions, to determine the wind direction resulting in the maximum surge elevation at the site. Validation of the surge model was performed by comparing predicted water levels to measured water levels for a number of historic lake storm surges; the validation indicates that the model over predicts surge elevations at moderate to high surge values.

2.4.4 References

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Table 2.4-1: Summary of Hurricane Parameters

Name	Year	Month	Day	Latitude	Longitude	Direction [degrees]	Forward Speed [mph]	Wind Speed [mph]	Pressure [mb]	Storm Type
N/A	1878	September	13	44.0N	78.5W	10	28	50	n/a	ET
N/A	1893	October	14	42.7N	77.6W	5	46	70	n/a	TS
N/A	1901	September	29	44.2N	76.5W	40	25	30	n/a	ET
N/A	1903	September	17	43.0N	77.0W	335	13	45	n/a	ET
N/A	1915	August	22	43.5N	79.0W	55	17	30	n/a	ET
N/A	1923	October	24-25	43.6N	76.9W	N/A	19.4-22.5	33.4-39	n/a	ET
N/A	1926	August	2	44.0N	78.8W	50	19	30	n/a	ET
Hazel	1954	October	16	45.2N	78.6W	350	48	70	n/a	ET
Audrey	1957	June	29	43.7N	77.1W	35	58	60	n/a	ET
Hugo	1989	September	23	42.2N	80.2W	20	43	40	988	ET
Opal	1995	October	6	43.3N	78.4W	50	23	40	997	ET
Fran	1996	September	8	43.4N	79.9W	15	6	35	999	TD
Dennis	1999	September	8	43.5N	76.5W	90	9	25	1006	ET
Isabelle	2003	September	19	43.9N	80.9W	350	34	35	1000	ET
Frances	2004	September	9	42.8N	77.7W	35	32	40	1001	ET
Katrina	2005	August	31	40.1N	82.9W	50	26	30	996	ET
Ernesto	2006	September	3	43.1N	77.5W	350	20	25	1014	ET
Sandy	2012	October	30	40.1N	77.8W	n/a	n/a	57.5	995	ET

Note 1: Data were selected according to HURDAT data from the latitude and longitudinal coordinates with closest proximity to Lake Ontario.

Note 2: Wind speed is the 1-minute, 10-meter wind speed

Note 3: ET indicates Extra-Tropical; TS indicates Tropical Storm and TD indicates Tropical Depression

Table 2.4-2: Storms Causing High Recorded Surges on Lake Ontario

(6-Minute Water Level Data)

Date	Wind Speed[1] (mph)	Setup/down(feet)
3/25/1996-3/26/1996	57.5	0.46
2/22/1997	70.2	1.54
3/28/1998-3/29/1998	71.3	0.82
5/31/1998	79.4	0.82
8/24/1998	58.7	0.78
11/10/1998-11/11/1998	62.1	0.53
12/11/2000-12/12-2000	63.3	0.82
2/10/2001	76	1.10
10/25/2001	71.3	0.53
2/10/2001	76.0	1.30
2/1/2002	72.5	1.31
3/9/2002-3/10/2002	65.6	1.31
2/4/2003	78.3	0.43
10/15/2003	74.8	0.46
11/13/2003	65.5	0.95
11/5/2004	44.7	0.66
12/24/2004	67.1	1.38
9/29/2005	44.7	0.88
2/17/2006	80.6	1.74
11/27/2007	40.2	0.95
1/9/2008	64.4	1.25
1/30/2008	59.8	1.18
9/14/2008-9/15/2008	57.5	1.22
12/28/2008	59.8	0.95
2/12/2009	59.8	0.43
5/8/2010	57.5	0.69
1/17/2012	59.8	1.28
2/24/2012-2/25/2012	66.7	1.02

Notes:

1. Maximum sustained wind or gust
2. Storms highlighted in red indicate the top ten surges according to the six minute water level data.

Table 2.4-3: Storms Causing Recorded High Water Surges on Lake Ontario

(1-Hour Water Level Data)

Date	Wind Speed (mph)	Setup/down(feet)
11/17/1965	n/a	1.21
2/16/1967	n/a	1.18
1/25/1972	n/a	1.25
11/10/1975	72.5	1.17
4/6/1979	n/a	1.81
4/6/1979	n/a	1.67
12/15/1991	57.5	1.42
11/13/1992	n/a	2.06
2/22/1997	70.2	1.41
2/10/2001	76.0	1.30
2/1/2002	63.3	1.43
3/10/2002	65.6	1.31
11/13/2003	65.5	1.40
2/17/2006	80.6	1.88
12/2/2006	67.9	1.21
1/30/2008	59.8	1.61
1/9/2008	74.8	1.17
1/18/2012	59.8	1.57
1/29/2012	n/a	1.22
2/25/2012	n/a	1.17

Note: Wind Speed is the maximum 1 minute sustained wind speed or gust where red highlighted storms indicated top ten surges.

Table 2.4-4: Storms Causing Recorded High Storm Surges at Rochester, NY

(1-Hour Water Level Data)

Date	Surge at Rochester (feet)	Storm Type	Wave Height at Ginna (feet)
10/14/1989	1.3	TSTM WIND	2.6
4/15/1996	1.0	none	3.0
3/10/1964	1.0	none	9.3
12/30/1996	0.9	none	5.5
10/29/2012	0.9	Hurricane Sandy	n/a
3/18/1989	0.8	none	5.6
11/8/1996	0.8	Flash Flood	3.8
9/16/1986	0.8	none	4.2
6/20/2001	0.8	none	n/a
3/5/1974	0.8	none	5.1
4/8/2006	0.7	none	n/a
3/10/1964	0.7	none	9.3
5/3/1992	0.7	none	4.0
5/13/2000	0.7	TSTM WIND	4.2
3/15/1973	0.7	none	4.2
3/18/1989	0.7	none	5.6
4/7/2001	0.7	TSTM WIND	n/a
5/17/1974	0.7	none	2.7
3/18/1989	0.7	none	5.6
7/17/1988	0.7	none	1.6
1/3/1999	0.7	none	6.7

Table 2.4-5: PMWS Pressure, Wind Speed, and Wind Direction on Lake Ontario

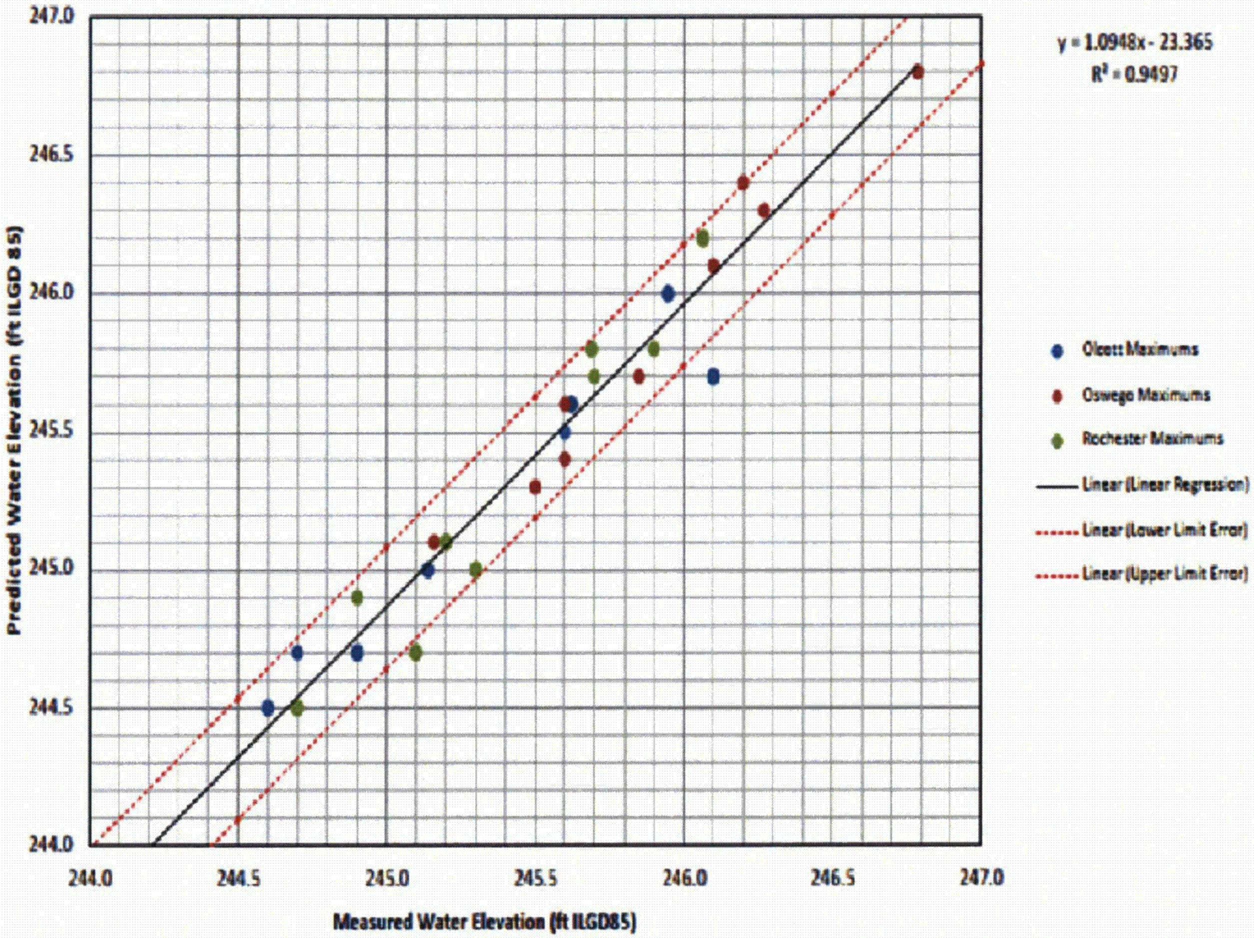
	Z1 (Western)				Z2 (Central)				Z3 (Eastern)				
Time (Hour)	P1 (mb)	S1 (mph)	S1 (kph)	D1 (deg)	P2 (mb)	S2 (mph)	S2 (kph)	D2 (deg)	P3 (mb)	S3 (mph)	S3 (kph)	D3 (deg)	P4 (mb)
0	971	50	81	120	973	60	96	130	977	44	72	130	979
1	969	52	84	110	972	49	80	110	975	46	74	110	977
2	967	55	89	100	970	49	79	100	973	46	74	90	975
3	965	51	81	110	968	50	80	110	971	47	75	100	973
4	964	44	71	130	966	50	80	120	969	48	78	120	971
5	962	41	66	130	965	47	75	120	967	45	73	110	969
6	961	43	69	110	963	42	68	110	966	44	70	100	967
7	959	45	73	110	962	42	68	110	964	38	60	100	966
8	958	44	71	110	960	45	73	110	963	37	60	110	964
9	956	44	71	100	958	46	74	110	961	39	62	110	963
10	954	46	74	90	957	47	76	110	960	41	66	110	961
11	953	37	60	120	955	48	77	140	958	40	64	140	960
12	952	29	47	140	954	46	73	140	956	41	66	160	958
13	951	27	43	130	953	39	62	160	955	43	69	160	957
14	951	25	40	210	952	28	44	190	954	36	58	180	955
15	951	34	54	190	951	34	55	185	953	27	43	180	954
16	954	58	94	300	951	36	57	190	953	28	45	190	953
17	958	76	122	290	953	36	58	280	952	30	49	190	953
18	961	100	161	300	956	66	106	300	952	47	76	200	950
19	965	95	152	300	960	100	161	300	954	94	151	290	950
20	968	94	152	300	963	83	134	300	958	100	161	290	954
21	971	89	143	300	966	87	141	300	961	84	135	290	958
22	974	81	130	300	970	90	145	300	964	82	131	300	961

	Z1 (Western)				Z2 (Central)				Z3 (Eastern)				
Time (Hour)	P1 (mb)	S1 (mph)	S1 (kph)	D1 (deg)	P2 (mb)	S2 (mph)	S2 (kph)	D2 (deg)	P3 (mb)	S3 (mph)	S3 (kph)	D3 (deg)	P4 (mb)
23	976	73	117	300	972	88	142	300	967	83	134	300	964
24	978	64	103	300	975	75	121	300	971	84	136	300	967
25	980	56	90	290	977	67	108	290	973	65	104	290	971
26	982	52	84	290	979	62	100	290	976	62	99	290	973
27	983	44	71	300	981	58	93	290	978	58	94	290	975
28	985	39	62	300	983	49	79	300	980	57	91	300	978
29	986	38	61	300	984	38	61	300	982	52	84	300	980
30	987	34	54	300	986	38	62	300	983	36	58	300	982
31	988	30	49	310	987	37	59	300	985	35	56	300	983
32	989	29	46	330	988	29	47	310	986	36	58	300	985
33	990	28	46	350	989	29	47	325	987	27	43	300	986
34	991	26	41	340	990	28	45	320	988	24	39	300	987
35	992	23	38	340	990	28	44	340	989	24	38	320	988
36	992	23	38	340	991	24	39	340	990	22	35	320	989

Table 2.4-6: SSPP Model Outputs

Wind Direction (degrees)	Wind Direction	Set-up at GNPP (ft.)	Surge Elevation (ft., IGLD85)	Surge Elevation (ft., NGVD29)
240	WSW	2.3	249.6	250.2
250	WSW	2.7	250.0	250.6
260	W	3.0	250.3	250.9
270	W	3.1	250.4	251.0
280	W	3.2	250.5	251.1
290	WNW	3.2	250.5	251.1
300	WNW	3.1	250.4	251.0
310	NW	2.9	250.2	250.8
320	NW	2.6	249.9	250.5
330	NNW	2.3	249.6	250.2
340	NNW	2.2	249.5	250.1
350	NNW	2.2	249.5	250.1
360	N	2.1	249.4	250.0
10	NNE	1.9	249.2	249.8
20	NNE	1.7	249.0	249.6
30	NE	1.4	248.7	249.3
40	NE	1.1	248.4	249.0

Figure 2.4-1: SSPP Model Verification for Nine Representative Storms



2.5 Seiche

A seiche is an oscillation of the water surface in an enclosed or semi-enclosed body of water initiated by an external cause. Once started, the oscillation may continue for several cycles; however, over time it gradually decays because of friction (NRC, 2011, Section 3.6).

2.5.1 Methodology

Ginna is located on the south shore of Lake Ontario, which has well-documented seiche events (Hamblin, 1982; Li et al., 1975; Simpson et al., 1964; Scheffner, 2008).

The HHA approach described in NUREG/CR-7046 (NRC, 2011) was used to determine whether a seiche in Lake Ontario or in the discharge canal can result in significant elevated water levels at Ginna. This approach initially involves the determination of the natural periods of oscillation in each water body. Once the seiche periods have been determined, they are compared to the forcing mechanisms to analyze the potential for resonance.

Specifically, the seiche evaluation methodology includes:

1. Definition of site and Lake Ontario conditions.
2. Evaluation of the fundamental periods of Lake Ontario at Oswego based on published data and a statistical analysis of water level data.
3. Evaluation of seiche forcing and record water level responses on Lake Ontario.
4. Evaluation of resonance and impulse response on Lake Ontario including statistical analysis of wind data.
5. Evaluation of the external forcing mechanism and periods on Lake Ontario to determine if resonance is expected and potential impacts.
6. Determination of the natural period of oscillation of the discharge canal using linear theory and the geometry of the canal.
7. Evaluation of the external forcing mechanism and periods in the discharge canal to determine if resonance is expected and potential impacts.

2.5.2 Results

Detailed results are provided in AREVA, 2013a.

2.5.2.1 Seiches in Lake Ontario

2.5.2.1.1 Periods of Oscillation in Lake Ontario

The natural period of Lake Ontario primarily depends on the geometry (length/width) and depth of the basin and is independent of the external forcing. Natural periods generally range from tens of seconds to several hours (Rabinovich, 2009; Scheffner, 2008). Research indicates that the fundamental period of oscillation for Lake Ontario is approximately five hours (Hamblin, 1982, Li et al., 1975 and Simpson et al., 1964). Hamblin's modeling results show the presence of higher order modes with periods of 3.23, 2.36, 1.74, 1.6[1], and 1.44 hours for modes 2 through 6, respectively. The modeling results of Rao and Schwab presented in the USACE CEM (Scheffner, 2008) are similar, indicating that the period of the six lowest modes in Lake Ontario are 5.11, 3.11, 2.13, 1.87, 1.78, and 1.46 hours for modes 1 through 6, respectively. The first three modes all rotate counter-clockwise around the basin. The spatial structure of the fourth mode is barely detectable.

[1] Hamblin notes that there is only weak evidence for the fifth mode.

2.5.2.1.2 Statistical Analysis of Water Level Data

To confirm the seiche modes of Lake Ontario and to determine the relative power of each seiche mode, a spectral analysis of the six-minute water level data from the two nearest NOAA Stations (Station 9052030: Oswego, NY and Station 9052058: Rochester, NY) was performed (NOAA, 2012). The analysis was performed by applying a discrete Fast Fourier Transform with no normalization of the output. The annual variation of lake levels indicates that the annual variability clearly overwhelms short-term variations such as surges and seiches. The annual variation is due to the annual hydrologic cycle and regulatory releases of water to control Lake Ontario water levels. The natural and anthropogenic cycles generally result in higher water levels in the spring and early summer with the highest water levels typically occurring during June on Lake Ontario (Wilcox et al., 2007).

Semi-diurnal and diurnal (12 and 24 hour period) peaks are also present. While the Great Lakes are considered non-tidal, gravitational forces of the sun and moon do impact the lakes causing fluctuations of less than two inches at spring (highest) tide (NOAA, 2013). The 12 and 24-hour periods are likely due to some combination of gravitational forces and daily variations in wind and barometric pressure (Wilcox et al., 2007 and Boegman et al., 2001).

Spectral peaks also occur at Oswego and Rochester for each of the seiche modes described in the literature. There are significant differences in the relative strength of each mode at the two sites due to the variation in amplitude of each mode around the basin. As expected the primary mode, with a period of 5.1 hours, is stronger at Oswego, while the secondary mode, with a period of 3.2 hours, is stronger at Rochester. Higher order modes are present, but are weak in comparison to the primary and secondary modes. Based on this observational analysis, the first and second modes may both be important considerations for analysis of seiche at Ginna.

2.5.2.1.3 Seiche Forcing

On Lake Ontario, seiches are typically caused by long period non-convective extra-tropical storms with winds blowing parallel to the long access of the lake causing a setup at the downwind end of the lake and a corresponding water level setdown at the upwind end of the lake (Scheffner, 2008; FEMA, 2012; Rabinovich, 2009). The resulting wind stress forcing on Lake Ontario is nearly uniform over the length of the lake. Wind speed and direction vary slowly over the whole lake during the 8-12 hour duration of the storm. These types of storms have caused the largest storm surges recorded in the lake.

Evaluation of nine non-convective extra-tropical storms shows decaying oscillations. These water level plots were prepared from the NOAA six-minute water level measurements at the Oswego, Rochester, and Cape Vincent gauges (NOAA, 2006) for nine storms that caused significant storm surges on Lake Ontario between 2001 and 2012. For the February 17, 2006 storm that resulted in one of the largest recorded storm surges at the east end of the lake, an initial storm surge is observed at the Oswego and Cape Vincent stations. The storm surge causes an impulse response, exciting the seiche modes and resulting in standing waves at the fundamental period of the lake (about every 5 hours). The amplitude of the oscillating waves decrease over time. This decaying of water level with time is characteristic of other storms on Lake Ontario.

2.5.2.1.4 Resonance in Lake Ontario

Resonance occurs when a forcing mechanism has the same frequency as a seiche mode. Resonance is a common concern in semi-enclosed basins where waves enter the open end of a basin at the same frequency as a seiche mode thus forcing a seiche that grows in amplitude with each successive oscillation. Since Lake Ontario is a closed basin, only atmospheric surface or seismic forcing with the correct frequency can cause resonance. If the frequency of the forcing is different than the frequency of a natural mode, the wave motion will become out of phase with the surface forcing and the average energy input from the forcing to the seiche will diminish to zero. With no energy input, the amplitude of the seiche will decay due to bottom friction.

The spatial scales of meteorological events that cause seiche on Lake Ontario are much larger than the lake itself. These events primarily excite the fundamental seiche mode due to the uniform wind stress. This nearly uniform wind stress does not excite the second mode directly and thus only the primary mode is considered in further discussion of resonance.

To investigate the potential for resonance between atmospheric forcing and the primary seiche mode, a spectral analysis of wind data on Lake Ontario was performed. Surface wind data has been recorded at the Rochester Airport (ROC) since 1930. The ROC wind data, which is the longest and most complete wind record on the south shore of Lake Ontario, provides 2-minute duration wind speeds and directions that are sampled at 1-hour intervals. The spectral power density of the wind speed was calculated using the same technique described for the water level.

Peaks in the power spectrum for the wind speed at 12 and 24 hours are related to diurnal and semi-diurnal atmospheric processes. The energy spectrum is smooth and flat at periods smaller than 12 hours with no spectral peaks near the period of the primary seiche mode of approximately 5 hours or the higher modes at 3.2 and 2.3 hours. The flat spectrum in this frequency range is called a white noise spectrum and contains equal energy at each frequency and shows no indication of an atmospheric process that could resonate with the primary mode of Lake Ontario.

2.5.2.1.5 Impulse Response in Lake Ontario

A seiche observed in the water level at Ginna need not result from a storm surge at Ginna. An impulse, such as a storm surge anywhere on the lake, will excite all the basin modes everywhere on the lake to some degree. The shape and location of the initial displacement generated by the storm surge will determine the resulting amplitude of each seiche mode.

The primary mode of Lake Ontario is still a relatively simple displacement of water from one end of the basin to the other. Rather than oscillating directly from end to end as in the one-dimensional case, because of the earth's rotation, the standing wave deflects around the cyclonic amphidromic point as it moves across basin; the deflection is to the north as the wave crest moves west and to the south as it moves east.

The second mode of Lake Ontario has two amphidromic points. When this mode is excited, two synchronized wave crests propagate counter clockwise around the edges of the basin. Along the southern shore the waves reflect off of one another as they continue across the basin to the northern shore.

As documented by Hamblin (1982) and confirmed in the spectral analysis of the Rochester water level, the second mode could be a particular concern for Ginna because the second mode has the potential to generate relatively large amplitudes near the site. However, as described previously, the spatial scales of meteorological events that cause seiches on Lake Ontario do not excite this mode directly.

The seiche modes of Lake Ontario are detectable in long, precise water level records using spectral signal processing techniques. However, the amplitude of these modes is generally only a few centimeters. The flooding risk to Ginna is negligible because the amplitude of the primary mode is minimal near the site and the energy in the secondary mode is less than half the energy in the primary mode (Hamblin, 1982). Regardless of the path and wind direction of the storm, the seiche resulting from a PMSS in Lake Ontario will never exceed the probable maximum storm surge at Ginna.

2.5.2.1.6 External Forcing Mechanism

Meteorological, astronomical, and seismic forcing can cause seiches in a water body such as Lake Ontario. However, for seiche to pose a risk to the Ginna, the forcing period must be at the natural frequencies of the basin.

Earthquakes: The typical frequency content of earthquakes falls outside the range of the estimated seiche periods of Lake Ontario. Resonance will not occur due to the difference in the natural period of Lake Ontario and the typical range of ground motion (shaking) periods from earthquakes which typically do not exceed 10 seconds.

Meteorological: Meteorological forcing has a much broader energy spectrum. Seiches can be caused by various meteorological events, including tropical storms, extra-tropical storms, changes in barometric pressure, frontal zones and short-period convective storms (squall lines with high winds, and thunderstorms).

Moving disturbances, such as storms, initially cause storm surges, followed by a series of oscillations (standing waves) which can be both forced (during the period of strong winds over the lake) and free (once the storm has passed). If the frequency of the disturbance is different than the fundamental frequencies of the lake, the amplitude of the seiches decay fairly rapidly (over a period of a few days) due to bottom friction as the seiche oscillates between opposing shorelines. Cessation of the external force causes periodic water level fluctuations as the standing wave reflects from the ends of the lake (Melby et al., 2012). The review of water level data and historical data indicates that amplification of storm surges does not occur on Lake Ontario.

Waves: Wind generated wave periods which can range from 4 to 20 seconds are too short to drive a resonant seiche in Lake Ontario.

Astronomical: While the Great Lakes are considered non-tidal, gravitational forces of the sun and moon do impact the lakes causing fluctuations of less than two inches at spring (highest) tide (NOAA, 2013). The periods of the seiche modes in Lake Ontario are too short to cause diurnal and semi-diurnal resonance.

2.5.2.2 Seiches in the Discharge Canal

The discharge canal at Ginna could potentially support longitudinal or transverse seiche modes. The first step in the HHA for the discharge canal is determining the fundamental period using linear theory. Once the period is determined, the possible forcing mechanisms are examined to evaluate the risk of seiche in the discharge canal causing flooding at Ginna.

The discharge canal at Ginna is primarily rectangular, running parallel to the shoreline, and connected to Lake Ontario by a perpendicular opening through the revetment as shown in Figure 2.5-1. A longitudinal seiche will propagate along the long axis of the canal between the mouth and the head. A transverse seiche will propagate along the short axis of the canal from north to south. The total length from the head of the canal to the revetment is 277 feet; the width ranges from 30 to 40 feet (Ginna, 2011, Section 10.6.2.8 and Appendix 2A Section 2A.1.4). The bottom of the discharge canal is at elevation of 238 feet. Using the regulated monthly mean water elevation 248.0 feet MSL (AREVA, 2013b) the discharge canal has an average water depth of 10 feet.

2.5.2.2.1 Determination of the Fundamental Period of Oscillation

Merian's Formula provides a method for estimating the natural periods of the one-dimensional seiche modes of an enclosed or semi-enclosed basin. For the PMS within the discharge canal at Ginna, the primary modes of the longitudinal and transverse seiche are of principal concern. In the longitudinal direction, the discharge canal is a semi-enclosed basin bounded by the western end of the canal on one end and open to Lake Ontario at the other. The length of the canal in the longitudinal direction is measured from the revetment at the shore of Lake Ontario to the western end of the canal. In the transverse direction, the discharge canal is an enclosed basin bounded by the walls of the canal.

The longitudinal seiche period is estimated at 62 to 88 seconds. The transverse seiche period is estimated at approximately 3.5 to 6.5 seconds. Table 2.5-1 and Table 2.5-2 provide a summary of the input geometry and results.

2.5.2.2.2 Evaluation of Forcing Events

Meteorological: Although there is generally significant energy in the wind spectrum at approximately one-minute period (Wells, 1997), which is close to the period of the primary longitudinal mode for the discharge canal, the canal's shape and high banks protect the water in the discharge canal from wind effects, and resonance due to wind gusts is not likely. For the transverse mode the steep banks and narrow cross section from north to south also make resonant wind forcing improbable.

Waves: Wind generated wave periods which can range from 4 to 14 seconds are too short to drive a resonant seiche in the longitudinal direction. In the transverse direction, wind waves have periods within the range of the discharge canal (3.5 to 6.5 seconds). Resonance of waves at east end of the discharge canal (opposite the opening) is possible. However, the landward side of the discharge at the opening is a vertical wall which will reflect waves at a 45 degree angle down the longitudinal length of the canal in which the period of the canal is much longer than the wind waves.

Astronomical: The astronomical tides in Lake Ontario are not significant since they are less than two inches at spring (highest) tide (NOAA, 2013) and therefore resonance of tides is not a concern.

Earthquakes: The frequency content of earthquakes can vary by earthquake and by the distance of the site from the earthquake epicenter (and amount of damping that occurs); however, the frequency content is typically less than 10 seconds. The period of the primary mode of the discharge basin (62 to 88 seconds) in the longitudinal direction is not within the typical range of ground motion (shaking) periods. The period of the primary mode of the discharge basin in the transverse direction (3.5 to 6.5 seconds) is within the range of earthquake frequency. The UFSAR states that the maximum expected earthquakes would not result in significant ground motion at the site (Ginna, 2011).

2.5.3 Conclusions

Based on the seiche evaluation for Ginna, the following conclusions are reached for Lake Ontario:

- The natural period of the primary and secondary seiche modes in Lake Ontario are approximately 5.1 and 3.2 hours, respectively.
- On Lake Ontario, the recorded seiches with the largest amplitudes are associated with long period, non-convective extra-tropical storms with winds blowing parallel to the long axis of the lake (west to east) causing a set-up at the downwind end of the lake and a corresponding water level set-down at the upwind end of the lake. The tracks of these storms are typically in a west to east (or southwest to northeast) direction and occur during the late Fall and Winter months.
- The PMS hazard for Ginna is bound by the PMSS elevation. Historical lake data indicates that amplification of storm surges does not occur.

The following conclusions are reached for Ginna Discharge Canal:

- The discharge canal is small, shallow and generally protected from meteorological forcing.
- The geometry of the discharge canal provides protection from wave induced seiche propagation.
- Significant earthquake-generated seiches in the discharge canal are not considered to be a hazard due to the relatively low anticipated ground motion at the site from the maximum expected earthquake.

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Table 2.5-1: Longitudinal Seiche Mode Geometry and Period for the Discharge Canal

Canal	Length (feet)	Depth (feet)	Basin Type	Period (seconds)
Discharge	277	5	semi-enclosed	88.0
Discharge	277	10	semi-enclosed	62.2

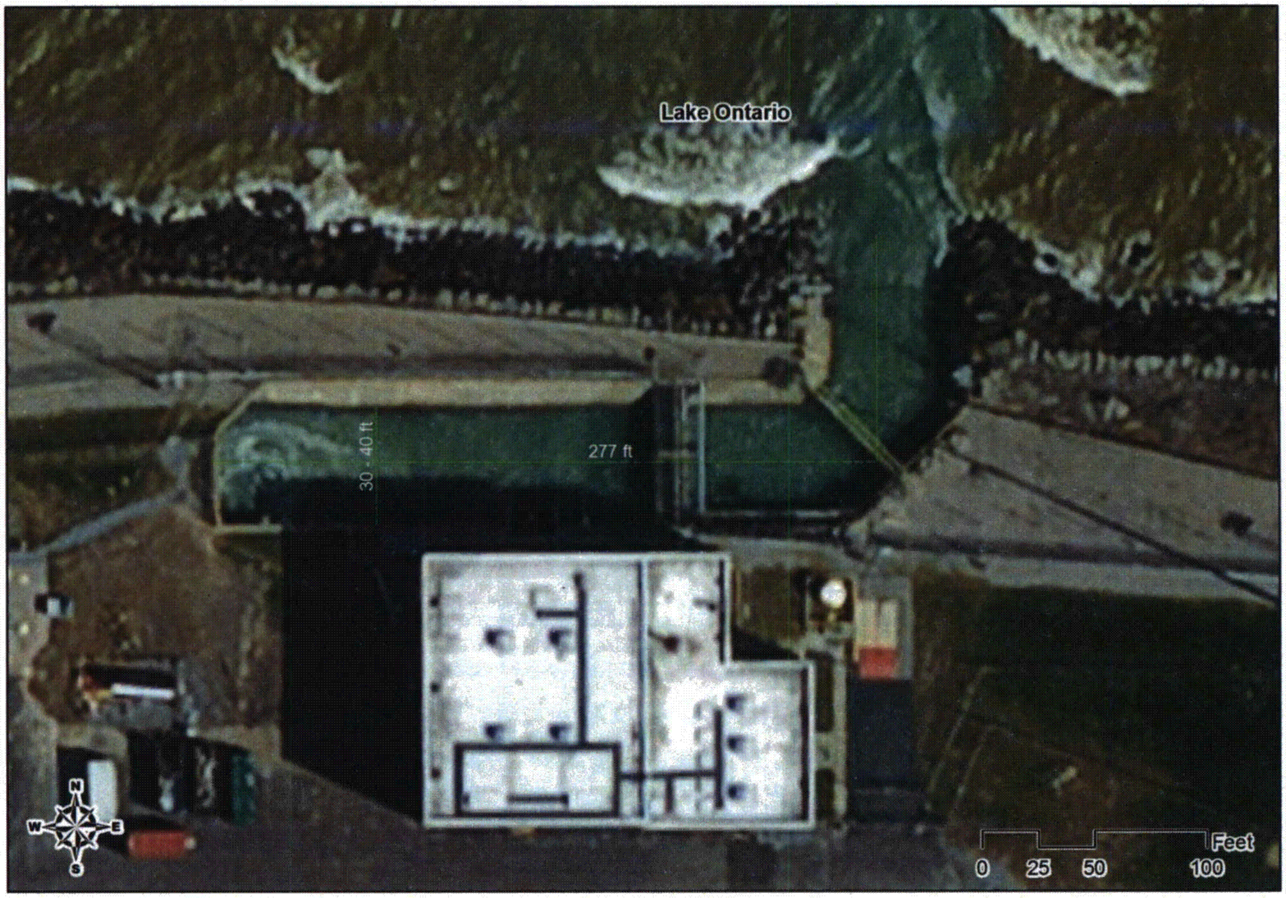
Note: A range of possible depths, 5 to 10 feet, is used to calculate the possible seiche period

Table 2.5-2: Transverse Seiche Mode Geometry and Period for the Discharge Canal

Canal	Length (feet)	Depth (feet)	Basin Type	Period (seconds)
Discharge	30	5	enclosed	4.7
Discharge	40	5	enclosed	6.4
Discharge	30	10	enclosed	3.4
Discharge	40	10	enclosed	4.5

Note: A range of possible lengths, 30 to 40 feet, and depths, 5 to 10 feet, is used to calculate the possible seiche period

Figure 2.5-1: Discharge Canal Dimensions



2.6 Tsunami

A tsunami is a series of water waves generated by a rapid, large-scale disturbance of a water body due to seismic, landslide, or volcanic tsunamigenic sources (NRC, 2009, Section 1.1). As an inland site, Ginna is not susceptible to oceanic tsunamis (NRC, 2009, Section 2.1). Instead, there is the potential of tsunami-like waves in Lake Ontario.

2.6.1 Methodology

The HHA approach described in NUREG/CR-6966 (NRC, 2009) was used for tsunamis and considered the first two of three steps (AREVA, 2013). The third step was unnecessary based on the results of the first two steps, which answered the questions:

1. Is the site region subject to tsunamis?
2. Is the plant site affected by tsunamis?

Question 1 was answered by performing a regional survey and assessment of tsunamigenic sources. The regional survey was in four parts.

The first part of the regional survey was to review the Global Historical Tsunami Database (NOAA, 2012a), maintained by the NOAA National Geophysical Data Center (NGDC), to determine the history of tsunamis. The second, third, and fourth parts of the regional survey included an assessment of the mechanisms likely to cause a tsunami.

Question 2 was answered by using the results from Question 1 to identify the primary effects of a tsunami wave near the Ginna site and then performing a site screening to determine the potential effects to the Ginna site.

2.6.2 Tsunami Results

2.6.2.1 Regional Survey

Tsunamis are generated by rapid, large-scale disturbance of a body of water. Therefore, only geophysical events that release a large amount of energy in a very short time into a water body generate tsunamis. The most frequent cause of tsunamis is an earthquake. Less frequently, tsunamis are generated by submarine and subaerial landslides and volcanic eruptions (NRC, 2009, Section 1.3). Meteorite impacts, volcanoes, and ice falls can also generate tsunamis, but were excluded from the regional survey because meteorite impacts and volcanoes are very rare events and ice falls are generally associated with glacial ice processes.

2.6.2.1.1 NGDC Database Review

The NGDC tsunami-source-event database is global in extent with information dating from 2000 B.C. to the present. As an inland site, Ginna is not susceptible to oceanic tsunamis (NRC, 2009, Section 2.1). Instead, there is the potential of tsunami-like waves in Lake Ontario. The regional survey, therefore, considered tsunami-like waves in the area around the Great Lakes, extending from 41° to 49° N Latitude and 76° to 92° W Longitude (Figure 2.6-1).

Seven events occurred in or near the Great Lakes. All events resulted in a seiche (tsunami-like wave) or disturbance in an inland river. Two of the events were caused by earthquakes, two by meteorological conditions, one by a landslide, and the two remaining unknown.

The maximum event water height increase was nearly 10 ft. in Lake Michigan; the maximum event water height increase in Lake Ontario was 5 ft. Both of these maximum heights were related to meteorological events. The maximum event water height related to an earthquake was 9 ft. in Lake Erie.

2.6.2.1.2 Earthquakes

To generate a major tsunami, a substantial amount of slip and a large rupture area is required. Consequently, only large earthquakes with magnitudes greater than 6.5 generate observable tsunamis (NRC, 2009, Section 1.3.1).

Based on the updated seismological information presented in the NMP3NPP COL application (NMP3NPP, 2009a, Section 2.5.3.1), the Lake Ontario region is relatively aseismic. A listing of the seismic events that have occurred within approximately a 300-mile radius of the NMP3NPP site (about 250-miles for Ginna) between 1732 and 2007 includes only two earthquakes with magnitudes estimates over 5.5. Both earthquakes were magnitude 5.7 and occurred at distances of about 170 and 230 miles from the Ginna site. As a result, the required level of seismic activity for development of a tsunami, i.e., an earthquake with a magnitude greater than 6.5, is essentially absent from the region.

Seismic activity outside the region can also produce seismic seiches (USGS, 2012). Seismic waves from the Alaska earthquake of 1964, for example, caused water bodies to oscillate at many places in North America. Seiches were recorded at hundreds of surface-water gaging stations. The seismic seiche distribution did not have an obvious dependence on distance or azimuth from the epicenter. Instead, the distribution had a regional pattern, which reflected the influence of major geologic features. The southeastern part of the United States had the greatest density of seiches, while areas west of the Rockies, the Middle Atlantic States, and New England experienced few or no seiches. A favorable environment for seismic seiche generation includes thrust faults and locations controlled by structural uplifts and basins (USGS, 2012). The Lake Ontario region, however, lacks such features.

2.6.2.1.3 Landslides

There are two broad categories of landslides: (1) subaqueous that are initiated and progress beneath the surface of the water body, and (2) subaerial that are initiated above the water and impact the water body during their progression or fall into the water body. In addition, landslide-generated tsunami-like waves have a very strong directivity in the direction of mass movement. Therefore, the outgoing wave from the landslide source propagates in the direction of the slide. Also, the amplitude of the outgoing wave from a subaqueous landslide is affected by the terminal velocity of the movement, which in turn is a function of the repose angle, i.e., the slope angle. The most common landslide mechanism is an earthquake. (NRC, 2009, Section 1.3.2)

Subaqueous Landslide - Lake Ontario Bathymetry

The perimeter of the lake, in general, has linear bathymetric features with uniform gradients. There are however, two shoreline areas with steep gradients that have the potential to produce a subaqueous landslide. They include the Niagara Fan, located on the lake's southwest shoreline at the mouth of the Niagara River, and a ledge line, extending from SW to NE of Toronto (Figure 2.6-2). The direction of a landslide in either area, if it occurred, would be toward the opposite lake shoreline. For the Niagara Fan, a landslide would be northwest toward Toronto and the resultant tsunami-like wave, if it occurred, would not affect the Ginna site. A landslide at the Toronto Ledge, if it occurred, would be SE toward the Niagara River, more than 120 miles west of the Ginna site. In addition, the steepest slope of the Toronto Ledge is about 5 degrees (Table 2.6-1). Thus, given a landslide, its speed would be limited and judged unlikely to generate an observable tsunami-like wave. As a result, the effect to the Ginna site would be minimal, if any.

There are also three distinct features within the lake basins that have the potential to produce a subaqueous landslide that could affect the Ginna site. The first is the Scotch Bonnet Ridge, which separates the Mississauga and Genesee Basins (Figure 2.6-2). The ridge is oriented NE-SW. Thus, the direction of a landslide on the east side of the ridge, if it occurred, would be SE, toward but north of the Ginna site. Also, the ridge has a relief of less than 20 meters and maximum slope of less than 5 degrees (Table 2.6-1). Thus, given a landslide, its mass and speed would be limited and judged unlikely to generate an observable tsunami-like wave.

The second feature is the Point Petre Ridge, northeast of the Genesee Basin (Figure 2.6-2). The ridge is oriented NNE-SSW. Thus, the direction of a landslide on the east side of the ridge, if it occurred, would be ESE, well north of the Ginna site. Also, like the Scotch Bonnet Ridge, the ridge has a relief of less than 20 meters and maximum slope of less than 5 degrees (Table 2.6-1). Accordingly, given a landslide, its mass and speed would be limited and judged unlikely to generate an observable tsunami-like wave.

The third feature is a series of distinct NE-SW ridges that occupy the floor of the Rochester Basin, Lake Ontario's deepest basin (Figure 2.6-2). These ridges have a relief of 15-25 meters and a natural spacing of 250-1000 meters, with a linear aspect and uniform width. Most of the ridges have relatively flat tops with steep side slopes, some of which are steeper to the northwest, others to the southeast, and some are symmetrical in cross-profile. The maximum slope of these ridges, however, is less than 10 degrees (Table 2.6-1). The direction of a landslide, if it occurred, would be SE toward but north of the Ginna site. Also, like both the Point Petre Ridge and Scotch Bonnet Ridge, given a landslide, its mass and speed would be limited and judged unlikely to generate an observable tsunami-like wave.

Subaerial Landslide - Lake Ontario Topography

The geographical areas where subaerial landslides occur are generally limited to areas of steep shoreline topography (NRC, 2009, Section 1.3.2).

The Lake Ontario shoreline has linear topographic features with uniform gradients around most of the perimeter (Figure 2.6-3). The land is either flat or gently rolling. The land on the eastern and northern shorelines also has similar characteristics.

There is, however, one dissimilar feature that has the potential to produce a subaerial landslide due to its steep gradient. The Scarborough Bluffs on the western Lake Ontario shoreline in Toronto is an escarpment that rises nearly 280 ft. above the lake and spans a shoreline length of 10 mi. (Eyles, 1985). Due to the bluffs general NE-SW orientation, the direction of a landslide and resultant wave, if it occurred, would be SE toward southwestern lake shoreline north of the Niagara River, located nearly 90 miles west of the Ginna site. Thus, given a landside, there would be little, if any, effect to the Ginna site due to the direction and distance of the wave from the site.

2.6.2.1.4 Findings

Based on the regional survey results,

- Ginna is not susceptible to oceanic tsunamis; instead, there is the potential of tsunami-like waves in Lake Ontario.
- Seven tsunami-like waves, identified as seiches by the NGDC, have occurred in or near the Great Lakes. Two of these events were caused by earthquakes, one by a landslide, two by meteorological conditions, and two by unknown sources.
- The Lake Ontario region is relatively aseismic. The largest recorded earthquakes are magnitude 5.7. The required level of seismic activity to generate an observable tsunami of magnitude greater than 6.5, therefore, is essentially absent from the region.
- Subaqueous landslides, if they occurred, are unlikely to generate an observable tsunami-like wave due to the limited bathymetric relief of ridges (less than 40 m) and their respective slopes (less than 10 degrees).
- Subaerial landslides are unlikely to occur around the perimeter of the Lake Ontario due to limited topographic relief. The one area with sufficient topographic relief, Scarborough Bluffs near Toronto, is oriented such that the direction of a landslide and resultant tsunami-like wave, if it occurred, would be toward the Niagara River on the southeastern lake shoreline nearly 90 miles west of the Ginna.
- No records were found of volcanic activity being a source mechanism to produce a tsunami or tsunami-like wave in or near the Great Lakes.

2.6.2.2 Site Screening

Based on the Regional Survey, tsunami-like waves (seiches) have occurred in or near the Great Lakes, including Lake Ontario. Most of the reported waves were caused by meteorological conditions or unknown sources. Two, however, are related to earthquakes and one to a landslide.

The primary effects of the tsunami-like waves on the Ginna site are flooding due to runup from the wave and loss of cooling water due to dry intakes during drawdown caused by the receding wave.

2.6.2.2.1 Flooding Due to Runup

The Ginna plant is protected from lake flooding by a breakwater with a top elevation of 261 ft. (Ginna, 2011, Section 2.4.2.1).

Lake Ontario is currently regulated, but if not regulated, projected lake levels could reach a maximum of 250.2 ft. (NMP3NPP, 2009b, Section 2.4.1.5). This lake level was determined for the Nine Mile Point Unit 3 Combined Operating License Application performed in 2008/2009 using historic lake level data. In this case, the unregulated maximum lake level is used as a conservative value as appropriate for the HHA process.

From the NGDC database results, the maximum reported tsunami-like wave in any of the Great Lakes, caused by other than a meteorological event, is 9 ft. and is the result of an earthquake. Adding this value to the maximum projected lake level of 250.2 ft. yields 259.2 ft., which is 1.8 ft. below the 261 ft. grade level of the Ginna breakwater.

2.6.2.2.2 Impacts Due to Drawdown

Cooling water for Ginna is drawn from a single intake structure located 3,100 ft. offshore near the bottom of Lake Ontario (Ginna, 2011, Section 2.4.8). The lowest allowable water elevation for plant operation is 224.4 ft (Ginna, 2013).

Prior to lake-level regulation, Lake Ontario reached a historic minimum level of 242.7 ft. (NMP3NPP, 2009b, Section 2.4.11.3). This lake level was determined for the Nine Mile Point Unit 3 Combined Operating License Application performed in 2008/2009 using historic lake level data. In this case, the unregulated minimum lake level is used as a conservative value as appropriate for the HHA process. The margin between the top of the intake and the historic minimum unregulated lake level is 18.3 ft. (242.7-224.4).

Thus, assuming that the amplitude of the drawdown is no larger than that of runup (9 ft), there is sufficient physical margin to protect safety-related SSC.

2.6.3 Conclusions

Based on the historical records and information above, tsunami flooding at the Ginna site, if it occurred, would not affect the safety-related SSC because:

- As an inland site, the Ginna site is not subject to oceanic tsunamis; however, tsunami-like waves (seiches) have occurred. Most of the reported waves were caused by meteorological conditions, but two were related to earthquakes and one to a landslide.
- Tsunami-like waves generated from
  - an earthquake are limited because the required level of seismic activity for development of a tsunami, i.e., an earthquake with a magnitude greater than 6.5, is essentially absent from the region;
  - a subaqueous landslide is unlikely to generate an observable tsunami-like wave due to the limited bathymetric relief of ridges and their respective slopes; and

  - a subaerial landslide is unlikely to occur due to limited topographic relief. The one area with sufficient topographic relief, Scarborough Bluffs near Toronto, is oriented such that the direction of a landslide and resultant tsunami-like wave, if it occurred, would be toward the southeastern lake shoreline, nearly 90 miles west of the Ginna site.

- Notwithstanding the occurrence of tsunami-like waves, the potential effects on the Ginna site (wave runup and drawdown) are negligible because there is sufficient physical margin to protect safety-related SSC. The margin is based on the maximum recorded tsunami-like wave resulting from an earthquake in the Great Lakes region occurring coincident with the maximum and minimum lake levels as applies to the tsunami-like wave runup and drawdown, respectively.

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Table 2.6-1: Lake Ontario Prominent Bathymetric Feature Slopes

Prominent Feature (Name or Description)	Gradient Length (m)	Gradient height (m)	Slope (degrees)
Toronto Ledge	500	40	4.6
Scotch Bonnent Ridge	750	22	1.7
Point Petre Ridge	2000	40	1.1
W. of Point Petre	400	24	3.4
Rochester Basin	144	24	9.5

Source: NOAA, 2012b

Figure 2.6-1: NGDC Tsunami-Source-Event Database Region

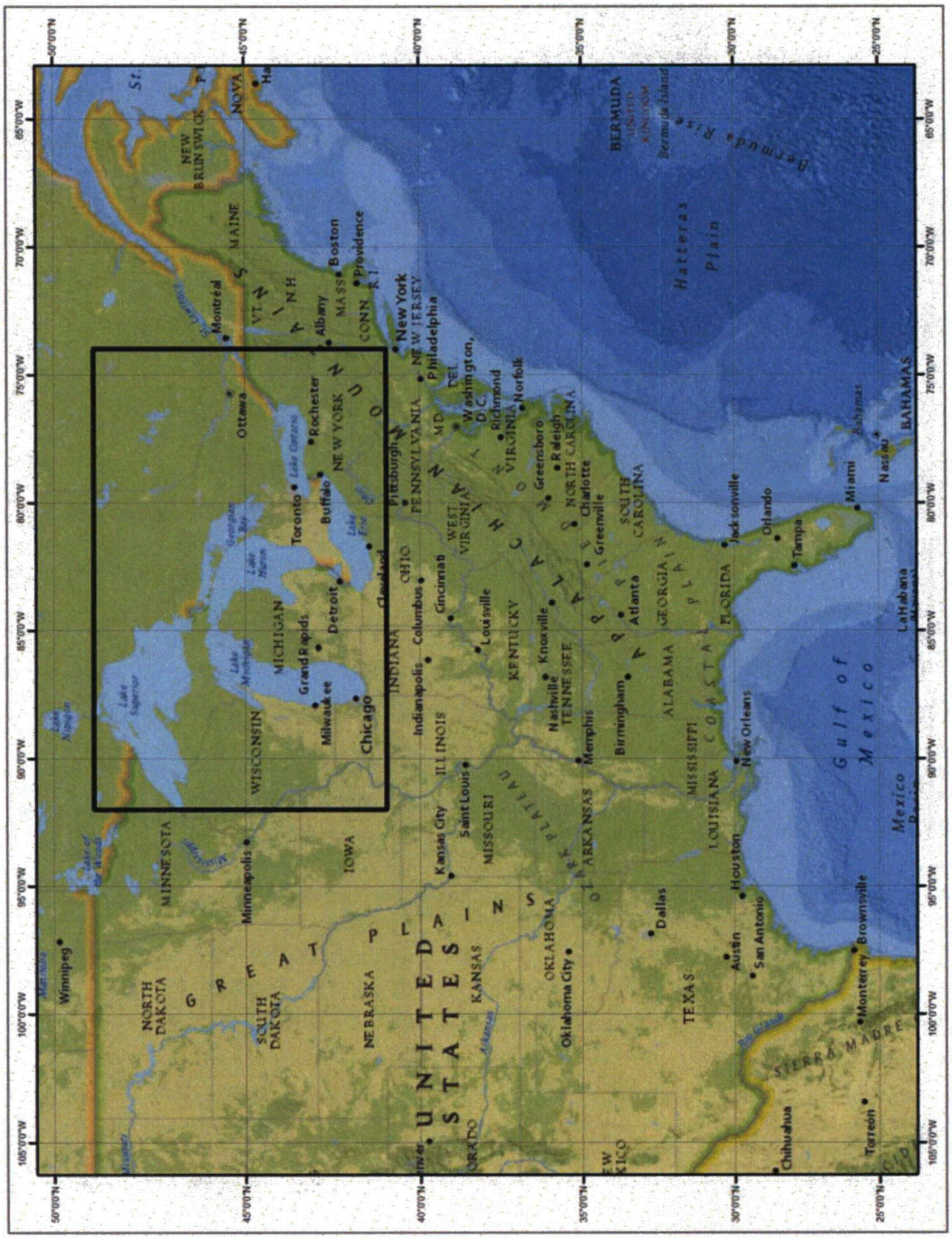
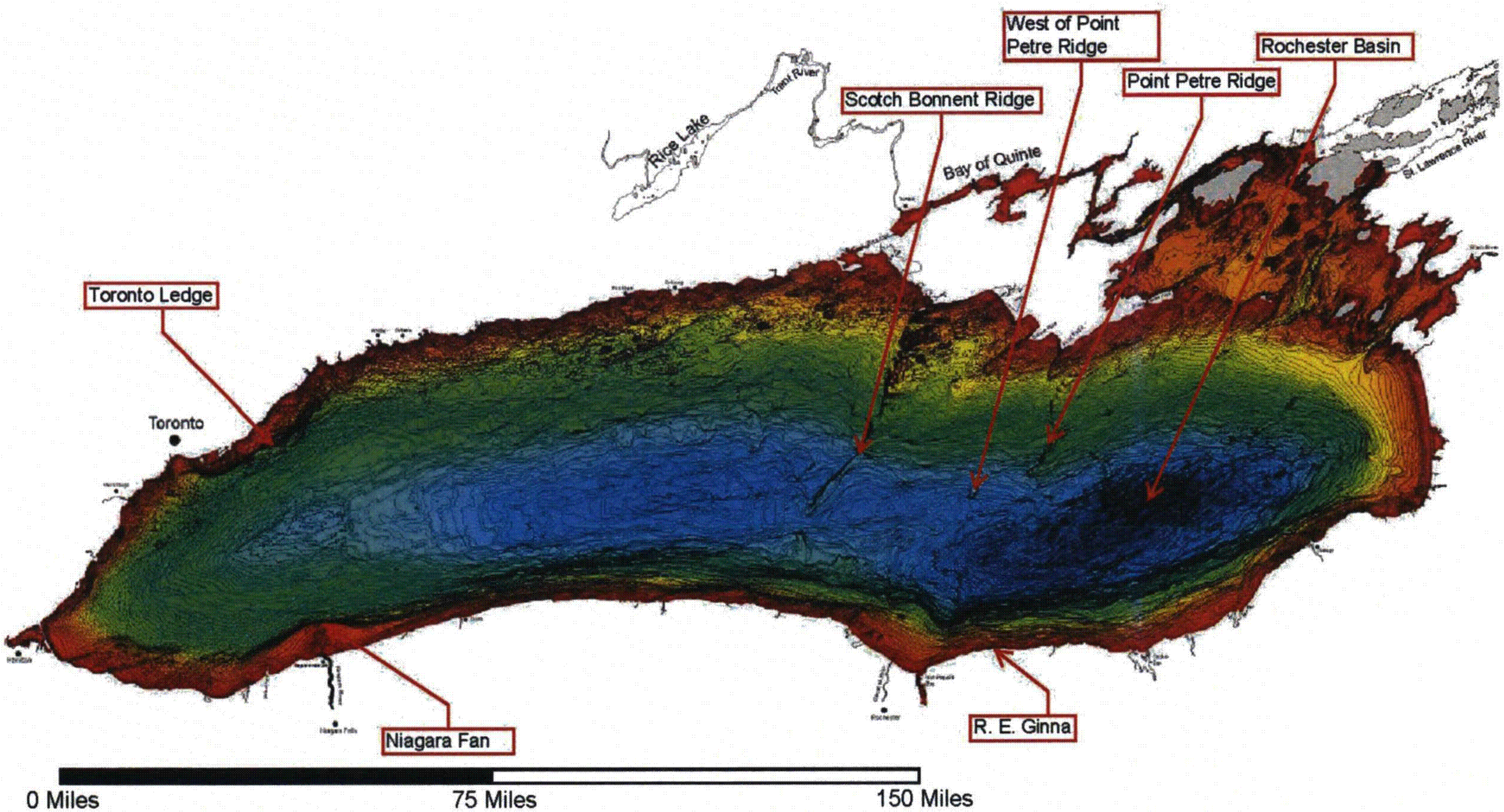
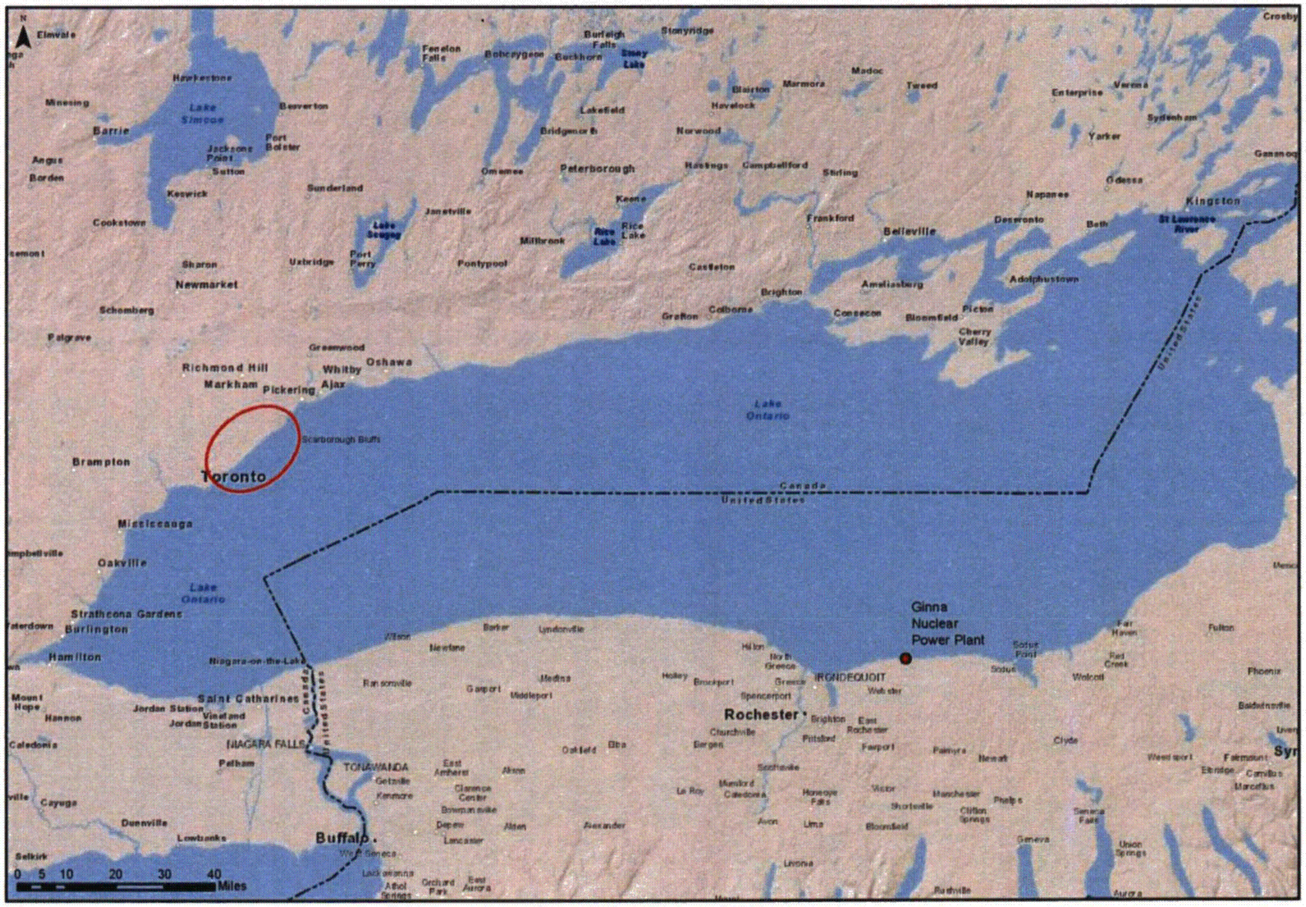


Figure 2.6-2: Lake Ontario Bathymetry Map



Source: NOAA, 2012c

Figure 2.6-3: Lake Ontario Topography Map



Source: WTBM, 2012.

2.7 Ice Induced Flooding

The extent of ice-induced flooding is limited to ice jams and ice dams in rivers and streams adjacent to a site that could lead to flooding by two mechanisms: (1) collapse of an ice jam or a dam upstream of the site can result in a dam breach-like flood wave that may propagate to the site and (2) an ice jam or a dam downstream of a site may impound water upstream of itself, thus causing a flood via backwater effects (NRC, 2011, Section 3.7).

2.7.1 Methodology

The HHA approach described in NUREG/CR-7046 (NRC, 2011) was used for Ice-Induced Flooding (AREVA, 2013) along with the analyses performed as part of the NMP3NPP COL application (NMP3NPP, 2009).

The proposed NMP3NPP project is located about 50 miles east of the Ginna site in the same hydroclimatic setting. As such, Ginna is characterized by the same ice induced flooding mechanisms as at the NMP3NPP site. Therefore, the ice induced flooding analysis performed at NMP3NPP for the regional applies to the Ginna site as well. See NMP3NPP, 2009, Section 2.4.7.

Also, as NUREG/CR-7046 notes, it is not possible at this time to predict a probable maximum ice jam or dam accurately and, therefore, recommends that historical records of ice jams and dams be searched to determine the most severe historical event in the vicinity of the site (NRC, 2011, Section 3.7).

2.7.2 Ice Induced Flooding Results

Regionally, historical data characterizing ice conditions have been collected and the effects evaluated as part of the NMP3NPP COL application (NMP3NPP, 2009). These data include ice jam records from the USACE. Although most tributaries to Lake Ontario are prone to ice formation, there has been no ice jam formation or flooding on Lake Ontario due to breaching of ice jams on upstream tributaries (NMP3NPP, 2009, Section 2.4.7).

In addition, there are no records of ice jam formation on the Saint Lawrence River causing flooding on Lake Ontario (NMP3NPP, 2009, Section 2.4.7.8). The ISLRBC regulates Lake Ontario outflow to the Saint Lawrence River and thereby controls lake levels in Lake Ontario. Following the close of the navigation season, ISLRBC reduces the Lake Ontario outflow to promote the formation of a smooth, stable ice cover on the St. Lawrence River. The stable ice cover formation is beneficial in that it reduces the risk of ice jams on the river (NMP3NPP, 2009, Section 2.4.7.8). Ice jam formation or breaching on the Saint Lawrence River, therefore, is unlikely and would not have an effect on the Ginna site.

Locally, the nearest historical ice jams data on record occurred in or near Rochester, N.Y. (Figure 2.7-1). The ice jams occurred in the Genesee River and Allen Creek, which drains into Irondequoit Bay (CRREL, 2012). Both the mouth of Irondequoit Bay and the Genesee River are greater than 10 mi by water west of the Ginna site. As a result, any river ice jam formation or breaching would not have an effect on the Ginna site.

Deer Creek, approaches the site from the west, passes south of the plant, and empties into the lake near the northeastern corner of the site. Its drainage area is 14.5 square miles.

The UFSAR states that in the event of Deer Creek ice blockage, combined with maximum surface runoff into Deer Creek, the site topography is such as to prevent flooding the plant (Ginna, 2011, Section 2.4.5). The UFSAR further notes that there is a large area immediately east of the plant where the grade levels would allow the discharge of Deer Creek to spill and reach the lake before the water level would rise to the 270-ft. grade level of the plant. The 270-ft grade level of the plant is also interposed between the channel of Deer Creek and the screen house and the surrounding area between the plant and the lake.

The site topography map, updated in the spring of 2012, confirms the UFSAR statements (Ginna, 2012). The elevation of the Deer Creek channel south of the plant is about 260 ft., and then gradually decreases to less than 250 ft. east of the plant at its discharge point into Lake Ontario. The most likely ice jam locations are an employee access bridge (Driveway Bridge, Figure 2.2-8) crossing the creek south of the plant and a small road bridge east of the plant. Each has a constriction that could promote ice jams. At the employee access bridge, the creek passes through several culverts and at the road bridge, the creek must flow around a security obstruction.

The 10-ft. elevation margin between the Deer Creek channel and the plant grade level (270 ft -260 ft, see Figure 2.2-9) is judged sufficient to prevent ice induced flooding at the plant. From the site topography map, there are large areas both south and east of the plant that would direct Deer Creek over flow to reach the lake before the water level would rise to the 270 ft. grade level of the plant.

2.7.3 Conclusions

Based on the historical records and information above, ice induced flooding at the Ginna site, if it occurred, would not affect the safety-related SSC because:

- The ISLRBC reduces the Lake Ontario outflow to promote the formation of a smooth, stable ice cover on the St. Lawrence River, which is beneficial in that it reduces the risk of ice jams on the river;
- The nearest historical ice jams data on record occurred on separate water bodies greater than 10 mi from the site;
- There are no perennial streams close to or on the site that would contribute to the potential of ice induced flooding; and
- Site topography is such as to prevent ice induce flooding from a nearby intermittent stream due to large areas both south and east of the plant that would direct over flow toward the lake before the water level would rise to plant grade level.

2.7.4 References

AREVA, 2013. AREVA Document No. 51-9191237-000, "Ice Induced Flooding at the R.E. Ginna Nuclear PowerStation Site."

CRREL, 2012. Cold Regions Research and Engineering Laboratory, Engineer Research and Development Center, U.S. Army Corps of Engineers, Website: http://crrel.usace.army.mil, accessed September 24, 2012, see AREVA Document No. 51-9191237-000.

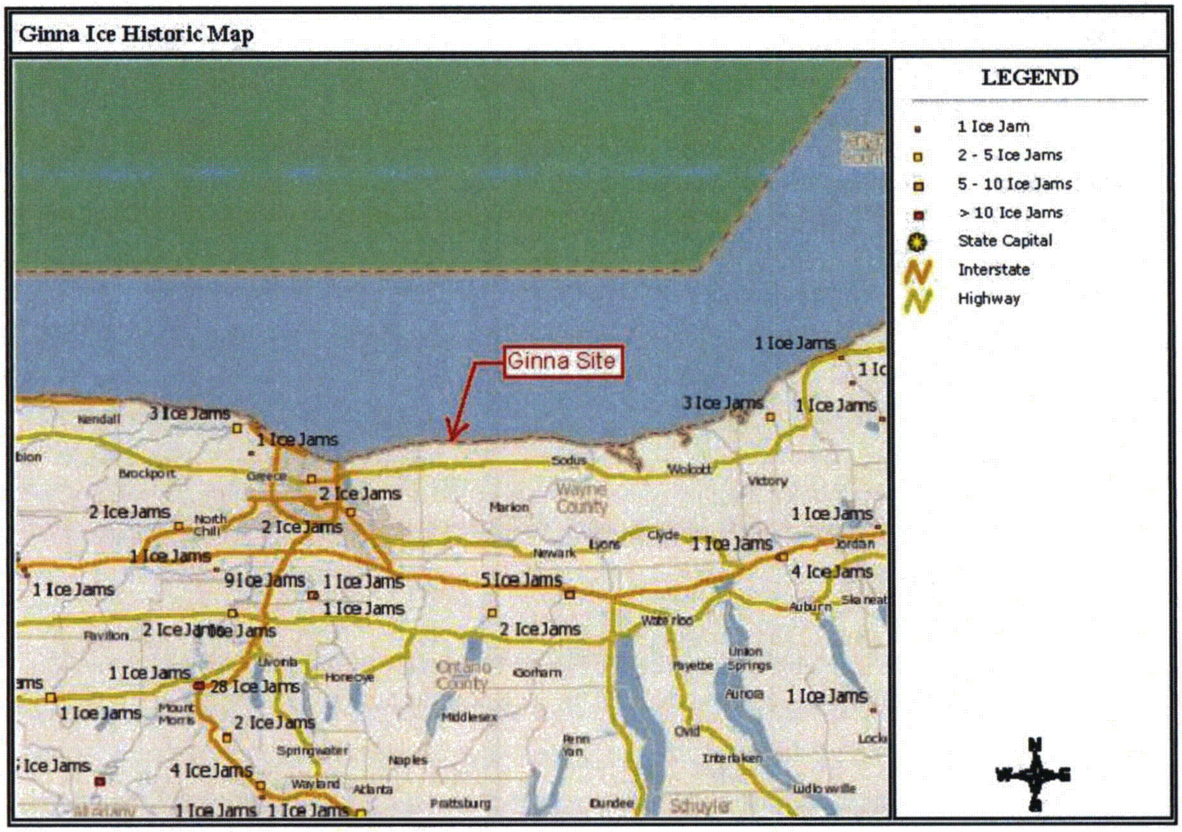
Ginna, 2011. R. E. Ginna Nuclear Power Plant Updated Final Safety Analysis Report (UFSAR) Revision 23, December 6, 2011, see AREVA Document No. 38-9191389-000.

Ginna, 2012. Ginna Topo by McMahon LaRue Associates 04-04-12.dwg, see AREVA Document No. 38-9191389-000.

NMP3NPP, 2009. Nine Mile Point 3 Nuclear Power Plant, Final Safety Analysis Report, Rev. 1, Section 2.4, Hydrologic Engineering. (ADAMS Accession No. ML082900653)

NRC, 2011. NUREG/CR-7046, Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America, U.S. Nuclear Regulatory Commission, November 2011.

Figure 2.7-1: Ginna Region Historic Ice Map



Source: CRREL, 2012

2.8 Channel Diversion and Migration

As detailed in NUREG/CR-7046 Section 3.8 (NRC, 2011), natural channels may migrate or divert either away from or toward the site. The relevant event for flooding is diversion of water towards the site.

2.8.1 Methodology

There are no well-established predictive models for channel diversions. Therefore, it is not possible to postulate a probable maximum channel diversion event. Instead, historical records and hydrogeomorphological data should be used to determine whether an adjacent channel, stream, or river has exhibited the tendency to meander towards the site. (NRC, 2011, Section 3.8)

In the case of Ginna, migration or diversion of Lake Ontario and Deer Creek was considered.

2.8.2 Results

2.8.2.1 Lake Ontario

The seismic, topographical, geologic, and thermal evidence in the region shows there is very limited potential for upstream diversion or rerouting of Lake Ontario (due to channel migration, river cutoffs, ice jams, or subsidence) to adversely impact safety-related facilities or water supplies.

2.8.2.2 Deer Creek

There are no perennial streams in the site vicinity that could impact SSC due to channel migration or diversion except Deer Creek, with a drainage area of about 14.5 square miles which enters the site from the west, passes south of the plant, and empties into the lake near the northeastern corner of the site (See Figure 1.2-1).

Migration of Deer Creek towards the safety-related SSC at the site is not anticipated to occur due to plant site management and practices.

2.8.3 Conclusions

Based on the evaluation of historical and geomorphological information, channel migration or diversion is a negligible hazard to safety-related SSC.

2.9 Combined-Effect Flood

This section addresses the effect of combined-effect flood mechanisms at Ginna. Ginna is located in Ontario, Wayne County, NY along the southern shore of Lake Ontario. Ginna is protected from flooding from Lake Ontario by a stone revetment. A concrete-lined discharge canal conveys flow from the site to Lake Ontario through an opening in the stone revetment.

The confluence of two streams, Deer Creek (which generally flows west to east) and Mill Creek (which generally flows south to north) is located near the southwestern portion of the site. The streams flow along the southern portion of the site into Lake Ontario.

In addition to waves within Lake Ontario, a rise in water level in Deer Creek near Ginna during the predicted PMF would temporarily create a lake-like body of water which would be susceptible to the formation of wind generated waves.

2.9.1 Method

The HHA approach described in NUREG/CR-7046 (NRC, 2011) was used for the evaluation of the effects of combined-effect flood mechanisms at Ginna.

The HHA approach is consistent with the following standards and guidance documents:

- NRC Standard Review Plan, NUREG-0800, revised March 2007;
- NRC Office of Standards Development, Regulatory Guides:
  - RG 1.102 – Flood Protection for Nuclear Power Plants, Revision 1, dated September 1976;
  - RG 1.59 – Design Basis Floods for Nuclear Power Plants, Revision 2, dated August 1977; and
- American National Standard for Determining Design Basis Flooding at Power Reactor Sites (ANSI/ANS 2.8 - 1992)

The criteria for combined events are provided in NRC, 2011, Appendix H. These criteria are:

1. Floods Caused by Precipitation Events

The criteria for floods caused by precipitation events were used as one input to the combined event result (NRC, 2011, Appendix H, Section H.1). These include hydrologic-induced dam failure. The criteria include the following:

- Alternative 1 - A combination of mean monthly base flow, median soil moisture, antecedent or subsequent rain, the PMP, and waves induced by 2-year wind speed applied along the critical direction;
- Alternative 2 - A combination of mean monthly base flow, probable maximum snowpack, a 100-year snow-season rainfall, and waves induces by 2-year wind speed applied along the critical direction; and
- Alternative 3 - A combination of mean monthly base flow, a 100-year snowpack, snow-season PMP, and waves induced by 2-year wind speed applied along the critical direction.

2. Floods Caused by Seismic Dam Failures

The criteria for floods caused by seismic dam failures (NRC, 2011, Appendix H, Section H.2) were also considered. The criteria include:

- Alternative 1 – A combination of a 25-year flood, a flood caused by dam failure resulting from a safe shutdown earthquake (SSE), and coincident with the peak of the 25-year flood, and waves induced by 2-year wind speed applied along the critical direction;
- Alternative 2 – A combination of the lesser of one-half of Probable Maximum Flood (PMF) or the 500-year flood, a flood caused by dam failure resulting from an operating basis earthquake (OBE), and coincident with the peak of one-half of PMF or the 500-year flood, and waves induced by 2-year wind speed applied along the critical direction.

The alternatives presented under floods caused by precipitation events and floods caused by seismic dam failures are bounded by failure of all the dams in the watershed coincident with the PMF. The riverine flooding combination used for this analysis is therefore failure of dams during the PMF, and waves induced by 2-year wind speed applied along the critical direction.

3. Floods along the Shores of Open and Semi-Enclosed Bodies of Water

The criteria for floods along the shore of open or semi-enclosed bodies of water (NRC, 2011, Appendix H, Section H.3) do not apply to Ginna since the site is not on an open or semi-enclosed body of water.

4. Floods along the Shores of Enclosed Bodies of Water

Ginna is located along the southern shore of Lake Ontario. Lake Ontario is an enclosed water body approximately 7,300 square miles in surface area. The criteria for floods along the shore of enclosed bodies of water (Streamside location) (NRC, 2011, Appendix H, Section H.4.2) was considered in this calculation. The criteria include:

- Alternative 1 – A combination of one-half of the PMF or the 500-year flood, surge and seiche from the worst regional hurricane or windstorm with wind-wave activity and the lesser of the 100-year or the maximum controlled water level in the enclosed body of water;
- Alternative 2 – A combination of the PMF in the stream, a 25-year surge and seiche with wind-wave activity and the lesser of the 100-year or the maximum controlled water level in the enclosed body of water;
- .Alternative 3 – A combination of a 25-year flood in the stream, probable maximum surge and seiche with wind-wave activity and the lesser of the 100-year or the maximum controlled water level in the enclosed water body.

These alternatives were analyzed to determine the controlling combined-effect alternative at Ginna.

5. Floods Caused by Tsunamis

Combined event floods associated with tsunamis are included as part of the analyses required by NUREG/CR-7046 (NRC, 2011, Appendix H, Section H.5). Evaluation of the potential for tsunamis at the Ginna site (AREVA, 2013i) concluded that tsunamis are not a significant flood-causing mechanism. Therefore, no further analysis of tsunami-induced flooding combined with other mechanisms has been performed.

2.9.1.1 Method Used

The combined event evaluation for Ginna used the following steps:

1. Calculate the maximum flood elevation (including dam failures) on Deer Creek at Ginna using the computer models developed for PMF on Rivers and Streams (AREVA, 2013a and AREVA, 2013b);
2. Calculate the wind wave effects and wave runup on Deer Creek at Ginna using the CEDAS-ACES v4.3 Computer Program (AREVA, 2013g);
3. Calculate the Probable Maximum Water Elevation at Ginna resulting from the combined-effect flood caused by Precipitation Events;
4. Calculate the Probable Maximum Water Elevation at Ginna resulting from combined-effect floods along the Shores of Enclosed Bodies of Water based on PMSS (AREVA, 2012d) and wind generated waves (AREVA, 2013e). Overtopping rates for the various alternatives for floods along the shores of enclosed bodies of water were calculated using CEDAS v4.3 Computer Program (AREVA, 2012g) and routed in the two-dimensional FLO-2D hydrodynamic model (FLO-2D, 2012).
5. Determine controlling (i.e., highest elevation) Probable Maximum Water Elevation at Ginna based on the results from the above analyses.

2.9.2 Results

2.9.2.1 Probable Maximum Water Elevation Resulting from Floods Caused by Deer Creek Flooding and Dam Failure

The elevation results from the PMF in Deer Creek and Mill Creek with the coincident failure of all three upstream dams in the Deer Creek and Mill Creek watersheds (MacInnis Marsh Dam, Fruitland Mill Dam and William Daly Marsh Dam, see Figure 2.9-1) are summarized in Table 2.9-1. Failure of the three upstream dams did not have an appreciable effect on the PMF peak flow rate at Ginna.

Wave runup resulting from Deer Creek flooding is not expected to influence the flood elevations at the site, with the exception of the southern end of the site, because the waves are likely to break against the buildings at the southern end of the site (consisting of the Standyby Auxiliary Feedwater Building Annex, the Canister Preparation Building and the Contaminated Storage Building). The maximum wave runup at the southern end of the power block at Ginna is 0.9 ft. This results from the greatest straight line fetch of 870 ft (Figure 2.9-3), an average water depth of 15.7 ft and a 2-year return period wind speed of 73.9 ft/sec. (AREVA, 2013f).

The probable maximum water surface elevations resulting from floods caused by PMF and dam failure events in Deer Creek are therefore the same as the probable maximum flood elevations summarized in Table 2.9-1.

2.9.2.2 Probable Maximum Water Elevation Resulting from the Combined-Effect of Floods along the Shores of Enclosed Bodies of Water

The results of the alternatives outlined under the criteria for floods along the shore of enclosed bodies of water (Streamside location) (NRC, 2011, Appendix H, Section H.4.2) are summarized below:

2.9.2.2.1 Combination of One-half of the PMF, Worst Regional Surge with Wind-wave Activity and the Maximum Controlled Water Level in Lake Ontario.

The peak flow rate from one-half of the PMF for Deer and Mill Creeks near Ginna was calculated to be 14,250 cfs (28,500 cfs divided by 2).

The highest regional historic surge was identified, based on water level data for Rochester, to be 1.3 ft (AREVA, 2013c). See Section 2.4.2.1 and Table 2.4-4.

The maximum controlled water level in Lake Ontario was calculated to be 248 ft (AREVA, 2013d), see Section 2.4.2.3.

The highest regional surge with wind-wave activity and the maximum controlled water level in Lake Ontario results in overtopping at various segments of the stone revetment along the southern shore of Lake Ontario at Ginna (Figure 2.9-2). The overtopping flow rates are shown in Table 2.9-2.

FLO-2D model results from the combination of one-half of the PMF, and the wave overtopping flow rates resulting from the combination of the worst regional surge with wind-wave activity and the maximum controlled water level in Lake Ontario (AREVA, 2013f) is shown in Table 2.9-5.

2.9.2.2.2 Combination of the PMF in Deer Creek, a 25-year Surge with Wind-wave Activity and the Maximum Controlled Water Level in Lake Ontario.

The Deer Creek PMF peak flow rate at Ginna (AREVA, 2013a) is 28,500 cfs as described in Section 2.2.

The 25-year surge elevation on Lake Ontario at Ginna was calculated using the hourly water levels in Rochester, NY for the period 1962 - 2012. The results of this evaluation is a 25-year surge of 0.95 ft (AREVA, 2013f, Appendix L).

The maximum controlled water level in Lake Ontario is 248 ft (AREVA, 2013d), see Section 2.4.2.3.

The 25-year surge with wind-wave activity and the maximum controlled water level in Lake Ontario results in overtopping at various segments of the stone revetment along the southern shore of Lake Ontario at Ginna (Figure 2.9-2). The overtopping flow rates are shown in Table 2.9-3.

Breaching of upstream dams during the PMF resulted in no increase in peak flow rates and peak water surface elevation at Ginna (AREVA, 2013f). FLO-2D model results from the combination of the PMF, and the overtopping flow rates resulting from the combination of the 25-year surge with wind-wave activity and the maximum controlled water level in Lake Ontario (AREVA, 2013f) are shown in Table 2.9-6 and Figures 2.9-4 through 2.9-6. The results of this flood scenario are peak flood elevations 0.1 ft higher than the Deer Creek PMF flood levels at the Turbine Building, Screen House, and Diesel Generator Building due to contributing flood waters from the 25-year storm surge and associated wave runup.

2.9.2.2.3 Combination of the 25-year Flood in Deer Creek, the Probable Maximum Surge with Wind-wave Activity and the Maximum Controlled Water Level in Lake Ontario.

The peak flow rate from the 25-year storm in Deer Creek at Ginna is calculated to be 3,000 cfs. The 25-year storm in Deer Creek was simulated using HEC-HMS (AREVA, 2013h). The peak flow rate of 3,000 cfs results from a total precipitation depth of 3.79 inches over 24 hours, which is based on a NRCC extreme precipitation events database (NRCC, 2013). The probable maximum surge is calculated to be

3.2 ft (AREVA, 2013d) and the maximum controlled water level in Lake Ontario is calculated to be 248 ft (AREVA, 2013d).

Model results from this scenario are shown in Table 2.9-7 (AREVA, 2013f). The overtopping flow rates are shown in Table 2.9-4. Flooding at Ginna from this scenario is limited to the Turbine Building, Screen House and the Diesel Generator Building due to wave activity (i.e., flooding in Deer Creek due to the 25-yr flood does not affect the site). Maximum Flood Elevations at the Turbine Building, Screen House and the Diesel Generator Building resulting from this scenario are 254.9 ft.

2.9.2.2.4 Determine the Controlling Probable Maximum Water Surface Elevations at Ginna

The combination of PMF in the Deer Creek at Ginna with the 25-year surge with wind wave activity and the maximum controlled water level in Lake Ontario yields the highest water surface elevations at Ginna (see Section 2.9.2.2.2). This alternative is the controlling scenario in determining the probable maximum water surface elevations at Ginna.

2.9.3 Conclusions

The bounding combined-effect flooding mechanism at Ginna is the combination of the PMF on the Deer Creek with the 25-year surge with wind-wave activity on Lake Ontario and the maximum controlled water level on the Lake. Under this alternative, waves overtop the stone revetment and discharge canal, increasing the PMF water surface elevations at the northern end of the site by 0.1 ft.

The Probable Maximum Water Elevation at Ginna including wave effects is calculated to be 272.4 ft at the Reactor Containment Building, 272.6 ft at the Auxiliary Building, 258.2 ft at the Turbine Building, 272.4 ft at the Control Building, 271.3 ft at the All-Volatile Building, 272.8 ft at the Standby Auxiliary Feedwater Pump Building, 273.5 ft at the proposed Standby Auxiliary Feedwater Pump Building Annex, 258.2 ft at the Screen House, and 258.4 ft at the Diesel Generator Building.

2.9.4 References

AREVA, 2013a. AREVA Document No. 32-9190273-000, "Probable Maximum Flood Flow in Streams and Rivers".

AREVA, 2013b. AREVA Document No. 32-9190274-000, "Probable Maximum Flood Elevations in Streams and Rivers".

AREVA, 2013c. AREVA Document No. 32-9190276-000, "Probable Maximum Winds and Associated Meteorological Parameters at R.E. Ginna".

AREVA, 2013d. AREVA Document No. 32-9190277-000, "Probable Maximum Storm Surge at R.E. Ginna".

AREVA, 2013e. AREVA Document No. 32-9190279-000, "Wind Generated Waves for R.E. Ginna".

AREVA, 2013f. AREVA Document No. 32-9190280-000, "Combined Events Flood Analysis for R.E. Ginna".

AREVA, 2013g. AREVA Document No. 38-9196713-000, "GZA Computer Program Certification for CEDAS-ACES Version 4.03 PC".

AREVA, 2013h. AREVA Document No. 38-9191662-000, "GZA Computer Program Certification for HEC-HMS Version 3.5 PC".

AREVA, 2013i. AREVA Document No. 51-9190872-000, "Tsunami Hazard Assessment at R.E. Ginna Nuclear Power Plant Site".

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FLO-2D, 2012. FLO-2D® Pro Reference Manual, FLO-2D Software, Inc., Nutrioso, Arizona

NRCC, 2013. Extreme Precipitation in New York and New England (http://precip.eas.cornell.edu\), Version 1.12, by Natural Resources Conservation Services (NRCS) and the Northeast Regional Climate Center (NRCC), revised October 19, 2011, assessed March 28, 2013, See AREVA Document No. 32-9190280-000.

Table 2.9-1: Probable Maximum Flood Elevations at Ginna from Deer Creek Flooding and Dam Failure

Structure	Design Basis Flood Levels (ft)	Peak Water Elevation (ft)	Maximum Flow Depth (ft)	Maximum Flow Velocity (fps)
Reactor Containment	272.0	272.4	2.2	1.1
Auxiliary Building	272.0 to 273.8	272.6	2.1	2.8
Turbine Building	256.6	258.1	4.1	3.1
Control Building	272.0	272.4	2.1	2.1
All-Volatile-Treatment-Building	272.0	271.3	0.7	5.3
Standby Auxiliary Feedwater Pump Building	273.0	272.8	2.7	4.1
Proposed Standby Auxiliary Feedwater Pump Building Annex	N/A	273.5	3.6	2.9
Screen House	256.6	258.1	4.5	3.3
Diesel Generator Building	256.6	258.3	4.7	4.3

Table 2.9-2: Overtopping Flow Rates for Worst Historic Surge with Wind-Wave Activity

Transect	Length (ft.)	Design Base Water Level (ft)	Depth at Structure Toe (ft.)	T Peak (T_p)	H_s (ft.)	H_o (Ft.) (CEDAS Calc.)	CEDAS Runup (ft.)	Runup Elev. (ft)	CEDAS Over-topping (CuFt/Sec -Ft.)	Over-toppin g Reach (CuFt/ Sec)
1	60	249.2	5.40	10	4.20	3.0	6.55	255.75	0	0.0
2	88	249.2	5.50	10	4.29	3.0	6.67	255.87	0	0.0
3	245	249.2	7.30	10	5.69	4.3	8.49	257.69	0.015	3.7
4	47	249.2	7.70	10	6.00	4.6	14.6	263.8	5.53	259.9
5	233	249.2	8.20	10	6.39	5.0	9.37	258.57	0.019	4.4
6	110	249.2	7.30	10	5.69	4.3	8.50	257.7	0.003	0.3
7	105	249.2	5.70	10	4.44	3.2	6.87	256.07	0	0.0

See Figure 2.9-2 for Transect Locations

Table 2.9-3: Overtopping Flow Rates for 25-year Surge with Wind-Wave Activity

Transect	Length (ft.)	Design Base Water Level (ft)	Depth at Structure Toe (ft.)	T Peak (T_p)	H_s (ft.)	H_o (Ft.) (CEDAS Calc.)	CEDAS Runup (ft.)	Runup Elev. (ft)	CEDAS Over-topping (CuFt/Sec-Ft.)	Over-topping Reach (CuFt/Sec)
1	60	248.8	5.00	10	3.85	2.7	6.08	254.88	0	0.0
2	88	248.8	5.10	10	3.95	2.8	6.21	255.01	0	0.0
3	245	248.8	6.90	10	5.38	4..0	8.10	256.90	0.005	1.2
4	47	248.8	7.30	10	5.68	4.3	14.15	262.95	4.13	194.1
5	233	248.8	7.80	10	6.07	4.7	8.97	257.77	0.007	1.6
6	110	248.8	6.90	10	5.38	4.0	8.10	256.9	0.001	0.1
7	105	248.8	5.30	10	4.13	2.9	6.46	255.26	0	0.0

See Figure 2.9-2 for Transect Locations

Table 2.9-4: Overtopping Flow Rates for Probable Maximum Surge with Wind-Wave Activity

Transect	Length (ft.)	Design Base Water Level (ft)	Depth at Structure Toe (Ft.)	T Peak (T_p)	H_s (Ft.)	H_o (Ft.) (CEDAS Calc.)	CEDAS Runup (Ft.)	Runup Elev. (ft)	CEDAS Over-topping (CuFt/Sec-Ft.)	Over-topping Reach (CuFt/Sec)
1	60	251.1	7.3	10	5.7	4.3	8.4	259.5	0.07	4.2
2	88	251.1	7.4	10	5.8	4.3	8.5	259.6	0.08	7.0
3	245	251.1	9.2	10	7.2	5.7	10.2	261.3	0.33	80.9
4	47	251.1	9.6	10	7.5	6.0	16.7	267.8	15.8	742.6
5	233	251.1	10.1	10	7.9	6.3	11.1	262.2	0.34	79.2
6	110	251.1	9.2	10	7.2	5.7	10.2	261.3	0.14	15.4
7	105	251.1	7.6	10	5.9	4.5	8.7	259.8	0	0.0

See Figure 2.9-2 for Transect Locations

Table 2.9-5: Peak Water Surface Elevations Based on the Combination of One-half of the Riverine PMF, Highest Historic Surge with Wind-wave Activity and Maximum Controlled Water Level in Lake Ontario

Structure	Representative Grid Element Number	Design Basis Flood Levels (ft)	PMF Peak Elevation (ft)	Maximum Flow Depth (ft)	Maximum Flow Velocity (fps)
Reactor Containment	6193	272.0	-	-	-
Auxiliary Building	6651	272.0 to 273.8	-	-	-
Turbine Building	4364	256.6	255.0	1.0	1.2
Control Building	5740	272.0	-	-	-
All-Volatile-Treatment-Building	5286	272.0	-	-	-
Standby Auxiliary Feedwater Pump Building	6879	273.0	-	-	-
Proposed Standby Auxiliary Feedwater Pump Building Annex	7105	N/A	270.3	0.4	0.5
Screen House	3840	256.6	254.9	1.2	0.4
Diesel Generator Building	4014	256.6	254.9	1.2	1.0

Note: "-"implies that the flooding from the scenario does not impact the given location.

Table 2.9-6: Peak Water Surface Elevations Based on the Combination of the Riverine PMF, 25-year Surge with Wind-wave Activity and Maximum Controlled Water Level in Lake Ontario

Structure	Design Basis Flood Levels (ft)	PMF Peak Elevation (ft)	Maximum Flow Depth (ft)	Maximum Flow Velocity (fps)
Reactor Containment	272.0	272.4	2.2	1.1
Auxiliary Building	272.0 to 273.8	272.6	2.0	2.8
Turbine Building	256.6	258.2	4.2	3.1
Control Building	272.0	272.4	2.0	2.1
All-Volatile-Treatment-Building	272.0	271.3	0.7	5.3
Standby Auxiliary Feedwater Pump Building	273.0	272.8	2.7	4.0
Proposed Standby Auxiliary Feedwater Pump Building Annex	N/A	273.5	3.6	2.8
Screen House	256.6	258.2	4.5	3.3
Diesel Generator Building	256.6	258.4	4.7	4.4

Table 2.9-7: Peak Water Surface Elevations Based on the Combination of the 25-year Flood in Deer Creek, Probable Maximum Storm Surge with Wind-wave Activity and Maximum Controlled Water Level in Lake Ontario

Structure	Design Basis Flood Levels (ft)	PMF Peak Elevation (ft)	Maximum Flow Depth (ft)	Maximum Flow Velocity (fps)
Reactor Containment	272.0	-	-	-
Auxiliary Building	272.0 to 273.8	-	-	-
Turbine Building	256.6	254.9	0.9	0.8
Control Building	272.0	-	-	-
All-Volatile-Treatment-Building	272.0	-	-	-
Standby Auxiliary Feedwater Pump Building	273.0	-	-	-
Proposed Standby Auxiliary Feedwater Pump Building Annex	N/A	-	-	-
Screen House	256.6	254.9	1.2	0.9
Diesel Generator Building	256.6	254.9	1.2	0.8

Note: "-"implies that the flooding from the scenario does not impact the given location.

Figure 2.9-1: Dam Locations

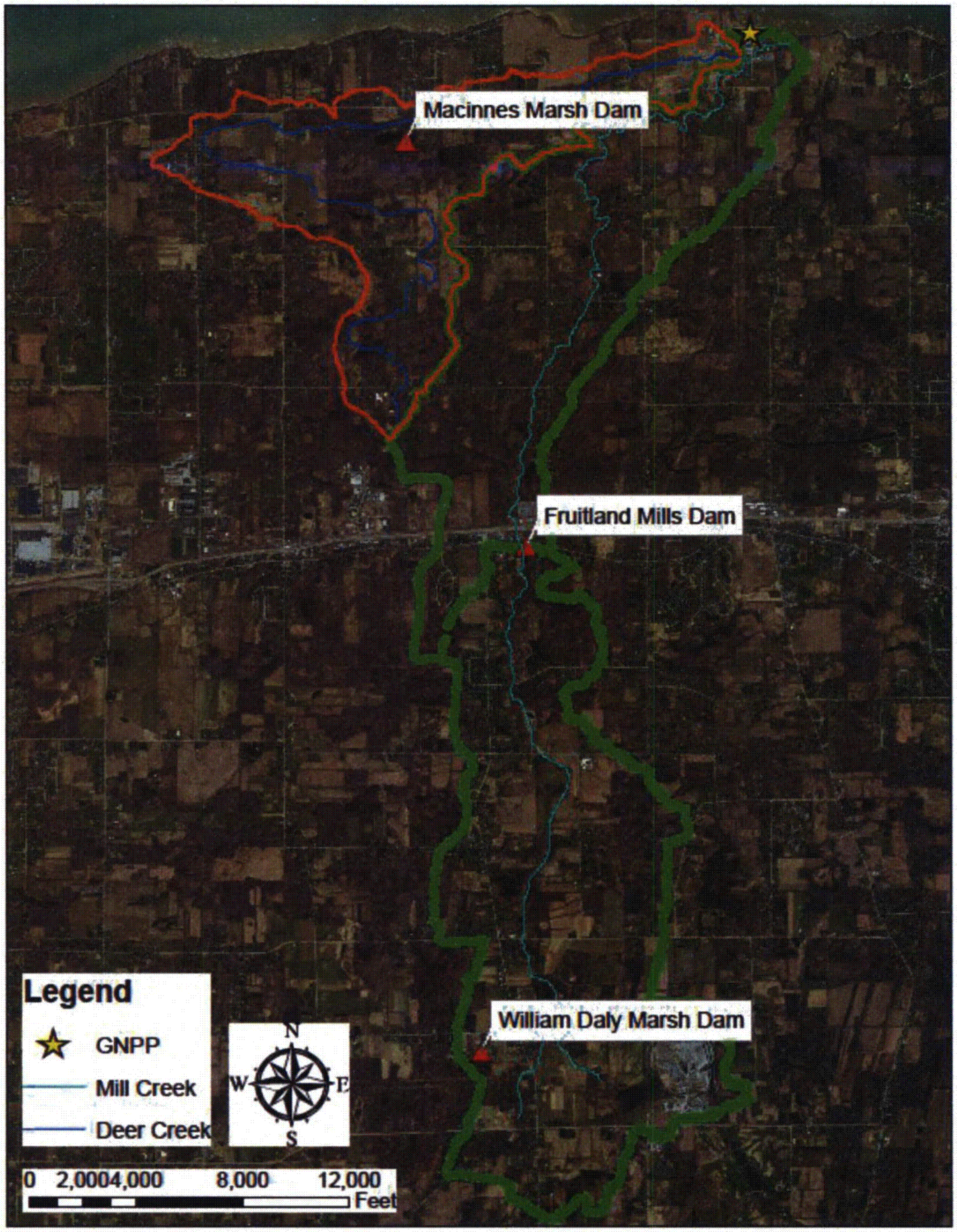

Figure 2.9-2: Transect Locations for Wave Overtopping

Figure 2.9-3: Straight Line Fetch over Deer Creek

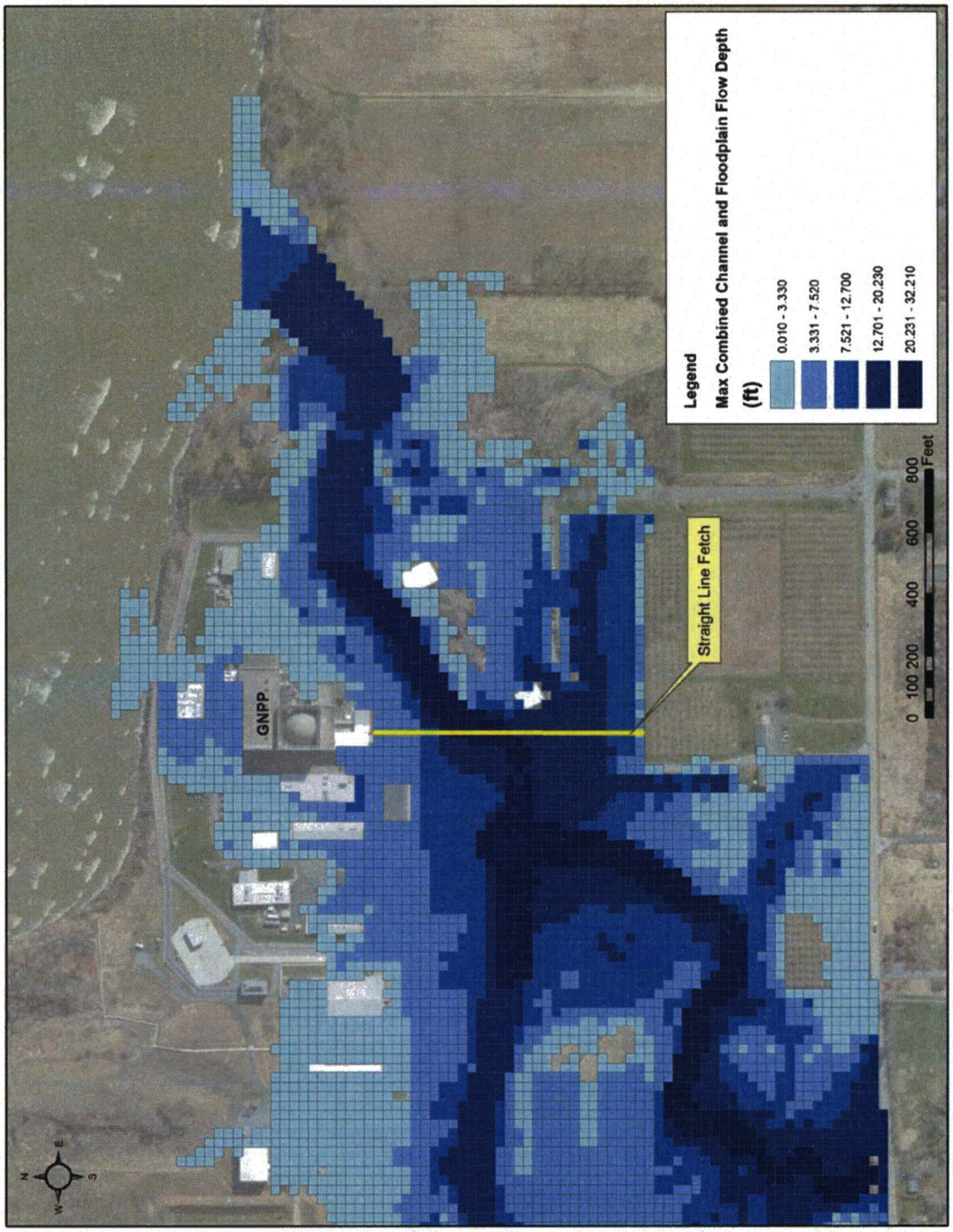

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Figure 2.9-4: Probable Maximum Water Surface Elevations at Ginna (ft) (Combination of PMF on Deer Creek and 25-year Surge with Wind-wave Activity and the Maximum Controlled Water Level in Lake Ontario)

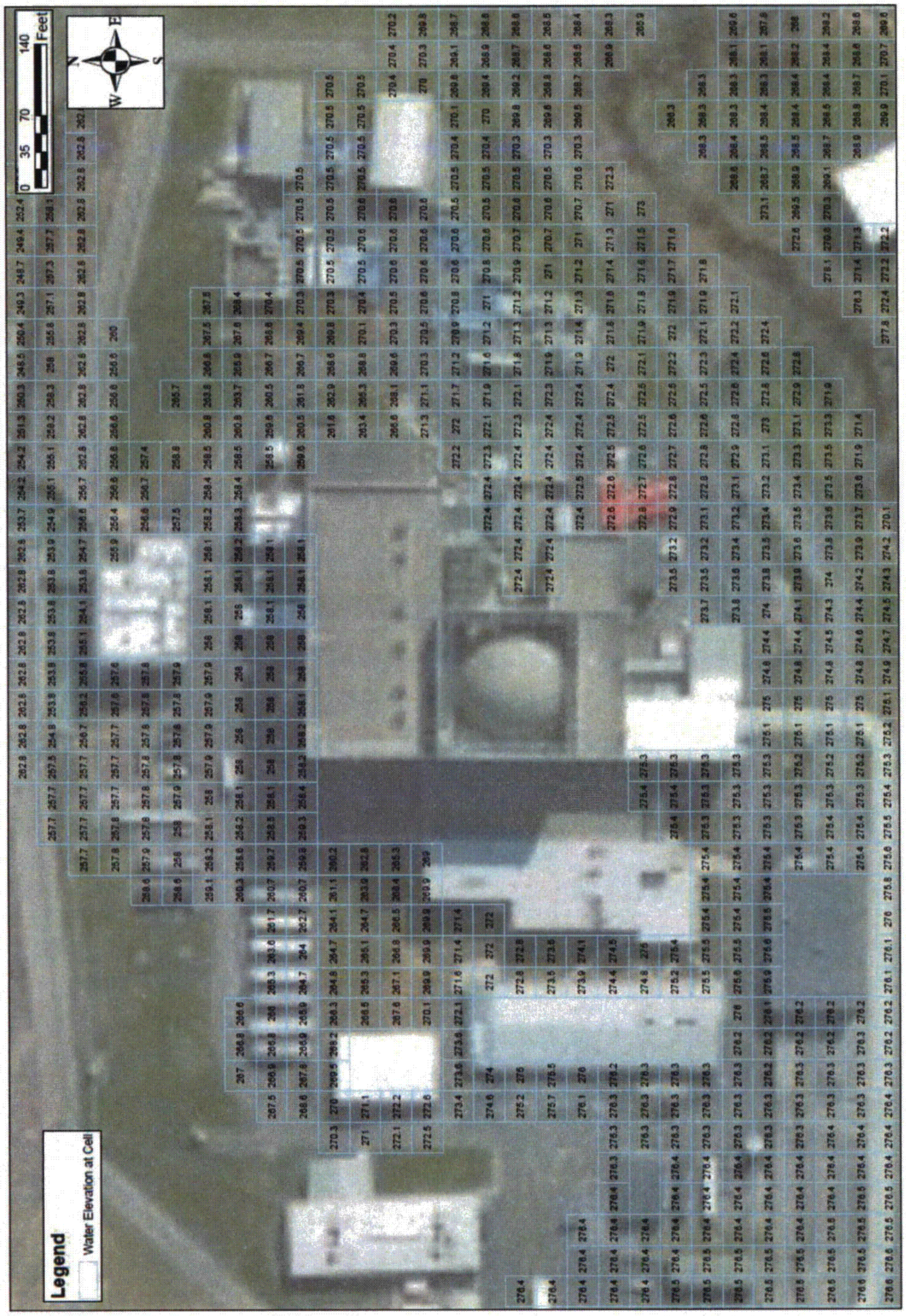
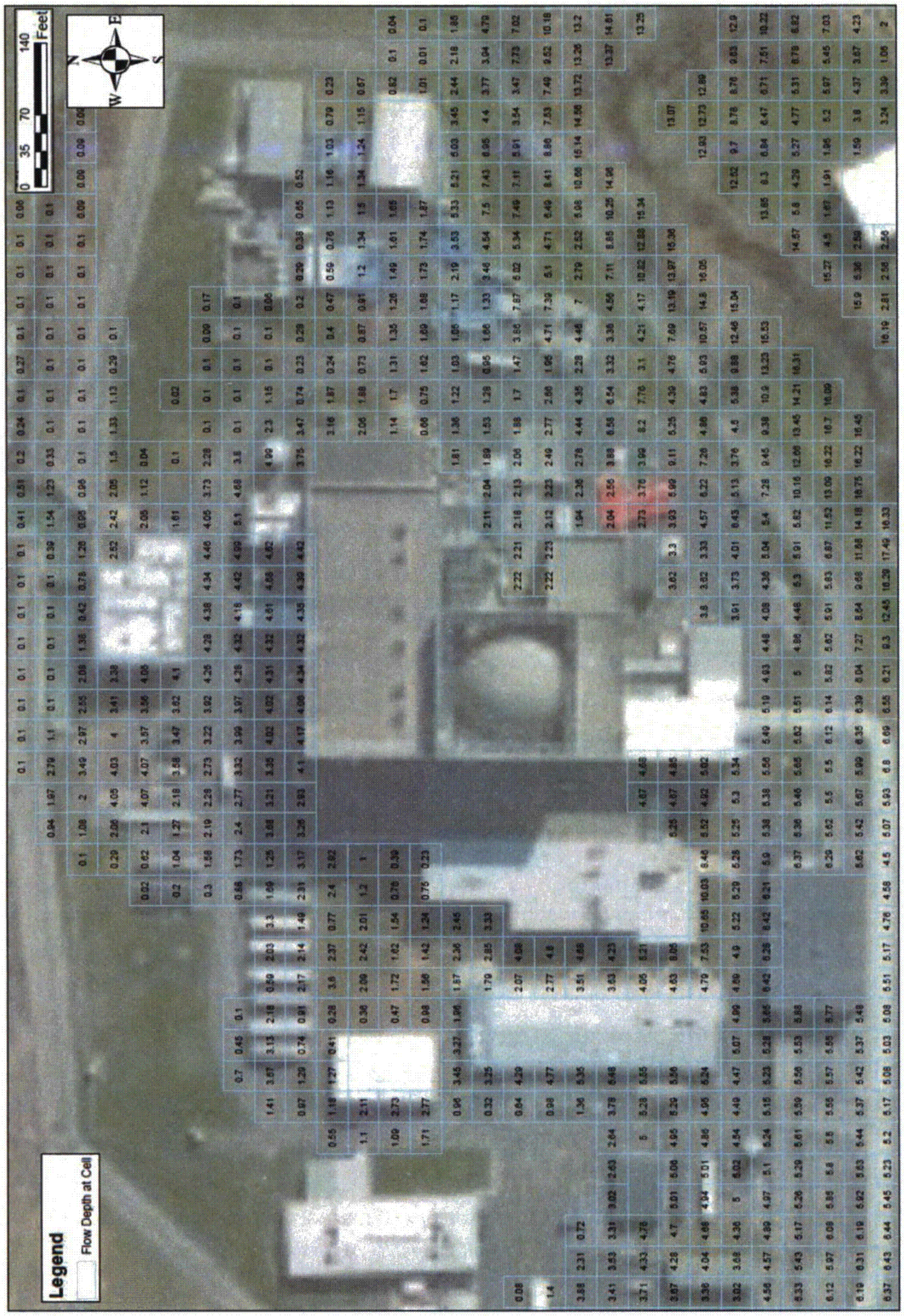


Figure 2.9-5: Ground Elevation at Grid Cell (ft)

Figure 2.9-6: Probable Maximum Flow Depths at Ginna (ft) (Combination of PMF on Deer Creek and 25-year Surge with Wind-wave Activity and the Maximum Controlled Water Level in Lake Ontario)



3.0 COMPARISON OF CURRENT AND REEVALUATED FLOOD CAUSING MECHANISMS

3.1 Summary of Flood Reevaluation Results

This section compares the current and reevaluated flood-causing mechanisms. It provides an assessment of the current licensing basis flood elevation to the reevaluated flood elevation for each applicable flood-causing mechanism.

The bounding flooding mechanism at Ginna is the combination of the PMF on the Deer Creek with the 25-year surge with wind-wave activity on Lake Ontario and the maximum controlled water level on the Lake.

3.1.1 Local Intense Precipitation

The CLB LIP event results in a flood elevation of 254.5 ft in the vicinity of the Screen House, but was not considered to impact safety related SSC which was located at elevation 254.8 ft (Ginna, 2011, Section 2.4.2.2). This event is based on a total rainfall depth of 6.11 inches in one hour and 19.17 inches over 24 hours (Ginna, 2012).

Based on the LIP re-evaluation calculation for the Ginna site, the following conclusions can be reached:

- The maximum water surface elevation due to the LIP at Ginna results from a total rainfall depth of 16 inches within one hour and 22.4 inches within 6 hours. In the immediate vicinity of the main buildings at Ginna, predicted maximum water surface elevations resulting from the LIP range from 255.8 ft at the Screen House to approximately 270.9 ft at the Auxiliary and All-Volatile-Treatment Buildings.
- At Ginna, the water elevation resulting from the LIP would result in flooding of the Screen House (255.8 ft flood level compared to a safe design elevation of 254.8 ft) and may impact safety-related SSC housed within.

See Section 2.1 for detailed information.

3.1.2 Flooding on Rivers and Streams

The CLB PMF event for Deer Creek results in flood elevations of 273.8 ft on the south wall of the Auxiliary Building, 272 ft east of the Auxiliary Building and the Turbine Building, and 256.6 ft in the north yard area near the Screen House. These flood elevations are based on a Deer Creek peak discharge of 26,000 cfs. (Ginna, 2012)

Based on the PMF re-evaluation calculation for the total contributory drainage area for the Deer Creek and the Mill Creek, the following conclusions can be reached:

- The probable maximum flood depth on streams results from the All-Season 72-hour PMP depth of 30.5 inches.
- The re-evaluated, peak PMF elevations at the SSC at Ginna generally range from 258.1 ft to 273.5, corresponding to the PMF peak flow of 28,500 cfs.
- Based on the re-evaluated peak PMF elevations, safety-related SSC would be impacted at the Screen House. Flooding may also occur in the Turbine Building and the All-Volatile Treatment Building, but no safety-related SSC would be affected in these buildings.
- The CLB did not previously include considerations of dynamic flood properties such as velocity or flow vectors.

See Section 2.2 for detailed information.