AREVA Inc.

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Entergy Fleet Fukushima Program
Flood Hazard Reevaluation Report for River Bend Station

Flood Hazard Reevaluation Report for River Bend Station

Safety Related? ☒ YES ☐ NO

Does this document establish design or technical requirements? ☐ YES ☒ NO

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Name and Title/Discipline	Signature	P/LP, R/LR, A-CRF, A	Date	Pages/Sections Prepared/Reviewed/ Approved or Comments
D.T. Brown Scientist III		LP	3/10/14	All
D.M. Leone GZA Hydraulic Engineer		P	3/10/14	Sections 3.1, 3.2, 3.3, 3.7, 3.8 and 3.9
Cynthia A. Fasano EHS Supervisor		LR	3/10/14	All
M.A. Rinckel Technical Manager, Radiological & Environmental Analysis	B Hubbard for M Rinckel	A	3/10/14	All

Note: P/LP designates Preparer (P), Lead Preparer (LP)
R/LR designates Reviewer (R), Lead Reviewer (LR)
A-CRF designates Project Manager Approver of Customer Required Format (A-CRF)
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Overview

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

Section 1 provides introductory information related to the flood hazard. The section includes background regulatory information, scope, general method used for the reevaluation, assumptions, the elevation datum used throughout the report, and a conversion table to determine elevations in other common datum.

Section 2 describes detailed RBS site information, including present-day site layout, topography, and current licensing basis flood protection and mitigation features. The section also identifies relevant changes since license issuance to the local area and watershed as well as flood protections.

Section 3 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 RBS site, a justification is included. The section also provides a basis for inputs and assumptions, methods, and models used.

Section 4 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 evaluated in Section 3.

Section 5 presents an interim evaluation and actions taken, or planned, to address those higher flooding hazards identified in Section 4 relative to the current licensing and design basis.

Section 6 describes the additional actions taken to support the interim actions described in Section 5.

The report also contains two appendices. Appendix A describes the software model FLO-2D used in the reevaluation, including the quality assurance criteria and a discussion of validation of model-derived results. Appendix B provides large scale drawings of the Local Intense Precipitation model setup and results, as well as time series plots for flood elevations at each safety-related door.

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Acronyms and Abbreviations

Acronym/Abbreviation	Description
ANS	American Nuclear Society
ANSI	American National Standards Institute
ARC	Antecedent Runoff Condition
ASCII	American Standard Code for Information Interchange
ASPRS	American Society for Photogrammetry and Remote Sensing
CFR	Code of Federal Regulations
cfs	cubic feet per second
CLB	Current License Basis
CN	Curve Number
DEM	Digital Elevation Model
DBFL	Design Basis Flood Level
DTM	Digital Terrain Model
HEC-HMS	Hydrologic Engineering Center Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center River Analysis System
HHA	Hierarchical Hazard Assessment
HMR	Hydrometeorological Report
HUC	Hydrologic Unit Code
ISFSI	Independent Spent Fuel Storage Installation
ISG	Interim Staff Guidance (NRC)
L	Lag Time
LIDAR	Light Detection and Ranging
LIP	Local Intense Precipitation
MCS	Morganza Control Structure

Acronyms and Abbreviations, continued

Acronym/Abbreviation	Description
MSL	Mean Sea Level
NAVD88	North American Vertical Datum of 1988
NCDC	National Climatic Data Center
NGDC	National Geophysical Data Center
NGVD29	National Vertical Datum of 1929
NID	National Inventory of Dams
NOAA	National Oceanic and Atmospheric Administration
NRC	U.S. Nuclear Regulatory Commission
NRCS	Natural Resources Conservation Service
NTTF	Near-Term Task Force
ORCS	Old River Control Structures
PDF	Project Design Flood
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PMWE	Probable Maximum Water Elevation
RBS	River Bend Station
RMSE	Root Mean Square Error
SOCA	Security Owner Controlled Area
SCS	Soil Conservation Service
SSCs	Structures, Systems and Components
USAR	Updated Safety Analysis Report
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation

Acronyms and Abbreviations, continued

Acronym/Abbreviation	Description
USGS	U.S. Geological Survey
VBS	Vehicle Barrier System

1.0 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.

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 River Bend Station (RBS), located on the Mississippi River approximately 24 mi. north-northwest of Baton Rouge, Louisiana, 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 Purpose

This report satisfies the "Hazard Reevaluation Report" Request for Information pursuant to 10CFR50.54(f) by the Nuclear Regulatory Commission dated November 12, 2012, NTTF Recommendation 2.1 Flooding Enclosure 2.

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

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). No additional flood causing mechanisms were identified for RBS.

Each of the reevaluated flood causing mechanisms and the potential effects on the RBS site is described in Sections 3 and 4 of this report.

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), NRC Interim Staff Guidance (ISG), as appropriate, and their 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 structures, systems, and components (SSCs) important to safety 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 SSCs important to safety, a more site-specific hazard assessment is performed for the probable maximum event.

The HHA approach was carried out for each flood-causing mechanism, with the controlling flood being the event that resulted in the most severe hazard to the SSCs important to safety at RBS. 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 SSCs important to safety are adversely affected by flood hazards, use site-specific data and/or more refined analyses to provide more realistic conditions and flood analysis, while ensuring that these conditions are consistent with those used by Federal agencies in similar design considerations.
4. Repeat Step 2 until all SSCs important to safety are unaffected by the estimated flood, or if all site-specific data and model refinement options have been used.

Section 3 of this report provides additional HHA detail for each of the flood-causing mechanisms evaluated.

Due to use of the HHA approach, the results (water elevation) for any given flood hazard mechanism may be significantly higher than results that could be obtained using more refined approaches. Where initial, overly conservative assumptions and inputs result in water elevations bounded by the CLB, no subsequent refined analyses are required to develop flood elevations that are more realistic or reflect a certain level of probability.

1.4 Assumptions

Assumptions used to support the flood reevaluation are described in Section 3 and its subsections, and depend on the mechanism being evaluated. Details relating to assumption justifications are discussed further in referenced supporting documentation. None of the assumptions require verification, i.e., need to be confirmed prior to use of the results.

1.5 Elevation Values

The RBS Updated Safety Analysis Report (USAR; RBS, 2013) reports elevations in the MSL, or Mean Sea Level datum. This datum is typically assumed to represent the Mean Sea Level Datum of 1929, which for the RBS region is equivalent to the National Geodetic Vertical Datum of 1929 (NGVD29). Updated topographic data for the site was developed using aerial light detection and ranging (LIDAR) and supporting ground control surveying performed in 2013 (AREVA, 2013). This topographic survey provided results in NGVD29 and North American Vertical Datum of 1988 (NAVD88). During performance of the topographic survey and subsequent flood hazard analyses, an approximate discrepancy of 0.7 ft was identified between newer surveyed elevations (in NGVD29) and RBS licensing basis and design drawing elevations (in MSL). The discrepancy was identified by comparing updated topographic survey results (AREVA, 2013) to RBS licensing drawings and the RBS Updated Safety Analysis Report (USAR) (RBS, 2010; RBS, 2013). National Geodetic Survey (NGS) geoid adjustments between the original site survey and the 2013 survey, as well as differences due to modern survey methodologies and standards were identified as likely sources of the discrepancy.

Elevations listed as MSL in this report refer to elevations provided in plant documentation such as the USAR or engineering drawings.

Conversion factors for all vertical datums used in this report are provided below. The conversion factor between NGVD29 and NAVD88 is determined through the National Geodetic Survey VertCon tool (NGS, 2013). The MSL conversion factor shown below is an approximate value used to compare plant document elevations against 2013 topographic survey results.

		To:		
	Datum	MSL (RBS) (ft)	NGVD29/MSL (ft)	NAVD88 (ft)
From:	MSL (RBS)	0	~ -0.74	~ -0.7
	NGVD29/MSL	~ +0.74	0	0.046
	NAVD88	~ +0.7	-0.046	0

1.6 References

AREVA, 2013, AREVA Document No. 38-9208278-002, "RBS Topographic Survey Deliverables", 2013.

NGS, 2013. "VERTCON – North American Vertical Datum Conversion", National Geodetic Survey, http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html, Date accessed September 30, 2013, Date modified January 24, 2013, See AREVA Document 32-9207350-000.

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, 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.

RBS, 2010. "Door Location Plan Sheet 2", Drawing No. EA-006K Revision 6, Entergy Operations, Inc., River Bend Station - Unit 1, June 14, 2010, See AREVA Document No. 38-9210629-000.

RBS, 2013. "RBS Updated Safety Analysis Report", Revision 23, 2013, See AREVA Document No. 38-9210629-000.

2.0 INFORMATION RELATED TO THE FLOOD HAZARD

2.1 Detailed Site Information

The RBS site consists of approximately 3,342 acres located adjacent to the Mississippi River about 24 miles north-northwest of Baton Rouge, Louisiana in the municipality of St. Francisville. The site is on the east bank of the Mississippi river, between river miles 262 to 265, with the plant sited approximately 1.5 miles from the river bank. See Figure 2.1-1.

The site is drained by Grants Bayou on the east and Alligator Bayou on the west. West Creek is a small channelized drainage feature that is located on the south side of the site, which drains into Grants Bayou. Grants Bayou enters Alligator Bayou to the south of the site. It then flows south into Thompson Creek, which enters the Mississippi River approximately 7 miles downstream of the RBS embayment. (RBS, 2013, Section 2.4.1.1)

All safety-related equipment is contained in Seismic Category I buildings. Equipment in buildings not sealed from floodwater entry is at a minimum elevation of 98 ft MSL according to the USAR. (RBS, 2013, Section 2.4.1.1).

2.1.1 Site Layout

Figure 2.1-2 shows the RBS site layout and topography, including important features related to flood modeling. Key site features relative to flood modeling include the West Creek drainage channel, the Vehicle Barrier System, the Unit 2 Excavation, and the Unit 2 Excavation Berm.

The site incorporates a concrete vehicle barrier system (VBS) as a security measure. Vehicle and personnel access ways in the VBS allow surface water to flow through the protected area into natural drainage areas, which ultimately drain into the Mississippi River. Otherwise, the site is in the direct path of natural drainage to the west from the local watershed, with surface drainage flowing toward the river.

2.1.2 Site Topography

The RBS site includes two terrace levels. The alluvial floodplain on the east side of the Mississippi River varies from 3,000 to 4,000 ft wide, and is at about 35 ft MSL. The upper terrace has an average elevation of over 100 ft MSL. RBS buildings and all safety-related equipment are located on the upper terrace. The pre-construction ground elevation in this area was approximately 110 ft MSL. The finished ground grade elevation is reported in the USAR as 95 ft MSL (RBS, 2013, Section 2.1.1.1).

The southern portion of the site (in the undeveloped areas surrounding the existing plant and its facilities) is rough and irregular, with steep slopes and deep-cut stream valleys and drainage courses. Ground elevations in this portion of the plant site range from approximately 35 ft MSL to more than 95 ft MSL inland. Elevations up to 150 ft MSL occur on the hilltops; most hilltop areas are at elevations near 100 ft MSL. (RBS3, 2008a, Section 2.1)

There are no apparent erosion issues on the Mississippi River bank that would reduce the acreage of the RBS site. Along the adjacent area of the Mississippi River, banks on outside bends of the river have been stabilized by rock and concrete structures called revetments. The inside bends have been stabilized by wing dams or dikes. Together, these structures serve to keep Mississippi River flow within the main river channel and to prevent erosion of the banks. (RBS3, 2008a, Section 2.1)

2.2 Current Design Basis Flood Elevations

The current design basis and related flood elevations for RBS are described in the USAR (RBS, 2013). Additional discussion on the design basis flood hazard level is included in the River Bend Nuclear Station

Flooding Walkdown Submittal Report for Resolution of Fukushima Near-Term Task Force Recommendation 2.3: Flooding (walkdown) (RBS, 2012) required as part of the response to the 10 CFR 50.54(f) letter.

RBS is designed to satisfy the requirements of NRC Regulatory Guide 1.59, Design Basis Floods, Rev. 2. The maximum flood level is based on the assumptions that the storm drains are inoperable and the culverts are blocked. Due to the vertical margin between the Mississippi River and the site, the flood mechanism considered to control plant flood design is the probable maximum precipitation (PMP) on the watersheds for the two local streams, Grants Bayou and West Creek, which includes the site (RBS, 2013, Section 2.4.2.2).

The design basis flood level due to the PMP was conservatively assumed to coincide with the project design flood (PDF) on the Mississippi River calculated by the United States Army Corps of Engineers (USACE). These and other flood levels are described below in Section 2.3.

2.3 Current Licensing Basis Flood Protection and Mitigation Features (CLB)

The CLB for flooding protection at RBS is described in the USAR (RBS, 2013, Section 2.4).

2.3.1 Flood Causing Mechanisms

The following is a summary of the flood causing mechanisms that are part of the CLB.

Some of the mechanisms were "screened" or evaluated in the USAR at a high level and determined to not be applicable to the flooding hazard for RBS as described below.

2.3.1.1 Local Intense Precipitation (LIP)

Flood hazard from Local Intense Precipitation (LIP) was quantified as part of the CLB at RBS. An evaluation of PMP data shows there are no areas that could produce ponding of runoff to an elevation greater than 96 ft MSL near plant buildings. Safety-related equipment is located in buildings protected from floodwater entry or situated at a minimum elevation of 98 ft MSL. Overland runoff can enter West Creek by overtopping West Plant Road (former railroad spur) at 95 ft MSL or by overflowing a drainage ditch and exceeding 94 ft MSL; it can enter East Creek by overtopping the cooling tower access road at about 92.5 ft MSL. (RBS, 2013, Section 2.4.2.3.1)

2.3.1.2 Flooding in Rivers and Streams (PMF)

Flood hazard from flooding in rivers and streams was quantified as part of the CLB at RBS. For rivers, the PDF on the Mississippi River, developed by the USACE, using upstream reservoir storage constitutes the basis for a determination of the Probable Maximum Flood (PMF) at the site (RBS, 2013, Section 2.4.2.2). The estimated flood level at the site for this flow is 54.5 ft MSL. The PDF is confined between the manmade levee on the west bank of the river and the eastern edge of the river floodplain. The levee elevation along the west bank opposite the site is about 57.5 ft MSL, three ft above the PDF crest level. (RBS, 2013, Section 2.4.3.5.1)

For local streams, the PMF is a PMP-induced event (RBS, 2013, Section 2.4.3.1). The PMP values for the local basins were based on data contained in National Oceanic and Atmospheric Administration (NOAA) Hydrometeorological Reports (HMR-51 and HMR-52; NOAA, 1977 and NOAA, 1982). The PMF flows were computed using the HEC-2 computer program, developed by the USACE, and conservatively assumed to coincide with the PDF on the river. The maximum water level on Grants Bayou near the plant varies from 95.3 to 101.8 ft MSL. The adjacent cooling tower yard is at about 104 ft MSL, above the flood level. Additionally, no safety-related equipment is located in this area. The maximum water level on West Creek near the plant is about 94.3 ft MSL. This is below the top of the adjacent railroad spur at 95.0 ft MSL, and plant area flooding would not occur. (RBS, 2013, Section 2.4.3.5.2)

2.3.1.3 Dam Breaches and Failures

Flood hazard due to upstream dam breaches and failures was screened as part of the CLB at RBS. The effects of a flood wave or flood flows generated by a dam failure or series of failures anywhere in the river basin that could affect safety-related equipment at the site were considered to be extremely unlikely due to (a) the distance of dams from the site, greater than 100 river miles, (b) the elevation of the site with respect to surrounding topography and the river floodplain, and (c) the broad expanse of tributary and river floodplain available to overbank flows. Additionally, all safety-related equipment is more than 35 ft above the PMF peak level, well above any potential effect from dam failures. (RBS, 2013, Section 2.4.4.1)

There are no dams or similar water control structures on the local streams (RBS, 2013, Section 2.4.4.2).

2.3.1.4 Storm Surge

Flood hazard due to storm surge was screened as part of the CLB at RBS. These events were not considered applicable to RBS because the site is not located in a coastal region (RBS, 2013, Section 2.4.5).

2.3.1.5 Seiche

Flood hazard due to seiches was screened as part of the CLB at RBS. These events were not considered because the site is not near a lake and the Mississippi River does not permit the formation of a seiche-type oscillation due to the rapid flow velocity (RBS, 2013, Section 2.4.5).

2.3.1.6 Tsunami

Flood hazard due to tsunamis was screened as part of the CLB at RBS. These events were not considered because the site is 262 river miles from the Gulf of Mexico and there is no danger of flooding due to geoseismic activity in the Gulf (RBS, 2013, Section 2.4.6).

2.3.1.7 Ice-Induced Flooding

Flood hazard due to ice-induced flooding was screened as part of the CLB at RBS. These effects were not considered because ice does not form in the Mississippi River near the site due to water temperatures being above freezing, making the occurrence of ice jams unlikely (RBS, 2013, Section 2.4.7).

2.3.1.8 Channel Migration or Diversion

Flood hazard due to channel migration or diversion was screened as part of the CLB at RBS. These effects were not considered because the USACE maintains the Mississippi River in its present channel by means of an extensive program that includes channel stabilization and protection, revetment, dredging, and levee and dike maintenance, making it extremely unlikely for the current course of the river to be jeopardized by sudden natural diversion processes (RBS, 2013, Section 2.4.9).

Flood hazard due to cooling water canals and reservoirs was screened as part of the CLB at RBS. The only canal at the station is the cold water flume that connects the individual mechanical-draft cooling tower basins. Failure of the flume does not jeopardize plant safety (RSB, 2013, Section 2.4.8.1). The only cooling water reservoir, other than the main cooling tower basins and cold water flume, is the ultimate heat sink (RSB, 2013, Section 2.4.8.2), which is designed to withstand the effects of natural phenomena such as floods (RBS, 2013, Section 9.2.5.1).

2.3.1.9 Combined Effects

Flood hazard due to combinations of extreme flood mechanisms was quantified as part of the CLB at RBS (RBS, 2013, Section 2.4.2.2). An operational basis earthquake combined with a 1/2 PMF and a safe shutdown earthquake combined with a 25-yr flood were assumed to occur. Neither occurrence would produce water levels higher than the PMF.

Flood hazard due to the PMF with coincident wind wave activity was quantified as part of the CLB at RBS (RBS, 2013, Section 2.4.3.6.1). Plant safety is not jeopardized by even the most extreme conditions of Mississippi River flooding because plant grade and any safety-related equipment are well above any wind-wave water level (RBS, 2013, Section 2.4.3.6.1). The PMF level in the plant area would not be increased by coincident wind wave activity in local streams because no substantial fetch could be generated (RBS, 2013, Section 2.4.3.6.2).

2.3.2 CLB Flood Protection and Mitigation Features

Flood protection of safety-related systems and components, as identified in USAR Table 3.2-1, is provided for all postulated flood levels and conditions discussed above (RBS, 2013, Section 3.4.1.1.1). Structures that house the safety-related equipment and offer flood protection to this equipment are identified on USAR Figure 1.2-2 and described in USAR Sections 3.8.2, 3.8.4, and 3.8.5 (RBS, 2013, Section 3.4.1.1.2).

Internal and external flood protection is provided for the safety-related systems and components identified in USAR Table 3.2-1 for all postulated flood levels and conditions by one of the following methods (RBS, 2013, Section 3.4.1.1.3):

1. Housing them in Seismic Category I structures designed to withstand the flood loads.
2. Locating them above the maximum postulated flood level.
3. Locating them in watertight cubicles (of a structure) designed to withstand external and/or internal flood loads.

When exposed to earth, the structural components of Seismic Category I structures are designed using wall thicknesses below flood levels of not less than two ft and waterstops at construction joints below flood level.

Waterproofing of foundations and exterior walls of Seismic Category I structures below grade is accomplished principally by the use of waterstops at expansion and construction joints. All the penetrations through the exterior walls of the Seismic Category I structures below the Design Basis Flood Level (DBFL) are designed to withstand the hydrostatic head of water and are made watertight using air, water, and fire seals and waterstops around them as applicable.

The access openings to the structures housing safety-related components are either located above the DBFL or are required to be closed to prevent any adverse effect from flooding of the structures. If local seepage occurs through the walls, it is controlled by sumps and sump pumps. The operation of the plant, therefore, is not affected by flood conditions.

There is no permanent plant dewatering system (RBS, 2013, Section 3.4.1.2).

The Seismic Category I structures are designed and analyzed for the maximum hydrostatic head and the buoyant forces due to the Probable Maximum Flood, in accordance with the loads and load combinations indicated in Section 3.8.4 of the USAR (RBS, 2013). A safety factor of 1.1 is used in designing these structures against flotation (RBS, 2013, Section 3.4.2).

The most critical postulated flood condition results in standing water at about 96 ft MSL, which would be caused by an occurrence of the PMP in the immediate plant area prior to completion of excavation backfilling operations. The dynamic effect resulting from wave forces at this low level of ponding (1 ft to 1.5 ft at the plant buildings) is considered negligible. Therefore, the hydrodynamic loads due to floods are not considered in designing the Seismic Category I structures. (RBS, 2013, Section 3.4.2)

Additionally, Severe Weather Operation Procedures provide preparation and protection instructions before, during, and after hurricanes, tornadoes, and severe thunderstorms. Temporary active or passive flood protection measures are not required to be installed for protection of SSCs important to safety during flooding conditions (RBS, 2012, Section 3.5).

As a result, the plant is suitably protected against external flooding with respect to the DBFL. The equipment required for reactor shutdown is within buildings that would be protected from flooding and the alternate cooling water system would be available for shutdown cooling.

Water accumulation in the Unit 2 Excavation is also considered for impact to SSCs important to safety at RBS. Based on plant documentation, the Unit 2 Excavation becomes inundated to an elevation of 80.3 ft MSL during a probable maximum precipitation event. Based on evaluations, the Unit 2 Excavation can safely be inundated up to 81.0 ft MSL. (RBS, 2011)

2.4 Licensing Basis Flood-Related and Flood Protection Changes

The plant design features and their functional requirements that provide protection against the design basis external flood mechanisms are provided in the USAR (RBS, 2013, Section 3.4). Attributes of the overall plant configuration that support the design for external flooding are also identified.

As noted in the walkdown report, no flood protection features were determined to be nonfunctional and no deficiencies were observed (RBS, 2012, Section 7.1).

2.5 Watershed and Local Area Changes

2.5.1 Watershed Changes

There have been no significant watershed changes to the site vicinity (RBS, 2013, Section 2.4.1 and RBS3, 2008a, Section 2.4.1). The Mississippi River watershed is extremely large, and many contributing tributaries and sub-watersheds have experienced both man-made and natural changes since the construction of RBS. The Mississippi River in the vicinity of RBS, however, has been stabilized to maintain navigability and flood control measures by the USACE. The numerous programs in place to stabilize the Mississippi River channel are discussed in Section 3.8.

2.5.2 Local Area Changes

Local area changes have been minimal since plant operation began at the site in 1985. Off-site areas within 5 miles of the plant remain rural with largely forested and agricultural land use (RBS3b, 2008, Section 2.2.1).

On site, the most notable major change since plant operation began is the addition of a security barrier around the plant, known as the VBS. Other significant construction projects potentially affecting site drainage include:

- West Plant Road development along the former railroad spur,
- new parking area in the Grants Bayou watershed,
- ISFSI (Independent Spent Fuel Storage Installation), inside the VBS and southwest and adjacent to the Turbine Building, and
- the Generation Support Building inside the VBS north of the plant.

Other minor changes have been made, but none significant enough to affect site drainage.

2.6 Additional Site Details – Walkdown Results

A total of 36 walkdown flood protection features that included 214 attributes were reviewed during the walkdown completed at RBS in 2012 (RBS, 2012, Section 7.0).

Of the total flood protection features, 207 were defined as passive-incorporated, none as passive-temporary, seven as active-incorporated, and none as active-temporary. The walkdown scope included evaluation of external doors with respect to design specifications and capacity to withstand CLB flood elevations. None of the flood protection features reviewed were determined to be non-functional and no deficiencies were observed (RBS, 2012, Section 7.1). However, several of the features were inaccessible or restricted access (RBS, 2012, Section 7.4).

All observations that did not meet the walkdown acceptance criteria were entered into the plant's corrective action program (CAP) and an operability determination associated with the observation. All observations entered into the CAP have subsequently been dispositioned (RBS, 2012, Section 7.2). As a result, there are no planned corrective actions (RBS, 2012, Section 7.4).

2.7 References

NOAA, 1977. Probable Maximum Precipitation Estimates - United States East of the 105th Meridian", Hydrometeorological Report No. 51 (HMR-51) by US Department of Commerce & USACE, August 1977.

NOAA, 1982. "Application of Probable Maximum Precipitation Estimates – United States East of the 105th Meridian", NOAA Hydrometeorological Report No.52 (HMR-52) by US Department of Commerce & USACE, August 1982.

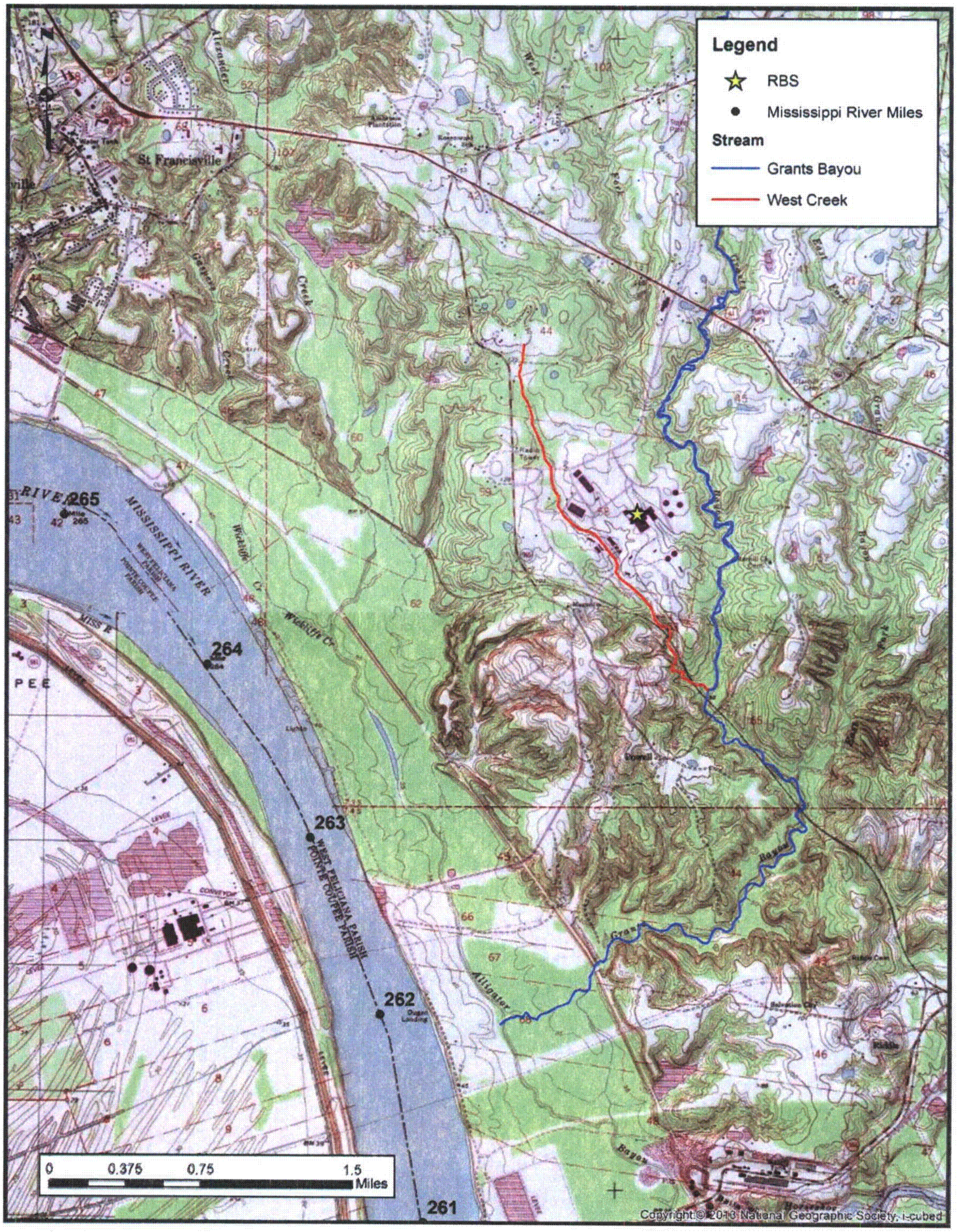
RBS, 2011. "Entergy Condition Report CR-RBS-2011-06331", Initiated 8/24/2011, Closed 2/23/2012, See AREVA Document 38-9212620-000.

RBS, 2013. "RBS Updated Safety Analysis Report", Revision 23, 2013, See AREVA Document No. 38-9210629-000.

RBS3, 2008a. "River Bend Station Unit 3 Combined License Application, Part 2: Final Safety Analysis Report", Revision 0, September 2008. (ADAMS Access No. ML082830247)

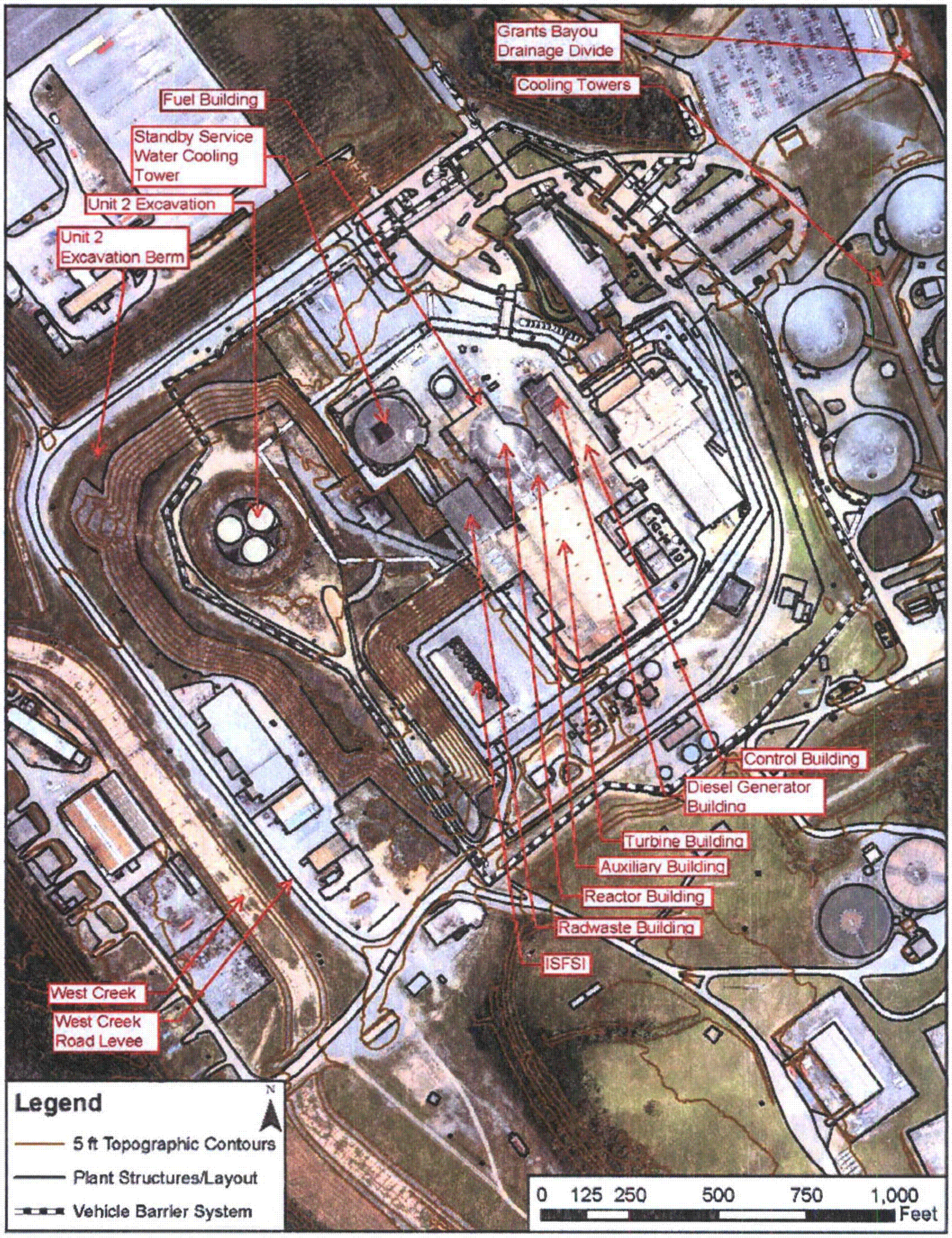
RBS3, 2008b. "River Bend Station Unit 3 Combined License Application, Part 3: Environmental Report, Revision 0", September 2008. (ADAMS Access No. ML082830263)

Figure 2.1-1: Site Location Map



Any illegible text or features in this figure are not pertinent to the technical purposes of this document.

Figure 2.1-2: Site Topography and Layout



Illegible text or features in this figure are not pertinent to the technical purposes of this document.

3.0 FLOOD HAZARD REEVALUATION

This section details the evaluation of the eight flood causing mechanisms and combined effects for RBS as detailed in Attachment 1 to Enclosure 2 of the NRC information request. No additional flood causing mechanisms were identified for RBS. Flooding due to LIP is the only scenario that results in standing water in the vicinity of SSCs important to safety at RBS. Debris loading and transportation during the LIP scenario is not considered a hazard for SSCs important to safety at RBS (See Section 3.1.3).

3.1 Local Intense Precipitation

This section addresses the potential for flooding at RBS due to the 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.

This section summarizes the LIP evaluation performed in AREVA Calculation No. 32-9207350-000 (AREVA, 2014a).

3.1.1 Method

3.1.1.1 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 RBS.

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

1. Define FLO-2D model limits for 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 estimate maximum water surface elevations at RBS.

3.1.2 Results

The SSCs important to safety at RBS are enclosed within a series of connected concrete security barriers called the VBS. Openings within the VBS allow flow away from the SSCs important to safety. These openings through the VBS represent the primary flow path for LIP water to exit the vicinity of the SSCs important to safety.

The FLO-2D model for LIP flooding analysis at RBS utilizes 2013 topographic mapping results (AREVA, 2013b) to generate ground elevations and associated flood water surface elevations. Elevations used in the LIP analysis were found to be inconsistent with the plant design elevations due to different survey datum, changes in the survey geiod over time, as well as calibration and survey techniques (See discussion in Section 1.5). To determine potential for flood impacts to SSCs important to safety, the depth of LIP-related flood water will be directly compared to the USAR documented height of protection above a given ground level. This approach provides a consistent means by which to judge flood levels for this study, eliminating any potential for misinterpretation due to the different elevation results.

3.1.2.1 Local Intense Precipitation

3.1.2.1.1 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 (FLO-2D, 2013; see Appendix A.1) that routes flood hydrographs and rainfall-runoff over unconfined flow surfaces or in channels using the dynamic wave approximation to the momentum equation (AREVA, 2013a). The watershed applicable for the LIP Analysis was computed internally within FLO-2D based on the digital terrain model (DTM) limits input into FLO-2D (AREVA, 2013b).

The FLO-2D model includes topography, site location, and building structures. Grid elements along the model computational boundary were selected as outflow grid elements.

3.1.2.1.2 FLO-2D Computer Model with Site Features

The FLO-2D model developed for the LIP analysis was based on RBS site features including: topography, site location, VBS layout, channels and culverts, and structures. The selected grid element size for the project was 20 feet by 20 feet. The elevation data used to develop the FLO-2D model consist of 2013 DTM data (AREVA, 2013b) for RBS. Flow obstructions due to buildings were also included in the model. The main input parameters for the RBS FLO-2D model include:

Elevation: The elevation data used to develop the FLO-2D model was the surveyed topographic data of the site provided in AutoCAD format (AREVA, 2013b). The surveyed topographic map is in North American Datum (NAD) 83 Louisiana South State Plane (horizontal) datum and elevations are in NAVD88 (vertical) datum. The unit of the survey is U.S. feet. The elevation data imported into the FLO-2D model consists of spot elevations. The surveyed topographic data was converted into American Standard Code for Information Interchange (ASCII) format before being imported into FLO-2D.

The methodology of the topographic survey was aerial LIDAR mapping of the site with sufficient ground control points for calibration meeting the mapping standard, and conventional ground survey loops for the critical structures and locations. The topographic data for RBS was developed based on a site-specific aerial survey using methodology consistent with the need for first-order level of accuracy (i.e. +/- 0.1 feet). The topographic survey performed in 2013 at RBS was required to meet the American Society for Photogrammetry and Remote Sensing (ASPRS) Class I Accuracy Standard for 1" = 100' planimetrics and 1-foot contour intervals, with +/- 1 feet horizontal accuracy, +/- 0.33 feet Root Mean Square Error (RMSE) vertical accuracy for 1 foot contours and +/- 0.17 feet RMSE vertical accuracy for spot elevations, at well-defined points. Additional designated critical structures and locations with respect to site flooding impacts were identified and surveyed with a vertical accuracy of +/- 0.1 feet. (AREVA, 2013b)

FLO-2D grid element elevation data was interpolated based on imported DTM points from the topographic survey of the site that were added to the working region. Interpolation methods available in FLO-2D include:

- Using a user specified minimum number of closest DTM points within the vicinity of a grid element to compute the grid elevation;
- Using a user specified radius of interpolation which defines a circle around each grid element node to select DTM points for use in computing the grid element elevation; and
- Using an inverse distance weighting formula exponent to assign elevations to the grid element from the DTM points.

Model grid elevations cannot be more accurate than the survey they are based upon. Therefore model grid elevations have a minimum level of uncertainty of +/- 0.1 feet. A minimum of two closest DTM points within the vicinity of a grid element was used in computing grid elevations. The density of spot elevations on the DTM provided for adequate coverage for each grid element. Interpolated grid elevations at all critical points were spot checked against the survey elevations and adjustments were made as needed. Model interpolation errors are therefore believed to be very minimal.

Uncertainty regarding onsite flood elevations is generally limited to the level of accuracy of the site survey. The nature of the two dimensional flow model is such that the impact of potential inaccuracy in the elevation of any single grid element is generally mitigated by the surrounding grid elements.

Buildings and Roof Tops: Buildings were incorporated as completely blocked grid elements based on assessment of the topographic site survey (AREVA, 2013b). FLO-2D calculates runoff from blocked grid elements (e.g., roof top areas) and translates it to the nearest unblocked grid element.

Channels and Culverts: The model includes one channel segment as shown in Figure 3.1-1, to model West Creek. The channel is approximately 110-feet wide and extends from the upstream boundary of the concrete-lined channel to the downstream boundary of the concrete-line channel south of the site. The cross sectional geometry was based on the USAR (RBS, 2013a). The channel bottom elevations were based on the topographic site survey (AREVA, 2013b).

An inflow grid element was created upstream of the channelized section of West Creek to add the West Creek watershed inflow hydrograph. The hydrograph from the West Creek watershed resulting from the 6-hour LIP was calculated in the PMF calculation for RBS (AREVA, 2014b). A grid element upstream of the channelized portion of West Creek was selected as the inflow grid element for the West Creek PMF.

Culverts were not incorporated into the FLO-2D model. All culverts at RBS are considered to be completely blocked or otherwise non-functional for the purpose of this LIP evaluation.

VBS and other barriers: The VBS and the berm around the Unit 2 excavation at RBS were modeled using the levee structure component in FLO-2D, shown in Figure 3.1-1. The top elevation of the VBS was established based on direct measurements (RBS, 2013b). Simulation of the LIP with the VBS results in a more conservative water surface elevation than without the VBS. Openings in the VBS for pedestrians and/or vehicles are as follows:

1. Pedestrian opening at the northeast VBS near the Security Owner Controlled Area (SOCA) Building east of the Generation Support Building.
2. Pedestrian opening at the southwest VBS near the ISFSI.
3. Vehicle access opening at the north VBS near the SOCA Building west of the Generation Support Building.

The berm surrounding the northwestern portion of the Unit 2 excavation and in the vicinity of the yard area was modeled using a levee structure as it conservatively blocks flow that would otherwise flow away from SSCs important to safety. Top elevations for the levee were based on the topographic site survey (AREVA, 2013b). West Plant Road was modeled as a levee structure as it is a local high spot that blocks flow from West Creek from entering the Unit 2 excavation (AREVA, 2013b). Top elevations for West Plant Road were based on the RBS topographic site survey (AREVA, 2013b).

Infiltration and Surface Roughness: Rainfall was directly transformed into runoff within the FLO-2D computational domain. No initial abstractions and/or infiltration were used in the FLO-2D model. However, the upper portion of the West Creek watershed was modeled in a separate calculation using the Soil Conservation Service method because it is predominately forested and undeveloped. A curve number of 87.9 and a lag time of 1.0 hour were used in calculating the runoff from West Creek watershed (AREVA, 2014b).

Selected Manning's roughness coefficients used in the model were based on recommended values in the FLO-2D Manual (FLO-2D, 2013, Table 1).

Unit 2 Excavation: The Unit 2 excavation was assumed dry at the start of simulation as the excavation is maintained dry based on RBS Procedure OSP - 0031 (RBS, 2014).

3.1.2.1.3 LIP/PMP Inputs

The LIP parameters were defined using HMR-51 and HMR-52; (NOAA, 1977 and NOAA, 1982, respectively) as prescribed in NUREG/CR-7046 (NRC, 2011, Section 3.2). The total rainfall depth for the 1-hour, 1-mi^2 PMP is 19.4 inches, with peak intensity of 6.2 inches during the first 5 minutes of the event. The total rainfall depth for the 6-hour PMP is 32.0 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 3.1-2). (AREVA, 2013c)

3.1.2.1.4 LIP Simulation Results

Results of the RBS FLO-2D LIP model are summarized in Table 3.1-1. Critical locations are shown on Figure 3.1-3. Based on the LIP model simulation, maximum LIP flood elevations at modeled plant structures generally range from 96.3 ft NAVD88 near the Diesel Generator Building to 97.6 ft NAVD88 at the Auxiliary Building and Control Building, with corresponding flow depths approximately 0.5 feet to as high as 3 feet. The maximum water surface elevation with in the Unit 2 excavation is about 79.1 ft NAVD88. Maximum velocities range from 0.3 feet per second (fps) to 5 fps, with the highest velocity occurring to the east of the Diesel Generator Building. Maximum flow depth in the vicinity of the RBS ISFSI pad ranges from 0.1 to 0.6 ft. Large drawings showing the LIP surface water elevations, depths, velocity and direction are provided in Appendix B. Time-series plots showing surface water elevation vs. time at the grid cell location for each critical doorway and the ISFSI are shown in Appendix B.

High maximum depths at doors in the vicinity of the Diesel Generator Building are the result of flow entering through the opening in the VBS. Note that water levels do not fully recede at some grid elements due to ongoing inflow from other upgradient areas and/or mild slopes that are slow to drain. The presence of the VBS, which fully encompasses RBS, is also a contributing factor to the slow rate at which water levels recede. The durations of flooding calculated are generally conservative because site drainage features are not considered.

3.1.3 Conclusions

The maximum water surface elevations at all locations on the site due to the LIP at RBS result from a PMP depth of 19.4 inches in 1 hour and 32.0 inches within 6 hours. The maximum water surface elevation in the Unit 2 Excavation resulting from the LIP is 79.1 ft NAVD88. The maximum flood depths range from less than 6 inches to locally as high as approximately 3 feet above grade as shown in Table 3.1-1.

Significant debris loading/transportation is not a safety hazard due to the relatively low velocity and depth of LIP flood waters in the vicinity of SSCs important to safety at RBS, in addition to the lack of natural debris sources on site.

3.1.4 References

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AREVA, 2013b. AREVA Document No. 38-9208278-002, "RBS Topographic Survey Deliverables", 2013.

AREVA, 2013c. AREVA Document No. 32-9207351-000, "River Bend Station Flooding Hazard Reevaluation - Probable Maximum Precipitation", 2013.

AREVA, 2014a. AREVA Document No. 32-9207350-000, "River Bend Station Flood Hazard Re-evaluation – Local Intense Precipitation – Generated Flood Flow and Elevations Calculation", 2014.

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RBS, 2013a. "RBS Updated Safety Analysis Report", Revision 23, 2013, See AREVA Document No. 38-9210629-000.

RBS, 2013b. "Transmittal of Vehicle Barrier System Height", 2013, See AREVA Document No. 38-9214240-000.

RBS, 2014. "RBS FHE Unit 2 Excavation Dewatering", See AREVA Document No. 38-9217124-000.

Table 3.1-1: LIP Model Results

Door	Representative Grid Element Number	Grid Cell Ground Elevation (ft, NAVD88)	LIP Peak Elevation (ft, NAVD88)	Maximum Flow Depth (ft)[1]	Maximum Flow Velocity (fps)	Elevation at Bottom of Door (ft, NAVD88)[2]	Flood Height above Elevation at Bottom of Door (ft)[3]
DG-098-H01	9,549	93.8	96.4	2.6	4.9	97.3	0.9
DG-098-H02	9,549	93.8	96.4	2.6	4.9	97.3	0.9
DG-098-01	9,227	94.1	96.3	2.3	2.8	97.3	1.0
DG-098-02	9,549	93.8	96.4	2.6	4.9	97.3	0.9
DG-098-03	9,711	93.9	96.4	2.6	4.0	97.3	0.9
DG-098-H03	9,711	93.9	96.4	2.6	4.0	97.3	0.9
CB-098-01	9,875	93.9	96.4	2.5	2.5	97.3	0.9
DG-098-11	9,705	94.5	96.2	1.7	0.6	97.4	1.2
JRB-D01HTCH	10,194	93.1	96.2	3.1	1.6	93.1	-3.1
AB-098-03	11,036	97.0	97.5	0.5	0.6	97.2	-0.3
AB-098-04	11,206	97.2	97.6	0.5	0.4	97.2	-0.4
CB-098-17	11,207	97.2	97.6	0.4	0.3	97.4	-0.2
FB-095-01	10,186	94.0	96.0	2.0	2.5	94.3	-1.7
SP-098-01	10,348	94.1	96.0	1.9	4.4	97.7	1.7
FB-098-04	11,025	94.2	95.9	1.7	1.2	97.3	1.4
AB-098-06	11,872	95.9	96.4	0.5	1.1	97.3	0.9
AB-098-05	12,041	96.3	96.6	0.4	0.8	97.2	0.6

Notes:

1. Maximum Flow Depth is the difference between LIP Peak Elevation and Grid Cell Ground Elevation in the vicinity of doors.

2. Elevations at Bottom of Doors are surveyed door bottom elevations from the critical structures survey (AREVA, 2013b) and may be different from general Grid Cell Ground Elevations, which were interpolated from the topographic site survey (AREVA, 2013b).

3. Flood Height above Elevation at Bottom of Door is the difference between LIP Peak Elevation and Elevation at Bottom of Door; negative numbers indicate water elevation is above the bottom of the door.

Figure 3.1-1: FLO-2D Modeled Site Features

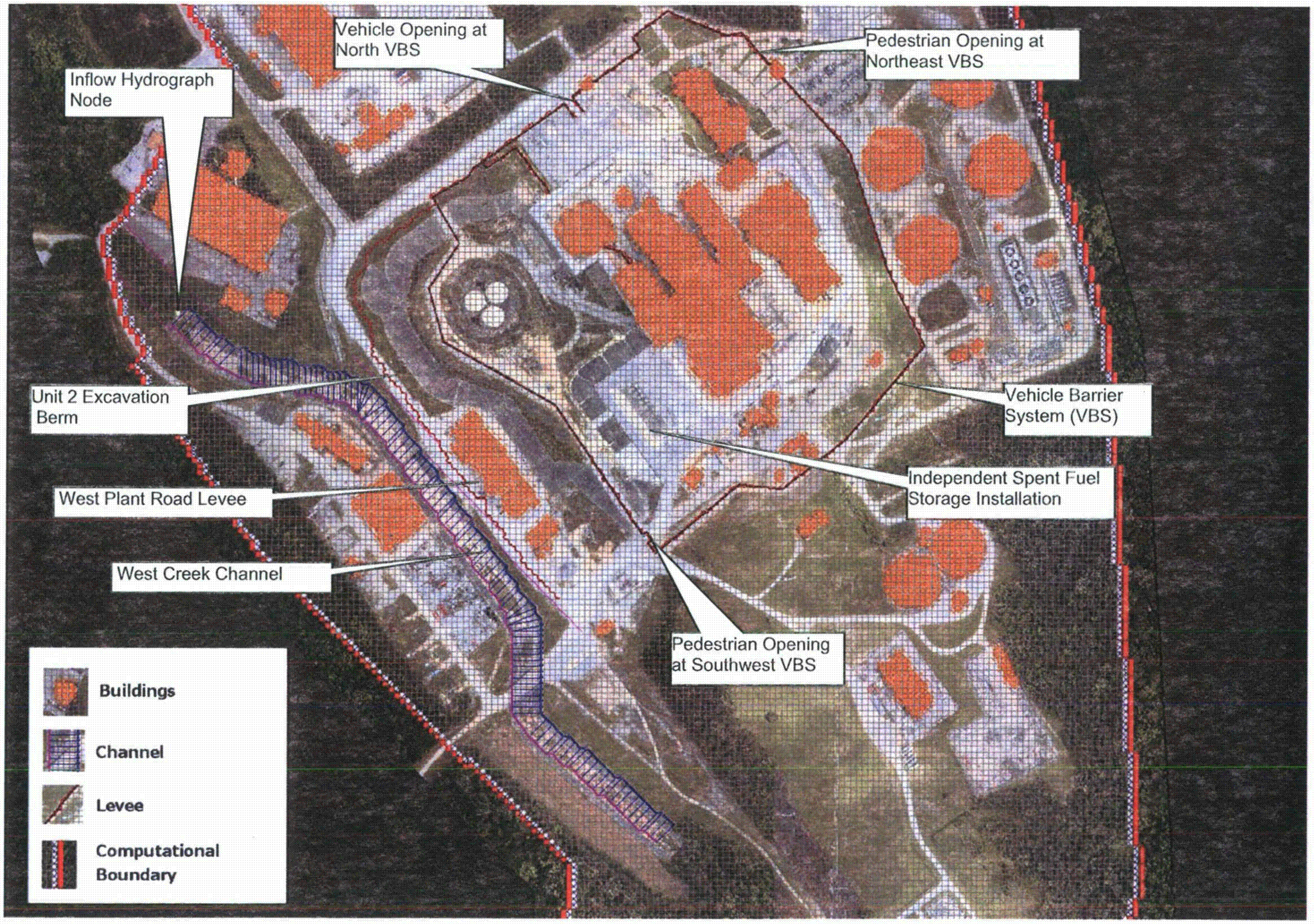


Figure 3.1-2: LIP Hyetograph

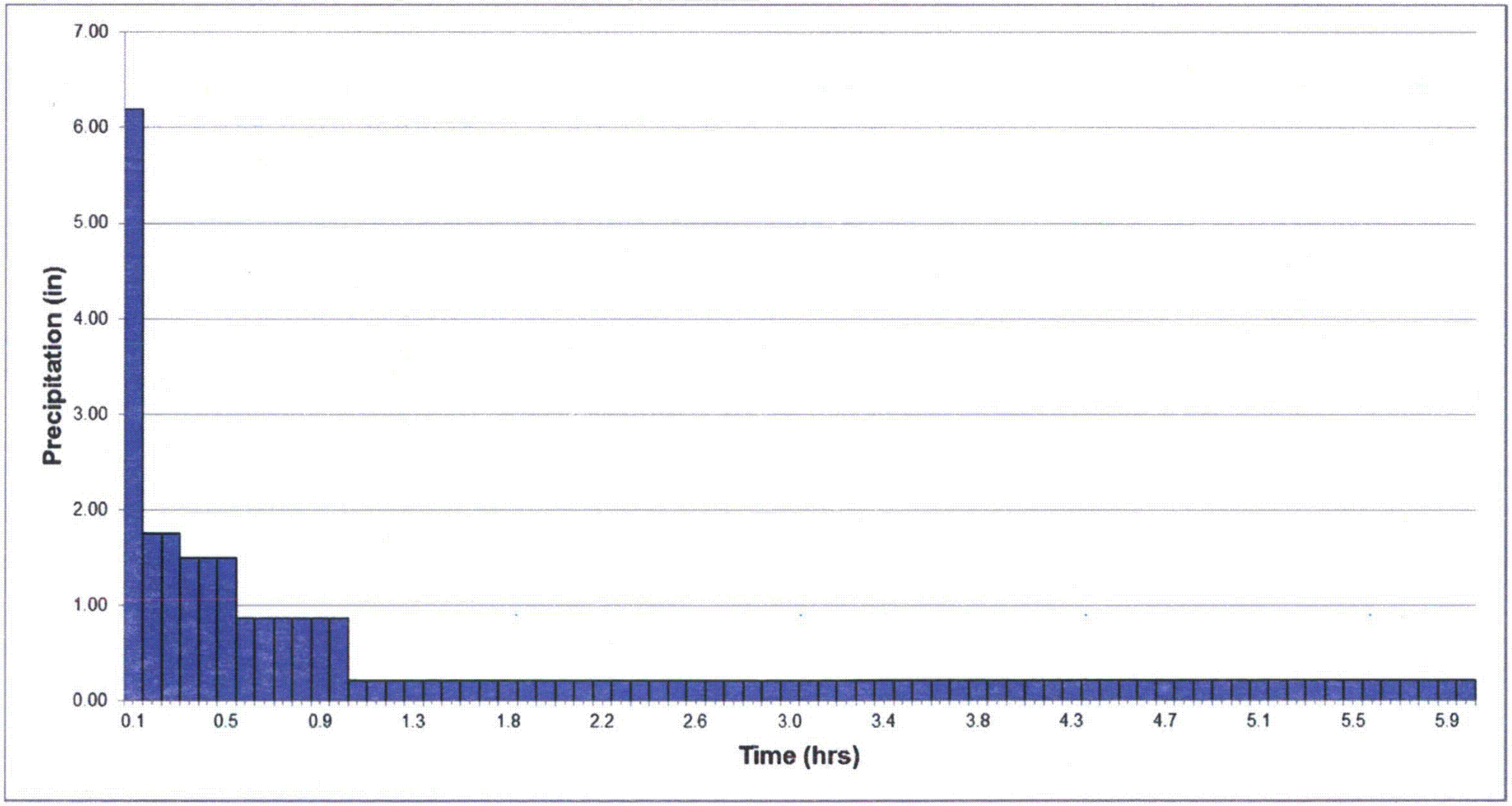
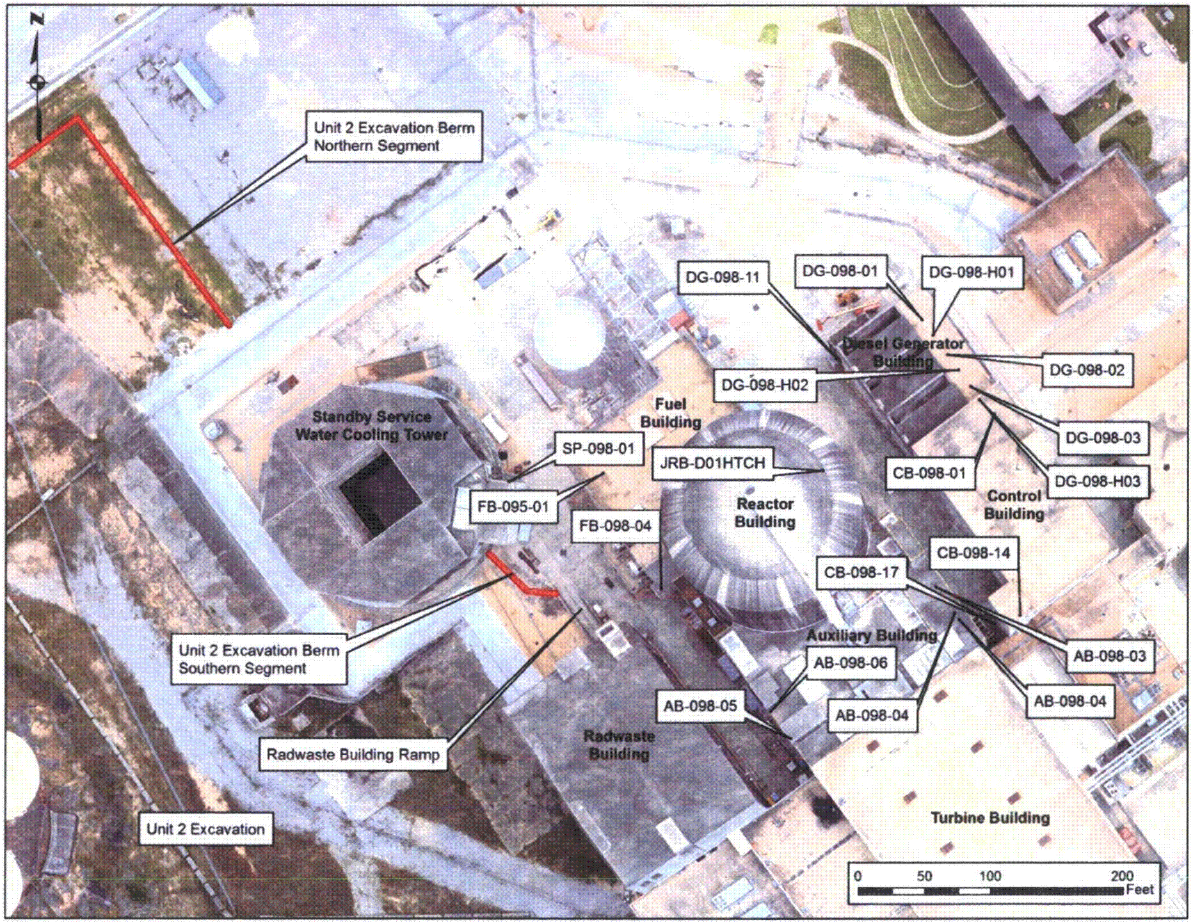


Figure 3.1-3: RBS Critical Door Locations



Basemap source: (AREVA, 2013b)
Building locations based on USAR Station Arrangement (RBS, 2013a; USAR Figure 1.2-2)

3.2 Flooding in Rivers and Streams

This section addresses the potential for flooding at RBS due to the PMF on streams and rivers. The PMF is the hypothetical flood (peak discharge, volume, and hydrograph shape) that is considered to be the most severe reasonably possible, based on comprehensive hydrometeorological application of the PMP and other hydrologic factors favorable for maximum flood runoff such as sequential storms and snowmelt." (NRC, 2011).

This section summarizes the PMF on Streams and Rivers evaluations performed in AREVA Calculation Nos. 32-9207352-000 (AREVA, 2014a) and 32-9207353-000 (AREVA, 2014b).

3.2.1 Method

The HHA approach described in NUREG/CR-7046 (NRC, 2011) was used for the evaluation of the PMF on rivers and streams and resultant water surface elevation at RBS.

With respect to PMF on the Mississippi River, the HHA used the following steps:

1. Estimate the PMF flow on the Mississippi River at RBS based on literature review and engineering judgment.
2. Develop HEC-RAS steady flow hydraulic computer model cross sections.
3. Calibrate HEC-RAS Model.
4. Perform PMF hydraulic simulations.

The methodology used to develop the PMF on Grants Bayou used the following steps:

1. Calculate Probable Maximum Precipitation using the methodology of HMR-51 and HMR-52.
2. Delineate watershed and perform PMF simulation using HEC-HMS. Since Grants Bayou does not have historical stream gage data, calibration and verification of the HEC-HMS model is not possible. The Soil Conservation Service (SCS, now known as the Natural Resources Conservation Service, NRCS) Method was used to simulate the hydrology of the watershed.
3. Calculate the Probable Maximum Flood Elevation on Grants Bayou River near RBS.
    a. Develop HEC-RAS unsteady flow hydraulic computer model cross sections.
    b. Perform PMF hydraulic simulations.

The methodology used to develop the PMF on West Creek was the same as that employed for Grants Bayou.

3.2.2 PMF Results

3.2.2.1 Probable Maximum Flood – Mississippi River

3.2.2.1.1 Estimate the PMF flow on the Mississippi River

The USACE PDF was judged to be a reasonable basis for estimating the Probable Maximum Flood for the Lower Mississippi River Basin and its 1.2 million-square-mile watershed (RBS, 2013). The PDF is generally 40 to 60 percent of the PMF (Chow, 1964). The PDF was conservatively assumed to be 40 percent of the PMF for this analysis.

Flood control structures are maintained by the USACE along the Mississippi River to lessen the impacts of the PDF and alleviate stress on mainline levees (MRC, 2007). There are two major diversions upstream of RBS, shown in Figure 3.2-1: the Old River Control Structures (ORCS) and Morganza Control Structure (MCS). The ORCS, located at about Mississippi River mile 315, and consists of four hydraulic structures that divert

Mississippi River flow into the Atchafalaya Floodway with a combined capacity of 700,000 cubic feet per second (cfs) (USACE, 2009). The MCS, located at about Mississippi River mile 280, is designed to divert approximately 600,000 cfs of Mississippi River flow into the Morganza Floodway (USACE, 2012). During the PDF, the ORCS and MCS divert 620,000 cfs and 600,000 cfs, respectively (MRC, 2007 and RBS, 2013; USAR Figure 2.4-16). The diversions were accounted for after the PDF was increased to the flow rate of the PMF (see below).

The PDF for the Mississippi River upstream of the ORCS, is 2,720,000 cfs (MRC, 2007 and RBS, 2013; USAR Figure 2.4-16). The PDF is assumed to be 40 percent of the PMF, resulting in a PMF for the Mississippi River in the vicinity of RBS of 6,800,000 cfs (PMF = PDF divided by 0.40). The diversions from the ORCS and the MCS are used during the PMF as reported by the USACE for the PDF (i.e., 620,000 cfs and 600,000 cfs, respectively). The PMF for the Mississippi River at RBS after accounting for the functions of the diversion structures is 5,580,000 cfs (PMF minus 1,220,000 cfs).

Peak stream flow data (USACE, 2013c) from stream gage upstream of ORCS on the Mississippi River at Natchez, Mississippi was checked to ensure that the PDF has not been exceeded. The stream gage data indicates that the highest recorded flow was 2,200,000 cfs on May 19, 2011 (USACE, 2013c). The PDF has not been exceeded according to the historical stream gage record.

3.2.2.1.2 Develop HEC-RAS Hydraulic Computer Model Cross Sections

A hydraulic computer model (HEC-RAS v4.1) was developed for a 205-mile-long reach of the Mississippi River near RBS using representative cross-section geometry data developed from bathymetric data from the U.S. Army Corps of Engineers (USACE, 2013a and USACE, 2013b) and digital elevation model (DEM) from the USGS. Due to the generally flat topography and wide extent of the floodplain, a limited number of cross-section elevation data points for the floodplain were selected for representative locations where elevation changes were noted. Levees, located along the west bank of the Mississippi River, were also added to the cross-sections in HEC-RAS (MRC, 2007). The HEC-RAS hydraulic model extends 103 miles upstream of the site and 102 miles downstream from the site (Figure 3.2-1). A steady flow (e.g., peak PMF flow rate) was then routed in the HEC-RAS model to establish flood elevations.

3.2.2.1.3 Calibrate HEC-RAS Model

Model calibration is performed by selecting and refining HEC-RAS input parameters to produce a simulated profile for a given event that shows good agreement with an accepted water surface profile for the given flood. For this application, the model was calibrated to the 2011 flood as well as the USACE PDF flow and elevation at RBS by adjusting the Manning's-n values for the cross-section geometry data and the friction slope used for the upstream and downstream boundary conditions until the HEC-RAS modeled flood elevation approximated the observed 2011 flood elevation at the Bayou Sara U.S. Geological Survey (USGS) gage (USACE, 2013d) and the USACE estimated PDF elevation at RBS, respectively. The 2011 flood resulted in 1.436 million cfs at Baton Rouge (USGS, 2013). The Bayou Sara gage is located approximately 1.5 miles upstream of RBS. The upstream and downstream boundary conditions were modeled within HEC-RAS as "normal depth."

The results of the RBS HEC-RAS model calibration show that the model output over-predicts water surface elevations at Bayou Sara for the 2011 flood by 0.4 feet and the PDF elevation by 0.9 feet, indicating that the HEC-RAS model is appropriately conservative.

3.2.2.1.4 Perform PMF Hydraulic Simulations

The peak PMF stage on the Mississippi River near RBS was calculated to be 59.0 ft NAVD88 using the calibrated HEC-RAS model. This indicates that the levees on the west bank of the river (top elevation of 57 ft to 58 ft NAVD88 at this location) are overtopped during the PMF flood (MRC, 2007).

3.2.2.2 Probable Maximum Flood – Grants Bayou

3.2.2.2.1 Estimate the PMP for the Grants Bayou Watershed

The PMP was calculated for the 8.4-square-mile Grants Bayou watershed (Figure 3.2-2) using the methodology of HMR-51 and HMR-52 (NOAA, 1977 and NOAA, 1982). The HMR52 computer program was used for the calculations. The maximum duration of 72-hours used in HMR-51 and HMR-52 was conservatively adopted for the evaluation. The total rainfall amount for the 72-hour event was calculated to be 55 inches (AREVA, 2013b)

3.2.2.2.2 Estimate the PMF flow on Grants Bayou

The watershed does not contain stream gages and observed flood flow and flood stage information is not available. Therefore, the SCS method was used and conservatively applied in this calculation to develop the curve number (CN) and lag time (L). The Antecedent Runoff Condition III (ARC III) CN (i.e., wet antecedent moisture conditions) for the watershed was calculated as 88.3. The calculated lag time for the watershed was 2.2 hours.

A HEC-HMS computer model was developed using watershed input parameters calculated above. The HEC-HMS results indicate that the calculated peak discharge is 41,500 cfs. Non-linearity adjustments were then applied to the input unit hydrograph as per NUREG/CR-7046 (NRC, 2011): the peak discharge of the unit hydrograph was increased by one-fifth and the time-to-peak was decreased by one third. The combined PMF peak discharge calculated using HEC-HMS and incorporating non-linearity adjustments is 44,900 cfs.

3.2.2.2.3 Estimate Water Surface Elevations for Grants Bayou

A hydraulic computer model (HEC-RAS v4.1) was developed for a 3.8-mile-long reach of Grants Bayou. The HEC-RAS computer model was executed for the PMF using the unsteady flow module of HEC-RAS allowing for mixed subcritical and supercritical flow. The upstream and downstream limits of the RBS HEC-RAS model are approximately 0.8 miles upstream and 3 miles downstream of RBS, respectively. A total of 31 cross sections were used. No water level data within the reach of interest was available; therefore, calibration of the HEC-RAS model was not possible. The downstream boundary for the Grants Bayou HEC-RAS model (i.e., Mississippi River) was conservatively assumed to be coincident with the PMF elevation of the Mississippi River. Manning's roughness coefficients judged appropriate based on observed land cover were also input into the HEC-RAS model (USACE, 2010).

The peak PMF stage was calculated to be 99.1 ft NAVD88 which is below the elevation of the drainage divide elevation of 100.8 ft NAVD88 between the Grants Bayou and the RBS site (AREVA, 2013a).

3.2.2.3 Probable Maximum Flood – West Creek

3.2.2.3.1 Estimate the PMP for West Creek Watershed

The PMP was calculated for the 0.9-square-mile West Creek watershed (Figure 3.2-2) using the methodology of HMR-51 and HMR-52 (NOAA, 1977 and NOAA, 1982). The HMR52 computer program was used for the calculations. The maximum duration of 72-hours used in HMR-51 and HMR-52 was conservatively adopted for the evaluation. The total rainfall amount was calculated to be 55 inches for the 72-hour event.

3.2.2.3.2 Estimate the PMF flow on West Creek

A HEC-HMS model using the SCS method was developed for the watershed of West Creek. There is no recorded stream flow information available. Thus, conservative input parameters were used, including the use of ARC III CN 89 (i.e., wet antecedent moisture conditions). Watershed lag time of approximately 1.2 hours was calculated based on the SCS Time of Concentration method. The calculated PMF on West Creek was 6,300 cfs.

Non-linearity adjustments were then applied (see Section 3.2.2.2.2). The adjusted PMF peak flow rate for West Creek was 6,900 cfs.

3.2.2.3.3 Estimate Water Surface Elevations for West Creek

HEC-RAS was used to estimate PMF water surface elevations for West Creek. The downstream and upstream limits for the West Creek HEC-RAS model were selected to be approximately the confluence with Grants Bayou and 8,930 feet upstream from the confluence with Grants Bayou, respectively. This represents a reach length of approximately 2 miles. A total of 22 cross-sections were used in the West Creek HEC-RAS model. The model downstream boundary condition accounted for backwater due to coincident flooding in Grant's Bayou.

The River Access Road culvert was modeled as an inline structure in the West Creek HEC-RAS model. A lateral structure was used to model the centerline of West Plant Road, which acts as the divide between West Creek and the Unit 2 excavation. West Plant Road centerline elevations were based on the 2013 RBS topographic survey (AREVA, 2013a). A storage area was used to model the Unit 2 excavation, which acts as a receiving area for flow that overtops West Plant Road. The stage – volume relationship for the storage area was developed based on 2013 survey DTM data (AREVA, 2013a). Culverts were conservatively assumed to be completely blocked.

The peak PMF elevation on West Creek at RBS was calculated to be 94.4 feet NAVD88, which overtops the crest of the West Plant Road and enters the Unit 2 excavation, which intercepts West Creek overflows before SSCs important to safety would be impacted. The top elevation of the West Plant Road drainage divide at the lowest point is 93.5 ft NAVD88 (AREVA, 2013a). The maximum accumulated water elevation within the Unit 2 excavation from the West Creek PMF runoff was calculated to be 77.6 feet NAVD88. West Creek PMF runoff progression onto the RBS site near SSCs important to safety is therefore negligible.

3.2.3 Conclusions

Based on the re-evaluated peak PMF elevation on the Mississippi River at RBS, the peak PMF water surface elevation from the Mississippi River flood is well below the plant grade elevation and would not affect safety-related structures, systems, or components at RBS. This PMF has not been exceeded within the historical record.

Grants Bayou is not anticipated to overflow the drainage divide between the stream and the RBS site during the PMF.

Flood water from the West Creek PMF overtops West Plant Road and drains into the Unit 2 excavation, but does not result in flooding at SSCs important to safety at RBS.

3.2.4 References

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AREVA, 2013b. AREVA Document No. 32-9207351-000, "River Bend Station Flooding Hazard Reevaluation - Probable Maximum Precipitation", 2013.

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USACE, 2013b. "2013 Multibeam Survey of Mississippi River", U.S. Army Corps of Engineers New Orleans District, Published 2013, Date accessed September 10, 2013, See AREVA Document No. 32-9207352-001.

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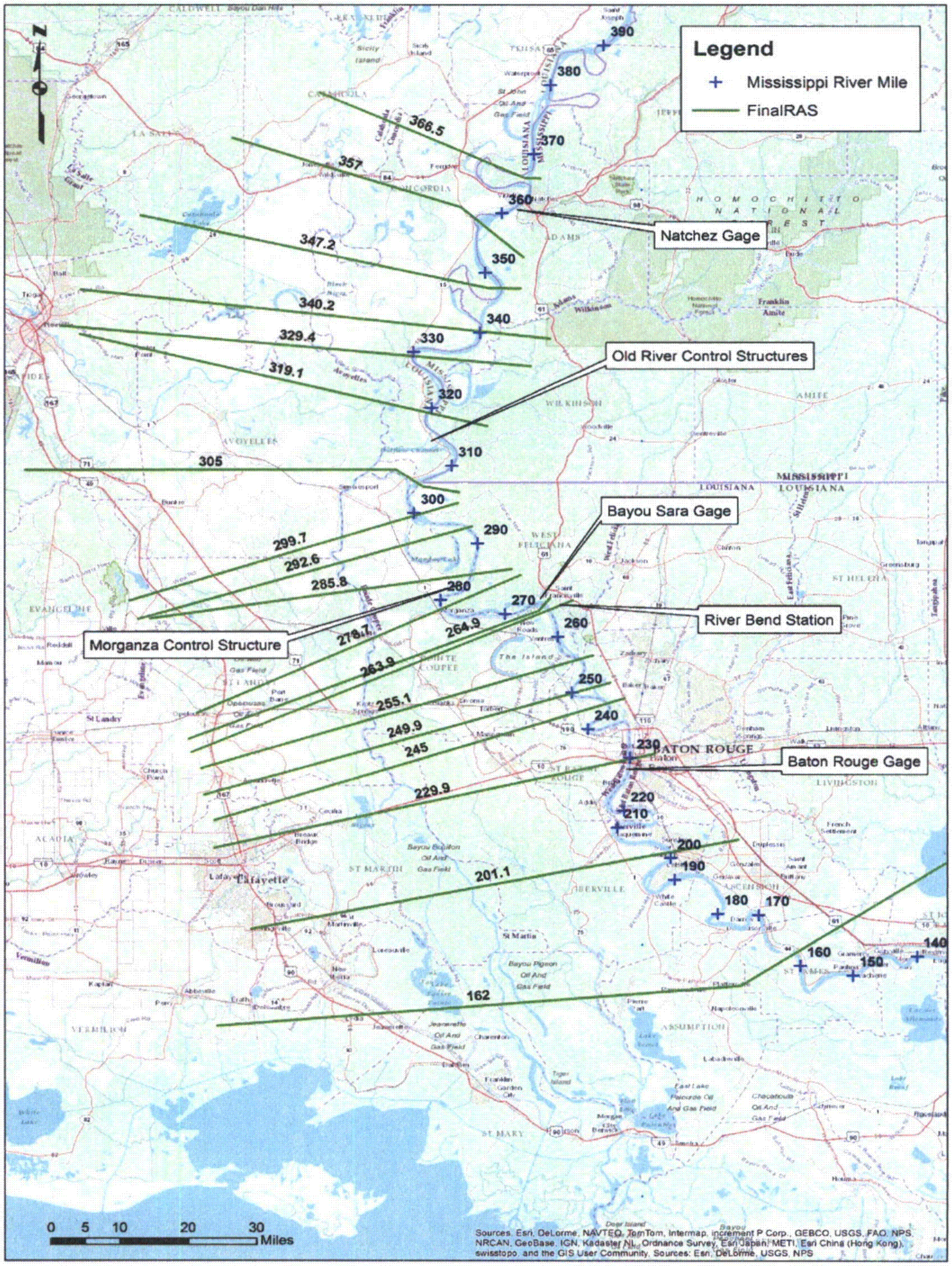
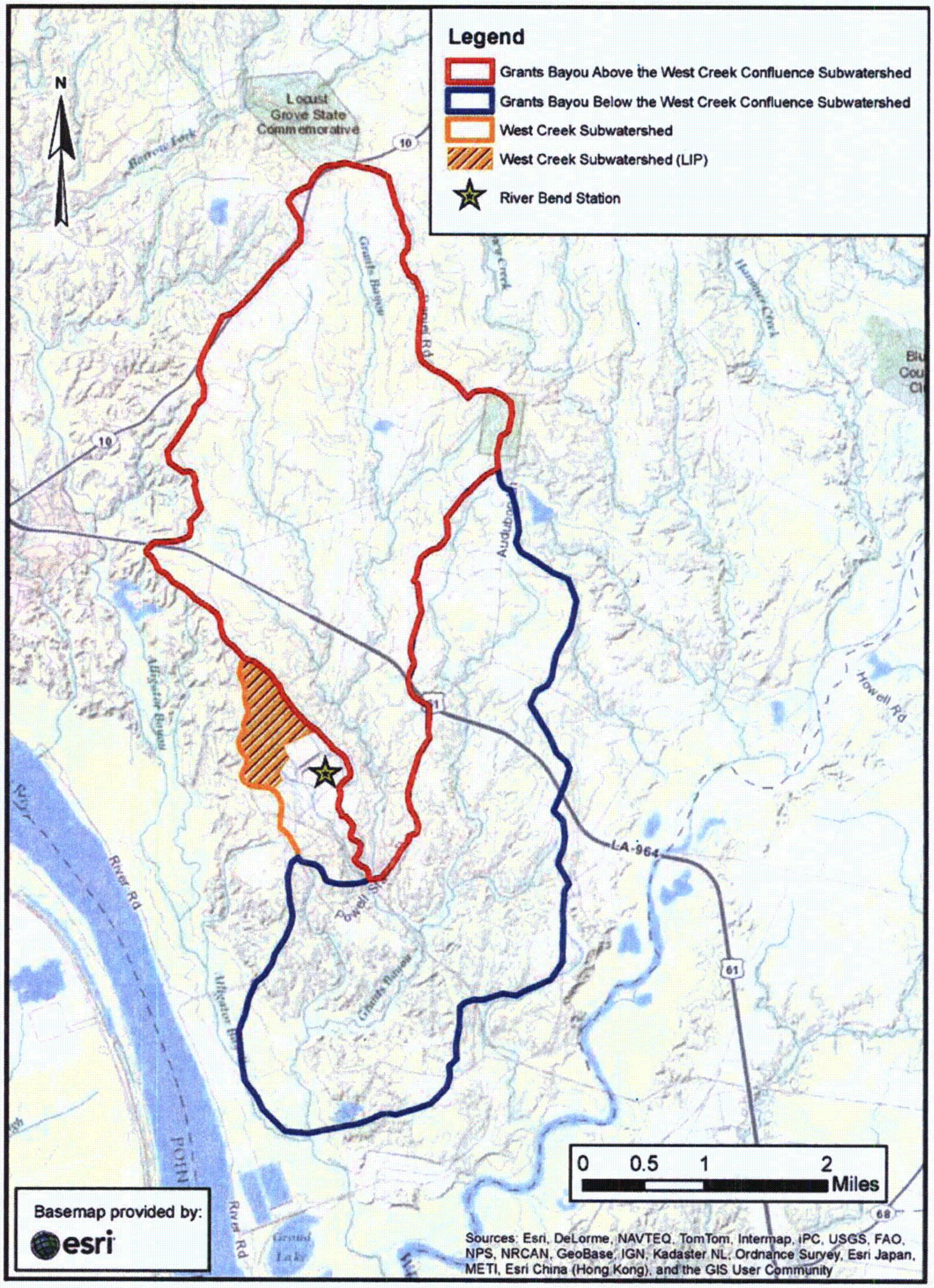
Figure 3.2-1: Mississippi River Control Structures and HEC-RAS Cross Sections



Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community. Sources: Esri, DeLorme, USGS, NPS

Any illegible text or features in this figure are not pertinent to the technical purposes of this document.

Figure 3.2-2: Grants Bayou and West Creek Watersheds Delineation

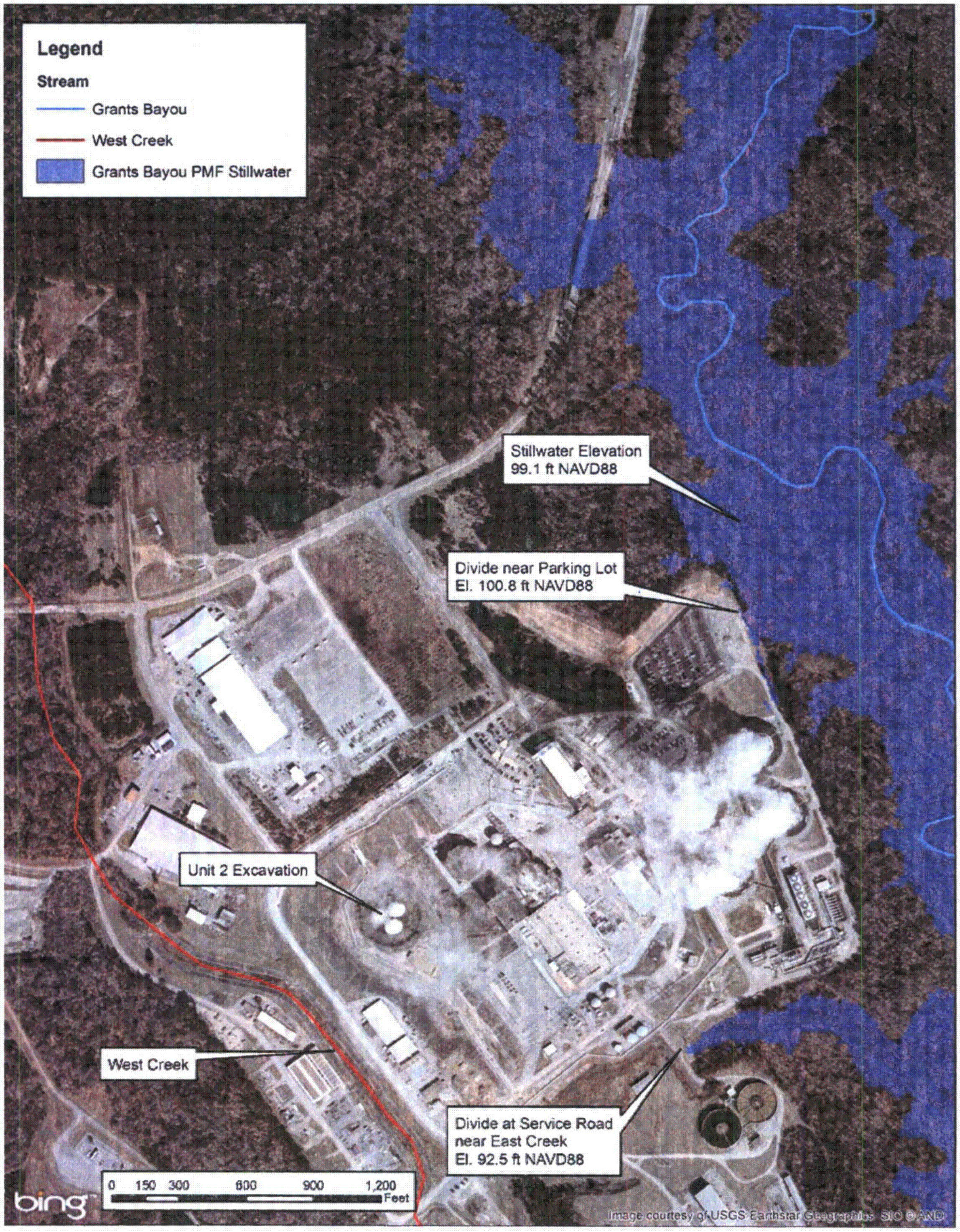


Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, iPC, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), and the GIS User Community

Any illegible text or features in this figure are not pertinent to the technical purposes of this document.

Figure 3.2-3: West Creek Inundation Map

Figure 3.2-4: Grants Bayou Inundation Map



3.3 Dam Breaches and Failures

This section addresses the effects of upstream dam failures on the Mississippi River PMF maximum water surface elevation at RBS. Dam breaches and failures may cause flood waves that impact the PMF level of the receiving water body. Dam breaches and failures of onsite structures, such as retaining ponds, can also impact site safety (NRC, 2011, Section 3.4).

There are no dams on the Mississippi River within 100 river miles upstream of RBS. The failure of a large hypothetical dam on the Mississippi River immediately upstream of RBS was used in this analysis. There are no dams or reservoirs on the unnamed local streams adjacent to RBS. There are no dams in the Grants Bayou watershed nor the West Creek watershed (USACE, 2013). Thus, dam failure was not evaluated within the Grants Bayou or West Creek watershed.

There are no on-site dams or levees which could impact site safety if breached (RBS, 2013, Section 2.4).

This section summarizes the Dam Failure evaluations performed in AREVA Calculation No. 32-9207355-000 (AREVA, 2014a).

3.3.1 Method

The HHA described in NUREG/CR-7046 (NRC, 2011, Section 2) was used for the evaluation of the effects of upstream dam failures on the Mississippi River PMF maximum water surface elevation at RBS (AREVA, 2013b). Additional guidance was provided by JLD-ISG-2013-01 - Interim Staff Guidance (ISG) Japan Lessons-Learned Project Directorate - Guidance For Assessment of Flooding Hazards Due to Dam Failure (NRC, 2013).

The criteria for flooding from dam breaches and failures evaluation is provided in NUREG/CR-7046, Appendix D (NRC, 2011). Two scenarios of dam failures are recommended and discussed in NUREG/CR-7046, Appendix D, including:

1. Failure of individual dams upstream of the site; and
2. Cascading or domino-like failures of dams upstream of the site.

The PMF scenario discussed below bounds Sunny Day and Seismic failure modes, since upstream reservoir levels used in the calculations were higher (i.e., coincident with top of dam).

Due to the large number of dams upstream of RBS, the application of the two scenarios of dam failure discussed in NUREG/CR-7046, Appendix D, for all dams is not realistic. The drainage area of the Mississippi River encompasses all or parts of 31 US states and 2 Canadian provinces. Accounting for all the dams within the Mississippi River watershed is unrealistic because the effect of dam breach within the upstream subwatersheds of the Mississippi River are unlikely to have any effect on water surface elevations at RBS due to the long distance the breach outflows will have to travel before reaching RBS. Dams within the upstream subwatersheds of the Mississippi River are far enough from the site such that the effects of dam failure could be expected to have been significantly attenuated before reaching the site. Therefore, only dams within the United States Geologic Survey delineated Hydrologic Unit Code (HUC) Lower Mississippi watershed (Figure 3.3-1) was used for this analysis (USGS, 2013).

The map layer "Major Dams of the United States" (DOI, 2013) was used as the source of data on dams within the Lower Mississippi River watershed. The Major Dams of the United States map layer is a subset of the 2005 National Inventory of Dams (NID), within the National Atlas of the United States. As stated by the National Atlas, "[The National Atlas Major Dams Layer] lists and describes more than 8,100 major dams in the United States, Puerto Rico, and the U.S. Virgin Islands. Major dams include dams 50 feet or more in height, dams with a normal storage capacity of 5,000 acre-feet or more, and dams with a maximum storage capacity of 25,000 acre-feet or more". (DOI, 2013)

The use of the Major Dams of the United States map layer served to screen inconsequential dams as recommended in the NRC's Interim Staff Guidance (ISG) for Assessment of Flooding Hazards Due to Dam Failure (NRC, 2013). All "Major Dams" upstream of the RBS site and within the Lower Mississippi River watershed were included in the model. Inconsequential dams, defined as dams whose failure poses no danger to life and property, or dams whose failure would only cause damage to property of the dam owner, were not included in this analyses. Dams which do not meet the technical definition of "inconsequential" contained in the ISG, but are not included on the "Major Dams" list were also not explicitly considered in this analysis. The vast majority of such non-major dams within the Lower Mississippi watershed are far enough from the site such that the effects of dam failure could be expected to have been attenuated before reaching the site. The effects of closer non-major dams is accounted for in the inherent conservatism included in the assumptions regarding the storage volume, height, and location of the hypothetical dam used in the dam failure model.

The methodology adopted in this calculation is based on the ISG (NRC, 2013) and involves the use of a single representative hypothetical dam having the total upstream storage volume of all major dams upstream of RBS within the Lower Mississippi watershed. The height of the hypothetical dam was conservatively assumed to be the height of the tallest dam within the Lower Mississippi watershed based on guidance contained in the ISG (NRC, 2013). The hypothetical dam was assumed to be located immediately upstream of the RBS site and no flood attenuation was considered.

3.3.2 Dam Failure Results

A total of 114 major dams were identified to be within the Lower Mississippi River drainage basin upstream of RBS, Figure 2.3-1. These major dams were used to estimate the characteristics of a single hypothetical dam which was in turn used to calculate the peak dam breach outflow to be directly translated to RBS. The calculated storage and height of the hypothetical dam is shown below:

Number of Dams	Total Storage (acre-feet)	Maximum Height (feet)
114	24,413,000	243

The Froehlich (Froehlich, 1995), U.S. Bureau of Reclamation (USBR) (USBR, 1982), and NRCS (NRCS, 1985) peak dam breach outflow regression equations were evaluated. The peak breach outflow from the Froehlich equation resulted in the greatest estimated breach flow at approximately 5,510,000 cfs. The PMF peak flow at RBS is 5,580,000 cfs (AREVA, 2014b). Therefore, the total flow at RBS with combined dam failure under PMF conditions is conservatively estimated to be 11,100,000 million cfs.

The peak PMF and dam break flow rate was input into the HEC-RAS steady flow model discussed in Section 3.2. The peak stage resulting from the combined dam failure and PMF peak flow rate was conservatively calculated to be 63.7 ft NAVD88 near RBS.

The flow capacity of the Mississippi River channel and floodplain, which includes the area on the typically "dry" side of the Mississippi levee system, corresponding to the site grade elevation of about 94.0 feet NAVD88 is estimated using the HEC-RAS model to be about 28,400,000 cfs. Therefore, an additional 17,300,000 cfs in floodplain capacity is available to accommodate other coincident dam failures without affecting RBS.

3.3.3 Dam Failure Conclusions

At RBS, the impact of dam breaches and failures on flooding hazard at the site is negligible for the following reasons:

- The combined dam break peak outflow and PMF at RBS, conservatively assuming no attenuation of the breach outflow to the RBS, is estimated to be 11,100,000 cfs.
- The resultant peak water surface elevation from the combined dam breach peak outflow and PMF in the Mississippi River at RBS is 63.7 ft NAVD88, which is more than 30 ft below the site grade elevation.
- The estimated Mississippi River channel and floodplain capacity at RBS is estimated to be about 28,400,000 cfs, with miles of floodplain storage available in the vicinity of RBS. Therefore, an additional 17,300,000 cfs is available to accommodate other coincident dam failures without affecting the site.

Based on the re-evaluation of upstream dam failures on the Mississippi River, the peak water surface elevation on the Mississippi River at RBS resulting from the failure of upstream dams and the PMF is below the plant grade elevation and would not affect SSCs important to safety at RBS. Even in the unlikely event of multiple major upstream dams failing simultaneously, the Mississippi River channel and floodplain capacity at RBS is expected to be adequate to contain the attenuated, non-synchronized peak flows without affecting safety-related structures, systems, or components. Additional refinement of the dam failure model is not necessary due to the sufficient margin indicated by the initial conservative analysis.

3.3.4 References

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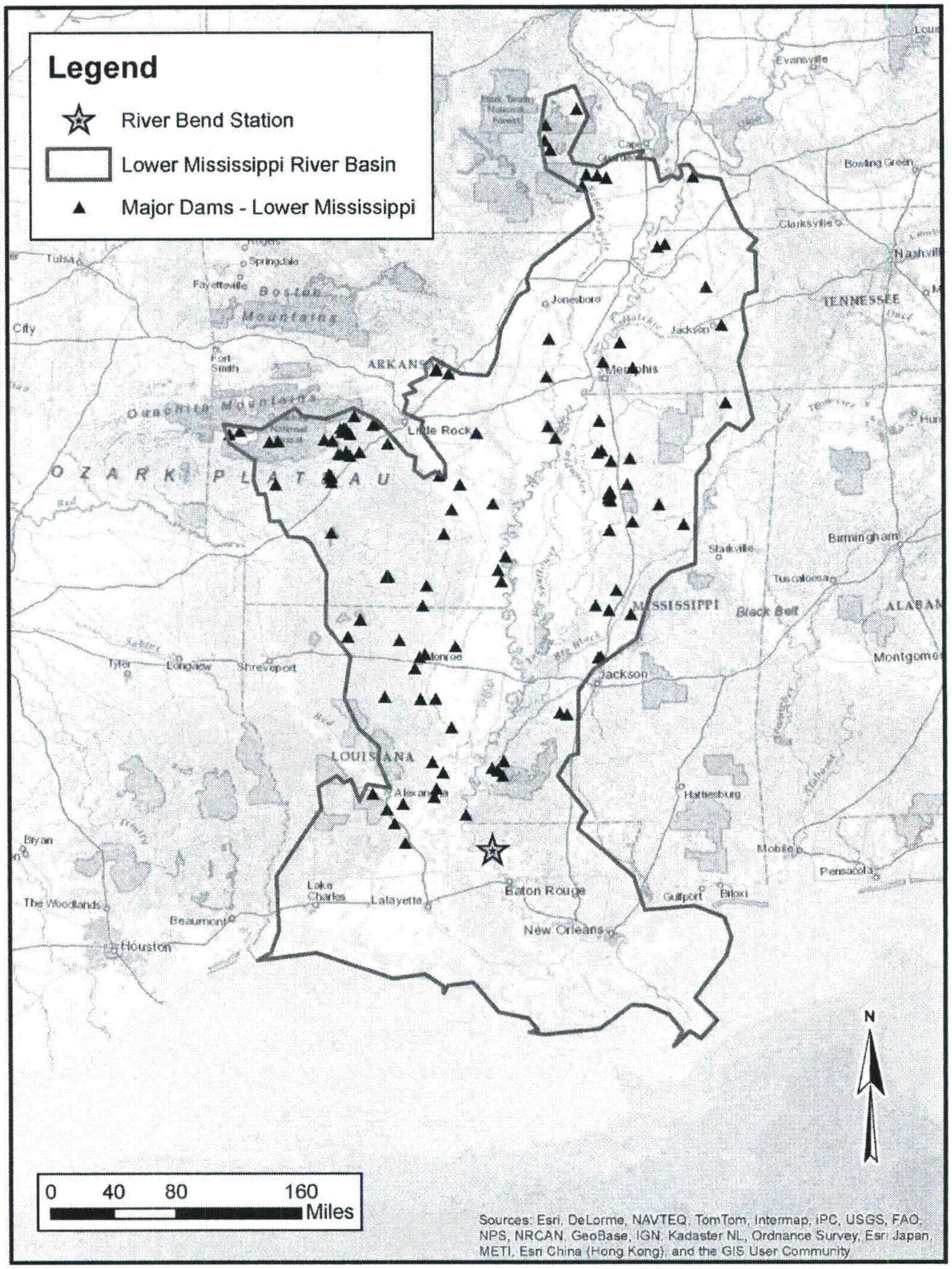
USGS, 2013. "U.S Subwatershed Boundaries (HUC) Shapefiles", United States Geologic Survey, (http://www.epa.gov/waters/doc/auxiliary/wbd.html) Date modified: July 2013, Date accessed: November 5, 2013, See AREVA Document No. 32-9207355-000.

Figure 3.3-1: Major Dam Locations – Lower Mississippi River Basin



Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, iPC, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), and the GIS User Community

Sources: DOI, 2013 and USACE, 2013;

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3.4 Storm Surge

3.4.1 Storm Surge Screening Discussion

All coastal nuclear power plant sites and nuclear power plant sites located adjacent to cooling ponds or reservoirs subject to potential hurricanes, windstorms, and squall lines must consider the potential for inundation from storm surge and windwaves (NRC 2013, Section 3).

The potential flooding hazard from storm surge at RBS is judged to be negligible because of the site's location and riverine setting.

RBS is located inland approximately 2 miles from the east bank of the Mississippi River near River Mile 262. There are no adjacent cooling ponds or reservoirs (Figure 1). As such, regional storm surge waves propagating from Gulf of Mexico coastal waters upstream to RBS will be dissipated due the river distance from the coast and the meandering nature of the river.

Locally, the hydrometeorlogical conditions limit the development of storm surges. The Mississippi River in the RBS area is both narrow (about 0.5 miles) and meandering, which reduces the broad and extensive water surface area needed to generate a storm surge. Also, the generation of sustained, hurricane-type winds (including from tropical depressions and storms) at RBS is minimized due to its inland location, which is about 70 miles from the Gulf of Mexico coastline (RBS 2013, Section 2.4.5).

3.4.2 References

NRC, 2013. "JLD-ISG-2012-06, Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment, Interim Staff Guidance", Revision 0, January 2013. (ADAMS Accession No. ML12314A412)

RBS, 2013. "RBS Updated Safety Analysis Report", Revision 23, 2013, See AREVA Document No. 38-9210629-000.

3.5 Seiche

3.5.1 Seiche Screening Discussion

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).

The potential flooding hazard from a seiche at RBS is judged to be negligible because of the site's riverine setting and elevation.

The Mississippi River in the RBS area is not an enclosed or semi-enclosed water body (Figure 2.1-1). Instead, the river is narrow (about 0.5 miles) and meandering, which constrains and limits the geometry needed to develop a seiche and its oscillation propagation. The river geometry also limits the height of any seiche oscillations and causes rapid attenuation of any seiche oscillations.

Thus, given a seiche, there would be little, if any, effect on the RBS site.

3.5.2 References

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, Springfield, VA, National Technical Information Service, 2011.

3.6 Tsunamis

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, RBS is not susceptible to oceanic tsunamis (NRC 2009, Section 2.1). Instead, there is the potential of tsunami-like waves in the Mississippi River.

3.6.1 Methodology

The RBS tsunami evaluation followed the HHA approach described in NUREG/CR-6966, Tsunami Hazard Assessment at Nuclear Power Plant Sites in the United States of America (NRC, 2009) and Interim Staff Guidance JLD-ISG-2012-06, Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment (ISG) (NRC, 2013).

With respect to tsunamis, the progressive HHA is considered as a series of three tests:

1. Is the site region subject to tsunamis?
2. Is the plant site affected by tsunamis?
3. What are the hazards posed to safety of the plant by tsunamis?

At RBS, the first two tests were considered. The third test was unnecessary based on the results of the first two tests.

The first test was answered by performing a regional survey and assessment of potential tsunamigenic sources. The regional survey was in four parts and included the relevant mechanisms that generate tsunamis. The first part was to review the Global Historical Tsunami Database, 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 tsunamigenic sources likely to cause a tsunami.

The second test was answered by evaluating the vulnerability of the site location relative to potential tsunami sources.

3.6.2 Tsunami Results

3.6.2.1 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. (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 in comparison to earthquakes (NRC, 2009, Section 6.2) and ice falls, which are glacial ice processes (NRC, 2009, Section 1.3.2), are comparable to subaerial landslides (see Section 3.6.2.1.3).

3.6.2.1.1 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, RBS need only consider the possibility of a tsunami-like wave in water bodies in the region (NRC, 2009, Section 2.2). As a result, the regional survey considered tsunami-like waves in the area consisting of non-coastal southeast United States extending from latitude 30.5°N to 41°N, and 81°W to 100°W longitude.

Five tsunami events were recorded in the database, occurring between 1811 and 1895 (NOAA, 2013). Each event was associated with an earthquake event and caused a tsunami-like wave (seiche) in an inland river. The five events also produced eight runup observations, i.e., locations where tsunami-like effects occurred due to the tsunami source event. No wave heights were recorded.

3.6.2.1.2 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 regional seismicity information presented in the RBS USAR and RBS Unit 3 Combined License Application, seismicity within 200 miles of the site is sparse and minor (RBS 2013, Section 2.5.2; RBS3, 2008, Section 2.5.1.1.5.5). Thirty-six earthquakes of Magnitude 3.0 or greater have occurred during the period from 1758 to 2006 (RBS3, 2008, Section 2.5.1.1.5.5). None of these exceeded Magnitude 4.3. Only five have occurred within 50 miles of the site, with the largest being Magnitude 4.2. The closet was a Magnitude 3.2 event 19 miles from the 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, 2013a). Seismic waves from the Alaska earthquake of 1964 caused water bodies to oscillate at many places in North America, including the rivers and bayous of the New Orleans area as well as the Amite River, east of Baton Rouge (LGS, 2001). Favorable conditions for seismic seiche generation include thrust faults and locations controlled by structural uplifts and basins (USGS, 2013a). The RBS region, however, lacks such conditions (LGS, 2001).

3.6.2.1.3 Landslides

There are two broad categories of landslides:

1. Subaerial that are initiated above the water and impact the water body during their progression or fall into the water body, and
2. Subaqueous that are initiated and progress beneath the surface of 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. The most common landslide mechanism is an earthquake. (NRC, 2009, Section 1.3.2)

Subaerial Landslide – Area Topography

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

The USGS classifies the Mississippi River region near RBS as having a high susceptibility to landslides, but with a low incidence rate (USGS, 2013b). Locally, the potential for a subaerial landslide, however, is conspicuously less because the land area along the river east and west shoreline is flat due to the floodplain (Figure 2.1-1).

In addition, the levee along the west bank of the Mississippi River opposite the site is at elevation 57.5 ft MSL (RBS, 2013, Section 2.4.3.5.1), which is more than 37 ft below the nominal plant grade (RBS, 2013, Section 2.4.1). Thus, given a subaerial landside, there would be negligible effect to the RBS site due to its elevation above the river.

Subaqueous Landslide -Mississippi River Bathymetry

The outgoing wave from a subaqueous landslide source propagates in the direction of the slide with its amplitude affected by the terminal velocity of the movement, which in turn is a function of the repose angle, i.e., the slope angle (NRC, 2009, Section 1.3.2).

The Mississippi River bathymetry in the RBS area is relatively uniform (USACE, 2004) and actively managed to maintain navigability. There are limited areas with bathymetric gradients that have the potential to produce a subaqueous landslide. Thus, given a landslide, its velocity would be limited due to the low-angle slope.

In addition, as with the subaerial landslides, the Mississippi River is more than 37 ft below the nominal plant grade. Thus, given a subaqueous landside, there would be little, if any, effect to the RBS site due to its elevation above the river.

3.6.3 Conclusions

As an inland site, the RBS site is not subject to oceanic tsunamis. Based on the NGDC tsunami-source-event database regional survey screening results:

- Tsunami-like waves have been recorded in the region.
- 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 subaerial landslide is limited because of the flat topography along the east and west river shorelines; and
    - a subaqueous landslide is limited because of the low river bathymetric gradients.
- Given a tsunami-like wave, there is more than 37 ft physical margin between the Mississippi River and the nominal plant grade.

As a result, the flooding hazard potential at the RBS site from tsunami-like waves is judged to be negligible.

3.6.4 References

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NRC, 2013. "JLD-ISG-2012-06, Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment, Interim Staff Guidance", Revision 0, January 2013. (ADAMS Accession No. ML12314A412)

RBS, 2013. “RBS Updated Safety Analysis Report”, Revision 23, 2013, See AREVA Document No. 38-9210629-000.

RBS3, 2008. "River Bend Station Unit 3 Combined License Application, Part 2: Final Safety Analysis Report", Revision 0, September 2008. (ADAMS Access No. ML082830247)

USACE, 2004. "Mississippi River Hydrographic Survey 2004", Survey Maps 18 and 19, US Army Corps of Engineers, Published 2004.

USGS, 2013a. "Seismic Seiches", U.S. Geological Survey, Website: http://earthquake.usgs.gov/learn/topics/seiche.php; Abridged from Earthquake Information Bulletin, January-February 1976, Volume 8, Number 1; accessed March 5, 2014, last modified January 9, 2013, See AREVA Document No. 38-9219967-000.

USGS, 2013b. "Landslide Overview Map of the Conterminous United States", Website: http://landslides.usgs.gov/learning/nationalmap/; accessed August 6, 2013, See AREVA Document No. 38-9219967-000.

3.7 Ice-Induced Flooding

Ice jams and ice dams can form in rivers and streams adjacent to a site and may lead to flooding by two mechanisms (NRC, 2011):

- 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
- An ice jam or a dam downstream of a site may impound water upstream of itself, thus causing a flood via backwater effects.

This section summarizes the Ice-Induced Flooding evaluation performed in AREVA Calculation No. 32-9207359-000 (AREVA, 2013).

3.7.1 Method

The ice-induced flooding evaluation followed the HHA described in NUREG/CR-7046, Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America (NRC, 2011, Section 2).

With respect to ice effects, the HHA used the following two steps:

1. Review historical ice events and backwater effects due to ice jams in the Mississippi River in the vicinity of RBS.
2. Evaluate historical water temperatures to assess the possibility of the formation of ice jams in the Mississippi River in the vicinity RBS.

3.7.2 Ice-Induced Flooding Results

3.7.2.1 Review of historical ice events

The USACE maintains records of historical ice jams and dams on the Ice Jam Database (USACE, 2013b), which can be queried (using state name) to obtain information regarding historical ice events. There are no historic records of ice jams in the Mississippi River near RBS within the USACE Ice Jam Database.

3.7.2.2 Review of Water Temperatures in the Vicinity of RBS

Water temperature data for the Mississippi River is available for USGS gages in Vicksburg, Mississippi and Baton Rouge, Louisiana for the periods 1973 – 1999 and 2007 – 2013, respectively (NRC, 2003 and USGS, 2013). The Mississippi River water temperature data indicate that water temperatures in the Mississippi River were always above freezing at these locations during the periods of record. The water temperatures recorded during these periods range from 35°F to 91°F.

For the period 2000 – 2013, water temperature data for the Mississippi River at Natchez, Mississippi were obtained from the USACE, Vicksburg District (USACE, 2013a). The data indicates that temperatures in the Mississippi River at Natchez during this period range from 33°F to 91°F.

3.7.3 Conclusions

At RBS, the potential of ice-induced flooding impacting the site is judged to be negligible for the following reasons.

Water temperature data from the USGS and USACE indicate that water temperatures in the Mississippi River are above freezing. The formation of frazil ice is unlikely because water temperatures below freezing are required for a sustained period of time for the development of frazil ice. Frazil ice, ice jams, and ice dams are therefore not expected to form in the Mississippi River in the area of RBS. This conclusion is supported by information contained in the USACE Ice Jam Database, which indicates that no ice jams have been recorded in the Mississippi River near RBS.

In addition, the Lower Mississippi River (including the Mississippi River segment, which forms the west boundary of RBS) is heavily navigated, and USACE New Orleans District maintains navigable conditions. This active management of the river further reduces the potential for ice jams.

Even in the unlikely event that ice formation does occur in the Mississippi River in the vicinity of RBS, no flood impacts are expected. The plant is located on an upland terrace east of the river channel with a site grade approximately 37 ft above the river flood control levee system. Overtopping during a hypothetical ice jam would divert river flow away from the plant to the large floodplain west of the plant. Therefore, ice-induced flooding at RBS due to ice effects is not anticipated.

3.7.4 References

AREVA, 2013. AREVA Document No. 32-9207359-000, "River Bend Station Flooding Hazard Re-evaluation - Ice Induced Flooding", 2013.

NRC, 2003. "Grand Gulf Nuclear Station Early Site Permit Application, Part 3 – Environmental Report", Table 2.3-3, Revision 1, October, 2003, NRC Accession No. ML080640401.

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, Springfield, VA, National Technical Information Service, 2011.

USACE, 2013a. US Army Corps of Engineers, Vicksburg District, http://rivergages.mvr.usace.army.mil/WaterControl/new/layout.cfm, Date accessed August 12, 2013, Date updated August 12, 2013, See AREVA Document No. 32-9207359-000.

USACE, 2013b. "Ice Jam Database", U.S. Army Corps of Engineers, Ice Engineering Research Group, Cold Regions Research and Engineering Laboratory, https://rsgisias.crrel.usace.army.mil/apex/f?p=273:1:, Date accessed August 19, 2013, Date updated July 9, 2013, See AREVA Document No. 32-9207359-000.

USGS, 2013. United States Geologic Survey, Gage 07374000 Mississippi River at Baton Rouge, LA., Date accessed August 12, 2013, Date updated August 12, 2013, See AREVA Document No. 32-9207359-000.

3.8 Channel Migration or Diversion

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. 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 hydro-geomorphological 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)

This section summarizes the Channel Migration or Diversion evaluation performed in AREVA Document No. 51-9209602-000 (AREVA, 2013).

3.8.1 Method

The channel migration and diversion flooding evaluation followed the HHA approach described in NUREG/CR-7046, Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America (NRC, 2011).

With respect to channel migration and diversion, the HHA used the following two steps:

1. Review historical records and hydro-geomorphological data to assess whether the Mississippi River has exhibited the tendency to meander towards the site.
2. Evaluate present-day channel protection and stabilization measures in place to mitigate channel diversion of the Mississippi River.

3.8.2 Results

Lateral shifting of the Mississippi River near the RBS site is a known historical issue, as attested to by the presence of an oxbow lake located west of the RBS (False River), low-lying swamps adjacent to the river, and sand bars along the river banks. Although there is evidence of extensive lateral shifting near RBS, the present course is located west of the bank mapped in 1765, and in general, the river's tendency has been to meander away from the site and towards the low lying areas to the west of the bluffs in the vicinity of the site. A slower rate of meandering is observed on the section of the Mississippi River from Angola (approximate River Mile 300) to Baton Rouge (which includes RBS) due to thicker top stratum and low water slope (Saucier, 1994).

The Lower Mississippi River (including the Mississippi River segment, which forms the western boundary of RBS) is heavily navigated. The USACE New Orleans District is responsible for channel improvements, dredging, and navigation activities on the Lower Mississippi in the vicinity of RBS. As part of this mission, USACE New Orleans maintains over 360 miles of concrete mats and trench fill revetments including the Bayou Sara Revetments, which are near the RBS site (USACE, 2013).

The 2004 Mississippi River Hydrographic Survey (USACE, 2004) provides the locations of the revetments and other channel improvements constructed on the Mississippi River in addition to topographic characteristics of the river. Additional revetment and dike construction have been planned throughout the Mississippi River system (USACE, 2011a).

The Bayou Sara revetments, constructed along the eastern bank of the Mississippi River between river mile 260.1 to 265.3 (USACE, 2004), provide the primary protection against the erosion of the sedimentary Mississippi River bank near RBS. The top elevation of the Bayou Sara Revetment is generally lower in the vicinity of the RBS intake structure. Riprap has been placed along the eastern bank in the vicinity of the intake embayment area to compensate for the lower elevation of the revetments there. The effectiveness of the erosion protection is monitored and additional erosion control measures are implemented, if required, to protect the intake area (RBS, 2013, Section 2.4.9).

Levees maintained by the USACE confine flood flow to the channel and specified floodways. Levees with top elevations of around 55 ft MSL are located near RBS along the western bank of the Mississippi River (RBS, 2013, Section 2.4.3).

Floodways are operated by the USACE and provide additional storage and flow relief to the Mississippi River during large flood events. There are three major floodways that impact flow near RBS: the Atchafalaya River proper (Old River control structures complex located at River Mile 315), the West Atchafalaya Floodway (located at River Mile 302), and the Morganza Floodway (located at River Mile 285) (RBS, 2013, Section 2.4.1). Failure or mis-operation of these structures could result in significant portions of the flow of the Mississippi River being routed away from the current channel and into the Atchafalaya River. This would not result in increased risk of flooding or erosion to the RBS facility.

As the USAR notes, the Mississippi River meander nearest to the site is maintained such that it remains within the floodplain so that no erosion occurs on the upland slope (RBS, 2013, Section 2.5.1). A comparison of 1965 and 2012 USGS topographic maps illustrate continuity of the river course since the USACE constructed the Sara Bayou Revetment and Old River Control Structures (AREVA, 2013). A review of the USACE flood map depicting the flooding extents of the 1927 flood to the 2011 flood (USACE, 2011b) indicates that the Mississippi River was contained in its current channel during the 2011 flood and did not migrate towards RBS. The eastern extents of flood plain in area of RBS did not appreciably change when comparing the 1927 flood to the 2011 flood.

The floodplain in the vicinity of RBS is over 100 miles wide. This wide, low-lying floodplain provides additional protection against flooding of RBS due to potential migration of the Mississippi River in the event of the failure of the revetments or levees. RBS is located approximately 1.5 miles from the east bank of the Mississippi River on a high terrace. The site grade elevation is well above the eastern Mississippi River floodplain elevation which ranges from 30 to 45 ft MSL in the vicinity of the site (RBS, 2013, Section 2.5.1).

3.8.3 Conclusions

At RBS, the potential for river channel migration to impact the site is judged to be negligible for the following reasons:

The Lower Mississippi River (including the Mississippi River segment, which forms the western boundary of RBS) is heavily navigated, and the USACE New Orleans District is responsible for maintaining navigable conditions. As part of this responsibility, USACE actively maintains revetments and flood control structures that have been constructed to minimize the risk of channel diversions, bank erosion, and instability. A review of research on the river indicates that the river channel had migrated in the past, but the migration generally occurred on the west shore in the location of RBS (i.e. away from the site). A review of recent historical data indicates that the Mississippi River has not exhibited a tendency to meander towards or away from the site since the construction of the revetments and levees. RBS is located more than 1.5 miles from the current east bank of the river. Furthermore, all SSCs important to safety at RBS are located at an elevation above 95 ft MSL, well above the eastern Mississippi River floodplain elevation which ranges from 30 to 45 ft, MSL, thus providing a significant margin against changes in the channel alignment.

3.8.4 References

AREVA, 2013. AREVA Document No. 51-9209602-000, "River Bend Station Flooding Hazard Re-Evaluation – Channel Diversion Flooding", 2013.

Fisk, 1944. Fisk, Harold N, "Geological Investigation of the Alluvial Valley of the Lower Mississippi River", Mississippi River Commission, U.S. Army Corps of Engineers, December 1, 1944, See AREVA Document No. 51-9209602-000.

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, Springfield, VA, National Technical Information Service, 2011.

RBS, 2013. "RBS Updated Safety Analysis Report", Revision 23, 2013, See AREVA Document No. 38-9210629-000.

Saucier, 1994. Saucier, Roger T. "Geomorphology and Quaternary Geologic History of the Lower Mississippi Valley", Mississippi River Commission, U.S. Army Corps of Engineers, December 1994, See AREVA Document No. 51-9209602-000.

USACE, 2004. "Mississippi River Hydrographic Survey 2004", US Army Corps of Engineers, Published 2004, See AREVA Document No. 51-9209602-000.

USACE, 2013. "Channel Improvement and Stabilization Program", U.S. Army Corps of Engineers, New Orleans District, http://www.mvn.usace.army.mil/Missions/Engineering/ChannelImprovementandStabilizationProgram.aspx, Date accessed: August 6, 2013, Date updated August 29, 2011, See AREVA Document No. 51-9209602-000.

USACE, 2011a. "Mississippi River Channel Improvement Master Plan", US Army Corps of Engineers, Mississippi Valley Division, March 2011, See AREVA Document No. 51-9209602-000.

USACE, 2011b. "Flood Map: 1927 vs 2011", US Army Corps of Engineers, Mississippi Valley Division, June 2011, See AREVA Document No. 51-9209602-000.

3.9 Combined Effect Flood

This section addresses combined effect flooding at RBS. This evaluation includes the impacts of the PMF on the Mississippi River coincident with wind generated waves RBS. This evaluation also addresses the impacts of the PMF combined with wind generated waves on the maximum water surface in Grants Bayou near the northeast boundary of the site.

This section summarizes the Combined Effect Flood evaluation performed in AREVA Calculation No. 51-9207357-000 (AREVA, 2014e).

3.9.1 Method

The HHA approach described in NUREG/CR-7046 (NRC, 2011) was used for the evaluation of the effects of the combined-effects floods on the Mississippi River and Grants Bayou at RBS. The limited fetch for West Creek and shallow inundation depths at the flood fringe will not result in significant wind-generated waves.

The criteria for combined events are provided in NUREG/CR-7046, Appendix H, of which two apply to RBS: floods caused by precipitation events (H.1) and floods caused by seismic events (H.2). Other criteria for the determination of the effects of the combined-effect flood described in NUREG/CR-7046 (NRC, 2011, Appendix H, Sections H.3 – H.5) do not apply to RBS given the site is not a coastal site.

The criteria for floods caused by precipitation events were used (NUREG/CR-7046, Appendix H, Section H.1), which includes the following:

1. 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;
2. 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
3. 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.

Only Alternative 1 was considered, because snowpack in the vicinity of RBS is negligible (AREVA, 2014c and AREVA, 2014d).

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

1. Alternative 1 – A combination of a 25-year flood, a flood caused by dam failure resulting from a safe shutdown earthquake, and coincident with the peak of the 25-year flood, and waves induced by 2-year wind speed applied along the critical direction;
2. Alternative 2 – A combination of the lesser of one-half of PMF or the 500-year flood, a flood caused by dam failure resulting from an operating basis earthquake, 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 results of the dam failure calculation (AREVA, 2014a) indicate that floods caused by seismic dam failures (NRC, 2011, Appendix H.2) are bounded by the PMF with coincident dam failure on the Mississippi River at RBS.

Therefore "Alternative 1" under the "Floods Caused by Precipitation Events" sub-section H.1 of Appendix H (NRC, 2011) has been judged to be the controlling scenario for Combined-Effects Floods.

The combined event evaluation for RBS used the following steps:

1. Calculate the wind wave effects and wave runup on the Mississippi River and Grants Bayou at RBS using the CEDAS-ACES v4.3 Computer Program (AREVA, 2014b);

2. Calculate the Probable Maximum Water Elevation (PMWE) on the Mississippi River and Grants Bayou at RBS resulting from the combined-effect flood.

3.9.2 Results

3.9.2.1 Wind-Wave Effects

Many of the inputs used for the wave setup and wave runup calculations are judged to be conservative; therefore, the final effects of waves on the PMWE are judged to be likewise conservative. This approach is consistent with the HHA approach discussed in NUREG/CR-7046 (NRC, 2011, Section 2).

3.9.2.1.1 Greatest Straight Line Fetch

Fetch represents the unobstructed generating over-water pathway for wind-generated waves, with longer distance fetches allowing for larger wave generation.

Mississippi River Straight Line Fetch

A distance of 47.3 miles was determined to be the greatest straight line fetch for input to the CEDAS-ACES v4.03 module (AREVA, 2014c). This fetch is conservative; assuming the entire width of the Mississippi River floodplain is available for wind generated wave propagation.

Grants Bayou Straight Line Fetch

The inundation area created based on PMF stillwater elevations from the Grants Bayou HEC-RAS model (AREVA, 2014d) was used to calculate the greatest straight line fetch. The longest fetch across the inundated area was calculated to be 2,505 ft.

3.9.2.1.2 Sustained Wind Speed

The Gumbel Distribution was applied to the 2-minute wind speed data from National Climatic Data Center (NCDC) station at Baton Rouge Airport (NCDC, 2013), to determine the 2-year return period wind speed, which was calculated to be 43.4 mph.

3.9.2.1.3 Wave Height and Period

The Wave Prediction application of the CEDAS-ACES v.4.03 was used to determine the deep water significant wave height and period. Table 3.9-1 shows the inputs used in the application.

A negative 27°F air/sea temperature difference was selected as a conservative input for wave prediction. This temperature difference indicates air temperatures lower than the water temperatures, which is plausible during an extreme precipitation event such as the PMP. The duration of the final wind speed was selected to be 5.5 hours on the Mississippi River. This is a conservative estimate used for a 2-year wind speed. The deep water significant wave height for the Mississippi River was determined to be 11.8 ft with a period of 7.8 seconds.

The duration of the final wind speed of 15 minutes produces the maximum wave height on Grants Bayou at RBS and was determined based on a sensitivity analysis. The deep water significant wave height for Grants Bayou was determined to be 0.53 ft with a period of 0.99 seconds.

3.9.2.1.4 Wave Set-up

The wave setup was calculated using the Wave Setup across the Surf Zone application of CEDAS-ACES v.4.03. Table 3.9-2 shows the inputs used in the application.

The refraction coefficient was set to 1.0 for head on, perpendicular waves. The Mississippi River wave setup across the surf zone is determined to be 4.0 ft. The Grants Bayou wave setup across the surf zone is determined to be 0.1 ft.

3.9.2.1.5 Wave Run-up

The Wave Runup and Overtopping on Impermeable Structures application was selected to calculate the wave runup at RBS from the CEDAS-ACES v.4.03 program. Table 3.9-3 describes the parameters used by the application to solve the wave runup at RBS.

The water depth at the structure toe (i.e., toe of the river/stream bank) was calculated by subtracting the lowest Mississippi river valley elevation or Grants Bayou river bottom elevation from the PMF elevation. The wave runup was calculated to be 5.7 ft for the Mississippi River and 0.2 ft for Grants Bayou.

3.9.2.2 Calculate the Probable Maximum Water Elevation at RBS resulting from the combined-effect flood

The probable maximum stillwater elevation on the Mississippi River at River Bend Nuclear Station is 63.7 ft NAVD88 (AREVA, 2013c). The PMWE on the Mississippi River at RBS is the combination of this stillwater elevation and wave setup and wave runup induced by the 2-year wind speed:

63.7 ft NAVD88 + 4.0 ft+ 5.7 ft = 73.4 ft NAVD88 (Mississippi River)

The probable maximum stillwater elevation on Grants Bayou at River Bend Nuclear Station is 99.1 ft NAVD88 (AREVA, 2013d). The PMWE on Grants Bayou at RBS is the combination of this stillwater elevation and wave setup and wave runup induced by the 2-year wind speed:

99.1 ft NAVD88 + 0.1 ft+ 0.2 ft = 99.4 ft NAVD88 (Grants Bayou)

3.9.3 Conclusions

At RBS, impacts to the site from flooding on the Mississippi River or Grants Bayou coincident with wind generated waves are judged to be negligible for the following reasons:

The PMWE on the Mississippi River at RBS, including wave effects, is conservatively calculated to be 73.4 ft NAVD88, which is more than 20 ft below site grade.

The flood elevation in Grants Bayou, including wave effects, is approximately 1.4 ft below the elevation of the topographic divide between the Grants Bayou floodplain and the RBS site area.

Based on the re-evaluation of the combined-effect flood on the Mississippi River and Grants Bayou at RBS, the PMWE at RBS resulting from combined-effect flooding is at or below the plant grade elevation and, thus, would not affect SSCs important to safety at RBS.

3.9.4 References

AREVA, 2014a. AREVA Document No. 32-9207355-000, "River Bend Station Flooding Hazard Re-Evaluation – Dam Failures", 2014.

AREVA, 2014b. AREVA Document No. 38-9196713-000, "GZA Computer Program Certification for CEDAS-ACES Version 4.03 PC," 2013.

AREVA, 2014c. AREVA Document No. 32-9207352-000, "River Bend Station Flooding Hazard Re-Evaluation – Probable Maximum Flood on Streams and Rivers – Mississippi River Flow and Elevation Calculation", 2014.

AREVA, 2014d. AREVA Document No. 32-9207353-000, "River Bend Station Flooding Hazard Re-Evaluation – Probable Maximum Flood on Streams and Rivers – Grants Bayou and West Creek Flow and Elevations", 2014.

AREVA, 2014e. AREVA Document No. 32-9207357-000, " River Bend Station Flooding Hazard Re-Evaluation – Combined Events Flood Analysis", 2014.

NCDC, 2013. "GHCND: USW00013970 – Baton Rouge Ryan Airport, LA US: Fastest 2-Minute Wind Speed Data", National Climatic Data Center, National Oceanic and Atmospheric Administration, http://www.ncdc.noaa.gov/cdo-web/, Date accessed December 2, 2013, Date modified December 2, 2013, See AREVA Document No. 32-9207357-000.

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, Springfield, VA, National Technical Information Service, 2011.

Table 3.9-1: Wave Prediction Parameters for CEDAS-ACES

Input Parameter	Value	Units
Elevation of the Observed Wind Speed (Z_{obs})	32.8	Feet
Observed Wind Speed (U_{obs})	43.4	Miles/Hour
Air Sea Temperature Difference (dT)	-27	Fahrenheit
Duration of the Observed Wind (DurO)	2	Minutes
Duration of the Final Wind Speed (DurF)	5.5	Hours
Latitude of Observation (LAT)	30.8	Degrees
Wind Fetch Length (F)	47.3 (Mississippi River)	Miles
Wind Observation Type	Inland	n/a
Wind Fetch Options	Deep open water	n/a

Table 3.9-2: Wave Setup Parameters for CEDAS-ACES

Mississippi River

Input Parameter	Value	Units
Acceleration due to gravity (g)	32.2	Feet/second^2
Deep water significant wave height (H_0)	11.8	Feet
Wave period (T)	7.8	Seconds
Slope (m)	0.09	Vertical Feet / Horizontal Feet
Refraction Coefficient (K_r)	1	n/a

Grants Bayou

Input Parameter	Value	Units
Acceleration due to gravity (g)	32.2	Feet/second^2
Deep water significant wave height (H_0)	1.3	Feet
Wave period (T)	1.7	Seconds
Slope (m)	0.05	Vertical Feet / Horizontal Feet
Refraction Coefficient (K_r)	1	n/a

Table 3.9-3: Wave Runup Parameters for CEDAS-ACES

Mississippi River

Input Parameter	**Value**	**Units**
Wave Type	Irregular	n/a
Slope Type	Smooth	n/a
Breaking Criteria (k)	0.78	n/a
Incident Significant Wave Height (H_i)	11.8	Feet
Peak Wave Period (T)	7.8	Seconds
Cotangent of nearshore slope (cot phi)	28	Horizontal Feet / Vertical Feet
Water depth at the structure toe (d_s)	16.7	Feet
Cotangent of structure slope (cot theta)	10.7	Horizontal Feet / Vertical Feet
Structure height above toe (h_s)	68	Feet

Grants Bayou

Input Parameter	**Value**	**Units**
Wave Type	Irregular	n/a
Slope Type	Smooth	n/a
Breaking Criteria (k)	0.78	n/a
Incident Significant Wave Height (H_i)	1.3	Feet
Peak Wave Period (T)	1.7	Seconds
Cotangent of nearshore slope (cot phi)	30.3	Horizontal Feet / Vertical Feet
Water depth at the structure toe (d_s)	2.3	Feet
Cotangent of structure slope (cot theta)	20.8	Horizontal Feet / Vertical Feet
Structure height above toe (h_s)	3.7	Feet

4.0 FLOOD PARAMETERS AND COMPARISON WITH CURRENT LICENSING BASIS

Per the March 12, 2012, 50.54(f) letter (NRC, 2012a), Enclosure 2, the following flood-causing mechanisms were considered in the flood hazard reevaluation for RBS.

1. Local Intense Precipitation;
2. Flooding in Streams and Rivers;
3. Dam Breaches and Failures;
4. Storm Surge;
5. Seiche;
6. Tsunami;
7. Ice Induced Flooding; and
8. Channel Migration or Diversion.

Some of these individual mechanisms are incorporated into alternative 'Combined Effect Flood' scenarios per Appendix H of NUREG/CR-7046 (NRC, 2011).

The March 12, 2012, 50.54(f) letter, Enclosure 2, requests the licensee to perform an integrated assessment of the plant's response to the reevaluated hazard if the reevaluated flood hazard is not bounded by the current licensing basis (NRC, 2012a). This section provides comparisons with the current licensing basis flood hazard and applicable flood scenario parameters per Section 5.2 of JLD-ISG-2012-05 (NRC, 2012b), including:

1. Flood height and associated effects
   a. Stillwater elevation;
   b. Wind waves and run-up effects;
   c. Hydrodynamic loading, including debris;
   d. Effects caused by sediment deposition and erosion (e.g., flow velocities, scour);
   e. Concurrent site conditions, including adverse weather conditions; and
   f. Groundwater ingress.
2. Flood event duration parameters (per Figure 6, below, of JLD-ISG-2012-05 [add reference])
   a. Warning time (may include information from relevant forecasting methods (e.g., products from local, regional, or national weather forecasting centers) and ascension time of the flood hydrograph to a point (e.g. intermediate water surface elevations) triggering entry into flood procedures and actions by plant personnel);
   b. Period of site preparation (after entry into flood procedures and before flood waters reach site grade);
   c. Period of inundation; and
   d. Period of recession (when flood waters completely recede from site and plant is in safe and stable state that can be maintained).
3. Plant mode(s) of operation during the flood event duration
4. Other relevant plant-specific factors (e.g. waterborne projectiles)

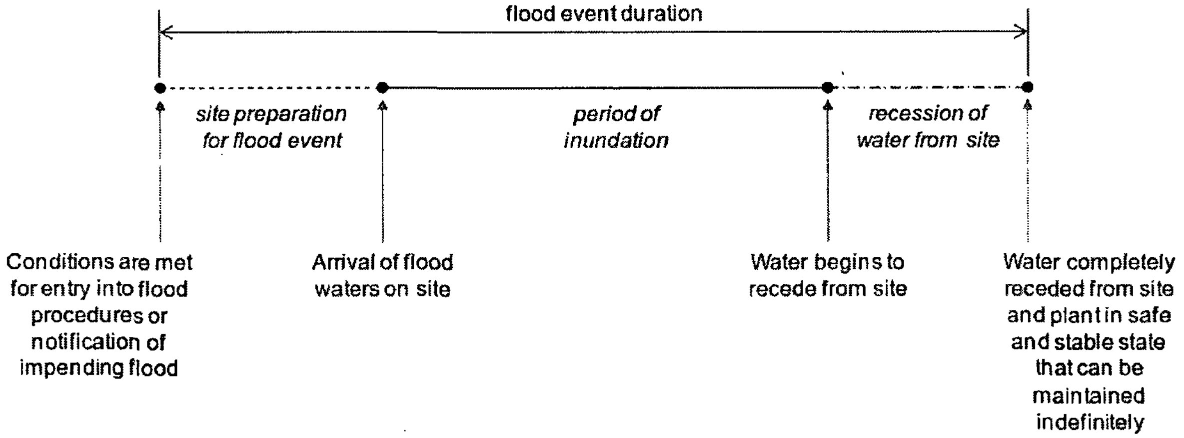


Illustration of Flood Event Duration (from Figure 6 of JLD-ISG-2012-05 NRC, 2012b)

Per Section 5.2 of JLD-ISG-2012-05 (NRC, 2012b), flood hazards do not need to be considered individually as part of the integrated assessment. Instead, the integrated assessment should be performed for a set(s) of flood scenario parameters defined based on the results of the flood hazard reevaluations. In some cases, only one controlling flood hazard may exist for a site. In this case, licensees should define the flood scenario parameters based on this controlling flood hazard. However, sites that have a diversity of flood hazards to which the site may be exposed should define multiple sets of flood scenario parameters to capture the different plant effects from the diverse flood parameters associated with applicable hazards. In addition, sites may use different flood protection systems to protect against or mitigate different flood hazards. In such instances, the integrated assessment should define multiple sets of flood scenario parameters. If appropriate, it is acceptable to develop an enveloping scenario (e.g., the maximum water surface elevation and inundation duration with the minimum warning time generated from different hazard scenarios) instead of considering multiple sets of flood scenario parameters as part of the integrated assessment. For simplicity, the licensee may combine these flood parameters to generate a single bounding set of flood scenario parameters for use in the integrated assessment.

For RBS, the following flood-causing mechanisms were either determined to be implausible or completely bounded by other mechanisms:

1. Probable Maximum Flood on Rivers and Streams including:
    a. Mississippi River PMF (bound by West Creek PMF);
    b. Grants Bayou PMF (does not exceed CLB and does not exceed drainage divide);
2. Dam Breaches and Failures;
3. Storm Surge;
4. Seiche;
5. Tsunami;
6. Ice-Induced Flooding;
7. Channel Migration or Diversion; and
8. Combinations in Section H.1 Alternative 1of NUREG/CR-7046 (NRC, 2012a) including:
    a. Mississippi River PMF + Dam Failure + Coincident Wind/wave interaction;

b. Grants Bayou PMF + Coincident Wind/wave interaction.

RBS was considered potentially exposed to the flood hazards (individual flood-causing mechanisms and/or combined-effects flood scenarios per Appendix H of NUREG/CR-7046 [RC, 2012a]) listed below. In some instances, an individual flood-causing mechanism (e.g. 'Flooding in Streams and Rivers') is addressed in one or more of the combined-effect flood scenarios.

1. Local Intense Precipitation; and
2. Probable Maximum Flood on West Creek due to Probable Maximum Precipitation event.

Section 4.1 summarizes the reevaluated flood levels for each flood mechanism and compares the flood elevations to the CLB flood parameters.

4.1 Summary of Current Licensing Basis and Flood Reevaluation Results

This section compares the current and reevaluated flood-causing mechanisms. It provides a comparison of the CLB flood elevation to the reevaluated flood elevation for each applicable flood-causing mechanism. A comparison of the CLB elevations and the reevaluated flood elevations is provided in Table 4.1-1.

Screened mechanisms have been evaluated at a high level and determined to not be applicable to the flooding hazard for RBS.

4.1.1 Local Intense Precipitation

The CLB LIP elevation does not exceed 96 ft MSL. The reevaluated LIP event results in a maximum flood level of 98.3 ft MSL (97.6 ft NAVD88, see Section 1.5) in the vicinity of SSCs important to safety at RBS.

The CLB flood elevation for LIP (96 ft MSL) is exceeded at all entrances to SSCs important to safety identified in Table 3.1-1. The CLB minimum protection elevation (98 ft MSL) is exceeded at three entrances to SSCs important to safety (Door IDs AB-098-03, AB-098-04 and CB-098-17. These entrances have a maximum 0.4 ft of flood water above the base of the doorways.

Two other entrances (JLB-D01HTCH and FB-098-01) have flood waters above the base of the doors, but not above the CLB minimum protection elevation of 98 ft MSL.

The maximum water surface elevation in the Unit 2 Excavation resulting from the LIP is 79.8 ft MSL (79.1 ft NAVD88), below the CLB value of 80.3 ft MSL and the safe capacity of 81.0 ft MSL.

Table 4.1-2 summarizes the parameters for the LIP flood hazard and provides comparisons with the current design basis flood. Table 4.1-3 provides specific flood heights at selected locations.

Impacts of LIP flood elevations are discussed in Section 5.

4.1.2 Probable Maximum Flood on Rivers and Streams

The CLB PMF elevation for the Mississippi River in the vicinity of RBS is 54.5 ft MSL. The reevaluated PMF elevation for the Mississippi River in the vicinity of RBS is 59.7 ft MSL (59.0 ft NAVD88).

The CLB PMF elevation for Grants Bayou is 95.3 ft to 101.8 ft MSL. The reevaluated PMF elevation for Grants Bayou is 99.8 ft MSL (99.1 ft NAVD88).

The CLB PMF elevation for West Creek is 94.3 ft MSL. The reevaluated PMF elevation for West Creek is 95.1 ft MSL (94.4 ft NAVD88).

The maximum accumulated water elevation within the Unit 2 excavation from the West Creek PMF runoff was calculated to be 78.3 ft MSL (77.6 feet NAVD88), below the CLB value of 80.3 ft MSL and the safe capacity of 81.0 ft MSL.

The CLB flood elevations are exceeded for the PMF on the Mississippi River and on West Creek. However, in both cases, the flood levels are well below both the controlling CLB flood level of 96 ft MSL and the CLB protection elevation of 98 ft MSL. Additionally, hydrologic features prevent West Creek from inundating the plant site in the vicinity of SSCs important to safety, and as a result, there are no impacts to safety due to the West Creek PMF.

Flooding on West Creek is considered the bounding scenario for PMF on Rivers and Streams due to elevation and proximity of inundation to SSCs important to safety at RBS.

Table 4.1-3 summarizes the parameters for the West Creek PMF flood hazard and provides comparisons with the current design basis flood.

4.1.3 Dam Breaches and Failures

Flood hazard due to upstream dam breaches and failures was screened as part of the CLB at RBS. The reevaluated dam failure event has a maximum elevation of 64.4 ft MSL (63.7 ft NAVD88).

There is no established flood elevation in the CLB for Dam Failure, so no direct comparison is possible. However, due to the physical margin available between the dam failure flood elevation and the site grade, no impact is anticipated.

4.1.4 Storm Surge

Flood hazard due to storm surge was screened as part of the CLB and the Flood Hazard Reevaluation at RBS.

4.1.5 Seiche

Flood hazard due to seiche was screened as part of the CLB and the Flood Hazard Reevaluation at RBS.

4.1.6 Tsunami

Flood hazard due to tsunami was screened as part of the CLB and the Flood Hazard Reevaluation at RBS.

4.1.7 Ice-Induced Flooding

Flood hazard due to ice-induced flooding was screened as part of the CLB and the Flood Hazard Reevaluation at RBS.

4.1.8 Channel Migration or Diversion

Flood hazard due to channel migration or diversion was screened as part of the CLB and the Flood Hazard Reevaluation at RBS.

4.1.9 Combined Effects

Flood hazard due to combinations of extreme flood mechanisms was quantified as part of the CLB at RBS, *including seismic induced flooding, as well as wind-wave interactions with the PMF events on the Mississippi* River. Grants Bayou and West Creek are considered too small to be capable of significant wave build up and as such are not evaluated. Seismic induced flooding is bound by the Mississippi River PMF plus dam failure evaluation, and is not addressed in this reevaluation.

The combined effect flood for Mississippi River PMF plus wind-wave interactions is screened in the CLB as not impacting safety at the site due to the available physical margin between the PMF flood level and site grade. The reevaluated flood level for Mississippi River PMF plus wind-wave interaction is 74.1 ft MSL (73.4 ft NAVD88), more than 20 ft below the plant grade elevation.

The reevaluated combined effect flood for Grants Bayou PMF plus wind-wave interaction results in a maximum water surface of 100.1 ft MSL (99.4 ft NAVD88), still below the CLB elevation for Grant's Bayou PMF and below the drainage divide between the river channel and RBS SSCs important to safety.

West Creek was determined to have insufficient fetch to generate significant waves, and was screened out as part of the reevaluation for combined effect mechanisms.

Table 4.1-1: Flood Elevation Comparison

Mechanism	CLB Flood Height	Reevaluated Flood Height	Difference
Local Intense Precipitation	96 ft MSL	98.3 ft MSL	+2.3 ft
Local Intense Precipitation Unit 2 Excavation Water Level	80.3 ft MSL	79.8 ft MSL	-0.5 ft
PMF on Rivers and Streams			
Mississippi River	54.5 ft MSL	59.7 ft MSL	+5.2 ft
Grants Bayou	101.8 ft MSL	99.8 ft MSL	-1.0 ft
West Creek	94.3 ft MSL	95.1 ft MSL	+0.8 ft
Dam Breaches and Failures	Screened	64.4 ft MSL	N/A
Storm Surge	Screened	Screened	N/A
Seiche	Screened	Screened	N/A
Tsunami	Screened	Screened	N/A
Ice-Induced Flooding	Screened	Screened	N/A
Channel Migration or Diversion	Screened	Screened	N/A
Combined Effect			
Mississippi River PMF + Dam + Wind/Wave	Screened	74.1 ft MSL	N/A
Grants Bayou PMF + Wind/Wave	Screened	100.1 ft MSL	N/A

Table 4.1-2: Local Intense Precipitation

Flood Scenario Parameter		CLB Flood Hazard	Reevaluated Flood Hazard	Bounded (B) or Not Bounded (NB)
Flood Level and Associated Effects	1. Max Stillwater Elevation (ft. MSL)	96.0	98.3	NB
	2. Max Wave Run-up Elevation (ft. MSL)	Wave runup coincident with LIP at RBS was assessed for the design of the Unit 2 Excavation Berm, but is not part of the CLB with respect to impacts to SSCs.	Wind/wave interaction was not evaluated coincident with the LIP event.	B
	3. Max Hydrodynamic/Debris Loading (psf)	Not identified in the CLB.	Hydrodynamic loading was not evaluated. Debris loading was not considered a credible hazard due to the relatively low flow velocities and limited debris sources within the protected area.	B
	4. Effects of Sediment Deposition/Erosion	Not identified in the CLB.	All culverts were assumed blocked for the LIP event.	B
	5. Concurrent Site Conditions	Antecedent storm results in 2 ft of standing water in Unit 2 Excavation prior to PMP event.	No antecedent storm was considered with the LIP event. The Unit 2 Excavation was assumed to be dry at the onset of the LIP event.	NB
	6. Effects on Groundwater	Plant structures can withstand groundwater levels at 70 ft MSL, 13 ft above normal levels. CLB has Unit 2 Excavation water level of 80.3 ft MSL	Groundwater level increase due to LIP was not evaluated. Unit 2 Excavation water level is 79.8 ft MSL.	B
Flood Event Duration	7. Warning Time (hours)	Not identified in the CLB.	Not identified.	B
	8. Period of Site Preparation (hours)	No preparation is indicated in the CLB.	No special preparation identified.	B
	9. Period of Inundation (hours)	Not identified in the CLB.	See Appendix B Time Series Plots	B
	10. Period of Recession (hours)	Not identified in the CLB.	Due to the assumption non-functioning storm drains, some areas do not recede.	B
Other	11. Plant Mode of Operations	Not identified in the CLB.	Normal Operations	B
	12. Other Factors	N/A	N/A	N/A

Table 4.1-3: LIP Flood Heights at Select Locations

Door	LIP Peak Elevation (ft MSL)	Depth vs. Grid Cell Elevation (ft)	Elevation at Bottom of Door (ft MSL)	LIP Elevation Relative to Bottom of Door (ft)
DG-098-H01	97.1	2.6	98.0	0.9
DG-098-H02	97.1	2.6	98.0	0.9
DG-098-01	97.0	2.3	98.0	1.0
DG-098-02	97.1	2.6	98.0	0.9
DG-098-03	97.1	2.6	98.0	0.9
DG-098-H03	97.1	2.6	98.0	0.9
CB-098-01	97.1	2.5	98.0	0.9
DG-098-11	96.9	1.7	98.1	1.2
JRB-D01HTCH	96.9	3.1	93.8	-3.1
AB-098-03	98.2	0.5	97.9	-0.3
AB-098-04	98.3	0.5	97.9	-0.4
CB-098-17	98.3	0.4	98.1	-0.2
FB-095-01	96.7	2.0	95.0	-1.7
SP-098-01	96.7	1.9	98.4	1.7
FB-098-04	96.6	1.7	98.0	1.4
AB-098-06	97.1	0.5	98.0	0.9
AB-098-05	97.3	0.4	97.9	0.6

Table 4.1-4: West Creek PMF

Flood Scenario Parameter		CLB Flood Hazard	Reevaluated Flood Hazard	Bounded (B) or Not Bounded (NB)
Flood Level and Associated Effects	1. Max Stillwater Elevation (ft. MSL)	94.3	95.1	NB
	2. Max Wave Run-up Elevation (ft. MSL)	Not evaluated due to insufficient fetch.	Screened due to insufficient fetch.	B
	3. Max Hydrodynamic/Debris Loading (psf)	Not identified in the CLB.	Not evaluated due to no inundation around plant structures.	B
	4. Effects of Sediment Deposition/Erosion	In the vicinity of the site, all culverts were assumed blocked.	In the vicinity of the site, all culverts were assumed blocked. No erosion of the channel was anticipated due to concrete lining.	B
	5. Concurrent Site Conditions	Not identified in the CLB.	The PMP event driving the PMF is preceded by a 40% PMP antecedent storm on the West Creek watershed.	B
	6. Effects on Groundwater	Not identified in the CLB.	Effect on groundwater is not evaluated. Unit 2 Excavation water level is 78.3 ft MSL.	B
Flood Event Duration	7. Warning Time (hours)	1.2 hour lag time.	1.2 hour lag time.	B
	8. Period of Site Preparation (hours)	Not identified in the CLB.	No special site preparation is identified as necessary for this event.	B
	9. Period of Inundation (hours)	Not identified in the CLB.	Inundation occurs in the Unit 2 Excavation. No dewatering is assumed to be operational for the event, so duration of inundation is not evaluated.	B
	10. Period of Recession (hours)	Not identified in the CLB.	Water accumulation in the Unit 2 Excavation will not recede without active plant measures or infiltration.	B
Other	11. Plant Mode of Operations	Not identified in the CLB.	Normal Operations	B
	12. Other Factors	N/A	N/A	N/A

4.2 References

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, Springfield, VA, National Technical Information Service, 2011.

NRC, 2012a. "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.

NRC, 2012b. "JLD-ISG-2012-05, Guidance for Performing the Integrated Assessment for External Flooding, Interim Staff Guidance", Revision 0, 2012. (ADAMS Accession No. ML12311A214)

5.0 INTERIM EVALUATION AND ACTIONS TAKEN OR PLANNED

5.1 Impacts of Reevaluated Flood Elevations

Flooding due to LIP is the controlling flood mechanism in the flood hazard reevaluation for RBS. Areas in the immediate vicinity of RBS SSCs important to safety are inundated by the LIP event. Flooding due to other mechanisms including the West Creek PMF scenario does not inundate plant areas in the vicinity of SSCs important to safety. As a result, further evaluation and actions are only necessary for LIP induced flooding.

Reevaluated LIP elevations exceed the minimum protection elevation of 98 ft MSL (RBS, 2013) in two locations on-site: adjacent to the ISFSI pad to the south of the power block, and in the corridor between the Auxiliary Building and the Control Building (see Figure 5.1-1). No SSCs important to safety are located in the vicinity of the ISFSI pad that may be impacted by the LIP flood elevation. Three exterior doors are located in the corridor between the Auxiliary Building and the Control building where LIP flood elevations are above 98 ft MSL (doors CB-098-17, AB-098-03 and AB-098-04, see Figure 5.1-2). No other external penetrations to SSCs important to safety are identified below an elevation of 99 ft MSL in the area shown in Figure 5.1-2 (RBS, 1995, RBS, 1996, and RBS, 2012b). Impacts of LIP flood water elevations at the three entrances are discussed below.

5.1.1 Door CB-098-17

Door CB-098-17 is not sealed from external flooding; therefore water could penetrate into the adjacent structure during a LIP event. Flood water penetrating Door CB-098-17 would potentially inundate and penetrate Doors CB-098-16 and CB-098-15. Water penetrating through Door CB-098-16 will enter the bottom of a stairwell, with no impact to SSCs important to safety. Water penetrating Door CB-098-15 will flow into an elevator shaft, with no impact to SSCs important to safety, and would pond against Door CB-098-14, which provides access to SSCs important to safety. The interior area that would be inundated due to leakage through Door CB-098-17 is highlighted blue in Figure 5.1-2. (RBS, 2010)

Door CB-098-14 is classified as a watertight door (RBS, 2002), and is specified to withstand 28 ft of hydraulic head on either side of the doorway without leakage (RBS, 1985b, page 1-16). The LIP water elevation at Door CB-098-14 is not expected to exceed 0.3 ft based on the modeled flood elevation of 98.3 ft MSL and the Control Building floor elevation of 98 ft MSL (RBS, 2010). As a result, LIP flood levels at Door CB-098-17 will not impact SSCs important to safety.

5.1.2 Doors AB-098-03 and AB-098-04

Doors AB-098-03 and AB-098-04 are classified as missile protected doors (RBS, 2003) and are specified to be watertight to elevation 98 ft MSL (RBS, 1985a, Page 1-12), and airtight to a pressure differential of 3.8 psi (RBS, 1985a, Page 1-14). Due to flood levels at these two doors above elevation 98 ft MSL, an evaluation was performed to determine flooding impacts to SSCs important to safety (see Section 5.2), if any.

5.1.2.1 Evaluation of Doors AB-098-03 and AB-098-04

Entergy performed an evaluation of the flood protection provided by missile protected doors (RBS, 2014), which are airtight to a pressure differential of 3.8 psi (RBS, 1985a, Page 1-14). The results of the evaluation indicate that RBS missile protected doors provide adequate leakage protection for the LIP flood levels (RBS, 2014). The maximum inundation above the base of the doors AB-098-03 and AB-098-04 is 0.4 ft (see Table 4.1-3). Based on the results of the evaluation, LIP flood levels at Doors AB-098-03 and AB-098-04 will not impact SSCs important to safety.

5.2 Conclusions

All doors discussed in this section are maintained closed and sealed during normal operations for security and operational procedures. Based on the walkdown scope and subsequent findings (RBS, 2012a), all doors are functional in accordance with the appropriate design specifications, as discussed below (RBS, 1985a and RBS, 1985b). The doors preventing impacts to SSCs important to safety (AB-098-03, AB-098-04 and CB-098-14) are routinely inspected, lubricated, aligned, and examined for seal damage, loss of resiliency, and contact per RBS procedures.

There are no impacts to SSCs important to safety at RBS due to the LIP event. LIP flood water levels exceed the minimum protected elevation of 98 ft MSL (RBS, 2013) in two areas on the RBS site (Figure 5.1-1), but do not inundate SSCs important to safety. Door CB-098-17 may allow water ingress, but Door CB-098-14 prevents flood waters from impacting or inundating SSCs important to safety. Doors AB-098-03 and AB-098-04 will not be compromised by flood elevations based on the evaluation results.

As a result, no interim actions or mitigative measures are necessary.

5.3 References

RBS, 1985a. "Specification for Missile Protected Doors", Specification No. 210.460, River Bend Station Unit 1, Revision 2, September 13, 1985, See AREVA Document No. 38-9219997-000.

RBS, 1985b. "Specification for Pressuretight Doors, Watertight Doors, and Special Doors", Specification No. 210.461, River Bend Station Unit 1, Revision 2, September 17, 1985, See AREVA Document No. 38-9219997-000.

RBS, 1995. "Sleeve Location Plan Auxiliary Bldg SH3", Drawing No. EP-119AC-8 Revision 8, Entergy Operations, Inc., River Bend Station - Unit 1, September 12, 1995, See AREVA Document No. 38-9210629-000.

RBS, 1996. "Sleeve Locations – Sections Auxiliary Building Sheet 7", Drawing No. EP-119AG Revision 8, Entergy Operations, Inc., River Bend Station - Unit 1, January 1, 1996, See AREVA Document No. 38-9210629-000.

RBS, 2002. "Door Schedule and Details", Drawing No. EA-006B Revision 14, Entergy Operations, Inc., River Bend Station - Unit 1, December 26, 2002, See AREVA Document No. 38-9210629-000.

RBS, 2003. "Door Schedule", Drawing No. EA-006A Revision 13, Entergy Operations, Inc., River Bend Station - Unit 1, January 17, 2003, See AREVA Document No. 38-9210629-000.

RBS, 2010. "Door Location Plan Sheet 2", Drawing No. EA-006K Revision 6, Entergy Operations, Inc., River Bend Station - Unit 1, June 14, 2010, See AREVA Document No. 38-9210629-000.

RBS, 2012a. "River Bend Nuclear Station Flooding Walkdown Submittal Report for Resolution of Fukushima Near-Term Task Force Recommendation 2.3: Flooding", Engineering Report Number RBS-CS-12-00002, Rev. 0, November 2012, See AREVA Document No. 38-9210629-000.

RBS, 2012b. "Sleeve Location Plan Control Bldg El 70'-0" & 98'-0" ", Drawing No. 12210 EP-145a-9 Revision 9, Entergy Operations, Inc., River Bend Station - Unit 1, October 3, 2012, See AREVA Document No. 38-9210629-000.

RBS, 2013. "RBS Updated Safety Analysis Report", Revision 23, 2013, See AREVA Document No. 38-9210629-000.

RBS, 2014. "Evaluate Doors AB098-03, and AB098-04 as Watertight During a Local Intense Precipitation (LIP) to Support Fukushima Flood Reevaluation", Engineering Change EC-49418, River Bend Station Unit 1, Revision 0, March, 2014, See AREVA Document No. 38-9219997-000.

Figure 5.1-1: Areas with LIP Flood Elevation over 98 ft MSL

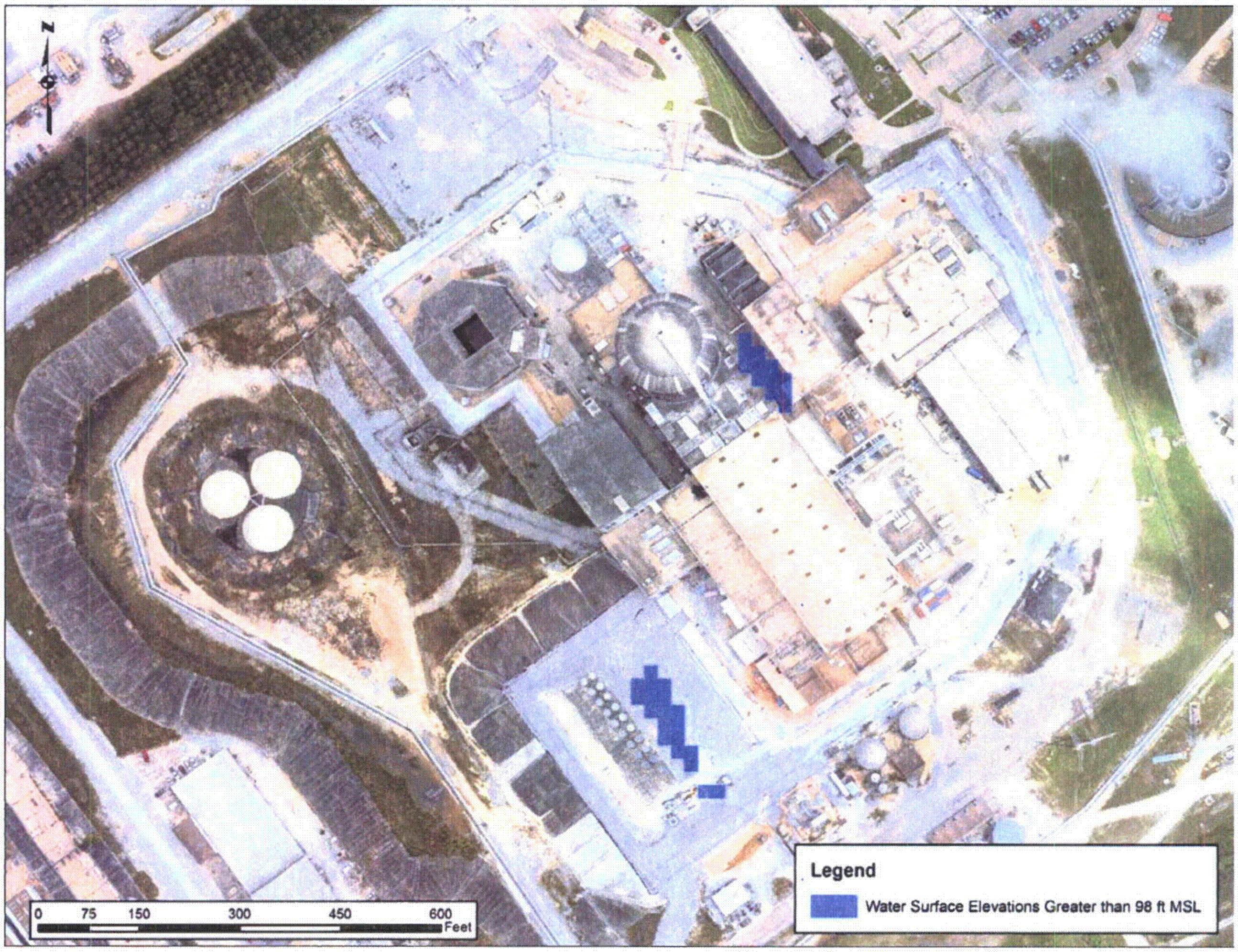
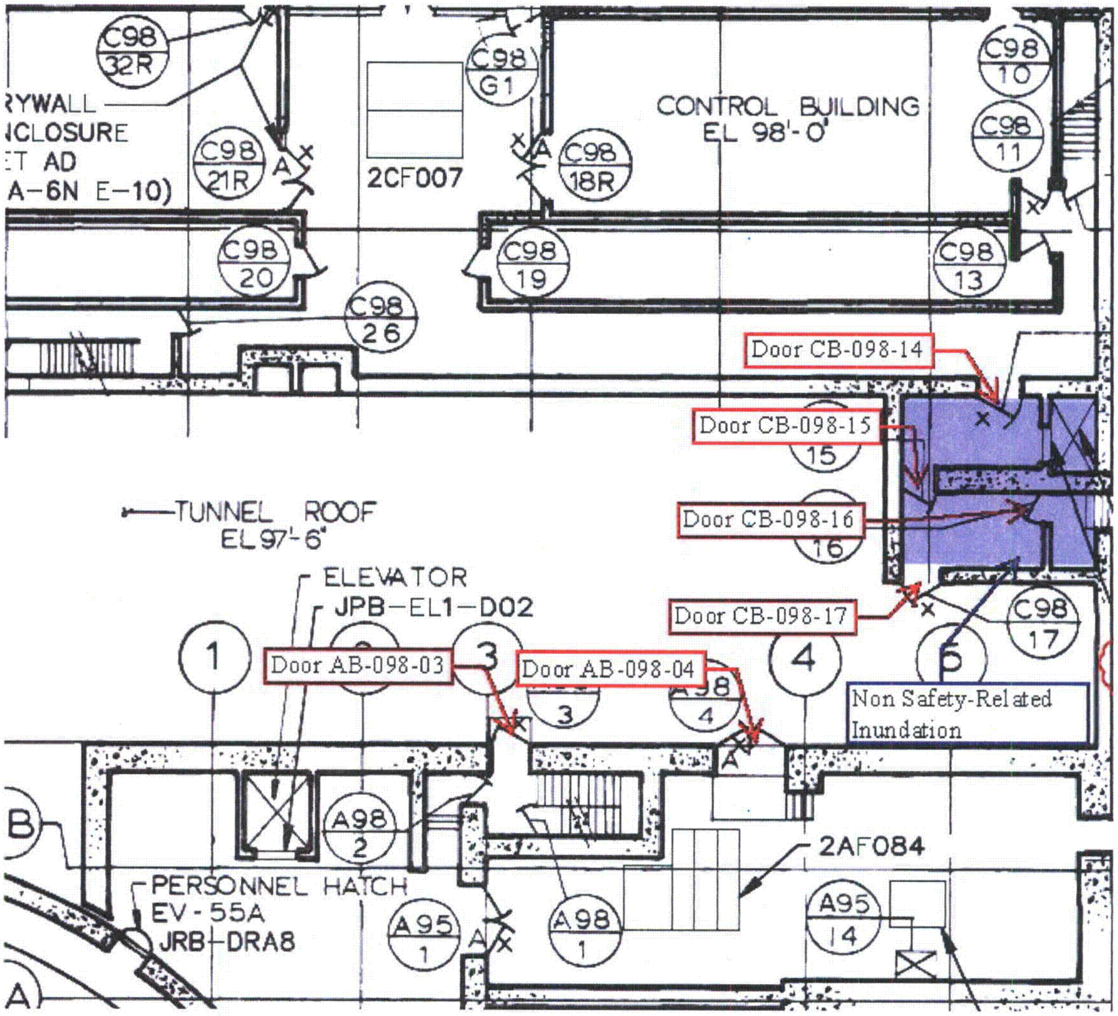


Figure 5.1-2: Critical Door Layout



Modified from RBS, 2010.

Illegible Text or features in this Figure are not pertinent to the technical purposes of this document.

6.0 ADDITIONAL ACTIONS

No additional actions are necessary.

APPENDIX A: FLO-2D COMPUTER PROGRAM

A.1 FLO-2D for LIP Simulations

The example LIP calculation presented in Appendix B of NUREG/CR-7046 (NRC 2011) used HEC-HMS and HEC-RAS, developed by Hydrologic Engineering Center of US Army Corps of Engineers. The hydrologic part of the calculation was performed within HEC-HMS, whereas the hydraulic part of the calculation was performed within HEC-RAS. In this flood re-evaluation study, FLO-2D was selected for calculation of the LIP-induced PMF at River Bend Station (RBS). For the LIP calculation, rainfall runoff in the site area was calculated internally by FLO-2D and translated into overland flow within FLO-2D.

This appendix was prepared as per Section 5.3 of NUREG/CR-7046 (NRC, 2011).

A.1.1 Software Capability

The FLO-2D computer program was developed by FLO-2D Software, Inc., Nutrioso, Arizona. FLO-2D is a combined two-dimensional hydrologic and hydraulic model that is designed to simulate river and overbank flows as well as unconfined flows over complex topography and variable roughness, split channel flows, mud/debris flows and urban flooding.

FLO-2D is a physical process model that routes rainfall-runoff and flood hydrographs over unconfined flow surfaces using the dynamic wave approximation to the momentum equation. The model has components to simulate riverine flow including flow through culverts, street flow, buildings and obstructions, levees, sediment transport, spatially variable rainfall and infiltration and floodways. Application of the model requires knowledge of the site, the watershed (and coastal, as appropriate) setting, goals of the study, and engineering judgment. This software was used to simulate the LIP to establish LIP-induced maximum water surface elevations at RBS.

The major design inputs to the FLO-2D computer model are digital terrain model of the land surface, inflow hydrograph and/or rainfall data, Manning's roughness coefficient and Soil hydrologic properties such as the SCS curve number. The digital terrain model of the land surface is used in creating the elevation grid system over which flow is routed. The specific design inputs depend on the modeling purpose and the level of detail desired.

The following executable modules compose the FLO-2D computer program:

*.exe File	Size
FLOPRO.exe	10.90 MB
GDS PRO.exe	5.99 MB
PROFILES.exe	2.82 MB
HYDROG.exe	2.02 MB
Mapper ++	7.57 MB
Mapper ++	7.39 MB
Mapper PRO.exe	3.25 MB
MAXPLOT.exe	2.26 MB

FLOPRO.exe is the model code that performs the numerical algorithms for the aforementioned components of the overall FLO-2D computer model.

GDS_PRO.exe graphically creates and edits the FLO-2D grid system and attributes and creates the basic FLO-2D data files for rainfall – runoff and overland flow flood simulation. PROFILES.exe displays the channel slope and permits interactive adjustment of the channel properties. HYDROG.exe enables viewing of channel outputs hydrographs and lists average channel hydraulic data for various reaches of river. Mapper ++.exe, Mapper_2009.exe and Maxplot.exe enables graphical viewing of model results and inundation mapping.

A description of the major capabilities of FLO-2D which will be used for this project is provided in Section A.1.2 below.

A.1.2 Model Components

Overland Flow Simulation

This FLO-2D component simulates overland flow and computes flow depth, velocities, impact forces, static pressure and specific energy for each grid. Predicted flow depth and velocity between grid elements represent average hydraulic flow conditions computed for a small time step. For unconfined overland flow, FLO-2D applies the equations of motion to compute the average flow velocity across a grid element (cell) boundary. Each cell is defined by 8 sides representing the eight potential flow directions (the four compass directions and the four diagonal directions). The discharge sharing between cells is based on sides or boundaries in the eight directions one direction at a time. At runtime, the model sets up an array of side connections that are only accessed once during a time step. The surface storage area or flow path can be modified for obstructions including buildings and levees. Rainfall and infiltration losses can add or subtract from the flow volume on the floodplain surface.

Channel Flow Simulation

This component simulates channel flow in one-dimension. The channel is represented by natural, rectangular or trapezoidal cross sections. Discharge between channel grid elements are defined by average flow hydraulics of velocity and depth. Flow transition between subcritical and supercritical flow is based on the average conditions between two channel elements. River channel flow is routed with the dynamic wave approximation to the momentum equation. Channel connections can be simulated by assigning channel confluence elements.

Flood Channel Interface

This FLO-2D component exchanges channel flow with the floodplain grid elements in a separate routine after the channel, street and floodplain flow subroutines have been completed. An overbank discharge is computed when the channel conveyance capacity is exceeded. The channel-floodplain flow exchange is limited by the available exchange volume in the channel or by the available storage volume on the floodplain. Flow exchange between streets and floodplain are also computed during this subroutine. The diffusive wave equation is used to compute the velocity of either the outflow from the channel or the return flow to the channel.

Floodplain Surface Storage Area Modification and Flow Obstruction

This FLO-2D component enhances detail by enabling the simulation of flow problems associated with flow obstructions or loss of flood storage. This is achieved by the application of coefficients (Area reduction factors (ARFs) and width reduction factors (WRFs) that modify the individual grid element surface area storage and flow width. ARFs can be used to reduce the flood volume storage on grid elements due to buildings or topography and WRFs can be assigned to any of the eight flow directions in a grid element to partially or completely obstruct flow paths in any of the eight directions simulating floodwalls, buildings or berms.

Rainfall – Runoff Simulation

Rainfall can be simulated in FLO-2D. The storm rainfall is discretized as a cumulative percent of the total. This discretization of the storm hyetograph is established through local rainfall data or through regional drainage criteria that defines storm duration, intensity and distribution. Rain is added in the model using an S-curve to define the percent depth over time. The rainfall is uniformly distributed over the grid system and once a certain depth requirement (0.01-0.05 feet) is met, the model begins to route flow.

Hydraulic Structures

Hydraulic structures including bridges and culverts and storm drains may be simulated in FLO-2D Pro. Discharge through round and rectangular culverts with potential for inlet and outlet control can be computed using the U.S. Department of Transportation procedures (Hydraulic Design of Highway Culverts; Publication Number FHWA-NHI-01-020 revised May, 2005). Discharge through hydraulic structures can also be simulated using user-specified depth-discharge relationships.

Levees

This FLO-2D component confines flow on the floodplain surface by blocking one or more of the eight flow directions. A levee crest elevation can be assigned for each of the eight flow directions in a given grid element. The model predicts levee overtopping. When the flow depth exceeds the levee height, the discharge over the levee is computed using the broad-crested weir flow equation with a 3.1 coefficient. Weir flow occurs until the tailwater depth is 85% if the headwater depth. At higher flows, the water is exchanged across the levees using the difference in water surface elevations.

A.1.3 FLO-2D Model Theory

Governing equations and solution algorithm are presented in details in FLO-2D Reference Manual (FLO2D, 2013a). The general constitutive fluid equations include the continuity equation and the equation of motion (dynamic wave momentum equation) (FLO-2D, 2013a, Chapter II):

$$\frac{\partial h}{\partial t} + \frac{\partial h V}{\partial x} = i$$

$$S_f = S_o - \frac{\partial h}{\partial x} - \frac{V}{g}\frac{\partial V}{\partial x} - \frac{1}{g}\frac{\partial V}{\partial t}$$

where

h = flow depth;

V = depth averaged velocity in one of the eight flow directions;

x = one of the eight flow directions;

i = rainfall intensity;

S_f = friction slope based on Manning's equation;

S_0 = bed slope

g = acceleration of gravity

The partial differential equations are solved with a central finite difference numerical scheme, which implies that final results are approximate solutions to the differential equations. Details on the accuracy of FLO-2D solutions are discussed in FLO-2D Validation Report (FLO-2D, 2011).

A.1.4 Model Inputs and Outputs

Inputs to FLO-2D are entered through a graphical user interface (GUI), which creates ASCII text files used by the FLO-2D model (FLO-2D, 2013b). The ASCII text files can be viewed and edited by other ASCII text editors such as Microsoft WordPad.

Calculated results from FLO-2D simulations are saved in the ASCII text format in a number of individual files. The results can be viewed with the post-processor programs as follows:

- Mapper PRO and Mapper ++ to view grid element results such as elevation, water surface elevation, flow depth and velocity, to create contour maps and to generate shapefiles that can later be used by GIS mapping software such as ArcMap.
- MAXPLOT – to view grid element maximum flood elevation, flow depth, velocity, channel flow depth/elevation/velocity, and levee minimum free board/overtopping.
- HYDROG – to generate hydrographs for channel elements.
- PROFILES – to plot channel water surface and channel bed profiles.

A.1.5 Conclusions

FLO-2D is a FEMA-approved software (FLO-2D, 2011). The model validation report prepared for FEMA and the FLO-2D software certification prepared for Flood Re-evaluation Projects (AREVA, 2013) have demonstrated its modeling capabilities and numerical accuracy. It is therefore judged to be an appropriate modeling tool for the RBS LIP flood re-evaluation study where 2-dimensional overland flow is predominant.

A.1.6 References

AREVA 2013. AREVA Document No. 38-9192635-000, Computer Software Certification – FLO-2D Pro, GZA GeoEnvironmental, Inc., 2013.

FLO-2D 2013a. FLO-2D Pro Reference Manual, FLO-2D Software, Inc., 2013.

FLO-2D 2013b. FLO-2D Data Input Manual, FLO-2D Software, Inc., 2013.

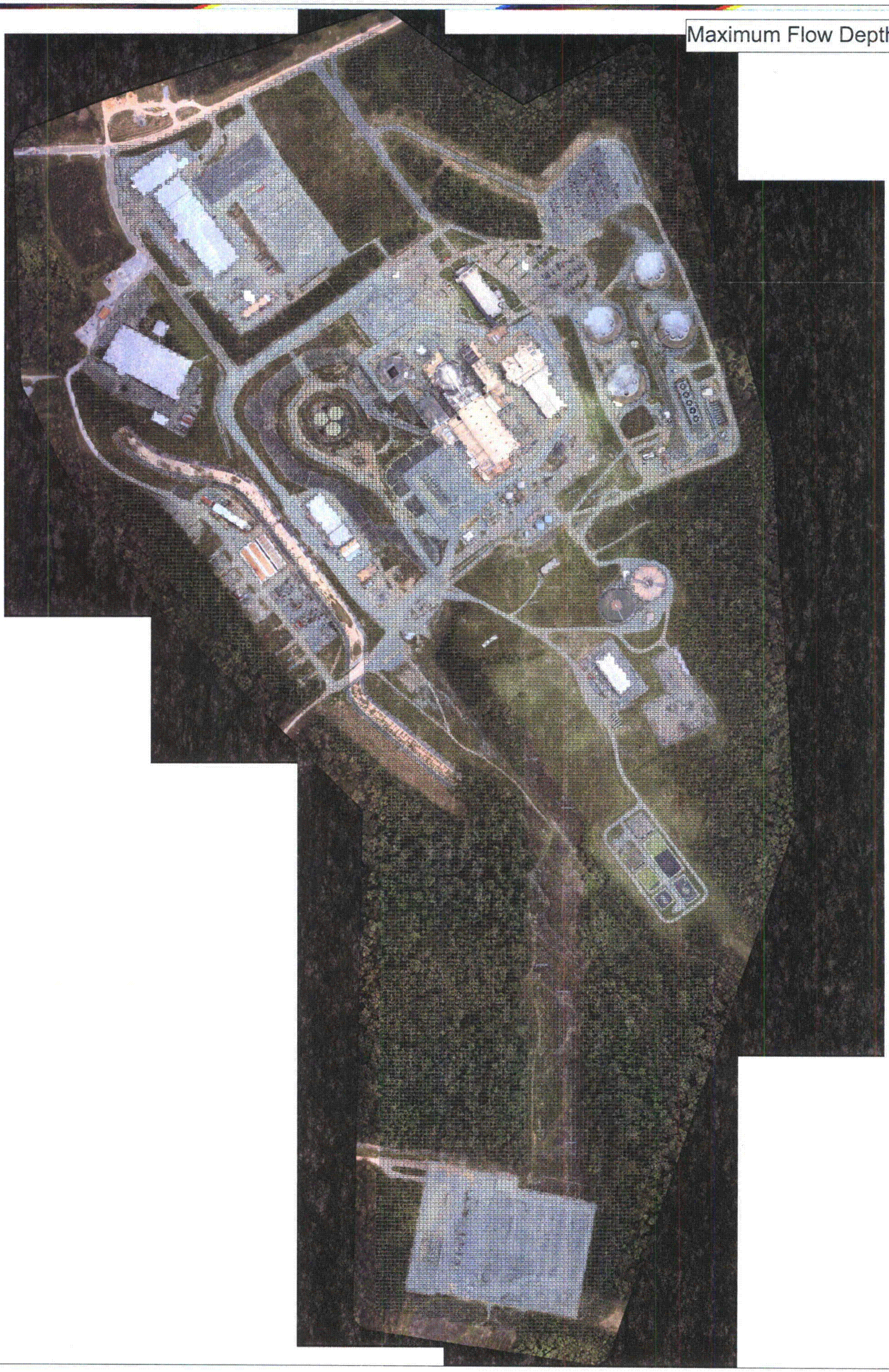
FLO-2D 2011. FLO-2D Model Validation for Version 2009 and up prepared for FEMA, FLO-2D Software, Inc, June 2011.

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.

APPENDIX B: LOCAL INTENSE PRECIPITATION FIGURES

Grid Element Numbers


Grid Element Elevation (ft, NAVD88)

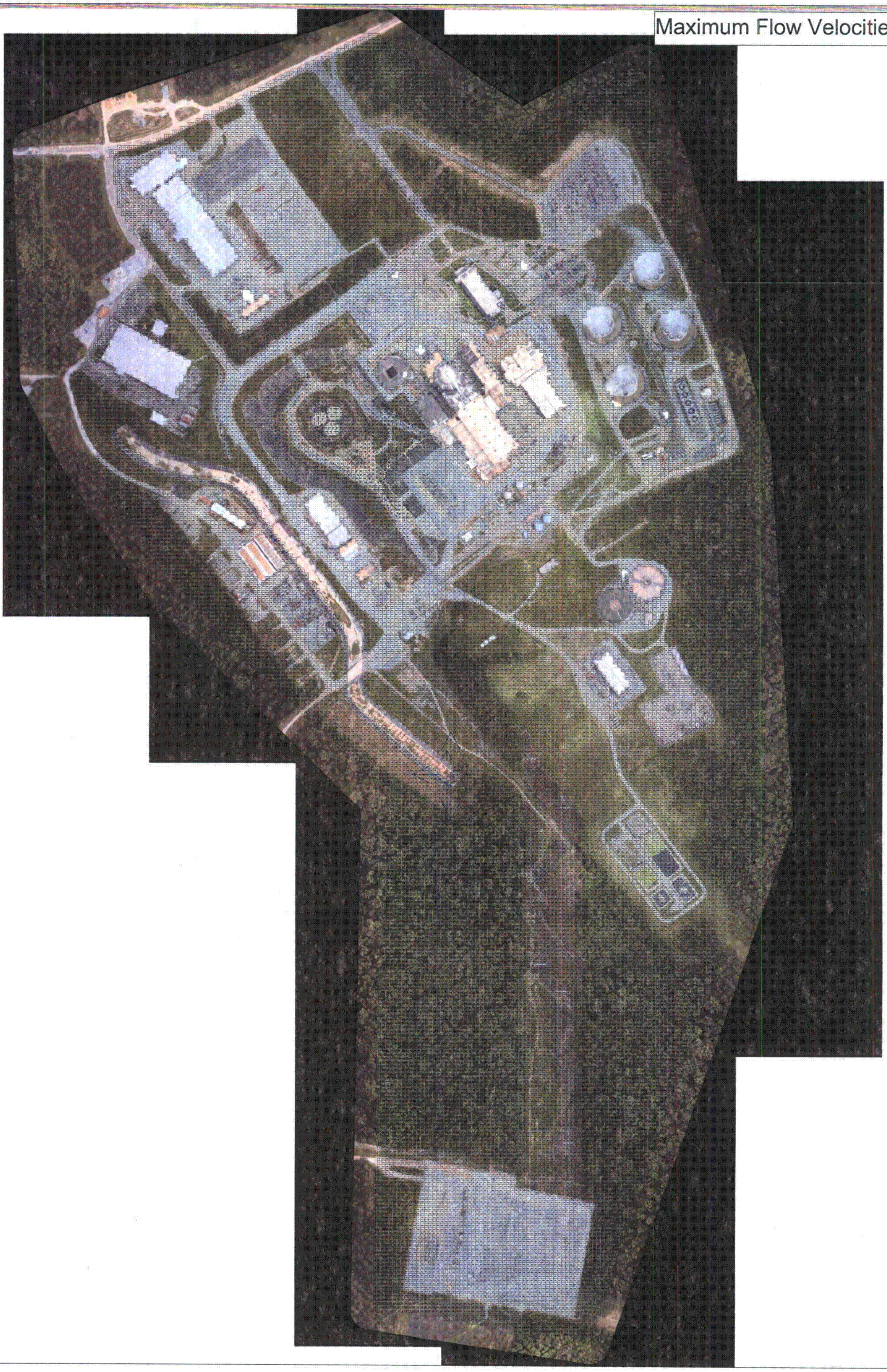


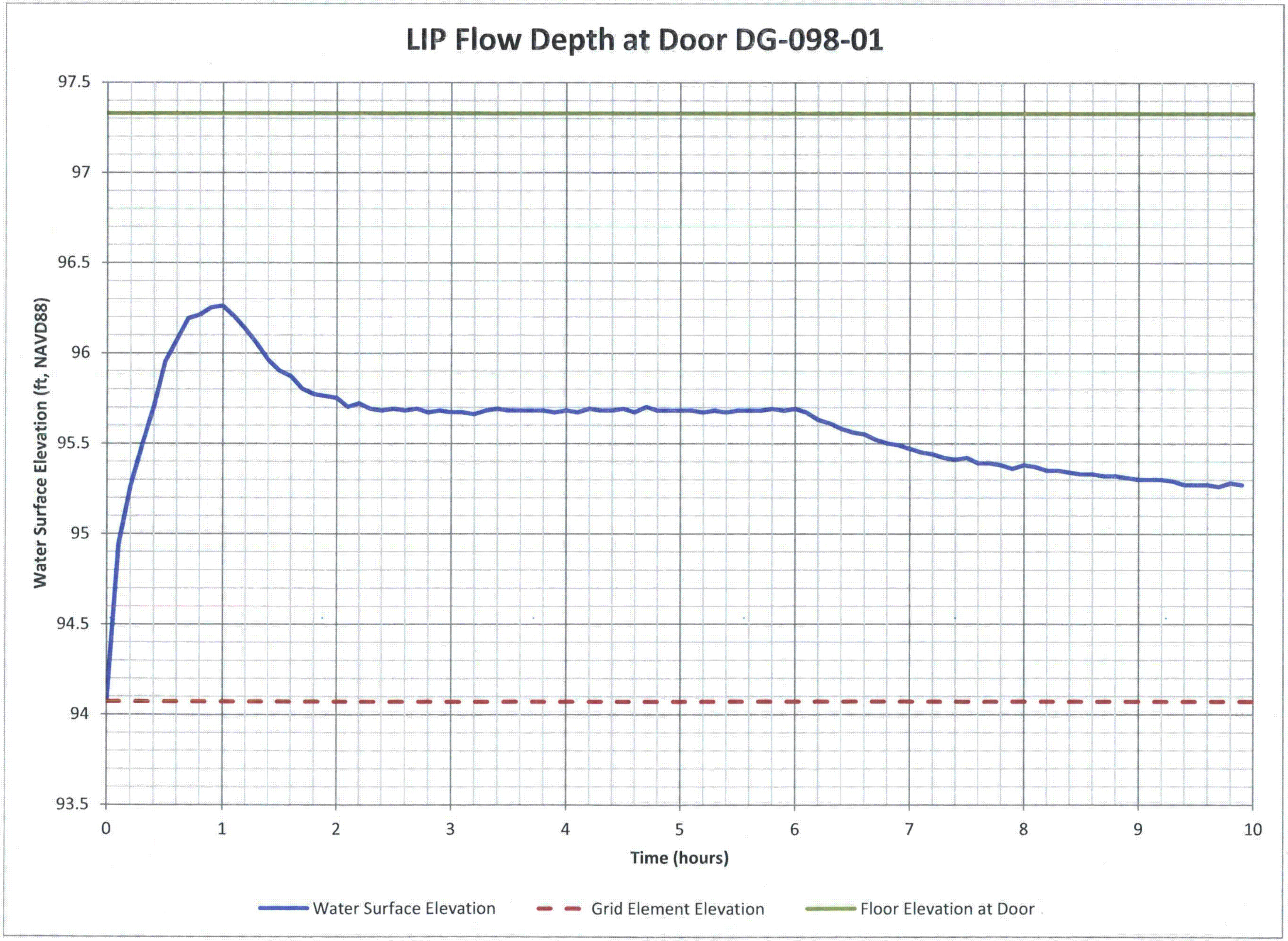
Maximum Flow Depths (ft)

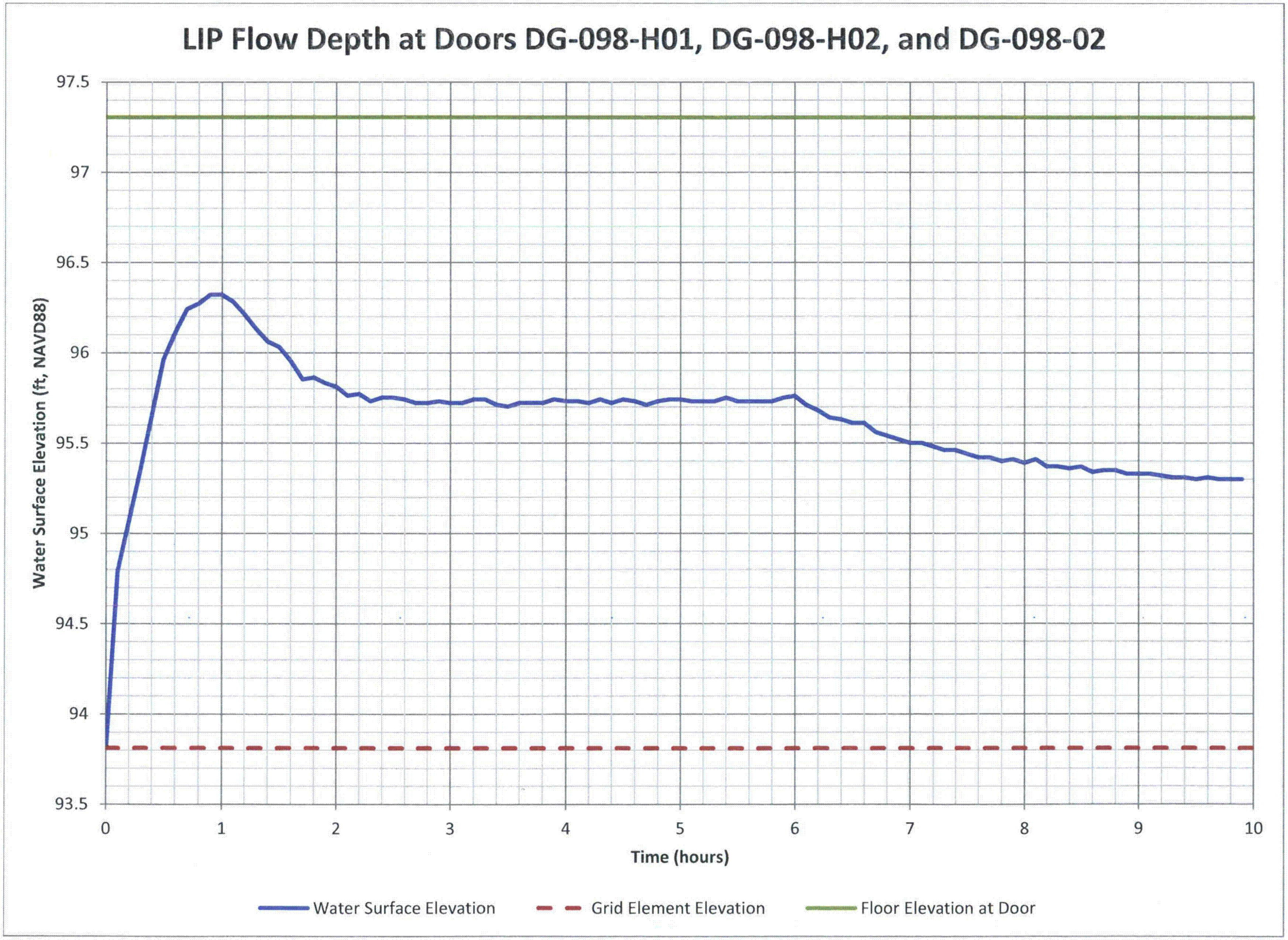
Maximum Water Surface Elevation (ft, NAVD88)

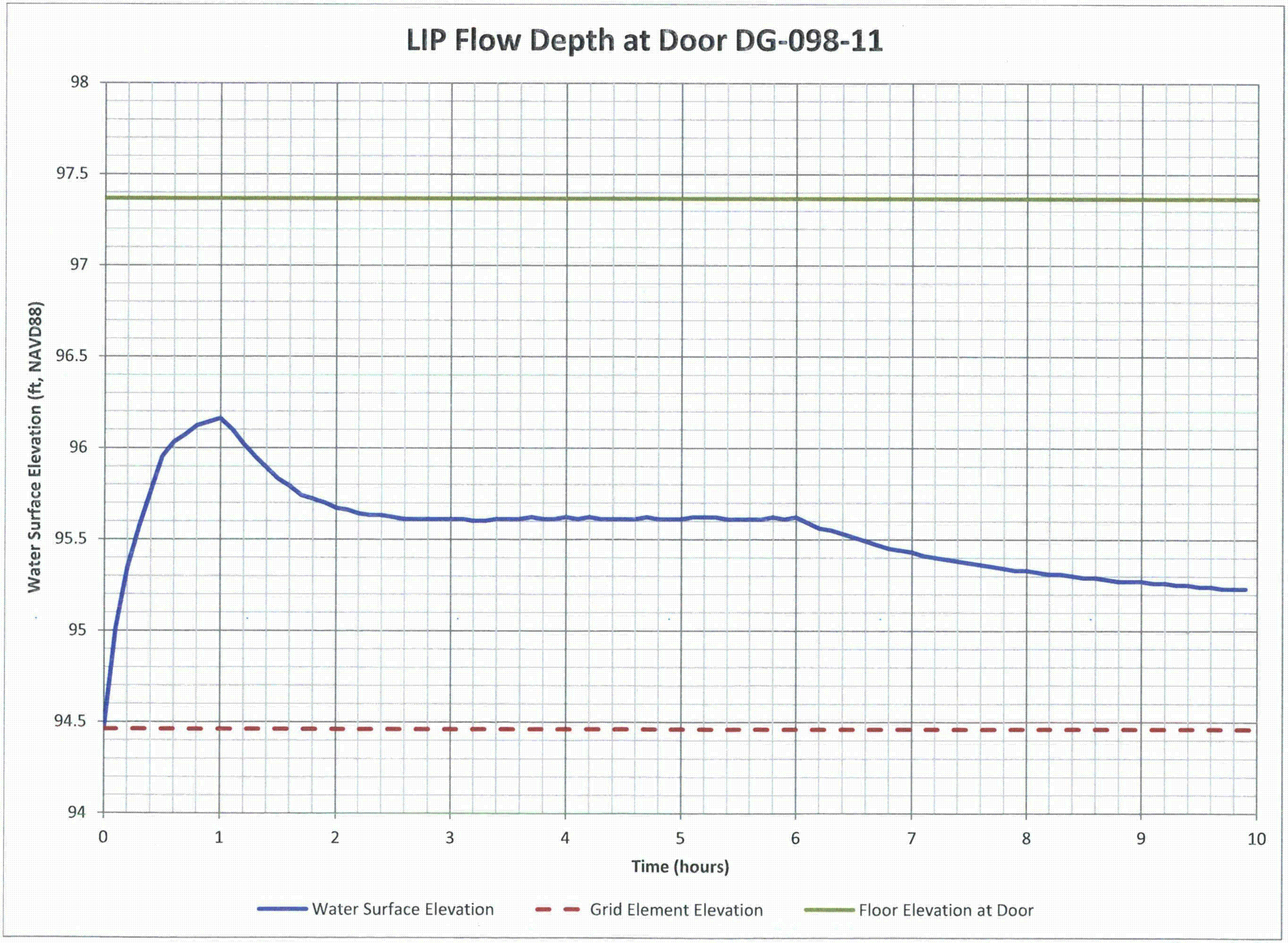
Final Water Surface Elevation in Unit 2 Excavation (ft, NAVD88)

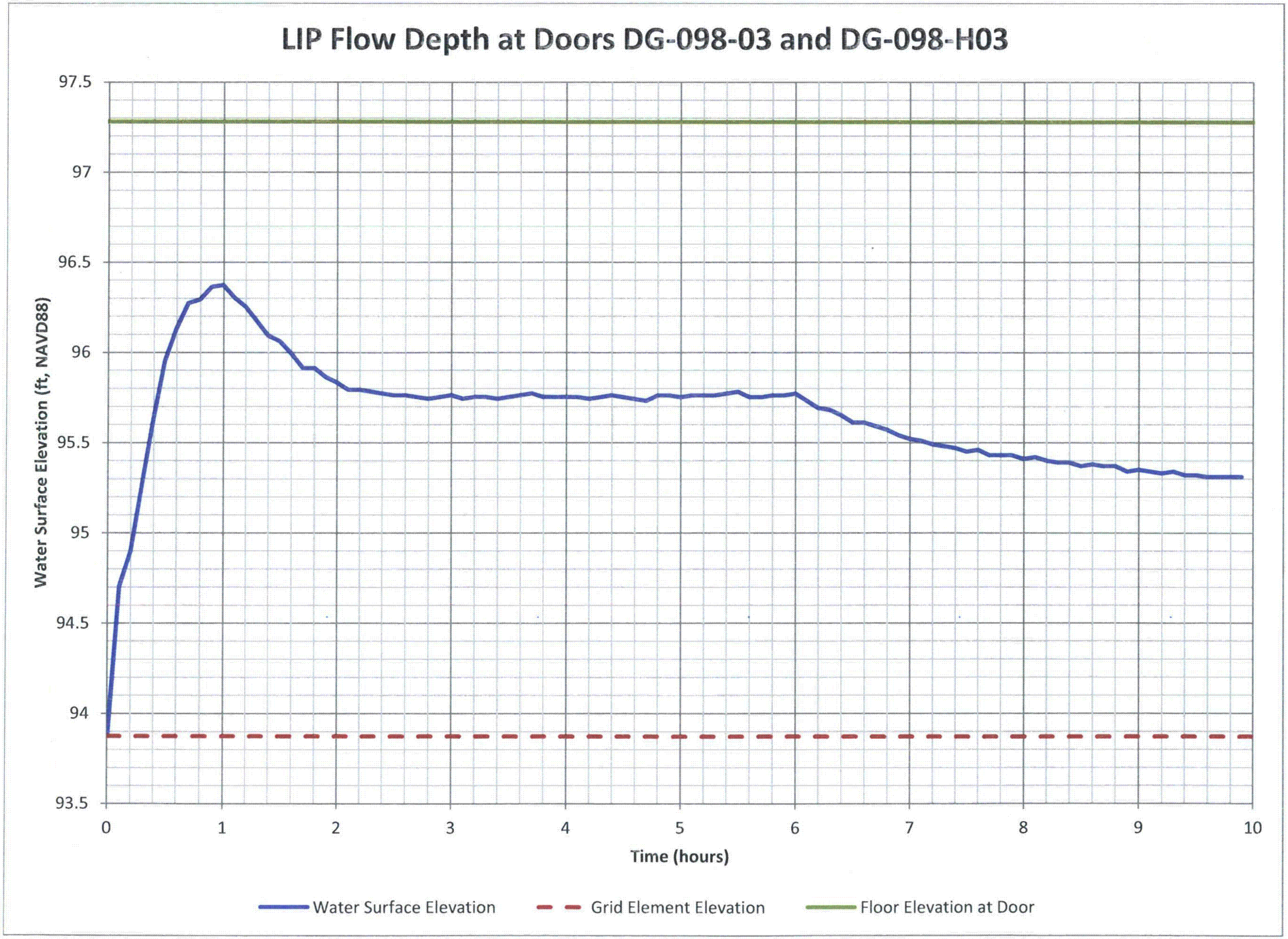
Maximum Flow Velocities (ft/s)

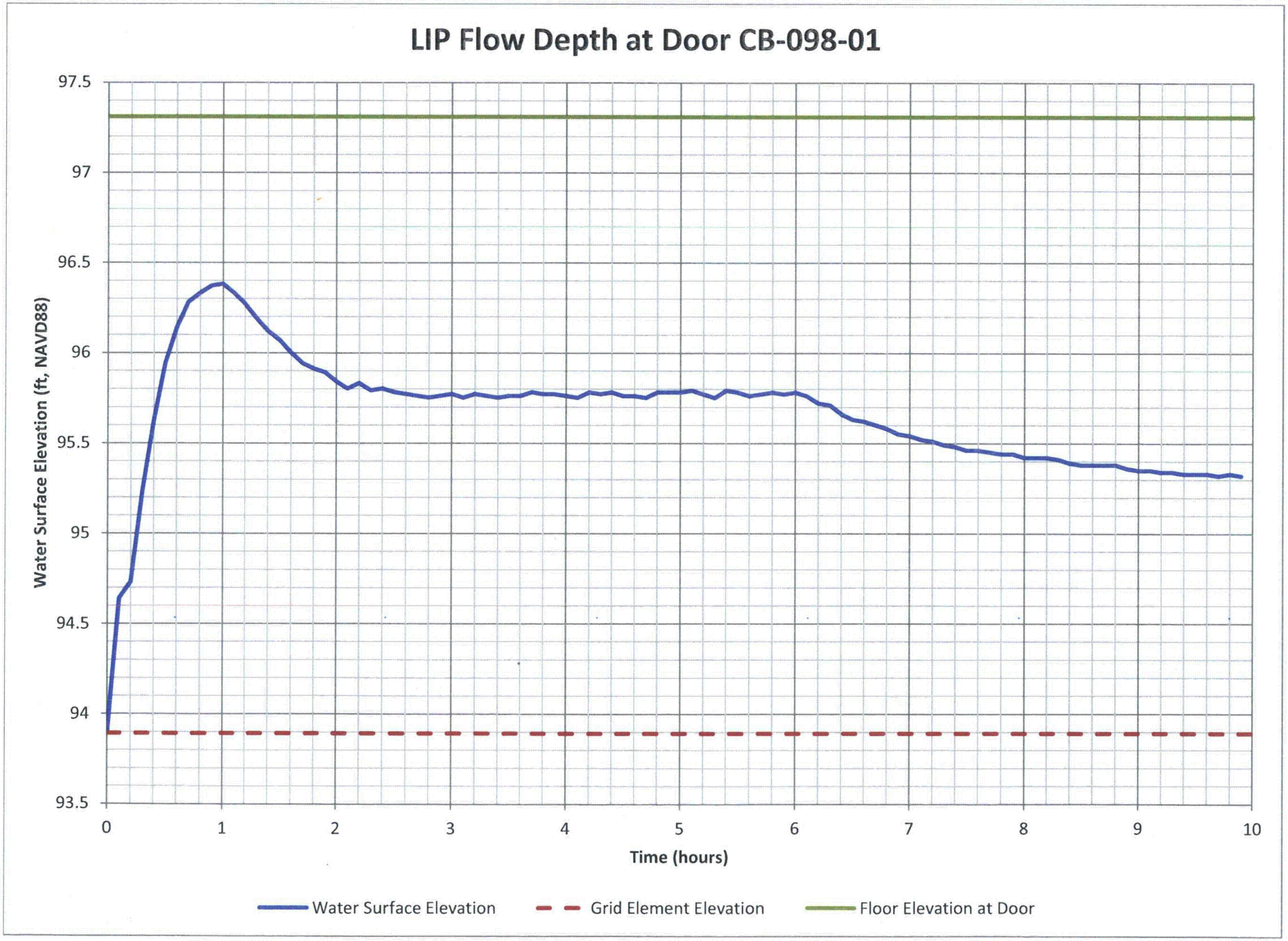


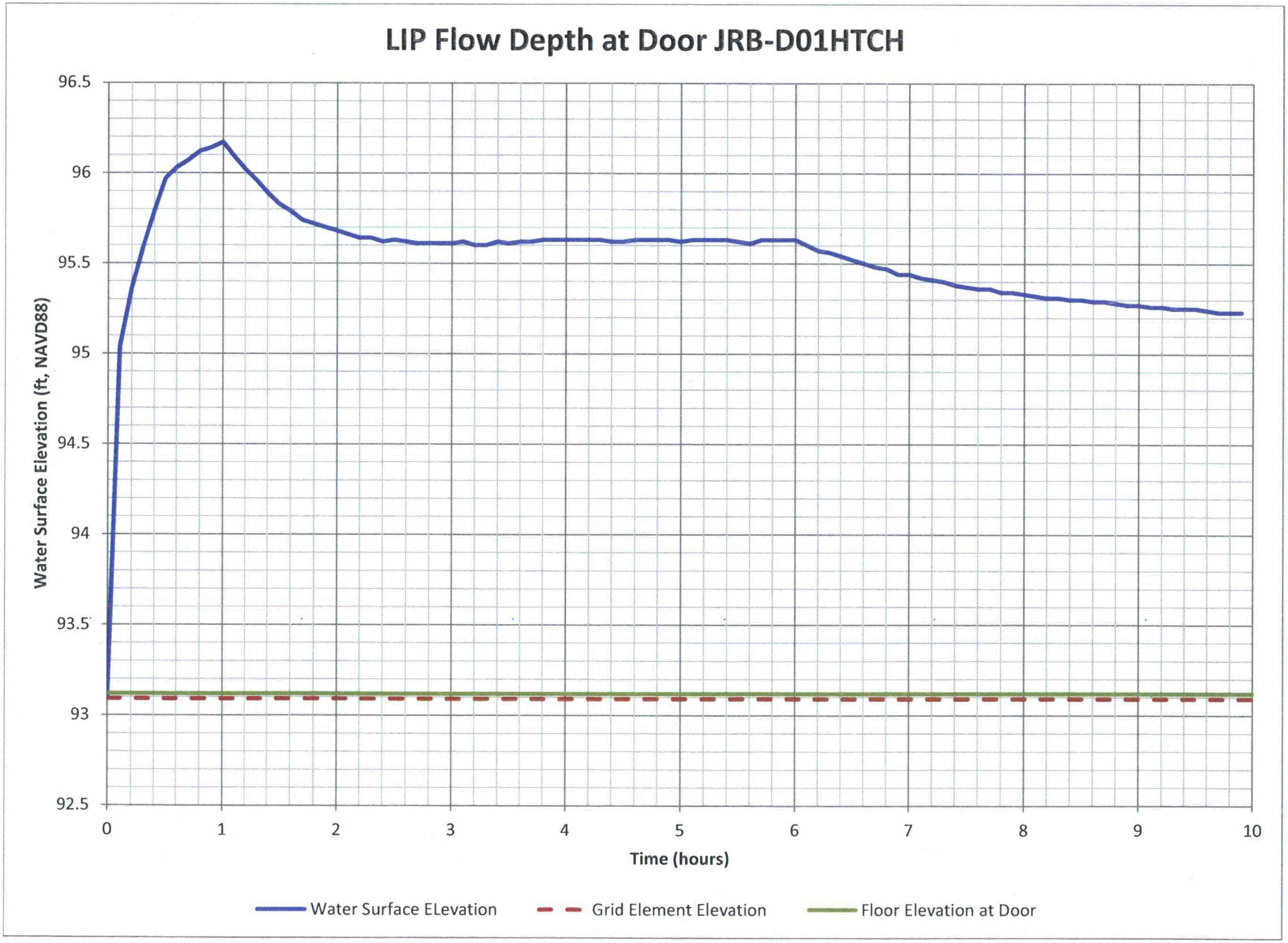

LIP Flow Depth at Door DG-098-01
Water Surface Elevation (ft, NAVD88)
97.5
97
96.5
96
95.5
95
94.5
94
93.5
0
1
2
3
4
5
6
7
8
9
10
Time (hours)
Water Surface Elevation
Grid Element Elevation
Floor Elevation at Door

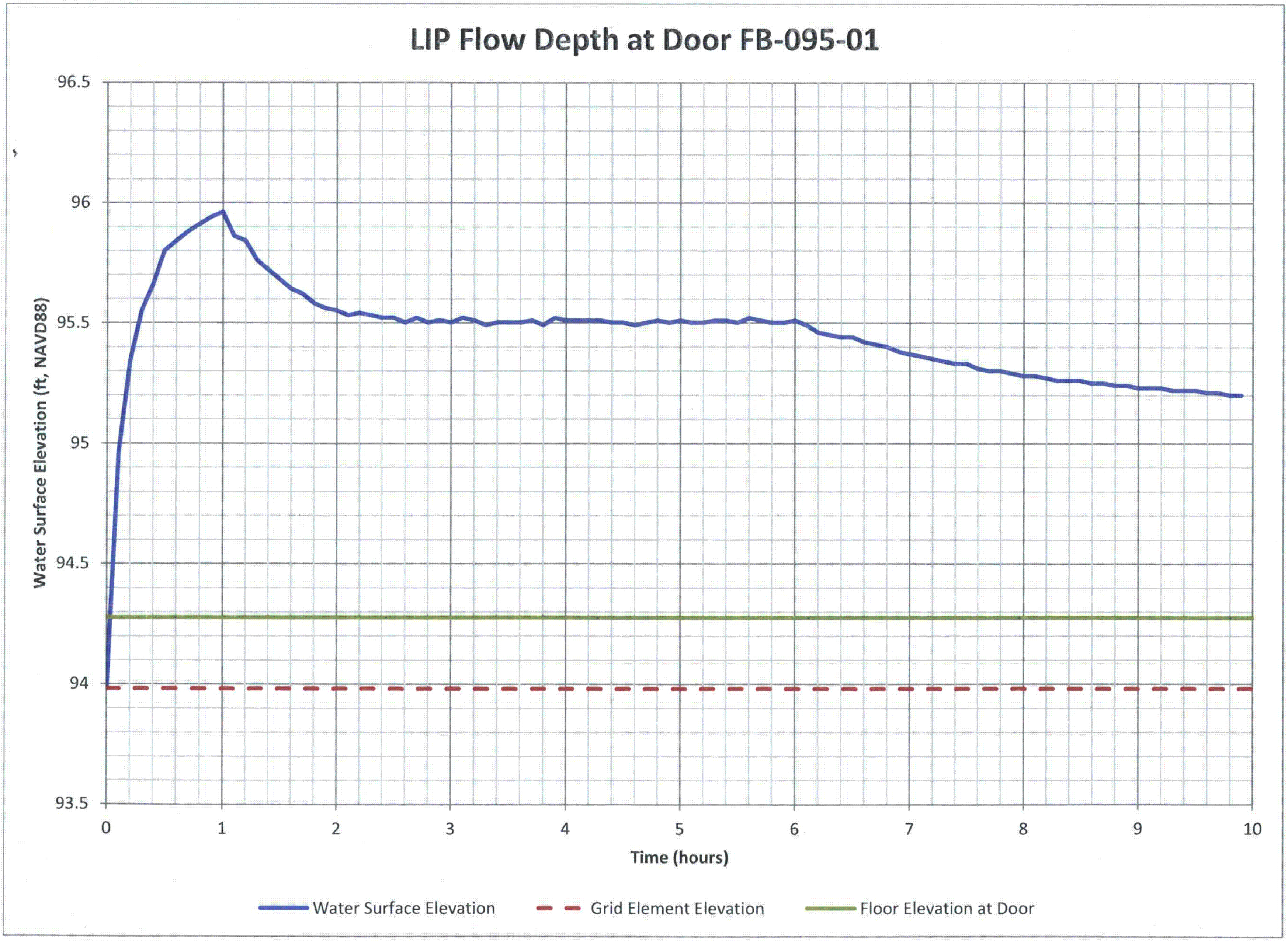

LIP Flow Depth at Doors DG-098-H01, DG-098-H02, and DG-098-02
Water Surface Elevation (ft, NAVD88)
97.5
97
96.5
96
95.5
95
94.5
94
93.5
0
1
2
3
4
5
6
7
8
9
10
Time (hours)
Water Surface Elevation
Grid Element Elevation
Floor Elevation at Door

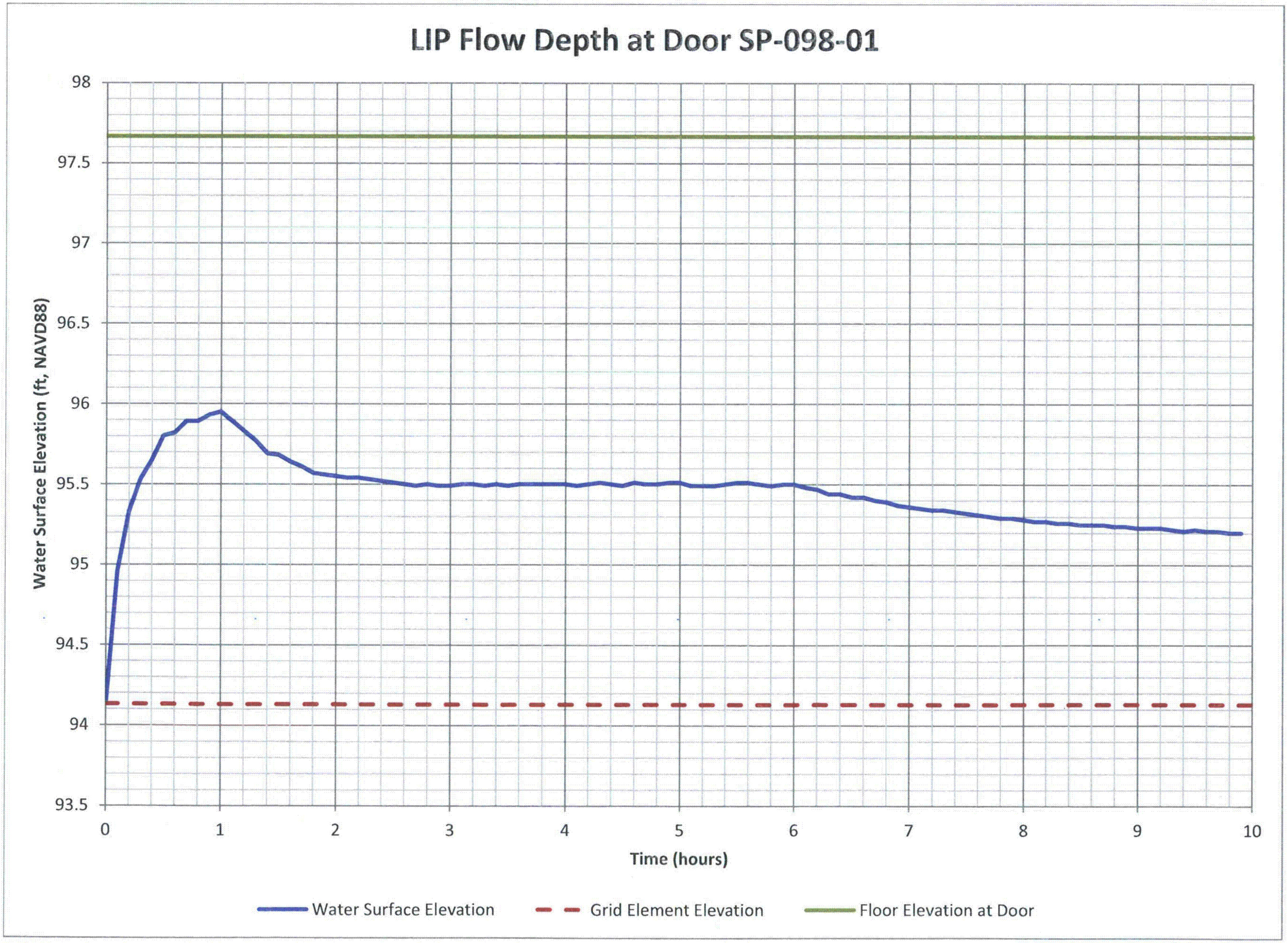

LIP Flow Depth at Door DG-098-11
Water Surface Elevation (ft, NAVD88)
98
97.5
97
96.5
96
95.5
95
94.5
94
0
1
2
3
4
5
6
7
8
9
10
Time (hours)
Water Surface Elevation
Grid Element Elevation
Floor Elevation at Door

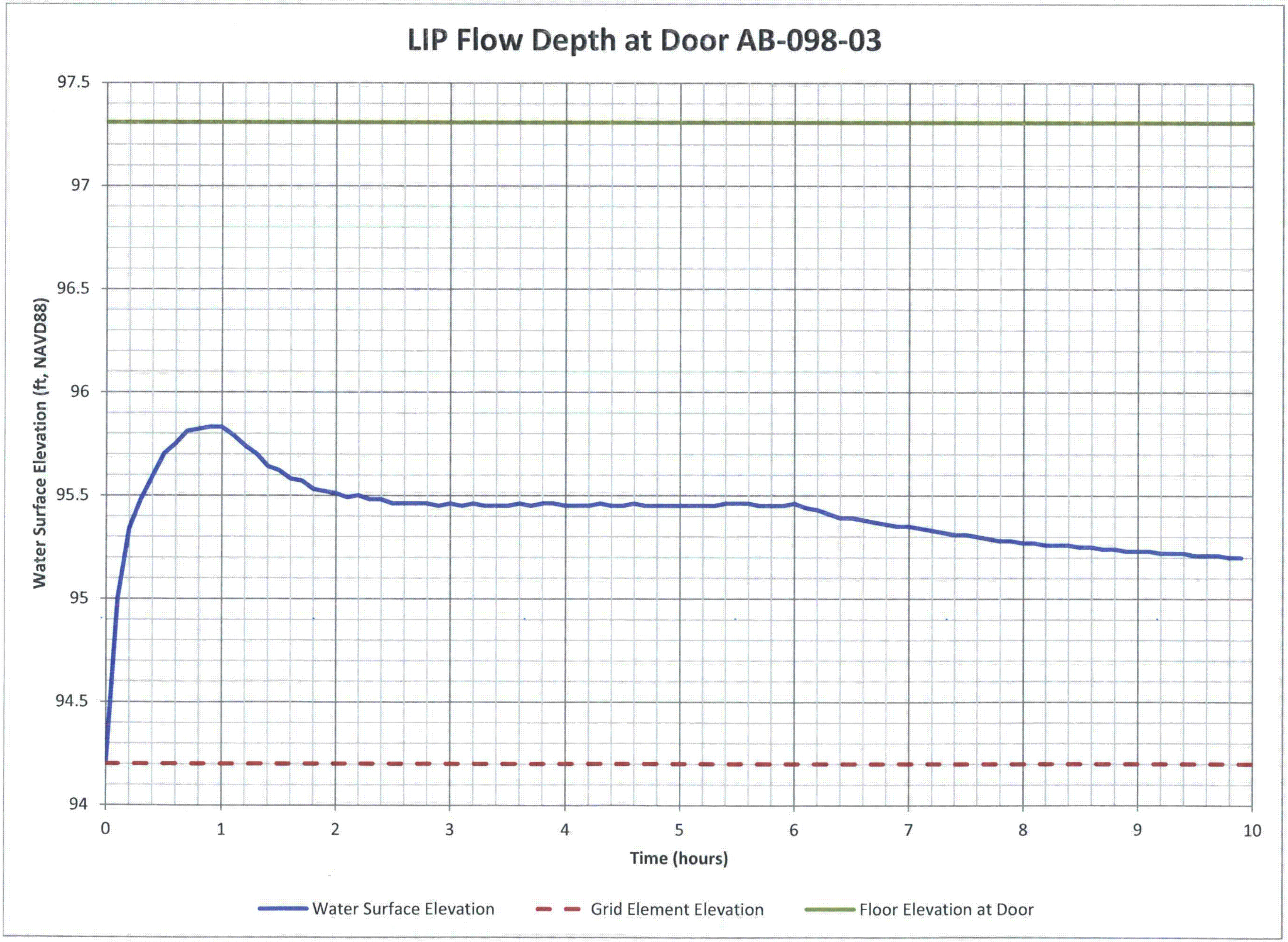

LIP Flow Depth at Doors DG-098-03 and DG-098-H03
Water Surface Elevation (ft, NAVD88)
97.5
97
96.5
96
95.5
95
94.5
94
93.5
0
1
2
3
4
5
6
7
8
9
10
Time (hours)
Water Surface Elevation
Grid Element Elevation
Floor Elevation at Door

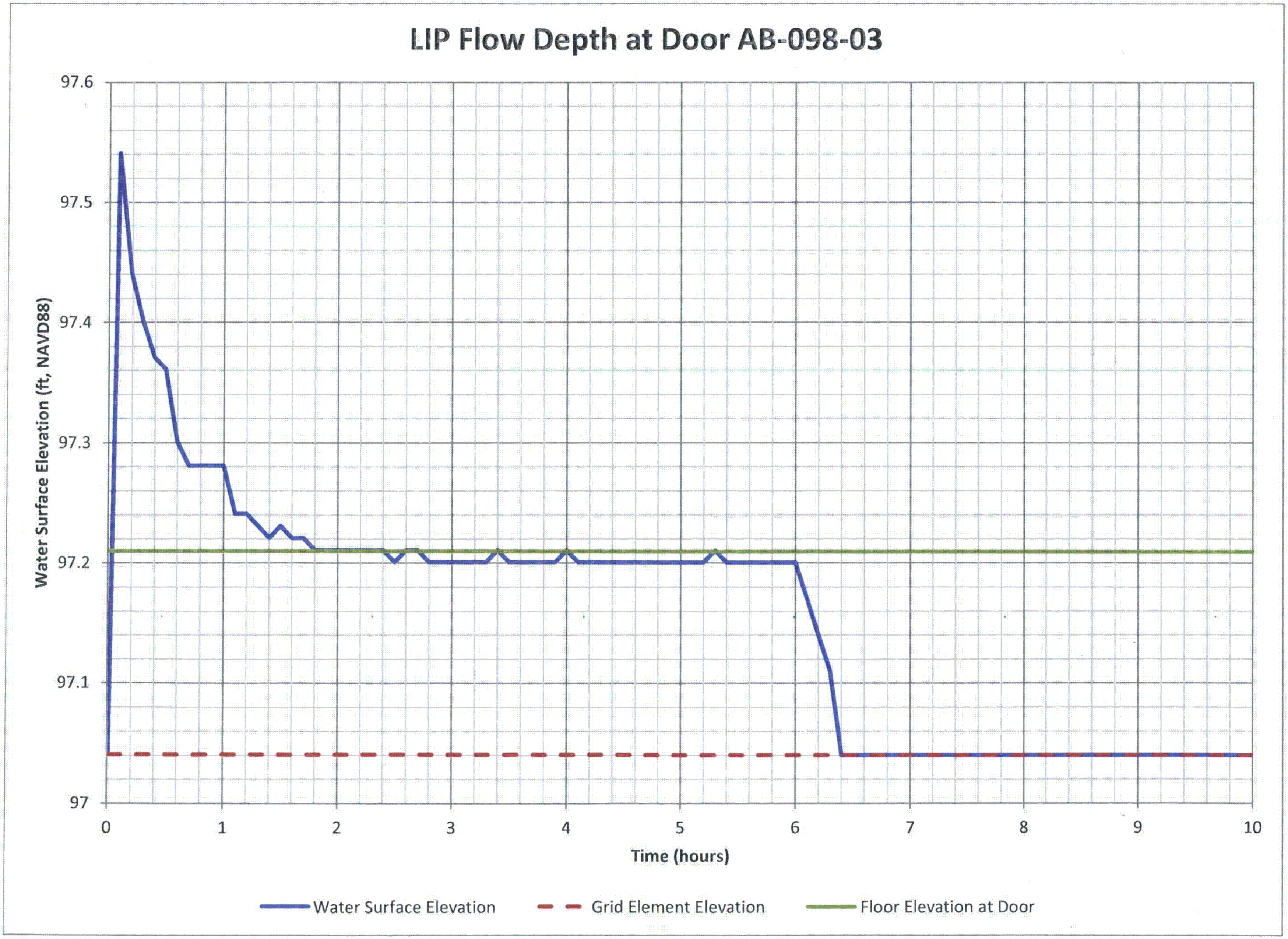

LIP Flow Depth at Door CB-098-01
Water Surface Elevation (ft, NAVD88)
97.5
97
96.5
96
95.5
95
94.5
94
93.5
0
1
2
3
4
5
6
7
8
9
10
Time (hours)
Water Surface Elevation
Grid Element Elevation
Floor Elevation at Door

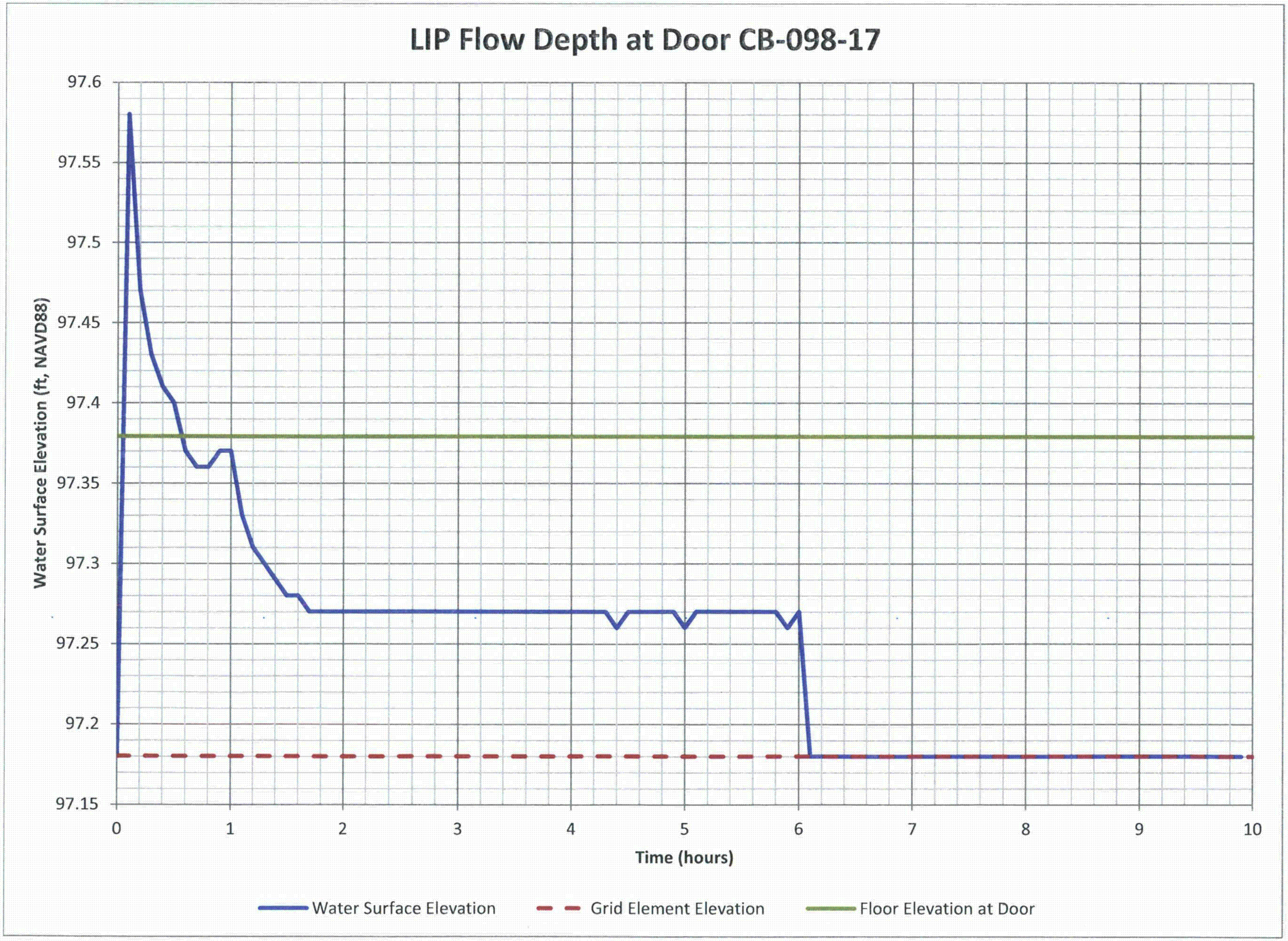

LIP Flow Depth at Door JRB-D01HTCH
Water Surface Elevation (ft, NAVD88)
96.5
96
95.5
95
94.5
94
93.5
93
92.5
0
1
2
3
4
5
6
7
8
9
10
Time (hours)
Water Surface ELevation
Grid Element Elevation
Floor Elevation at Door

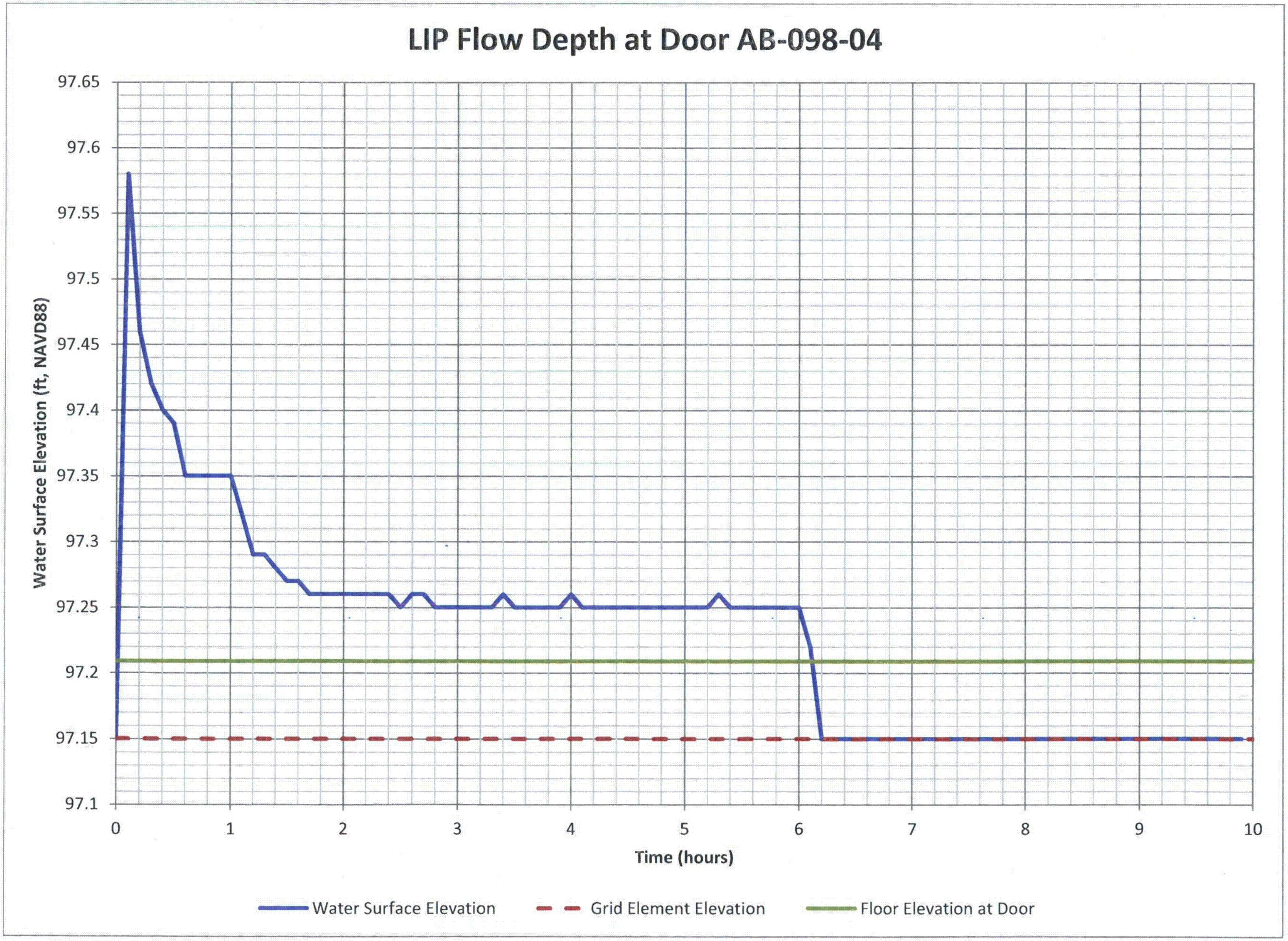

LIP Flow Depth at Door FB-095-01
Water Surface Elevation (ft, NAVD88)
96.5
96
95.5
95
94.5
94
93.5
0
1
2
3
4
5
6
7
8
9
10
Time (hours)
Water Surface Elevation
Grid Element Elevation
Floor Elevation at Door

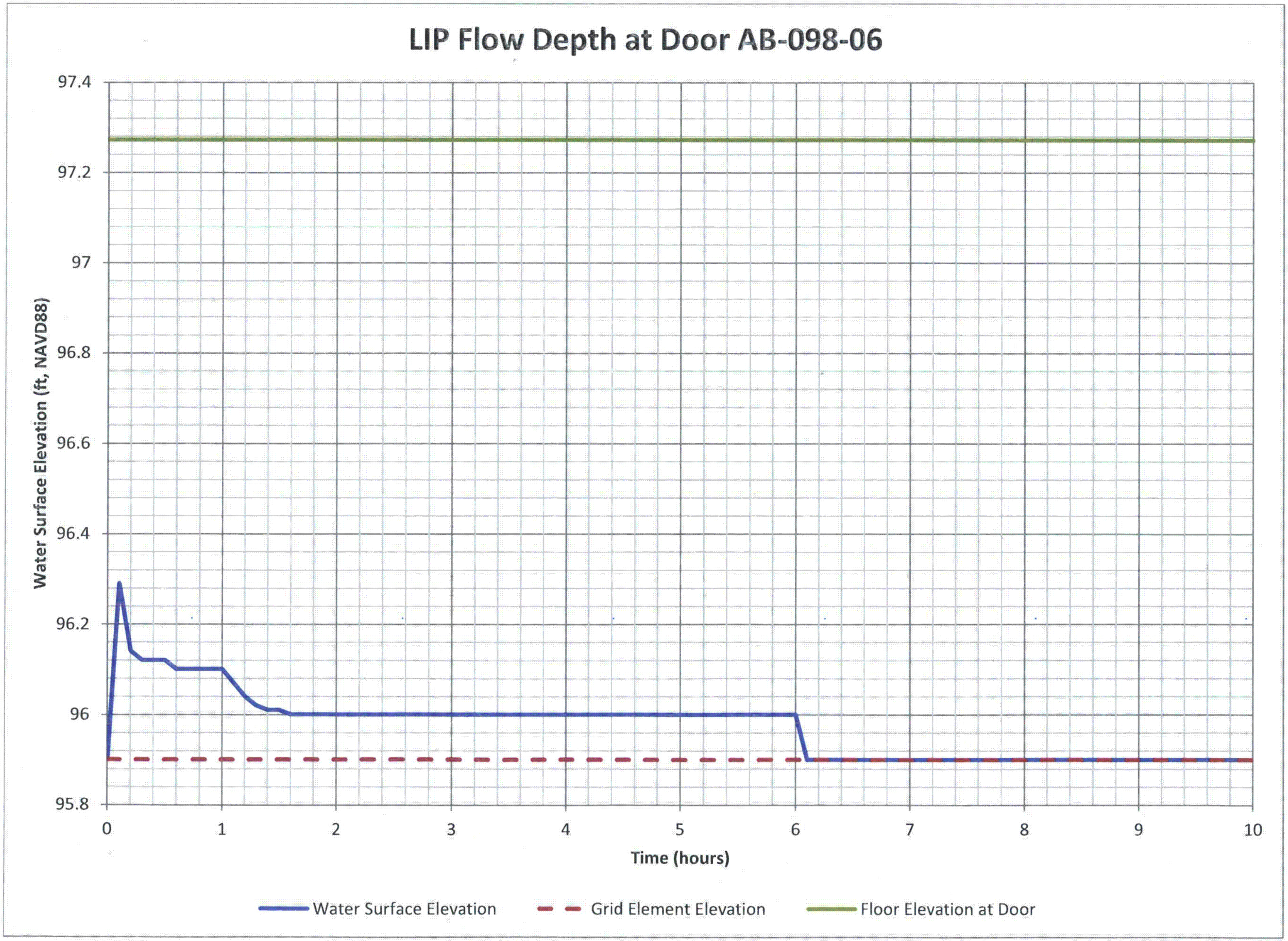

LIP Flow Depth at Door SP-098-01
Water Surface Elevation (ft, NAVD88)
98
97.5
97
96.5
96
95.5
95
94.5
94
93.5
0
1
2
3
4
5
6
7
8
9
10
Time (hours)
Water Surface Elevation
Grid Element Elevation
Floor Elevation at Door

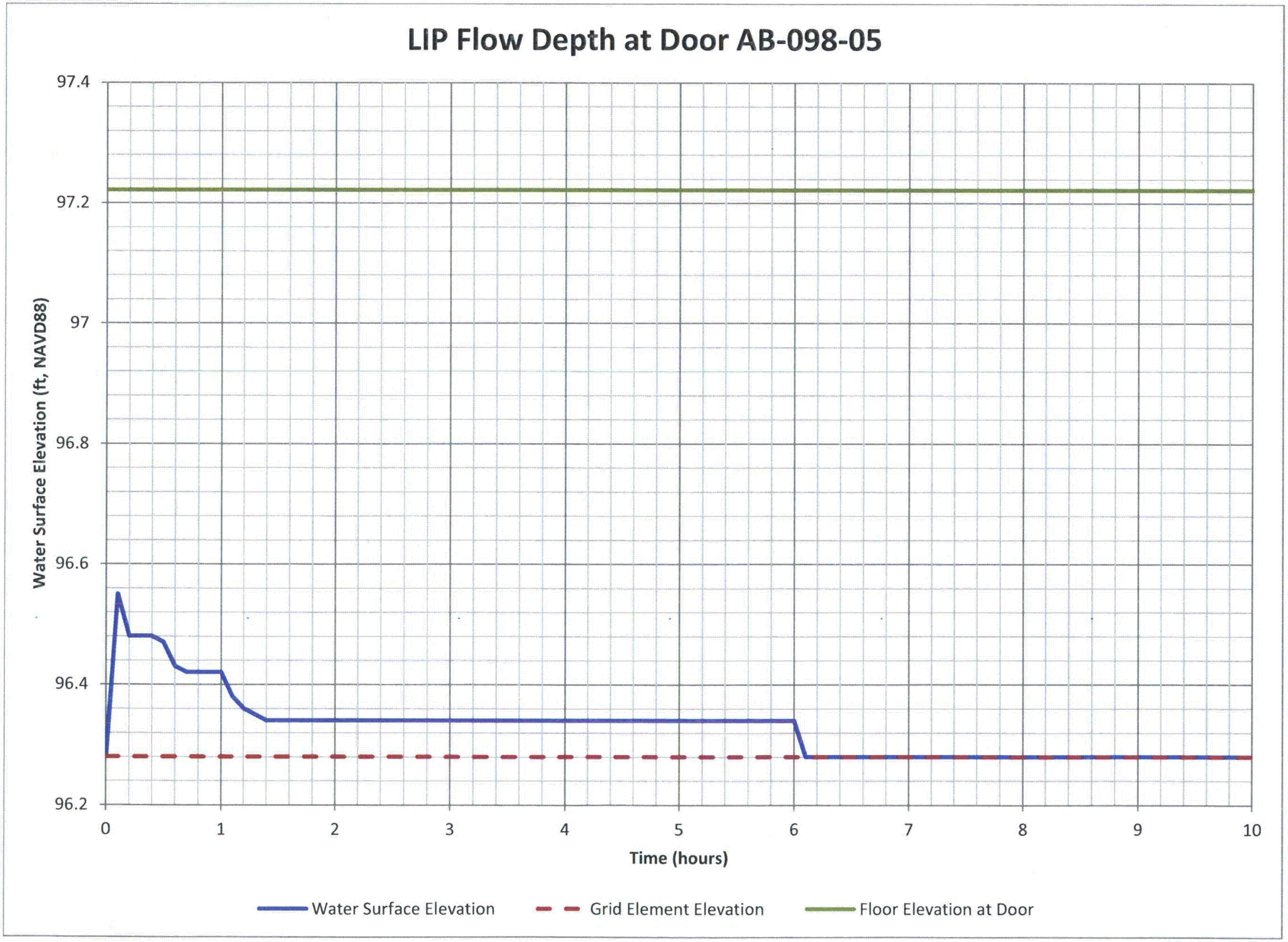

LIP Flow Depth at Door AB-098-03
Water Surface Elevation (ft, NAVD88)
97.5
97
96.5
96
95.5
95
94.5
94
0
1
2
3
4
5
6
7
8
9
10
Time (hours)
Water Surface Elevation
Grid Element Elevation
Floor Elevation at Door

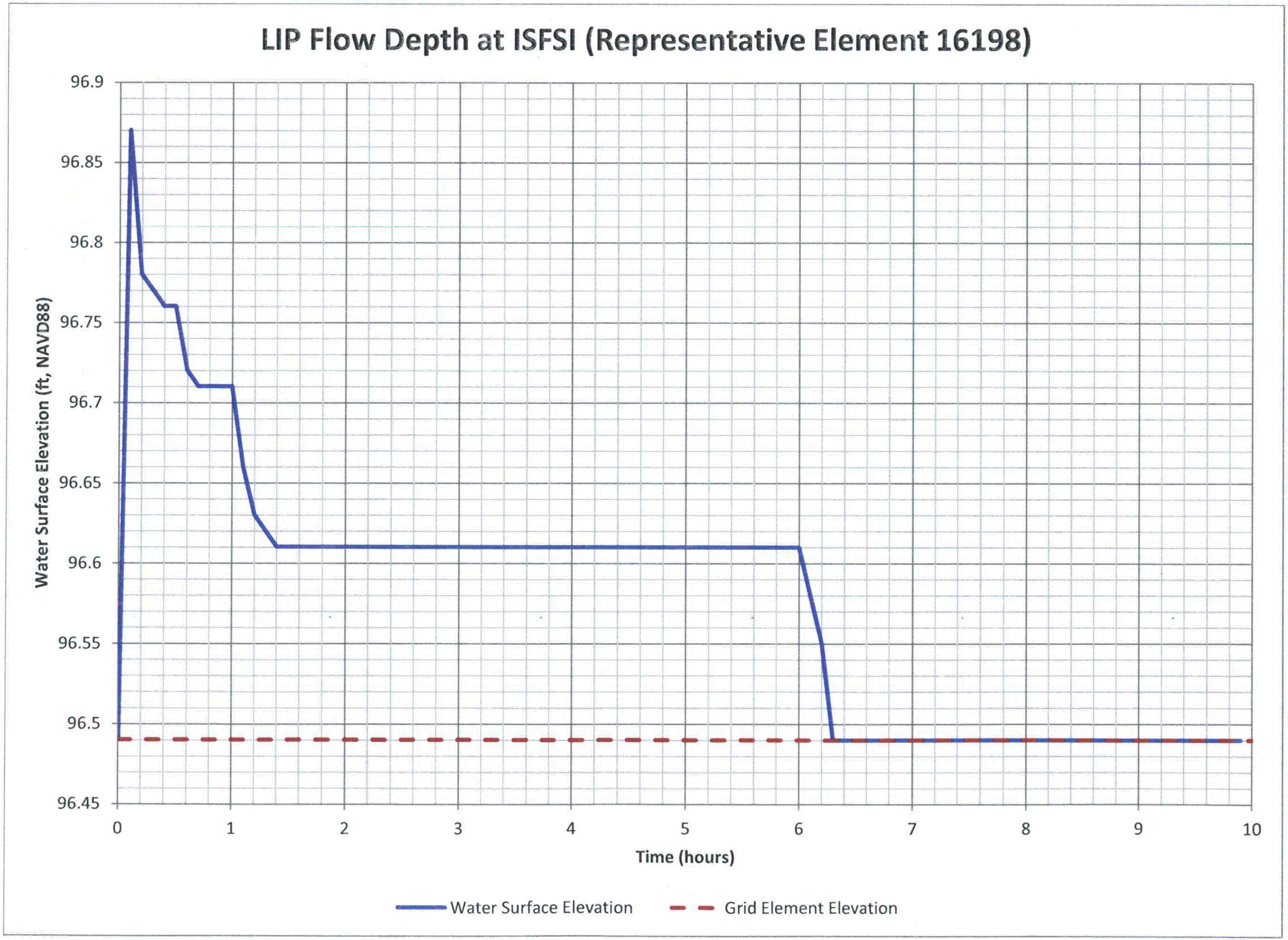

LIP Flow Depth at Door AB-098-03
Water Surface Elevation (ft, NAVD88)
97.6
97.5
97.4
97.3
97.2
97.1
97
0
1
2
3
4
5
6
7
8
9
10
Time (hours)
Water Surface Elevation
Grid Element Elevation
Floor Elevation at Door


LIP Flow Depth at Door CB-098-17
97.6
97.55
97.5
97.45
97.4
97.35
97.3
97.25
97.2
97.15
Water Surface Elevation (ft, NAVD88)
0
1
2
3
4
5
6
7
8
9
10
Time (hours)
Water Surface Elevation
Grid Element Elevation
Floor Elevation at Door


LIP Flow Depth at Door AB-098-04
Water Surface Elevation (ft, NAVD88)
97.65
97.6
97.55
97.5
97.45
97.4
97.35
97.3
97.25
97.2
97.15
97.1
0
1
2
3
4
5
6
7
8
9
10
Time (hours)
Water Surface Elevation
Grid Element Elevation
Floor Elevation at Door


LIP Flow Depth at Door AB-098-06
Water Surface Elevation (ft, NAVD88)
97.4
97.2
97
96.8
96.6
96.4
96.2
96
95.8
0
1
2
3
4
5
6
7
8
9
10
Time (hours)
Water Surface Elevation
Grid Element Elevation
Floor Elevation at Door


LIP Flow Depth at Door AB-098-05
Water Surface Elevation (ft, NAVD88)
97.4
97.2
97
96.8
96.6
96.4
96.2
0
1
2
3
4
5
6
7
8
9
10
Time (hours)
Water Surface Elevation
Grid Element Elevation
Floor Elevation at Door


LIP Flow Depth at ISFSI (Representative Element 16198)
Water Surface Elevation (ft, NAVD88)
96.9
96.85
96.8
96.75
96.7
96.65
96.6
96.55
96.5
96.45
0
1
2
3
4
5
6
7
8
9
10
Time (hours)
Water Surface Elevation
Grid Element Elevation