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September 2021

CITY OF
Charleston
SOUTH CAROLINA

Evaluation of Impacts of the Lake Dotterer Diversion

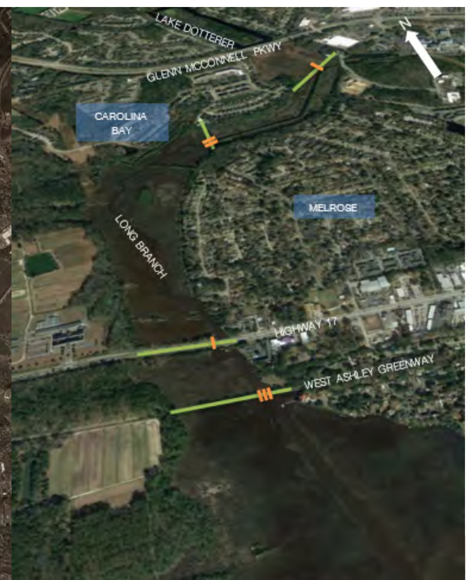



TABLE OF CONTENTS

Page

TABLE OF CONTENTS i

LIST OF FIGURES ii

LIST OF TABLES iii

LIST OF APPENDICES iv

1.0 BACKGROUND 1-2

2.0 MODEL DEVELOPMENT 2-2
- 2.1 Data Collection 2-2
- 2.2 Field Work 2-2
- 2.3 Model Development 2-2
  - 2.3.1 Boundary Conditions 2-2
- 2.4 Model Calibration 2-2
  - 2.4.1 Results 2-2

3.0 EXISTING CONDITIONS & MODELED IMPROVEMENTS 3-2
- 3.1 Church Creek & Lake Dotterer Connection 3-2
  - 3.1.1 Existing Conditions 3-2
  - 3.1.2 Modeled Improvements 3-2
- 3.2 Lake Dotterer & Long Branch Creek Connection 3-2
  - 3.2.1 Existing Conditions 3-2
  - 3.2.2 Modeled Improvements 3-2
- 3.3 Downstream Improvements in Long Branch 3-2
  - 3.3.1 Existing Conditions 3-2
  - 3.3.2 Modeled Improvements 3-2

4.0 MODEL RESULTS 4-2
- 4.1 Lake Dotterer Flow Restoration 4-2
- 4.2 Scenario Combinations for Lake Dotterer Flow Restoration 4-2

5.0 CONCLUSIONS & RECOMMENDATIONS 5-2

6.0 WORKS CITED 6-2

LIST OF FIGURES

Figure 1 - 1919 USGS Topographic Map Johns Island, South Carolina showing Ashley River, Stono River, Church Creek, and Long Branch. 1-2

Figure 2 - 1944 USGS Topographic Map Ravenel, South Carolina showing Ashley River, Stono River, Church Creek, and Long Branch. 1-2

Figure 3 - 2011 USGS Topographic Map Johns Island, South Carolina showing Ashley River, Stono River, Church Creek, and Long Branch. 1-2

Figure 4 - Aerial image of Lake Dotterer and neighboring residential developments. 1-2

Figure 5 - Aerial image showing location of key nodes. 2-2

Figure 6 - Aerial image showing level logger locations in Long Branch for data collection. 2-2

Figure 7 - Ashley River tidal condition set at Node A010 for Church Creek boundary input. 2-2

Figure 8 - Stono River tidal condition set at Node LB010 for Long Branch boundary input. 2-2

Figure 9 - Model calibration comparison of observed and simulated water surface elevations at Long Branch and West Ashley Greenway crossing, Node B020, for recorded storm event. 2-2

Figure 10 - Model calibration comparison of observed and simulated water surface elevations at Long Branch and Highway 17 crossing, Node LB110, for recorded storm event. 2-2

Figure 11 - Rice trunks connecting Lake Dotterer and Church Creek. 3-2

Figure 12 - Proposed alternate outfall for Lake Dotterer to Long Branch 3-2

Figure 13 - Long Branch and existing flow impediments location, type, and size. 3-2

Figure 14 - Normal conditions, low tide at the greenway. 3-2

Figure 15 - 1%, 24-hour storm, low tide at the greenway 3-2

Figure 16 - 1%, 24-hour storm, high tide at the greenway 3-2

Figure 17 - Normal conditions, high tide at the greenway 3-2

LIST OF TABLES

Table 1 - Lake Dotterer and Long Branch Node Descriptions....2-2
Table 2 - Max flow, velocity, and percentage of pipe capacity flowing full in existing conditions flow restrictions by storm event 3-2
Table 3 - Downstream improvements modeled with sizes, flows, and location....3-2
Table 4 - Peak staging elevations in Lake Dotterer for project simulations, all storms. 4-2
Table 5 - Peak staging elevations at Long Branch mid-point for project simulations, all storms....4-2
Table 6 - Peak Staging Elevations by Node for the Flow Restoration and Combination Scenarios. 4-2
Table 7 - Culvert size options for downstream improvements to accommodate flows....5-2

LIST OF APPENDICES

Appendix A..Model Results Table

Appendix B...Lake Dotterer Flow Restoration Nodal Map

Appendix C ....Hydrographs by Node for Lake Dotterer Flow Restoration

Appendix D ....Hydrographs by Node for Combination Scenarios

Appendix E..Single Hydrographs Output from Model

1.0 BACKGROUND

Prior to development in the area West of the Ashley, the Stono River and Ashley River interacted during major storm and tidal events through a web of low elevation lands and streams (United States Geological Survey). One such low area existed between Church Creek and Long Branch swamp. During heavy rains and tidal surge events overland flow between Church Creek and Long Branch would intermingle somewhere near present-day Glenn McConnell Parkway, which was a subtle natural break in the topography. Through development of the area for agriculture, mining, and residential communities the natural break became a slightly elevated road with narrow weir, a portion of the Church Creek flood plain was dammed, and a lake was formed (United States Geological Survey). By the late 1980s, the Church Creek and Long Branch drainage basins were being heavily developed for suburban sprawl and in 1989 plans were underway for the construction of Glenn McConnell Parkway as a bypass for the congested Highway 61. Glenn McConnell Parkway, completed in 1994, elevated the existing road south of Lake Dotterer an additional three feet completing the separation of Church Creek and Long Branch (United States Geological Survey). The topographic map images below show the historical progression of development within this section of West Ashley over the span of 90 years.

Figure 1 - 1919 USGS Topographic Map Johns Island, South Carolina showing Ashley River, Stono River, Church Creek, and Long Branch.

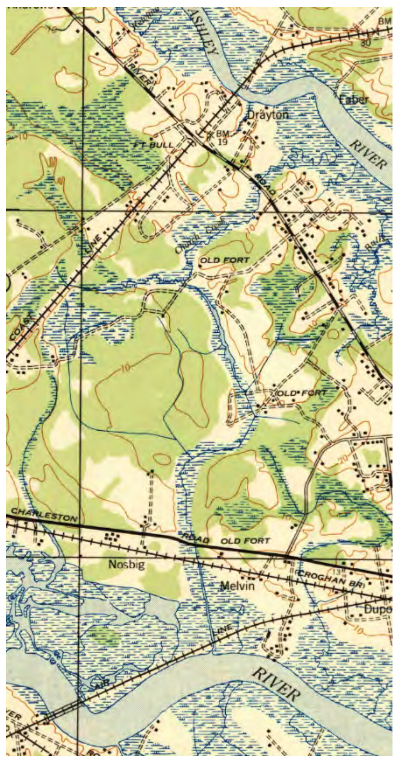


Figure 2 - 1944 USGS Topographic Map Ravenel, South Carolina showing Ashley River, Stono River, Church Creek, and Long Branch.

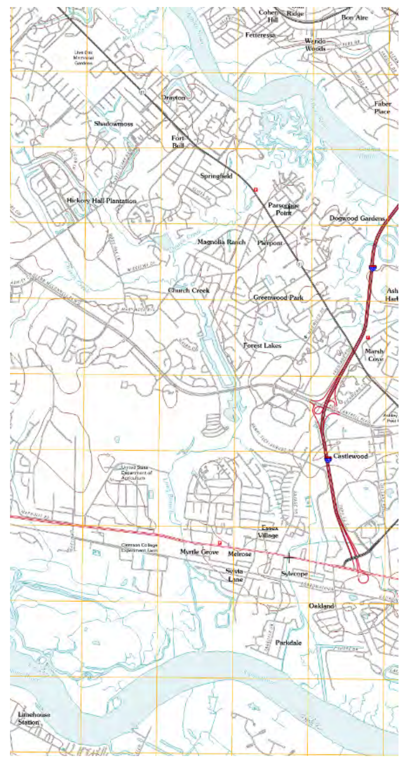


Figure 3 - 2011 USGS Topographic Map Johns Island, South Carolina showing Ashley River, Stono River, Church Creek, and Long Branch.

Lake Dotterer Area

Lake Dotterer Area

Lake Dotterer

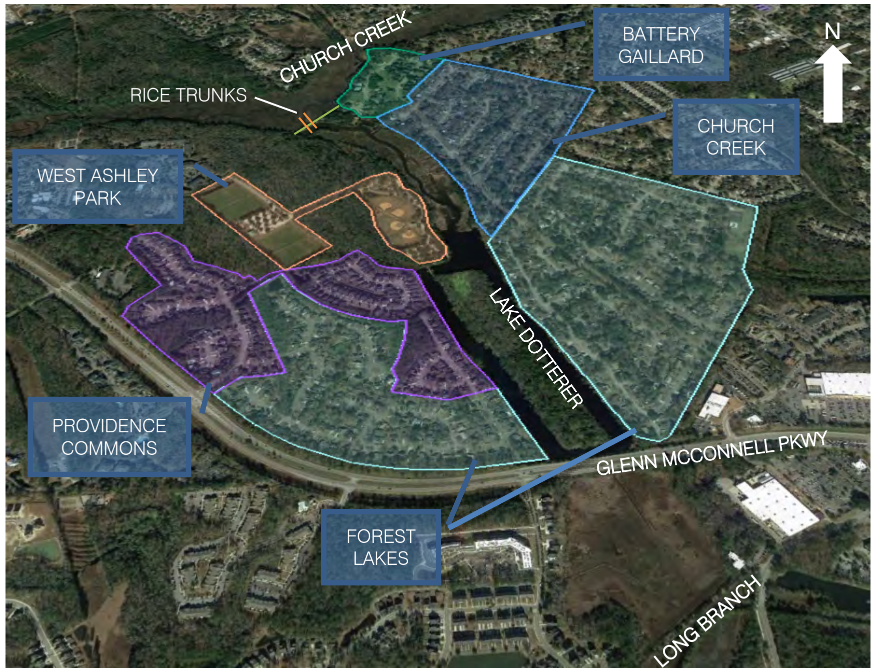


Figure 4 - Aerial image of Lake Dotterer and neighboring residential developments.

In the recent decades, Forest Lakes, Providence Commons and the areas west and immediately adjacent to Lake Dotterer experience flooding during tidal surges and major storm events. The capacity of Lake Dotterer as a stormwater facility is much larger than would typically be required to serve these neighborhoods collectively. This overall area is approximately 50 acres and was formerly part of the estuarine area which connected Church Creek with the Stono River making it a natural drainage point for the area. However, during storm events like Hurricane Irma where tidal surge causes higher staging, Church Creek overtops the dam at Lake Dotterer and uses the capacity that would otherwise accommodate stormwater runoff. Further, it takes Lake Dotterer days to recover from inundation as water flows through the rice trunks into Church Creek only during periods of low tide.

The purpose of this study is to evaluate the effects and improvements necessary to install a proposed alternate outfall under Glenn McConnell Parkway and restore the connection between Church Creek and Long Branch. Charleston County is currently designing a road widening project for the length of the Glenn McConnell Parkway between Bees Ferry Road and Interstate 526, making the Lake Dotterer Flow Restoration a project of opportunity. The project is consistent with the findings and recommendations of the Evaluation of the Church Creek Drainage Reduction Study Report by Weston & Sampson dated January 2018. This evaluation concentrated on four areas relative to the proposed alternate outfall: Church Creek, Lake Dotterer, Long Branch, and the Long Branch outfall at West Ashley Greenway. The alternate outfall and hydraulic restoration in Long Branch also align with recommendations of the Dutch Dialogues Charleston by creating “better connections between the creeks and other water systems…including where possible interconnections between the Ashley and Stono Rivers” (Waggonner & Ball).

2.0 MODEL DEVELOPMENT

The model for Long Branch was developed over a period of two months as an addition to the existing Church Creek model previously updated in 2017 by Weston & Sampson to ICPR4. Long Branch is an adjacent drainage basin south of the Church Creek drainage basin; it interacts with Church Creek via Lake Dotterer, though under existing conditions the interaction at Lake Dotterer is interrupted by Glenn McConnell Parkway.

2.1 Data Collection

Weston & Sampson's first step in developing the Long Branch Basin model was to collect all available data from the City, South Carolina Department of Transportation (SCDOT), United States Geological Survey (USGS), National Oceanic Atmospheric Administration (NOAA), South Carolina Department of Natural Resources (SCDNR), US Department of Agriculture's (USDA) Natural Resources Conservation Services (NRCS), and private stakeholders within the basin. Weston & Sampson used the following collected data:

- Stormwater asset GIS attributes from the City of Charleston GIS database.
- LiDAR and DEM from the SCDNR LiDAR Program.
- Soil survey maps from the NRCS Web Soil Survey tool.
- SCDOT record drawings for Glenn McConnell Parkway (S-461), Savage Road (S-1168), and Savannah Highway (US Route 17).
- Drainage reports from Thomas & Hutton for Ashley Park Phase 5 and Seamon Whiteside for Carolina Bay Phase 15, Benton House at Boltons Landing, and Sawgrass Apartments Phase II.
- Drainage reports for Carolina Bay development phases provided by the City Stormwater Management Program Manager, Kinsey Holton, which had been received by the City through the Construction Activity Application and stormwater permitting process.
- Historical USGS topographic maps.

During our data collecting, we found that the tidal gauge for the Stono River located at Limehouse Bridge (Station ID 8665475) was uninstalled in 1977. The tidal prediction information provided through NOAA for the Stono River are interpolated levels based upon previously collected data. Available NOAA data was not used for developing the Long Branch basin model.

2.2 Field Work

Prior to this study, the Long Branch Basin had never been modeled in its entirety. To supplement the available data collected, Weston & Sampson deployed a team to capture survey grade data throughout the basin. While, the study was limited in scope, survey was collected at key nodes, outlet structures, conveyance channels, and stormwater management assets identified as critical to creating a hydraulically comprehensive model. The following key stormwater assets and features were surveyed:

- The rice trunks and dam between Lake Dotterer and Church Creek.
- The Lake Dotterer normal water surface elevation.
- Inverts and pipe sizes along the northeastern conveyance channel starting at the Glenn McConnell Parkway and I-526 intersection, flowing behind St. Francis-Roper Hospital, under Henry Tecklenburg Dr, and discharging into Long Branch.
- The impoundment, pipe diameter and invert elevations in Long Branch between the Dermatology & Laser Center of Charleston and Essex Farms in Carolina Bay.

- The dam, pipe diameters, and invert elevations in Long Branch between Carolina Bay and Melrose.
- Major outfall pipes and structures within Carolina Bay between William E Murray Boulevard and Glenn McConnell Parkway.
- Long Branch culverts crossing under Savannah Highway.
- Top of West Ashley Greenway, pipe diameters, and invert elevations.
- Tide condition at the Stono River monitored from January 8,2020 - January 17,2020 both upstream and downstream of the West Ashley Greenway.

2.3 Model Development

To create a model that effectively evaluates the alternatives proposed by the City of Charleston, Weston & Sampson expanded the most up to date Church Creek Drainage Basin model. This consisted of incorporating the collected data and expanding the map layers used in the model's overland flow regions for the entire Long Branch Drainage Basin to create an Existing Conditions model. To incorporate the collected information, Weston & Sampson underwent the following model building process:

- Development of a 1D Nodal Network for the Long Branch Basin, including:
  1. Nodes – Time/stage nodes, stage-area, etc.
  2. Links – Channels, pipes, weirs, drop structures, etc.
  3. Channel and weir cross sections (developed either from the DEM, or manually entered).
- Incorporation of 2D overland flow elements, including:
  1. 1D node interface points
  2. Pond and channel control volumes
  3. Breaklines and breakpoints to refine computational meshes
  4. Boundary stage lines to allow for flow out of the overland flow region in the direction of the Stono River.
  5. 2D weir features for existing weirs and replacement of hydro-correction to the DEM.
- Expansion of map layers, including:
  1. Soils by hydrologic group and classification
  2. Land Uses
- Addition of boundary stage sets, including:
  1. Incorporation of Stono River synthetic tide generated from MHHW and MLW from the observed period.
  2. Incorporation of Stono River tide for the observed period for calibration purposes
- Creation of simulations for the following annual exceedance probability (AEP) storms:
  1. 10%, 24-hour
  2. 4%, 24-hour
  3. 1%, 24-hour

Once these items were incorporated, computational meshes were built for the model. This existing condition scenario was copied and modified for each analyzed alternative. Various changes were made in each alternative to simulate culvert installations, improvements, elevation changes of control structures to include the dam and connection between Lake Dotterer and Church Creek, US Highway 17, the West Ashley Greenway, and other impoundments within Long Branch.
The following table defines the newly added Long Branch nodes:

Table 1 - Lake Dotterer and Long Branch Node Descriptions

Node Label	Node Description
N-0210	Church Creek Downstream from Lake Dotterer
N-0530	Lake Dotterer North End
N-A120	Upstream of Railroad Culverts
N-B020	Upstream of Bees Ferry Road
N-B160	Convergence of Church Creek Upstream of Bees Ferry Road
N-LB100	Upstream of West Ashley Greenway
N-LB130	Upstream of Highway 17
N-LB240	Carolina Bay-Melrose Crossing
N-LB370	Upstream of St. Francis Parking Lot Bridge
OFNF-LB300	Carolina Bay Impoundment

See aerial image with these nodes identified on the following page.

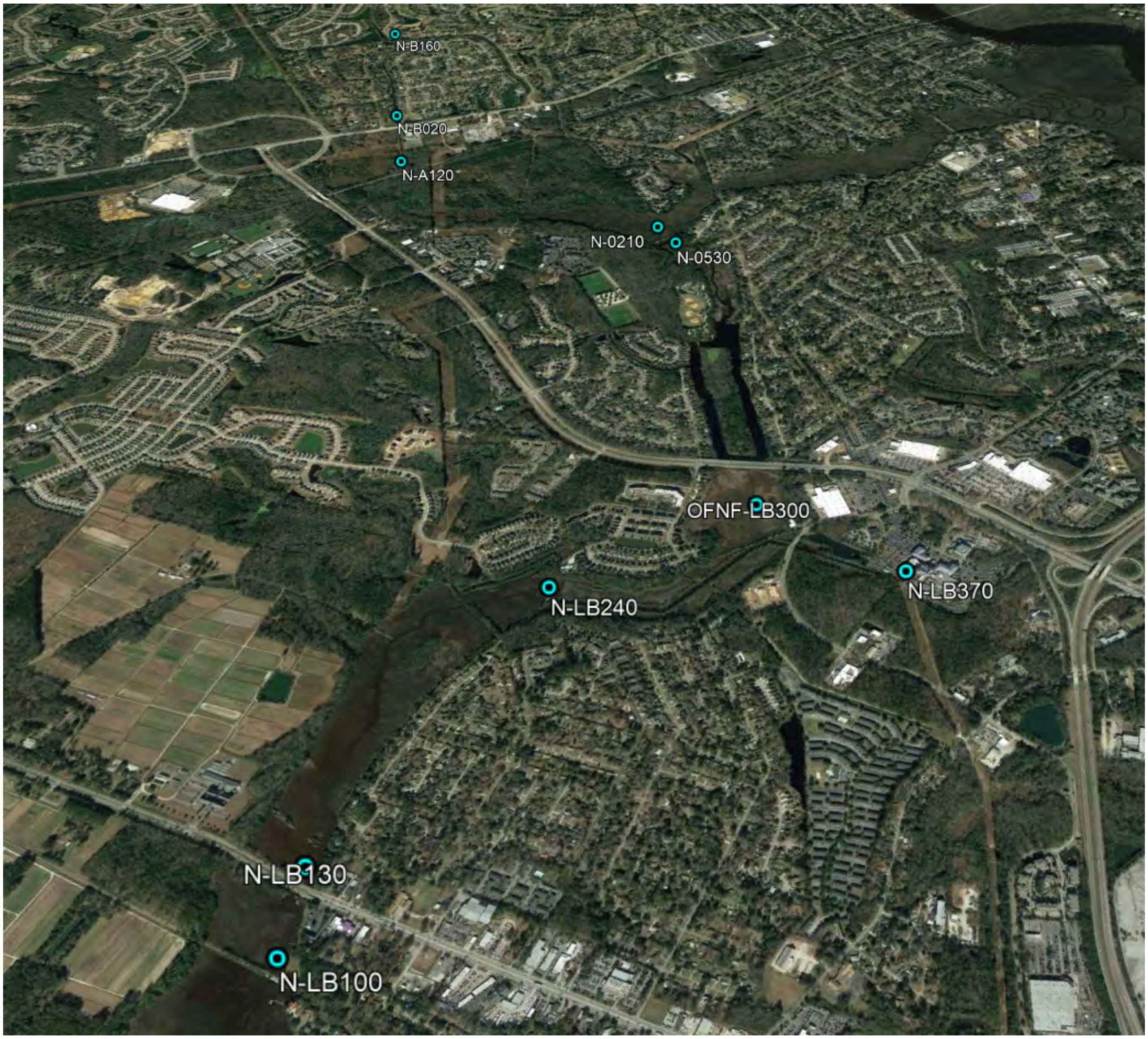


Figure 5 - Aerial image showing location of key nodes.

2.3.1 *Boundary Conditions*

The Stono River does not currently have a permanent tidal gauge installed anywhere along its length. An accurate boundary condition is immensely valuable to creating a comprehensive basin model with an intertidal zone. To establish a current tidal condition for the Stono River, Weston & Sampson deployed two *Solinst Levellogger® Edge Water Dataloggers*. The first was placed at the Stono River to monitor the tide entering Long Branch and the second between the West Ashley Greenway and US Highway 17. Weston & Sampson obtained permission from Rebekah Weigand and Creekside Lands Inn for access and use of the Sylvan Shores Community dock and the Creekside Lands Inn's dock respectively in order to deploy these gauges along Long Branch Creek. The gauges collected data for a period of 9 days between January 8 and January 17, 2020.

Figure 6 - Aerial image showing level logger locations in Long Branch for data collection.

The information from the gauge deployed at the Stono River was imported and used to establish the tidal boundary condition at the Stono River and assigned to Node N-LB010. In order to be consistent with the Church Creek existing conditions model, the average of the low water peaks over the entire observation period was used to establish a Mean Low Water level and the average of the alternate peak tides was used to establish a Mean Higher High Water level. A boundary stage line was added around the culvert crossing in the Greenway allowing for flow out of the Overland Flow Region in the direction of the Stono River.

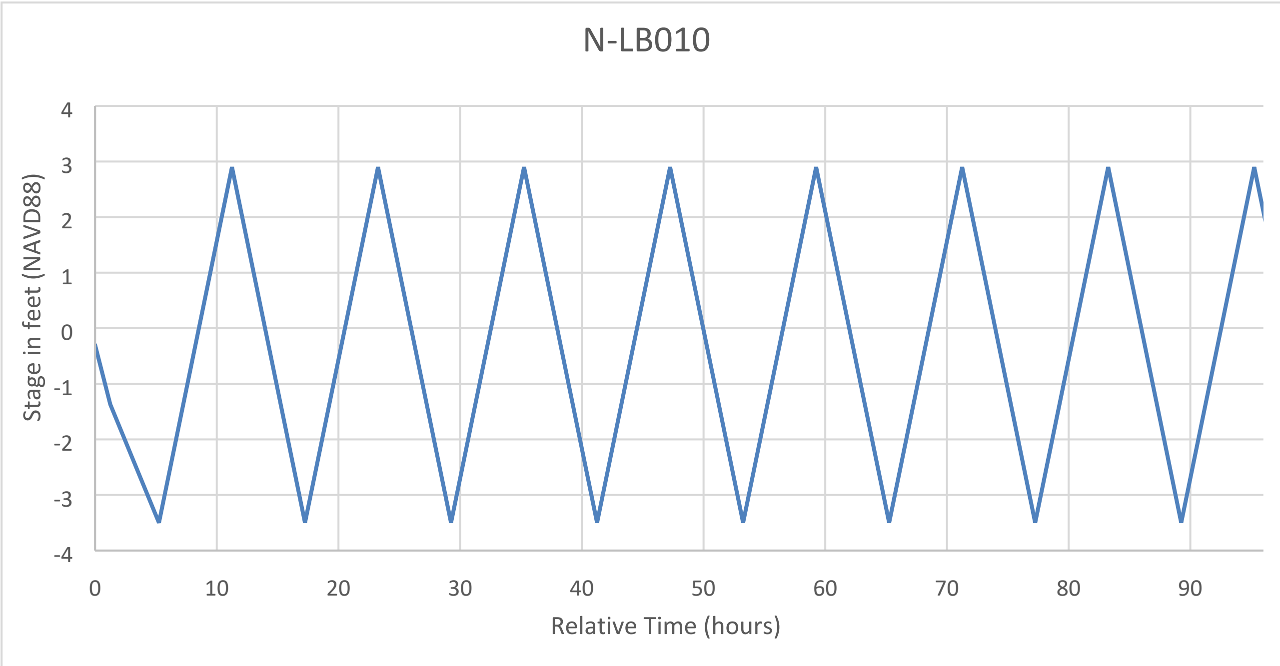


Figure 8 - Stono River tidal condition set at Node LB010 for Long Branch boundary input.

The Ashley River boundary condition at Node A010 remained the same as the Church Creek existing conditions model previously developed during the Church Creek Drainage Basin study, using Mean Low Water and Mean Higher High Water as its peaks.

2.4 Model Calibration

As in the Church Creek Drainage Basin Study, Weston & Sampson continues to find it valuable to compare or "calibrate" the ICPR4 simulated model with a known observed condition. Weston & Sampson used the information collected by the *Solinst* gauge at the Creekside Lands Inn dock to compare the water surface level in Long Branch observed at node N-LB110. The City of Charleston Maxwell gauge was used for comparison of the modeled and observed water surface elevations in Church Creek at Node B020. Rainfall information for the corresponding dates was also collected from the City of Charleston Maxwell gauge. The model simulation was set up to run for the period of 00:00 1/12 2020 to 00:00 1/15 2020 (72 hours) during which time 0.54" of rainfall occurred.

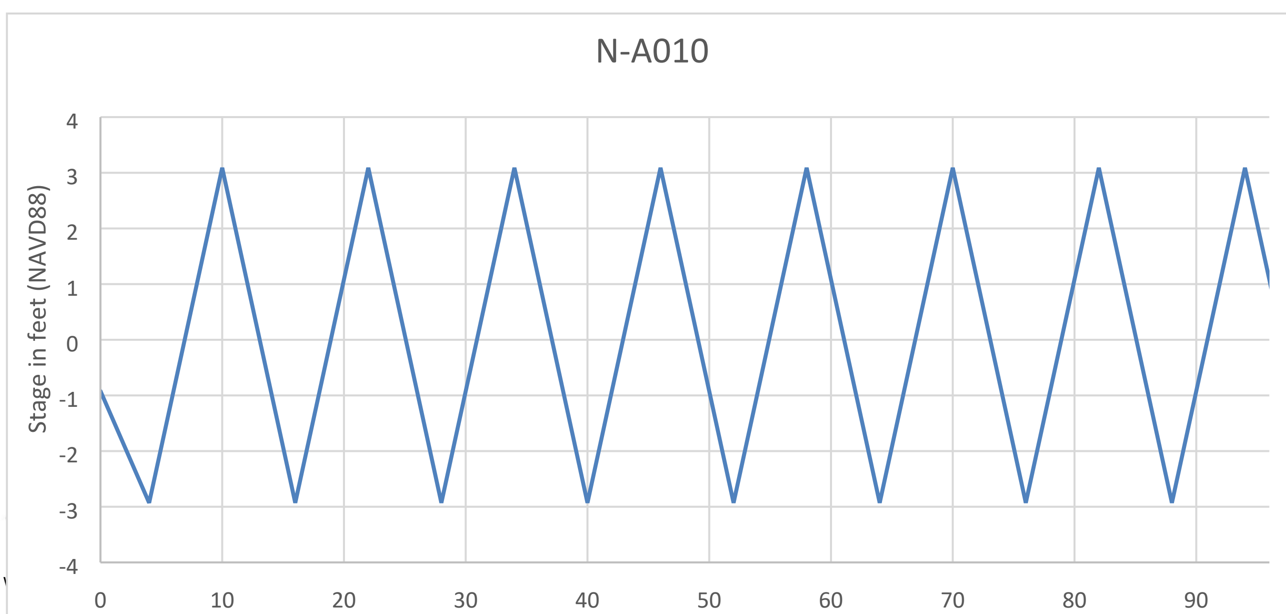


Figure 7 - Ashley River tidal condition set at Node A010 for Church Creek boundary input.

2.4.1 Results

A comparison of the observed and simulated stages at the Maxwell gauge (N-B020) are shown in the chart below. The match is considered good in showing the magnitude of reactions within the basin; however, the initial magnitude is offset causing a 3 to 4 hour offset for the timing of the water surface elevation changes.

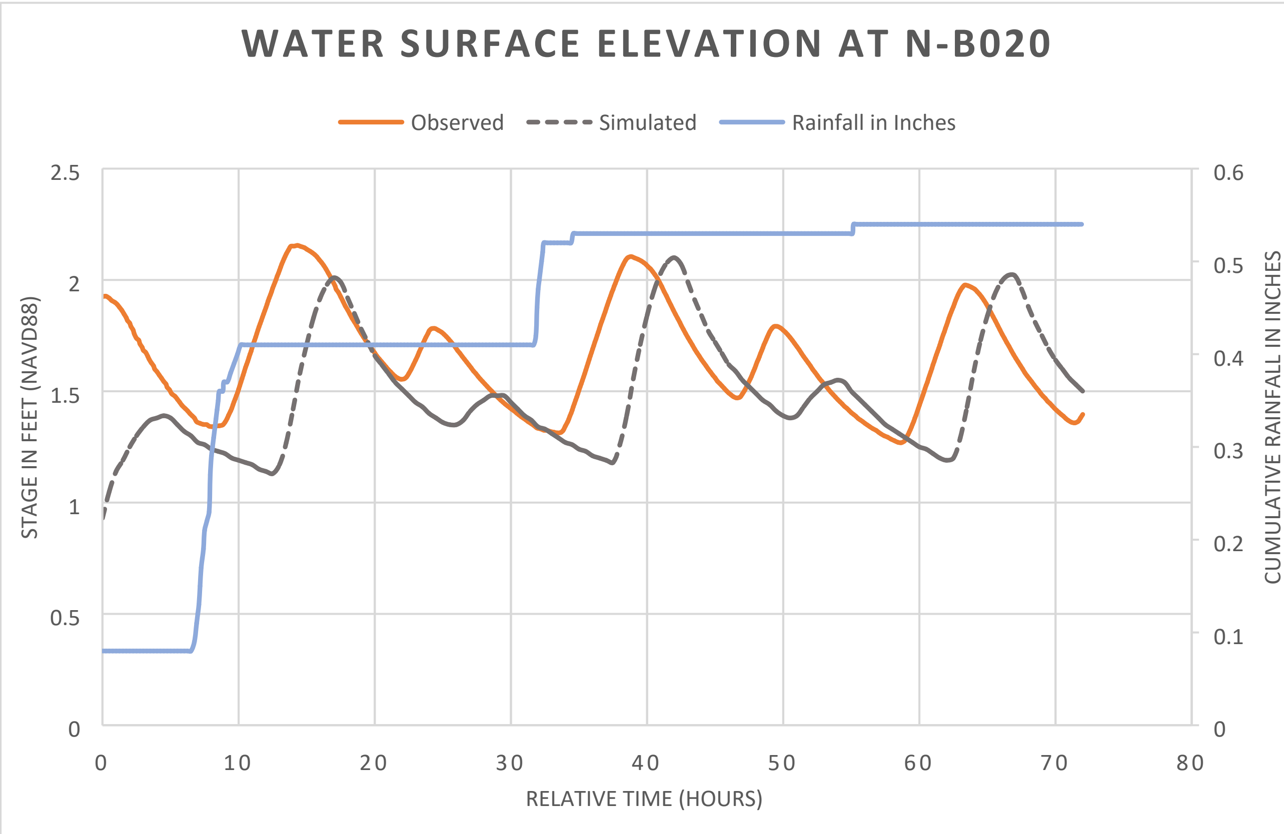


Figure 9 - Model calibration comparison of observed and simulated water surface elevations at Long Branch and West Ashley Greenway crossing, Node B020, for recorded storm event.

The simulated water surface elevation in Long Branch between US Highway 17 and West Ashley Greenway at Node LB110 is shown below. Like the comparison at Node B020, it also appears to be a good match to the observed water surface elevations for the magnitude of reactions; however, it too has an offset in the timing and initial magnitude of approximately one hour.

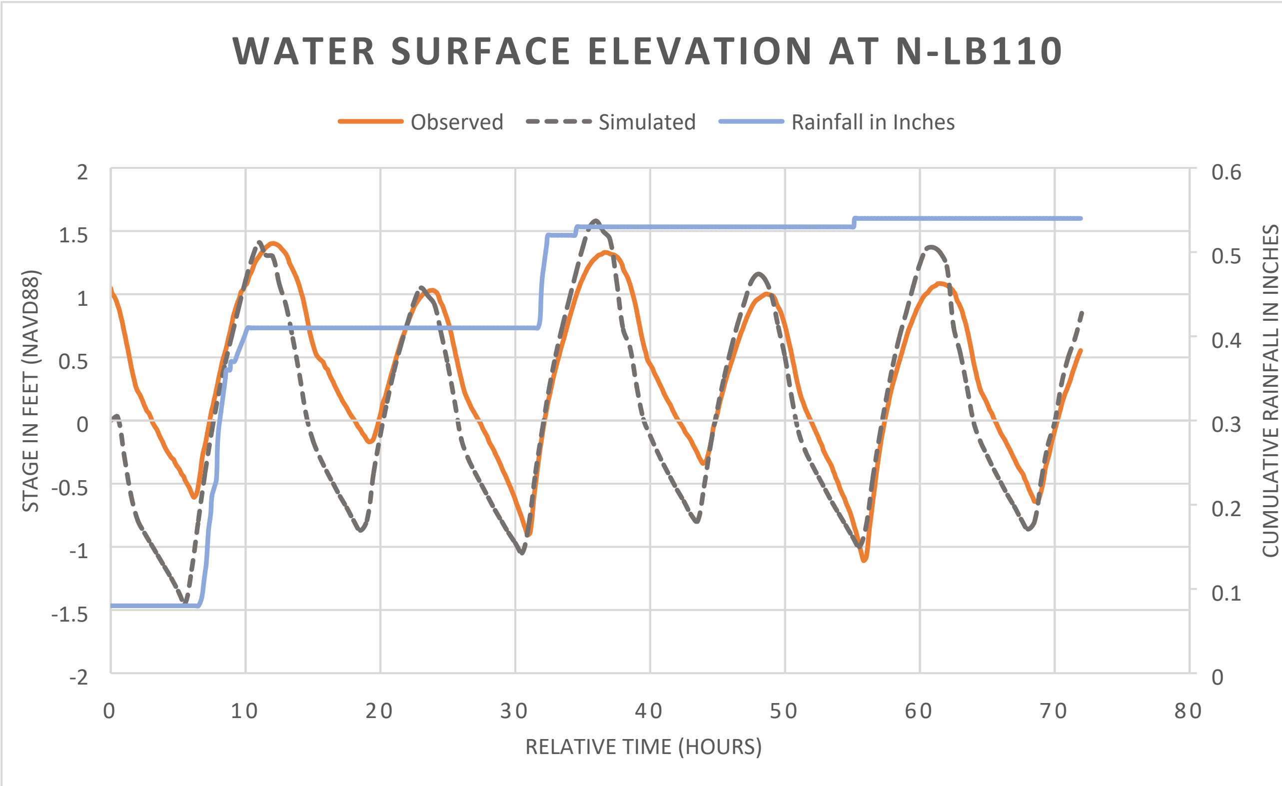


Figure 10 - Model calibration comparison of observed and simulated water surface elevations at Long Branch and Highway 17 crossing, Node LB110, for recorded storm event.

Weston & Sampson analyzed the total collected rainfall and water surface information to identify the cause of the initial and persisting offsets between simulated and observed staging. On January 11, 2020, 0.08 inches of rainfall was recorded in the West Ashley area, which was used to determine the cause of the offset at the Long Branch and Church Creek calibration nodes in both the initial staging and subsequent staging. The previous rainfall caused the water surface elevations to be slightly higher than simulated and the saturation of the soils caused the runoff volume of the 12,000-acre basin to reach conveyance channels more quickly. This could be better modeled by simulating a longer period of time to observe all collected information leading up to 00:00 1/12 2020, which would then be used to set an initial stage across the basins, known as a “hot start” of the model. Based upon the closely matching magnitude and frequency of peak water surface elevations for the observed and simulated rainfall, the model is considered calibrated and suitable for analysis of proposed improvements.

3.0 EXISTING CONDITIONS & MODELED IMPROVEMENTS

This proposed project began as a simple alternative outfall from Lake Dotterer into Long Branch to restore the hydraulic connection between Church Creek and Long Branch. As the model results were analyzed, Weston & Sampson expanded the scope to incorporate downstream improvements that were necessary to fully realize the benefits of the Lake Dotterer diversion. Additionally, it was believed that not all improvements as proposed would be able to be installed at the same time, thus scenarios were developed to demonstrate the effects of phasing the improvements over time. As a result of this wholistic project approach, the model improvements were divided into three areas: The Church Creek and Lake Dotterer connection, the Lake Dotterer and Long Branch Creek connection, and the Long Branch downstream improvements. These improvement sets were then run in various combinations to identify the range of options available to the City for implementation, recommended hydraulic requirements, and the expected outcomes.

3.1 Church Creek & Lake Dotterer Connection

3.1.1 Existing Conditions

The current outfall for Lake Dotterer is through two 5-foot by 2-foot rice trunks in an earthen dam structure separating Church Creek and Lake Dotterer. Under normal operations the gates are locked in the closed position on the Lake Dotterer side and allow one-way flow out of the lake through a weir at each trunk designed to maintain a maximum water surface elevation in the lake. During major storm events, the dam at 4-feet elevation NAVD 88 is overtopped by Church Creek causing the capacity of Lake Dotterer to be greatly reduced.

Figure 11 - Rice trunks connecting Lake Dotterer and Church Creek.

3.1.2 Modeled Improvements

Scenarios were modeled with this connection represented in the following three ways: 1) the existing connection operating in the open position, Existing Conditions model scenario, 2) the connection completely severed by a dam with elevation 8.0 ft (NAVD 88), Flow Restoration without Church Creek Connection model scenario, or 3) a connection permitted through the proposed dam with a 30-foot wide weir set at 4.0 ft elevation, Flow Restoration with Church Creek Connection model scenario. The selection of 8 feet for the dam elevation was based upon peak water surface elevations modeled for the 1% AEP storm. The selection of 4.0 feet elevation for the weir was determined by the observed modeled water surface elevation in Church Creek during the 4% AEP storm event. The water surface elevation of Church Creek is at bank-full during the 10% AEP storm, during the 4% storm, the Church Creek drainage basin begins to experience flooding due to capacity limitations of the creek and its major conveyance channels. As shown in the tables in Appendix A, the connection between Church Creek and Lake Dotterer with downstream improvements along Long Branch Creek is expected to provide significant relief to those neighborhoods immediately adjacent to Lake Dotterer and incremental relief to portions of the remainder of the Church Creek Basin.

3.2 Lake Dotterer & Long Branch Creek Connection

3.2.1 Existing Conditions

Currently, there is not a connection between Lake Dotterer and Long Branch Creek. Prior to agricultural and phosphorous mining operations and subsequent development in the West Ashley area, Church Creek and Long Branch were connected by low lying ground that flooded during heavy rains and provided a hydraulic interaction between the Church Creek and Long Branch drainage basins. On a larger scale, this connection extended between the Ashley and Stono Rivers. During the height of phosphorous mining in West Ashley, the land in what is now known as Lake Dotterer was altered to create access roads and water retention for use in mining operations. Sometime after 1920, a road was constructed at the southern edge of the lake, thus dividing the previously continuous flood plain between Church Creek and Long Branch.

3.2.2 Modeled Improvements

In order to restore the connection to Long Branch, three 42" round equivalent elliptical culverts were modeled under Glenn McConnell Parkway set with the upstream invert elevation at the Lake Dotterer normal water surface elevation. The culverts were established with one-way flow to protect Lake Dotterer from downstream drainage and potential headwater conditions in Long Branch. The elliptical culverts were selected to ensure the pipes had a low profile for crossing under Glenn McConnell Parkway while still providing the cross-sectional area necessary to allow large volumes of water to outfall from Church Creek through Lake Dotterer without increasing the Lake Dotterer water surface elevation above flood staging.

Figure 12

3.3 Downstream Improvements in Long Branch

3.3.1 Existing Conditions

Long Branch, between Glenn McConnell Parkway and the Stono

Figure 13 - Long Branch and existing flow impediments location, type, and size.

River, has four main impediments to flow. The most upstream is the impoundment between Henry Tecklenburg Road and Carolina Bay approximately 1,200 linear feet south of Glenn McConnell Parkway. This impoundment has one 36" corrugated metal pipe through it with a 42" corrugated metal pipe riser.

The next flow impediment, downstream from the first impoundment, is a dam between the Melrose and Carolina Bay neighborhoods that serves as part of a walking path. This dam has two 60" concrete culverts through it with flap gates installed on the downstream side. The flap gates are no longer operational and are stuck open approximately 6" and 9" from their closed position. The broken flap gates were modeled by approximating the effective cross-sectional area open to flow and sizing the pipe in the model with the upstream end at 60" nominal diameter tapering to the downstream end at 21" and 24" nominal diameter pipes respectively. During the 4% and 1% AEP storms, Long Branch stages at 3.31- and 4.35-feet elevation respectively and overtops the dam.

The third obstacle to unhindered flow in Long Branch is at the Highway 17 crossing. The roadway currently has one 8' X 8' box culvert to accommodate Long Branch flows; this culvert is adequate for the existing flow conditions in Long Branch during the 4% AEP storm. However, during the 1% AEP storm, the culvert capacities are exceeded and cause a slight restriction upstream of Highway 17. As upstream improvements are made to allow more flow through Long Branch, however, the box culvert creates a headwater condition in Long Branch that reduces the capacity of the drainage basin.

The final Long Branch flow restriction is at the West Ashley Greenway, which has three 42" HDPE pipes installed through the old railroad bed at varying invert elevations. These pipes restrict the flow of water into Long Branch during high tide and, under current conditions, are adequate to allow Long Branch to discharge freely at mid to low tide. The hydraulic grade lines in the figures below show the reaction at the greenway. The pipes under the greenway cause a headwater condition that affects the entire creek. The flow and velocity out of Long Branch through the greenway pipes has been observed to be very high causing turbulent flow on the downstream side of the pipes.

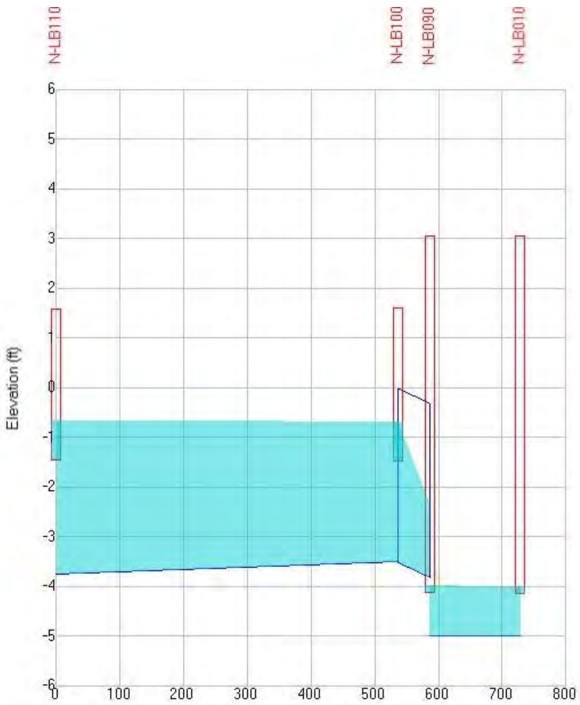


Figure 14 - Normal conditions, low tide at the greenway

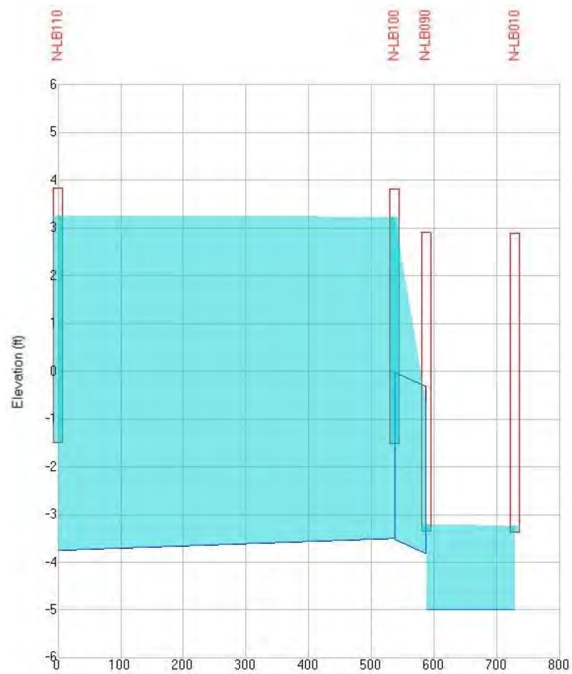


Figure 15 - 1%, 24-hour storm, low tide at the greenway

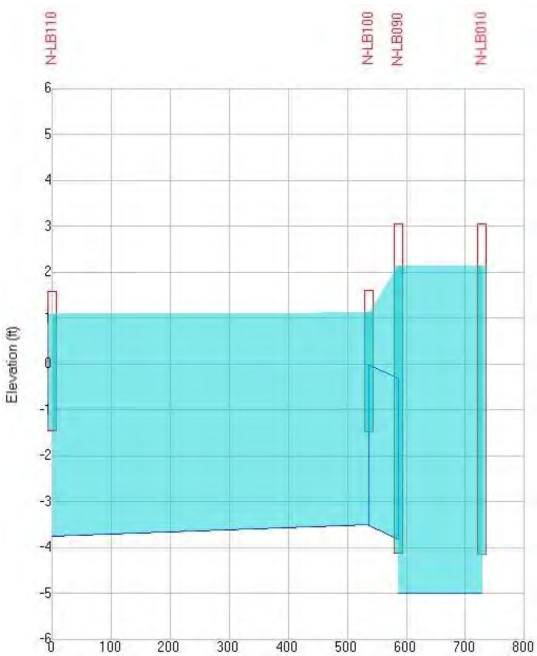


Figure 16 - 1%, 24-hour storm, high tide at the greenway

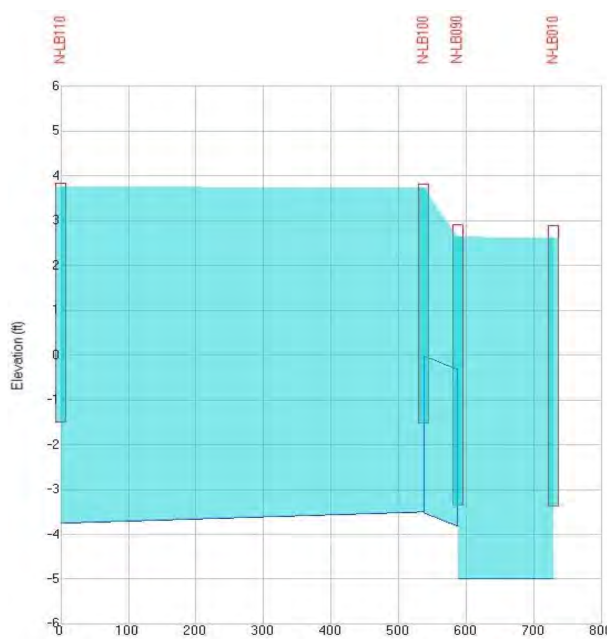


Figure 17 - Normal conditions, high tide at the greenway

A summary of the modeled peak flow rates, velocities, and percentage of pipe capacity flowing full for the existing culverts in Long Branch can be found in Table 2. It should be noted that the flows and velocities are not representative of Long Branch, as the culverts are flowing nearly at or over capacity during the 10%, 4%, and 1% AEP storm events.

Table 2 - Max flow, velocity, and percentage of pipe capacity flowing full in existing conditions flow restrictions by storm event

Existing Conditions Flow Restrictions										
Location	Culvert Quantity, Size & Shape	10% AEP Storm			4% AEP Storm			1% AEP Storm		
		Flow Rate (cfs)	Velocity (fps)	% Pipe Cap.	Flow Rate (cfs)	Velocity (fps)	% Pipe Cap.	Flow Rate (cfs)	Velocity (fps)	% Pipe Cap.
LDD	Does Not Exist	NA	NA	NA	NA	NA	NA	NA	NA	NA
Impoundment Outfall	(1) 36" Circular	23.9	3.4	100	26.0	3.7	100	28.3	4.0	100
Melrose-CB	(2)* 60" Circular	71.3	16.0**	95	85.0	18.9**	100	106.4	23.7**	100
HWY 17	(1) 8 X 8 Rectangular	225.3	4.9	92	253.0	4.8	99	281.6	4.6	100
WA Greenway	(3)* 36" Circular	249.7	9.1	100	278.3	9.9	100	313.0	11.0	100

*For multiple culverts, the higher flow rate, velocity, and percent pipe capacity of the group is represented in this table.

**Velocities for Melrose-CB pipes are higher than would be expected due to the flap gates being inoperable and partially open. The velocity shown represents the average peak velocity for the entire culvert. The peak velocity at the 60" opening is 9.0 fps during the10% AEP storm, 8.9 fps during the 4% AEP storm, and 8.9 during the 1% AEP storm.

3.3.2 Modeled Improvements

In order to ensure effective discharge of overflow water from Lake Dotterer each flow restriction downstream of Lake Dotterer was removed and modeled with oversized openings. The table below shows both the openings modeled, the effective cross-sectional area of that opening and the resulting simulated flow through that opening. The sizing recommendations for downstream improvements are based upon the predicted flow, not the modeled opening.

Table 3 - Downstream improvements modeled with sizes, flows, and location

Modeled Downstream Improvements					
Location	Link Name	Modeled Opening	10%, 24-hour Flow Rate* (cfs)	4%, 24-hour Flow Rate* (cfs)	1%, 24-hour Flow Rate* (cfs)
LDD	L-470P	(3) 42" EQ. Elliptical pipes	91.75	136.93	194.8
Impoundment Outfall	L-LB300P2	(2) 8'x8' Box Culvert	137	210	253.19
Melrose-CB	L-LB240P1	(4) 8'x8' Box Culvert	440.25	537.74	673.91
HWY 17	L-440P	(8) 8'x10' Box Culvert	936.62	1117.21	1411.32
WA Greenway	L-LB100P1	(10) 12'x12' Box Culvert	1025.34	1227.75	1567.96

*The flow rates represent the cumulative total across the group of modeled culverts.

The improvements were determined one at a time as flow could move through Long Branch unrestricted. To help reduce modeling runs and time, the openings were oversized with the intention of using the flow rate through the openings to determine the proper culvert and pipe sizes for design purposes.

4.0 MODEL RESULTS

The model simulations were divided into two categories: with or without a connection between Church Creek and Lake Dotterer and with or without downstream improvements in Long Branch.

Based upon the crude model simulation developed in July 2019 to determine if pursuit of the Lake Dotterer Flow Restoration project was a worthwhile endeavor, Weston & Sampson began this project with the intent of severing the connection between Lake Dotterer and Church Creek and determining the pipe size sufficient to convey overflow from Lake Dotterer under Glenn McConnell. The July 2019 memo indicated that allowing Church Creek to overflow into Lake Dotterer as it currently does with three one-way 36” outfall pipes into Long Branch reduces the maximum 1% AEP predicted to stage in Lake Dotterer by 0.42’ for normal tide conditions without increasing stages in Church Creek mid-basin. When the connection between Lake Dotterer and Church Creek was severed, the maximum 1% AEP was predicted to stage 0.57 feet lower in Lake Dotterer for normal tide conditions without increasing stages in Church Creek mid-basin. Because the impact to Church Creek was only 0.01 feet and the staging of Lake Dotterer was best without the connection to Church Creek, the scope of this study became to simply verify the effects downstream of Long Branch, a never-before modeled basin, when the alternative outfall was installed and Lake Dotterer’s existing outfall was dammed.

Once Weston & Sampson began to refine the Church Creek model to incorporate the Long Branch Basin, it became apparent that the July 2019 model was not comprehensive enough to accurately represent the hydraulic conditions of the downstream basin, which was due to not having a more complete understanding of the Long Branch Creek basin and setting a tidal boundary condition at the alternate outfall under the Glenn McConnell Parkway.

4.1 Lake Dotterer Flow Restoration

The following two tables show the model results for the existing conditions and four combination scenarios that were analyzed. At Lake Dotterer, the flow restoration without any downstream improvements lowers the peak staging elevation by approximately 5.5, 4.5, and 3 inches during the respective 10%, 4%, and 1% 24-hour storm events. However, the downstream water surface elevations in Long Branch staged slightly higher, by about 1 to 1.5 inches. While analyzing the hydraulic grade lines at each of the downstream restrictions, the headwaters were found to be significant enough to warrant elimination of all flow restrictions in Long Branch.

The effects of unimpeded flow through Long Branch, even with tidal influence of the Stono River, further reduced the water surface elevations in Lake Dotterer by an additional 10.5 to 11 inches for a total improvement of over 1 foot and up to 1 foot, 4 inches. The biggest impact of the downstream improvements was in Long Branch itself where the water surface elevations also greatly improved. During the 1% AEP storm, the water surface in Long Branch staged over 1 foot 4 inches lower than it currently does under existing conditions even with the proposed Lake Dotterer outfall. The increase in staging from the 10% AEP storm to the 1% AEP storm was less than 7 inches. These results demonstrate that by restoring the natural flow of Long Branch, the creek and its surrounding marsh areas regain their capacity to absorb both stormwater runoff and higher tides.

The predicted water surface elevations in Long Branch with downstream improvements were such that the Church Creek connection becomes a feasible option. In fact, the model predicts little to no changes in the water surface elevations within Lake Dotterer and Long Branch when Church Creek was allowed to flow into Lake Dotterer at a water surface elevation above 4.0 feet.

Table 4 - Peak staging elevations in Lake Dotterer for project simulations, all storms.

N-0530 (Lake Dotterer) Peak Staging (ft)					
Simulation	Existing Condition	No Downstream Improvements		With Downstream Improvements	
		Flow Restoration	Connected to Church Creek	Flow Restoration	Connected to Church Creek
10% 24- HR	3.59	3.13	3.13	2.67	2.67
4% 24-HR	4.17	3.78	3.79	3.24	3.24
1% 24-HR	4.97	4.71	4.82	4.08	4.11

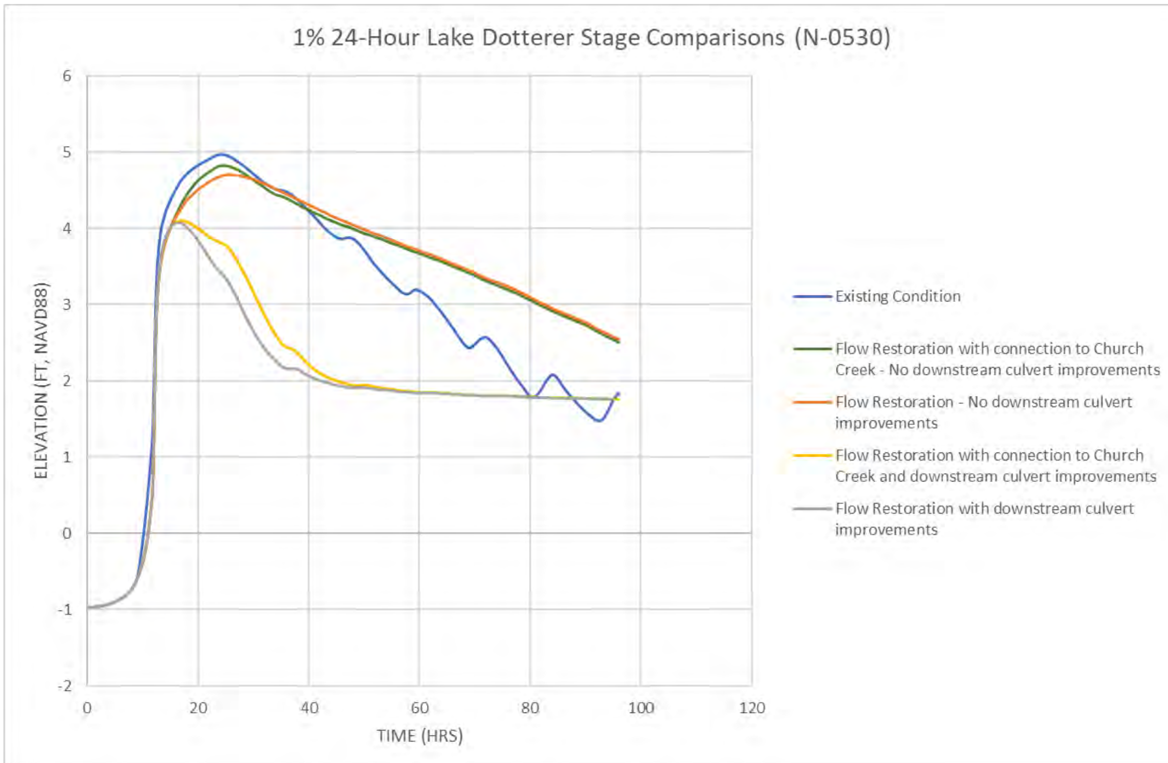
Table 5 - Peak staging elevations at Long Branch mid-point for project simulations, all storms.

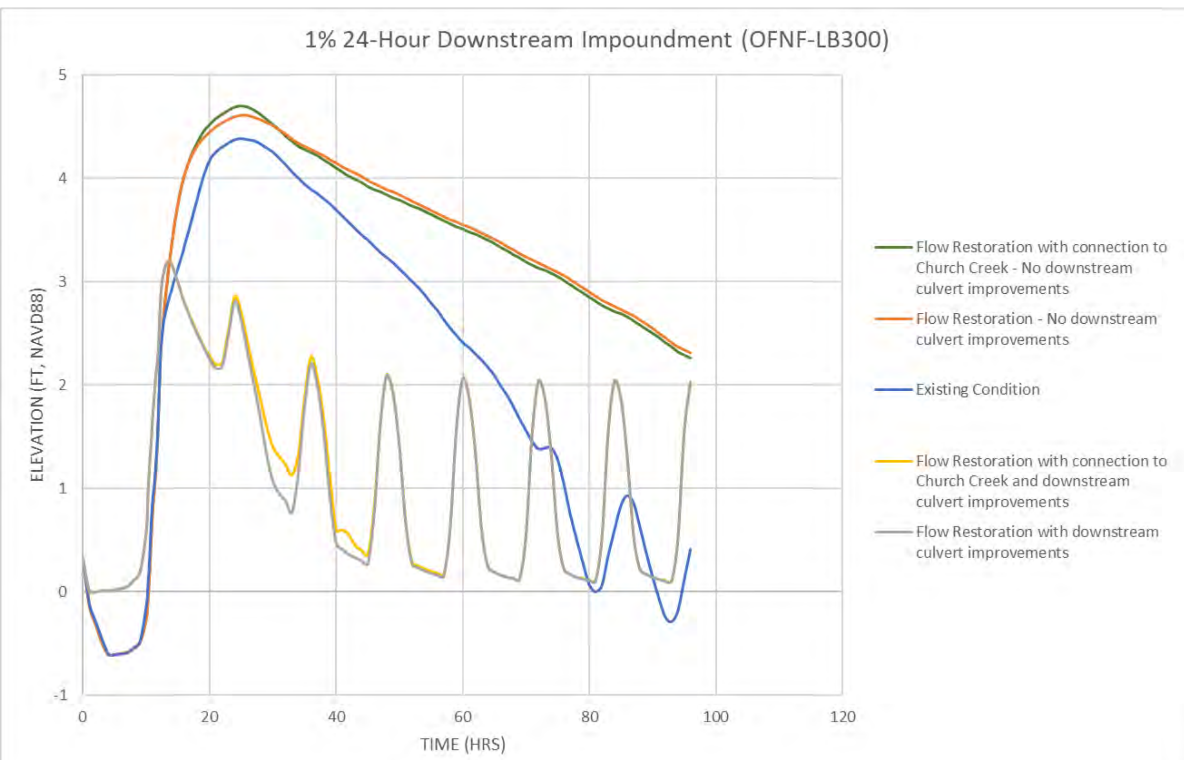
N-LB240 (Carolina Bay and Melrose Crossing) Peak Staging (ft)					
Simulation	Existing Condition	No Downstream Improvements		With Downstream Improvements	
		Flow Restoration	Connected to Church Creek	Flow Restoration	Connected to Church Creek
10% 24- HR	2.65	2.73	2.73	2.43	2.43
4% 24-HR	3.31	3.43	3.43	2.59	2.59
1% 24-HR	4.35	4.49	4.53	2.99	2.99

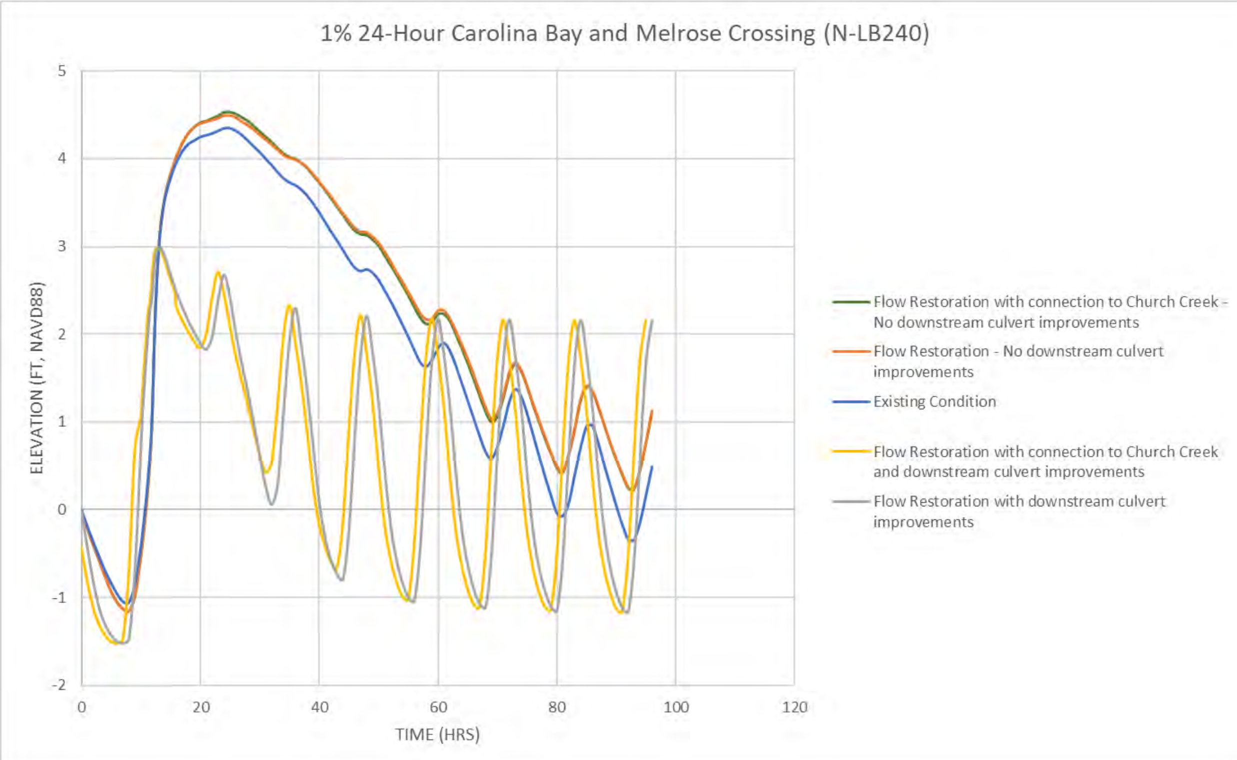
The hydrographs on the following pages show the projected benefits from upstream to downstream in Lake Dotterer and Long Branch during the 1% AEP storm. The best scenarios for the Church Creek, Lake Dotterer, and Long Branch water surface elevations are when they are able to interact as a system, restoring hydraulic flow between the Ashley and Stono Rivers and restoring the intertidal zone of Long Branch. In summary of the five modeled scenaios used to determine the effects in both Church Creek and Long Branch drainage basins and represented in the following hydrographs:

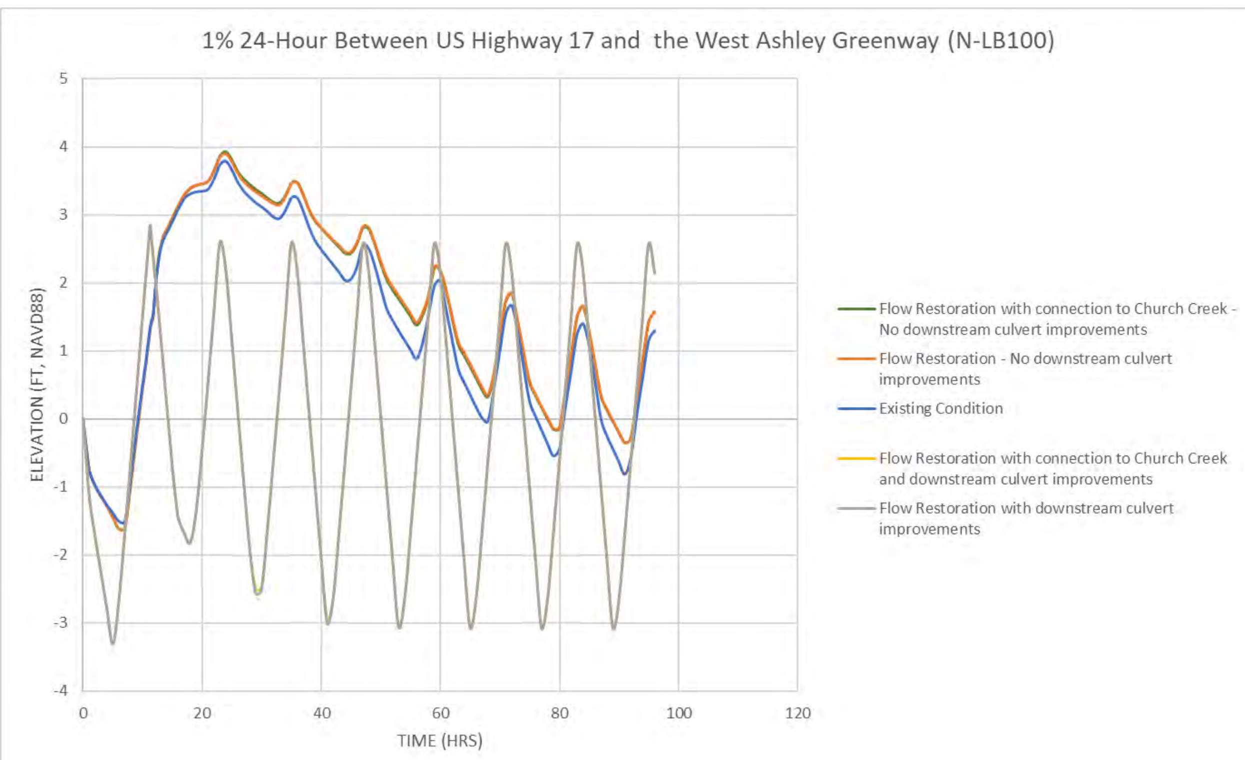
1. Existing Conditions: This scenario modeled the conditions present at the time of the report including the functioning of the rice trunks to allow for Lake Dotterer to flow into Church Creek at Node 0530 once the water surface elevation in Church Creek was drawn down. This scenario uses the existing 4-ft elevation as the height of berm between Church Creek and Lake Dotterer, which is overtopped in larger storm events. The scenario also has no connection between Lake Dotterer and Long Branch. Each of these conditions were changed one at a time in later model runs.

2. Flow restoration with connection to Church Creek – No downstream culvert improvements: This second scenario modeled the culverts under the Glenn McConnell Pkwy connecting Lake Dotterer to Long Branch with check valves preventing flow from Long Branch into Lake Dotterer. It did not allow flow through the rice trunks; however, the connection with Church Creek was modeled with an increased berm height to 8 feet elevation and a 30-foot wide weir set at 4 feet elevation. This allowed some water to flow between Church Creek and Lake Dotterer, but only above 4-ft. No downstream culvert improvements were completed along Long Branch between the Glenn McConnell Pkwy and the Stono River.
3. Flow restoration – No downstream culvert improvements: This third scenario modeled the culverts under the Glenn McConnell Pkwy connecting Lake Dotterer to Long Branch, with check valves preventing flow from Long Branch to Lake Dotterer. It also did not allow flow through the rice trunks and the berm was raised to 8-ft, but no weir was modeled, effectively severing the connection between CC and LD. No downstream culvert improvements were completed along Long Branch between Glenn McConnell Parkway and the Stono River.
4. Flow restoration with connection to Church Creek and downstream culvert improvements: The fourth scenario is the same as the second scenario (no rice trucks, 8-ft berm with 4-ft weir, Glenn McConnell Pkwy culverts) but with downstream culvert improvements being modeled at the impoundment, the Melrose/Carolina Bay crossing, US17, and the West Ashley Greenway allowing for unimpeded flow between Glenn McConnell Parkway and the Stono River.
5. Flow restoration and downstream culvert improvements: The last scenario is the same as the third scenario (no connection between Church Creek and Lake Dotterer with Glenn McConnell Pkwy culverts) along with downstream culvert improvements being modeled at the impoundment, the Melrose/Carolina Bay crossing, US17, and the Greenway allowing for unimpeded flow between Glenn McConnell Parkway and the Stono River.


1% 24-Hour Lake Dotterer Stage Comparisons (N-0530)
ELEVATION (FT, NAVD88)
TIME (HRS)
Existing Condition
Flow Restoration with connection to Church Creek - No downstream culvert improvements
Flow Restoration - No downstream culvert improvements
Flow Restoration with connection to Church Creek and downstream culvert improvements
Flow Restoration with downstream culvert improvements


1% 24-Hour Downstream Impoundment (OFNF-LB300)
ELEVATION (FT, NAVD88)
TIME (HRS)
Flow Restoration with connection to Church Creek - No downstream culvert improvements
Flow Restoration - No downstream culvert improvements
Existing Condition
Flow Restoration with connection to Church Creek and downstream culvert improvements
Flow Restoration with downstream culvert improvements


1% 24-Hour Carolina Bay and Melrose Crossing (N-LB240)
ELEVATION (FT, NAVD88)
5
4
3
2
1
0
-1
-2
0
20
40
60
80
100
120
TIME (HRS)
Flow Restoration with connection to Church Creek - No downstream culvert improvements
Flow Restoration - No downstream culvert improvements
Existing Condition
Flow Restoration with connection to Church Creek and downstream culvert improvements
Flow Restoration with downstream culvert improvements


1% 24-Hour Between US Highway 17 and the West Ashley Greenway (N-LB100)
ELEVATION (FT, NAVD88)
5
4
3
2
1
0
-1
-2
-3
-4
0
20
40
60
80
100
120
TIME (HRS)
Flow Restoration with connection to Church Creek - No downstream culvert improvements
Flow Restoration - No downstream culvert improvements
Existing Condition
Flow Restoration with connection to Church Creek and downstream culvert improvements
Flow Restoration with downstream culvert improvements

4.2 Scenario Combinations for Lake Dotterer Flow Restoration

The following table provides the peak staging elevations for the key nodes in Church Creek, Lake Dotterer, and Long Branch during the combination of Lake Dotterer Flow Restoration with the West Ashley Circle Retention Pond and Mid-Basin Storage projects. In general, there were no negative impacts found by combining any of the three projects together, though the best resulting overall impacts in Church Creek were when all three were simulated together. Please see Appendix B for a nodal map depicting the location of these nodes. Compared to model results from the Church Creek Drainage Improvements Analysis Report dated January 2020, during the 1% AEP 24-hour storm with Mid-Basin and West Ashley Circle storage facilities and flow restored between Church Creek and Long Branch the water surface elevation at N-B020 is predicted to be reduced by an additional 0.4 inches over the Mid-Basin and West Ashley Circle storage improvements alone. Hydrographs for each node can be found in Appendix D.

Table 6 - Peak Staging Elevations by Node for the Flow Restoration and Combination Scenarios.

Flow Restoration in Combination Node Peak Staging (ft)					
			Connected to Church Creek with Downstream Improvements		
1% 24-hour Simulation	Existing Condition	With Downstream Improvements	Mid-Basin Storage & WAC	Mid-Basin Storage	WAC Storage
N-0210	4.96	4.89	4.71	4.75	4.68
N-0530	4.97	4.08	4.11	4.11	4.12
N-A120	7.01	6.99	6.89	6.95	6.85
N-B020	7.35	7.34	7.10	7.17	7.19
N-B160	7.77	7.76	7.56	7.64	7.64
N-LB100	3.83	2.85	2.86	2.86	2.86
N-LB130	4.19	2.75	2.75	2.75	2.75
N-LB240	4.35	2.99	2.99	2.99	2.99
N-LB370	4.71	4.63	4.63	4.63	4.63
OFNF-LB300	4.38	3.2	3.20	3.20	3.20

5.0 CONCLUSIONS & RECOMMENDATIONS

In conclusion, the Lake Dotterer Flow Restoration project is to the benefit of both Church Creek and Lake Dotterer when fully implemented with a modified weir connection between Church Creek and Lake Dotterer, outfall pipes installed under Glenn McConnell between Lake Dotterer and Long Branch, and downstream improvements in Long Branch that restore open flow. Weston & Sampson recommends the following:

- For the immediate Glenn McConnell Parkway road widening project, the outfall connection should be large enough to convey a minimum flow of 230 cfs. The three 42" round equivalent elliptical pipes are predicted to be sufficient for the recommended project scope. The pipe shape is not restricted to elliptical so long as the culvert(s) can accommodate the minimum flow. Elevation of the inlet should be set at the "normal" water surface elevation for Lake Dotterer.
- While conducting field work for the study, the flap gates on the 60-inch culverts between Carolina Bay and Melrose were found to be stuck open approximately 6 and 8 inches and no longer functioning properly. It was believed that removing the gates would improve flows in Long Branch and provide positive impacts to the surrounding areas. The existing condition scenario was run for the 1% AEP storm with the existing broken flap gates and with the flap gates removed. The model results showed that there were no improvements within Long Branch by removing the gates because the flow during the 1% AEP storm overtops the dike regardless. Removing the gates would improve flow during less severe storm events, however, as the water surface elevation remains below flood levels in Long Branch under existing conditions it is not necessary. If the broken flap gates were removed, there would not be any adverse impacts upstream or downstream of the Carolina Bay and Melrose crossing.
- If the City of Charleston should choose to delay improvements to the long Branch downstream restrictions at the impoundment outfall, Carolina Bay and Melrose crossing, Highway 17, and West Ashely Greenway, then the connection between Lake Dotterer and Long Branch should be plugged until such time that improvements are installed as described in this study. During the 1% storm, without downstream improvements, the connection with Lake Dotterer will cause the water surface elevation at Nodes LB300 and LB240 to be above flood stage elevation and at Nodes LB130 and LB100 to increase, which under existing conditions is already above flood stage.
- The City, if it chooses to, can make downstream improvements to Long Branch in subsequent phases following the Lake Dotterer alternate outfall installation under Glenn McConnell Parkway. Once all improvements are made, the connection between Lake Dotterer and Church Creek can be modified and the connection between Lake Dotterer and Long Branch can be unplugged to allow restored flows between Church Creek and Long Branch.
- Predicted flows for downstream improvements during the 1% AEP storm and possible culvert sizes and quantities that can accommodate those flows are shown Table 6. The culvert sizes accommodate the pipe flowing at 75% full to allow for obstruction and debris collection between periods of maintenance. Manning's equation was used to calculate culvert sizes, slopes were assumed to be 0.5%, and Manning Roughness Factor was assumed to be 0.013 for smooth concrete. To reduce the size of the culverts, the slope could be increased, however, an increase in slope will also increase the velocity within the culvert; velocities during the 1% storm should not exceed 15 fps and velocities during the 50% storm should exceed 4.0 fps.

Table 7 - Culvert size options for downstream improvements to accommodate flows.

Culvert Sizes for Downstream Improvements							
Location	1%, 24-hour Flow Rate (cfs)	Circular	Circular Max Velocity @ 75% Full (fps)	Elliptical	Elliptical Max Velocity @ 75% Full (fps)	Rectangular	Rectangular Max Velocity @ 75% Full (fps)
LDD	194.8	(3) 42” ID	8.4	(3) 34” X 53”	8.7	(1) 8’ X 4’	11.6
Impoundment Outfall	253.19	(4) 42” ID	8.4	(4) 34” X 53”	8.7	(1) 8’ X 4’	11.6
Melrose-CB	673.91	(4) 60” ID	10.7	(4) 48” X 76”	10.8	(2) 10’ X 4’	12.3
HWY 17	1,411.32	(3) 90” ID	14.0	(4) 72” X 113”	14.2	(2) 14’ X 5’	14.7
WA Greenway	1,567.96	(4) 84” ID	13.3	(4) 87” X 136”	14.2	(2) 15’ X 5’	14.9

For the next phase of engineering, the following are recommended:

1. Determine the optimal height of the berm between Church Creek and Lake Dotterer to ensure that the two can be completely separated. Included in the determination should be the potential for a 2.5-ft sea level rise.
2. Model and design an adjustable weir to be able to fully control the exchange of water between Lake Dotterer and Church Creek. This should account for the possibility of slowly reducing the height of the weir at the end of a storm event to allow water staged in Church Creek to outfall through Long Branch while not adversely affecting Lake Dotterer or Long Branch.
3. Determine the downstream improvements along Long Branch and ensure no adverse effects are felt by any adjacent properties. Included in the determination should be the use of muted tide gates and culverts with check valves. Culverts should be sized with a 1.25 factor of safety to align with current Church Creek basin design standards.

6.0 WORKS CITED

United States Geological Survey. *Johns Island, South Carolina*. Reston: U.S. Department of the Interior, 1944. Map.

—. *Johns Island, South Carolina*. Reston: U.S. Department of the Interior, 2011. Map.

—. *Johns Island, South Carolina Topography*. Reston: U. S. Department of the Interior, 1919. Map.

Waggonner & Ball. *Dutch Dialogues Charleston*. Charleston: Waggonner & Ball, 2019.

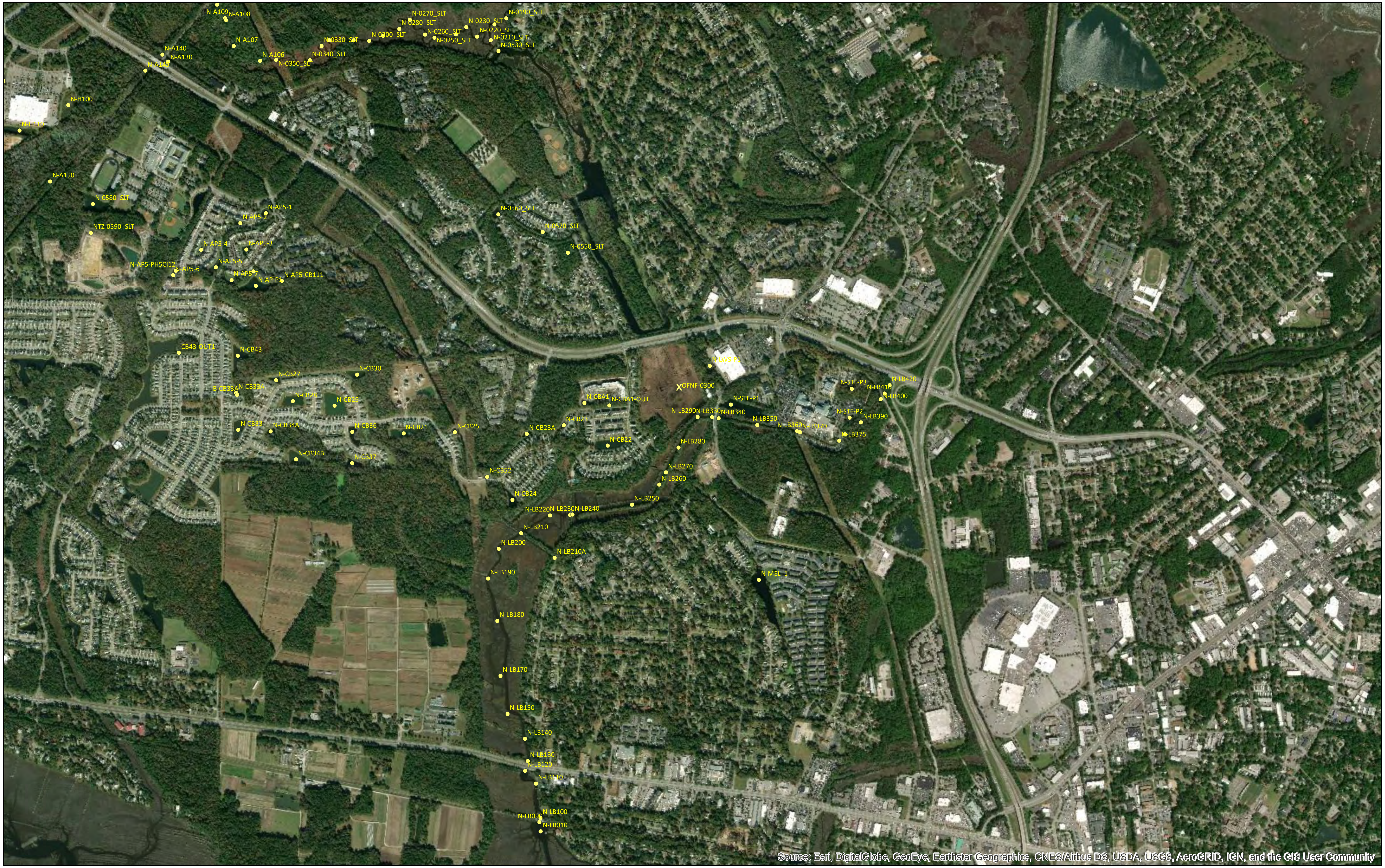
APPENDIX A

Model Results Table

Flow Restoration Peak Staging (ft)					
Simulation	Existing Conditions	With Downstream Improvements		No Downstream Improvements	
		Flow Restoration	Connected to Church Creek	Flow Restoration	Connected to Church Creek
N-0210					
10% 24-HR	3.58	3.65	3.65	3.65	3.64
4% 24-HR	4.15	4.14	4.41	4.14	4.14
1% 24-HR	4.96	4.89	4.75	4.89	4.83
N-0530					
10% 24- HR	3.59	2.67	2.67	3.13	3.13
4% 24-HR	4.17	3.24	3.24	3.78	3.79
1% 24-HR	4.97	4.08	4.11	4.71	4.82
N-A120					
10% 24- HR	5.39	5.39	5.39	5.39	5.39
4% 24-HR	6.09	6.08	6.08	6.08	6.08
1% 24-HR	7.01	6.99	6.96	6.99	6.97
N-B020					
10% 24- HR	5.78	5.79	5.79	5.79	5.79
4% 24-HR	6.48	6.48	6.48	6.48	6.48
1% 24-HR	7.35	7.34	7.33	7.34	7.33
N-B160					
10% 24- HR	6.12	6.13	6.13	6.13	6.13
4% 24-HR	6.86	6.87	6.87	6.87	6.87
1% 24-HR	7.77	7.76	7.76	7.76	7.76
N-LB100					
10% 24- HR	2.58	2.84	2.84	2.64	2.64
4% 24-HR	3.00	2.85	2.85	3.09	3.09
1% 24-HR	3.83	2.85	2.86	3.94	3.96
N-LB130					
10% 24- HR	2.54	2.67	2.67	2.60	2.60
4% 24-HR	3.14	2.70	2.70	3.26	3.26
1% 24-HR	4.19	2.75	2.75	4.33	4.36
N-LB240					
10% 24- HR	2.65	2.43	2.43	2.73	2.73
4% 24-HR	3.31	2.59	2.59	3.43	3.43
1% 24-HR	4.35	2.99	2.99	4.49	4.53
N-LB370					
10% 24- HR	3.14	3.41	3.41	3.14	3.14
4% 24-HR	3.82	3.90	3.90	3.83	3.83
1% 24-HR	4.71	4.63	4.63	4.75	4.75
OFNF-LB300					
10% 24- HR	2.65	2.50	2.50	3.00	3.01
4% 24-HR	3.27	2.76	2.76	3.68	3.69
1% 24-HR	4.38	3.20	3.20	4.61	4.70

APPENDIX B

Lake Dotterer & Long Branch Nodal Map



N-A109
N-A108
N-A107
N-A106
N-A140
N-A130
N-H100
N-A150
N-0580_SLT
NTZ-0590_SLT
N-0270_SLT
N-0280_SLT
N-0260_SLT
N-0250_SLT
N-0230_SLT
N-0220_SLT
N-0210_SLT
N-0190_SLT
N-0530_SLT
N-0330_SLT
N-0300_SLT
N-0340_SLT
N-0350_SLT
N-0560_SLT
N-0570_SLT
N-0550_SLT
N-AP5-1
N-AP5-3
N-AP5-4
N-AP5-6
N-AP5-PHSCI12
N-AP5-CB111
CB43-OUT1
N-CB43
N-CB27
N-CB30
N-CB28
N-CB29
N-CB33
N-CB34A
N-CB36
N-CB21
N-CB25
N-CB34B
N-CB37
N-CB23A
N-CB23
N-CB22
N-CBA1
N-CBA1-OUT
N-CB52
N-CB24
OFNF-0300
N-STF-P1
N-STF-P2
N-STF-P3
N-LB420
N-LB410
N-LB400
N-LB390
N-LB375
N-LB370
N-LB360
N-LB350
N-LB340
N-LB330
N-LB290
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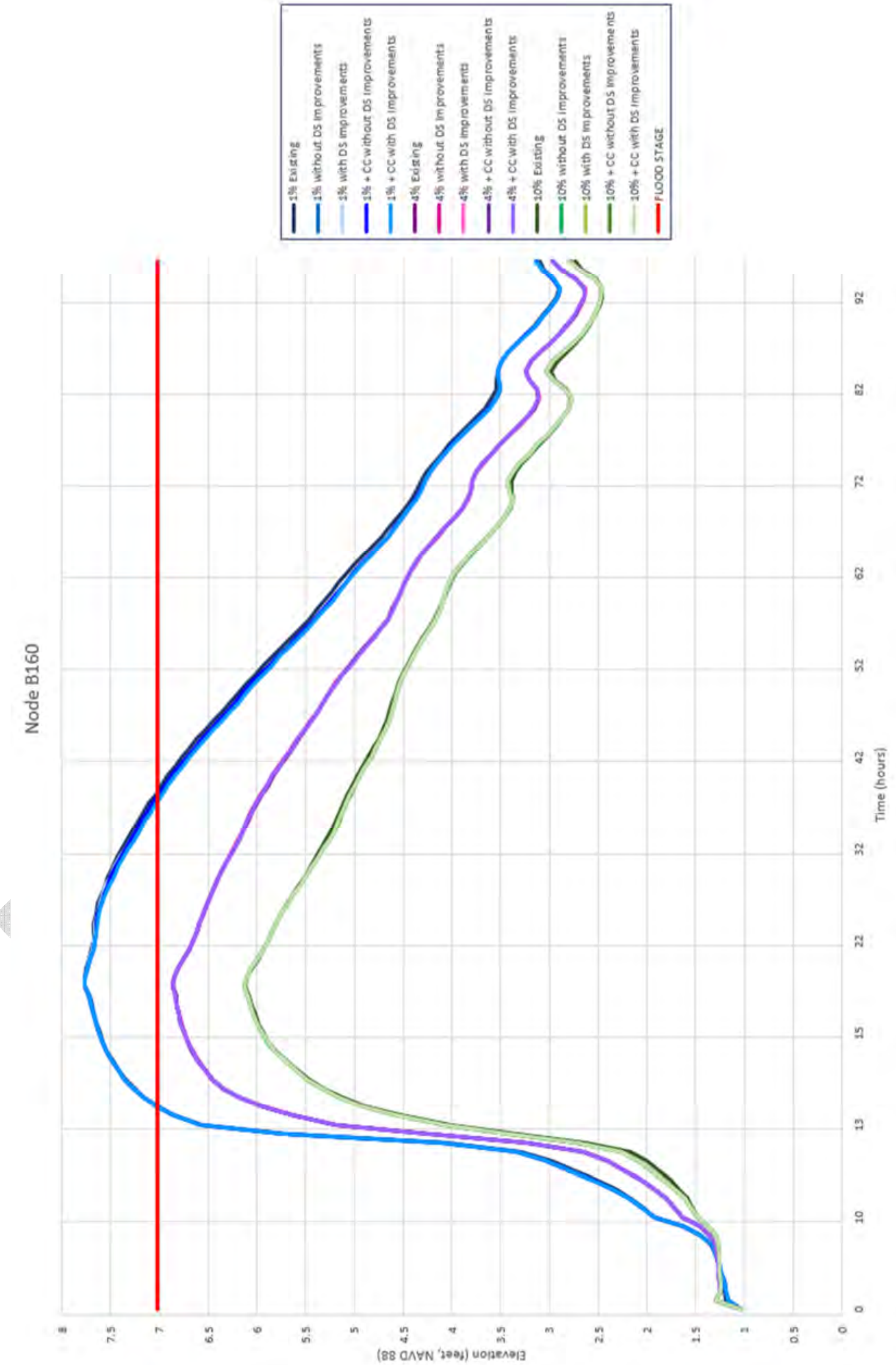
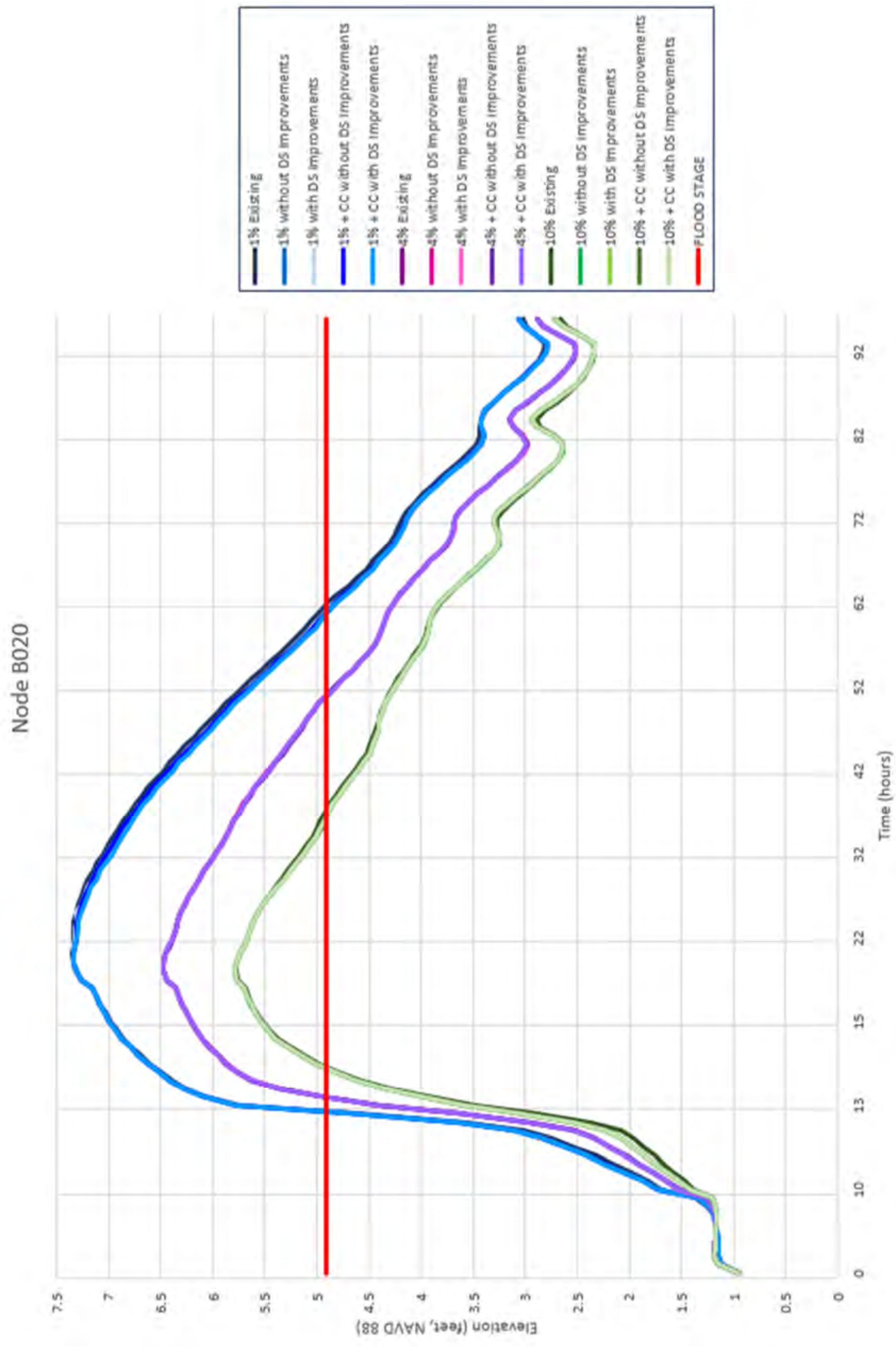
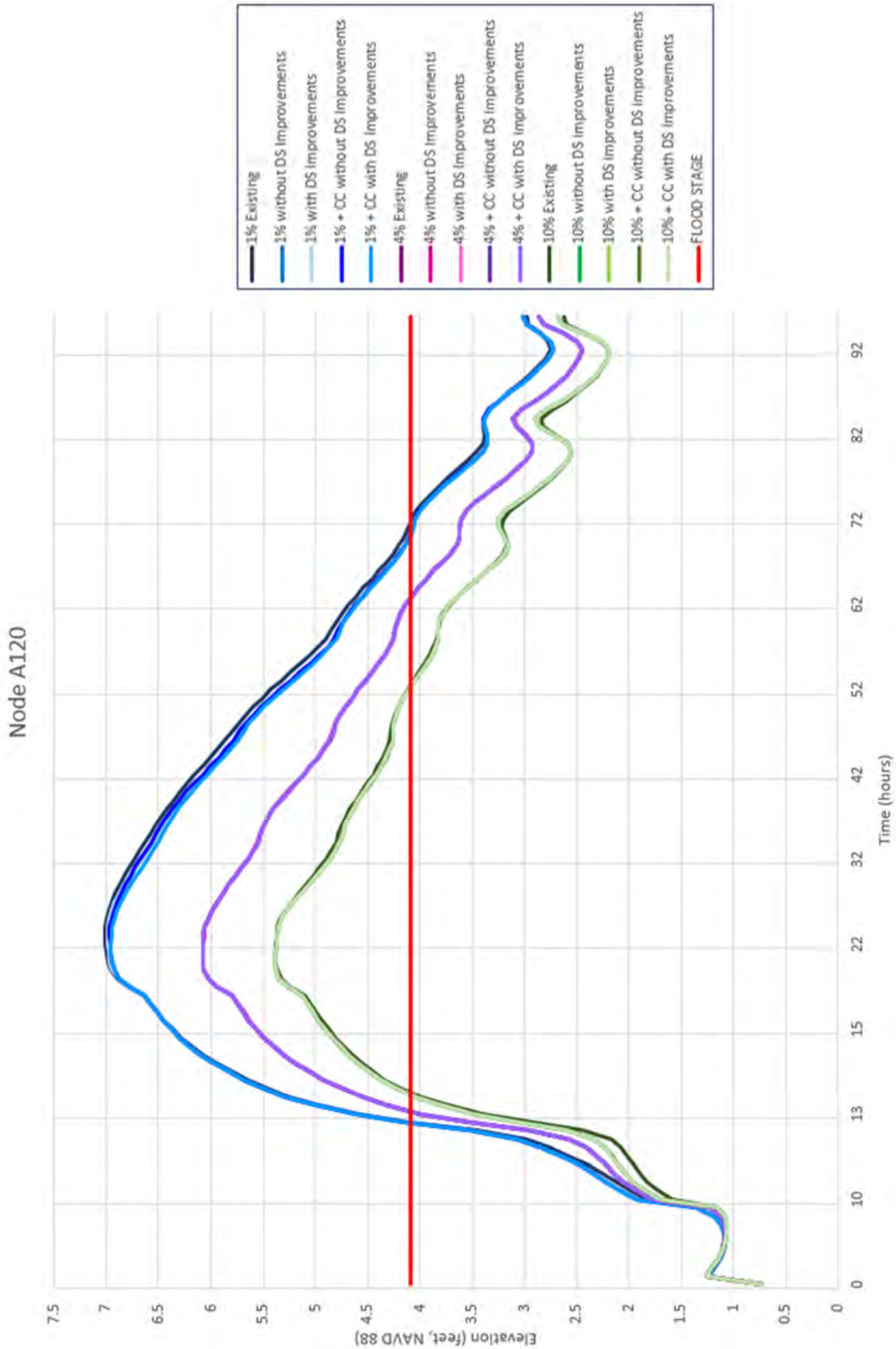
N-LB240
N-LB230
N-LB220
N-LB210
N-LB210A
N-LB200
N-LB190
N-LB180
N-LB170
N-LB150
N-LB140
N-LB130
N-LB120
N-LB110
N-LB100
N-LB090
N-LB010
N-MEL_1
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

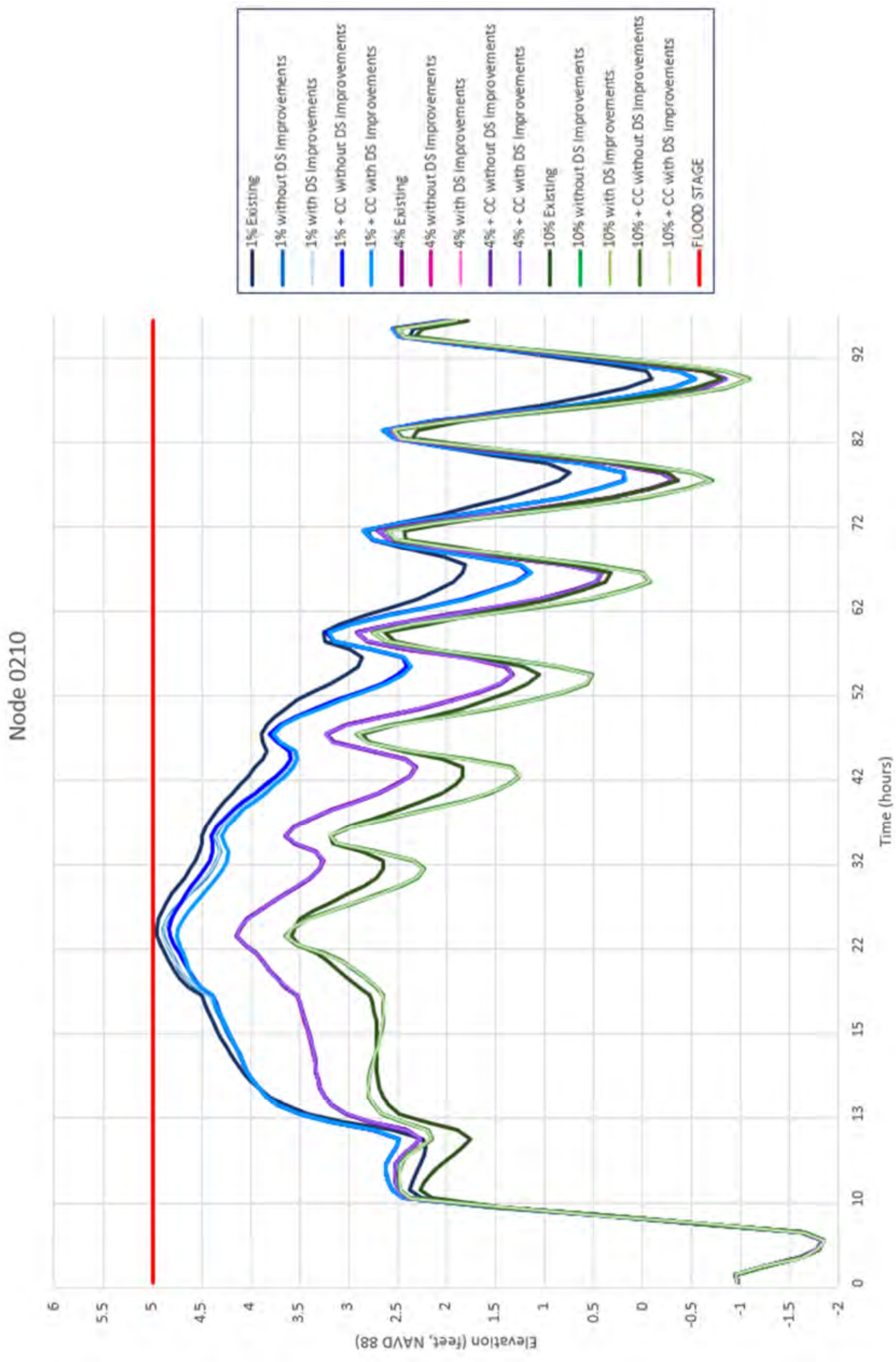
APPENDIX C

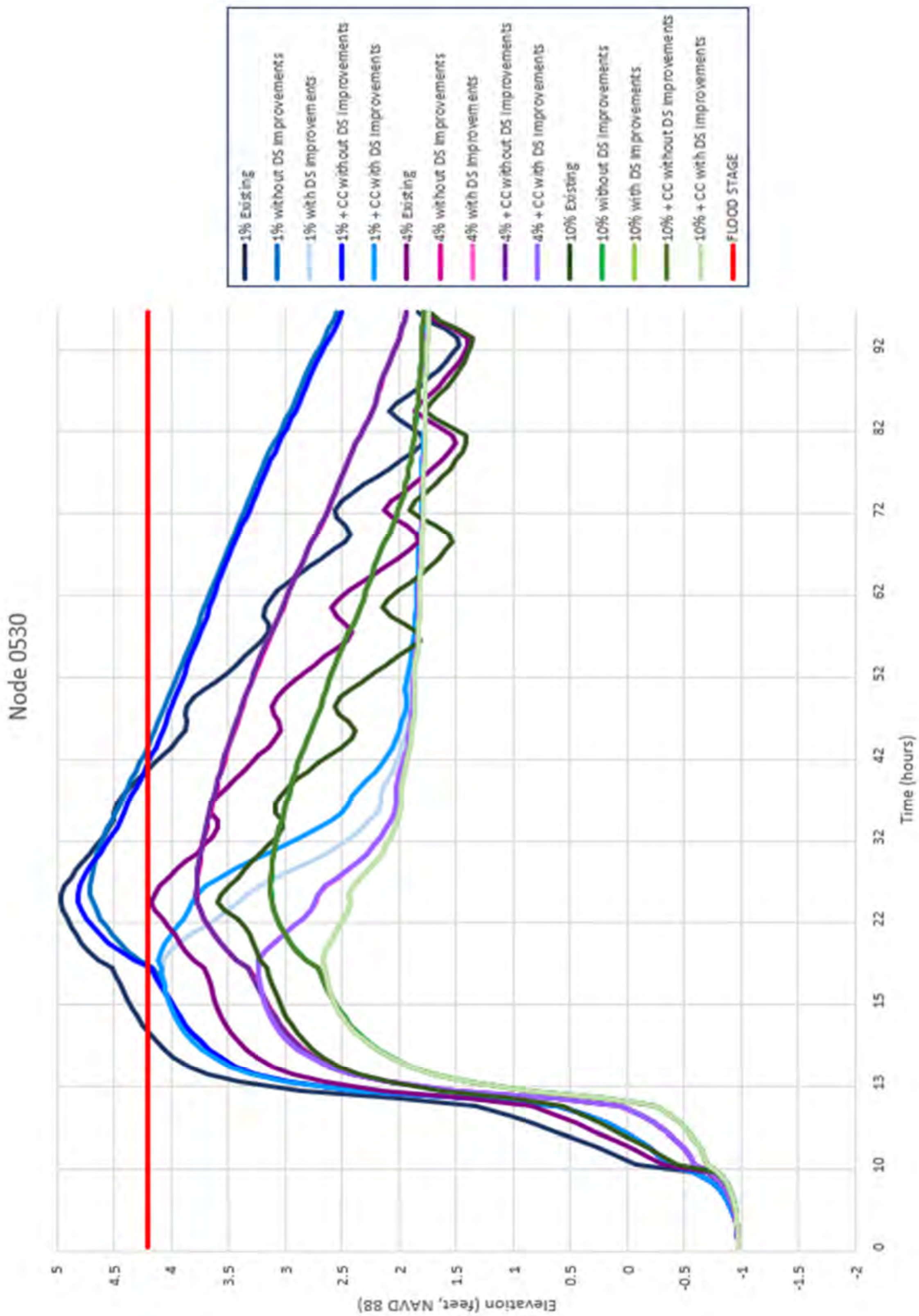
Hydrographs by Node for Lake Dotterer Flow Restoration

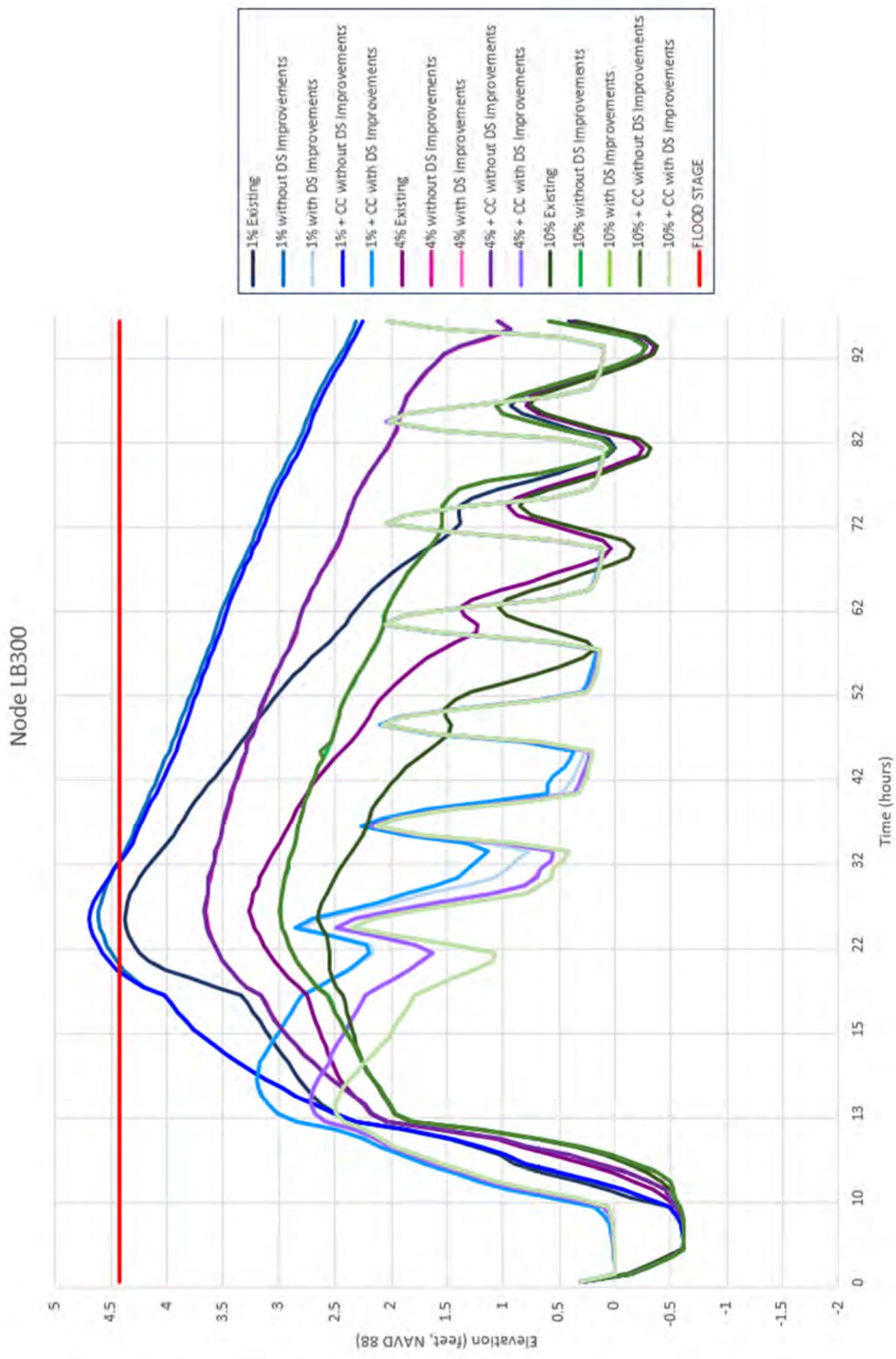

Node B160
Elevation (feet, NAVD 88)
Time (hours)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
10
13
15
22
32
42
52
62
72
82
92
1% Existing
1% without DS improvements
1% with DS improvements
1% + CC without DS improvements
1% + CC with DS improvements
4% Existing
4% without DS improvements
4% with DS improvements
4% + CC without DS improvements
4% + CC with DS improvements
10% Existing
10% without DS improvements
10% with DS improvements
10% + CC without DS improvements
10% + CC with DS improvements
FLOOD STAGE

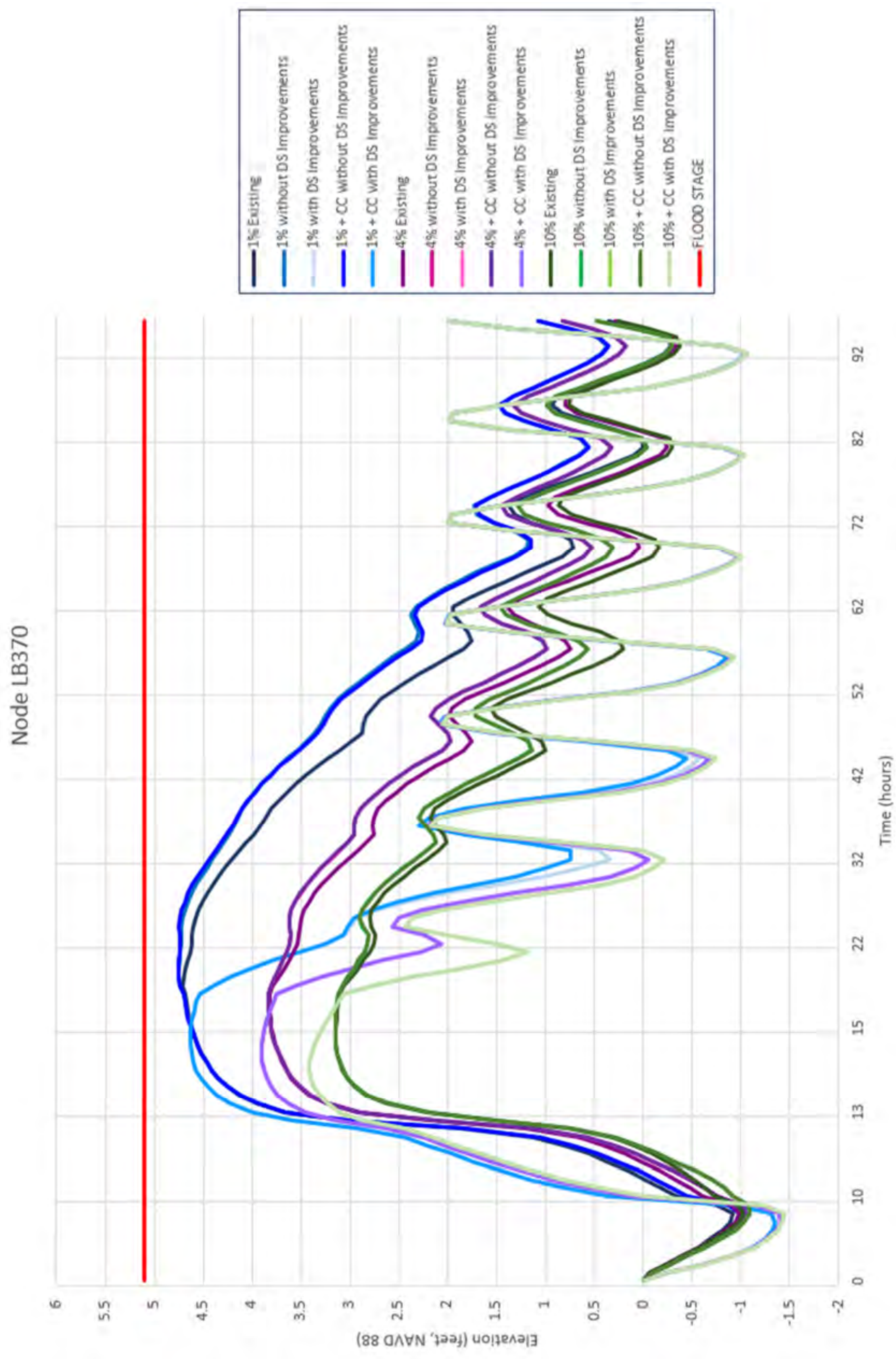

Node B020
1% Existing
1% without DS improvements
1% with DS improvements
1% + CC without DS improvements
1% + CC with DS improvements
4% Existing
4% without DS improvements
4% with DS improvements
4% + CC without DS improvements
4% + CC with DS improvements
10% Existing
10% without DS improvements
10% with DS improvements
10% + CC without DS improvements
10% + CC with DS improvements
FLOOD STAGE
Elevation (feet, NAVD 88)
Time (hours)

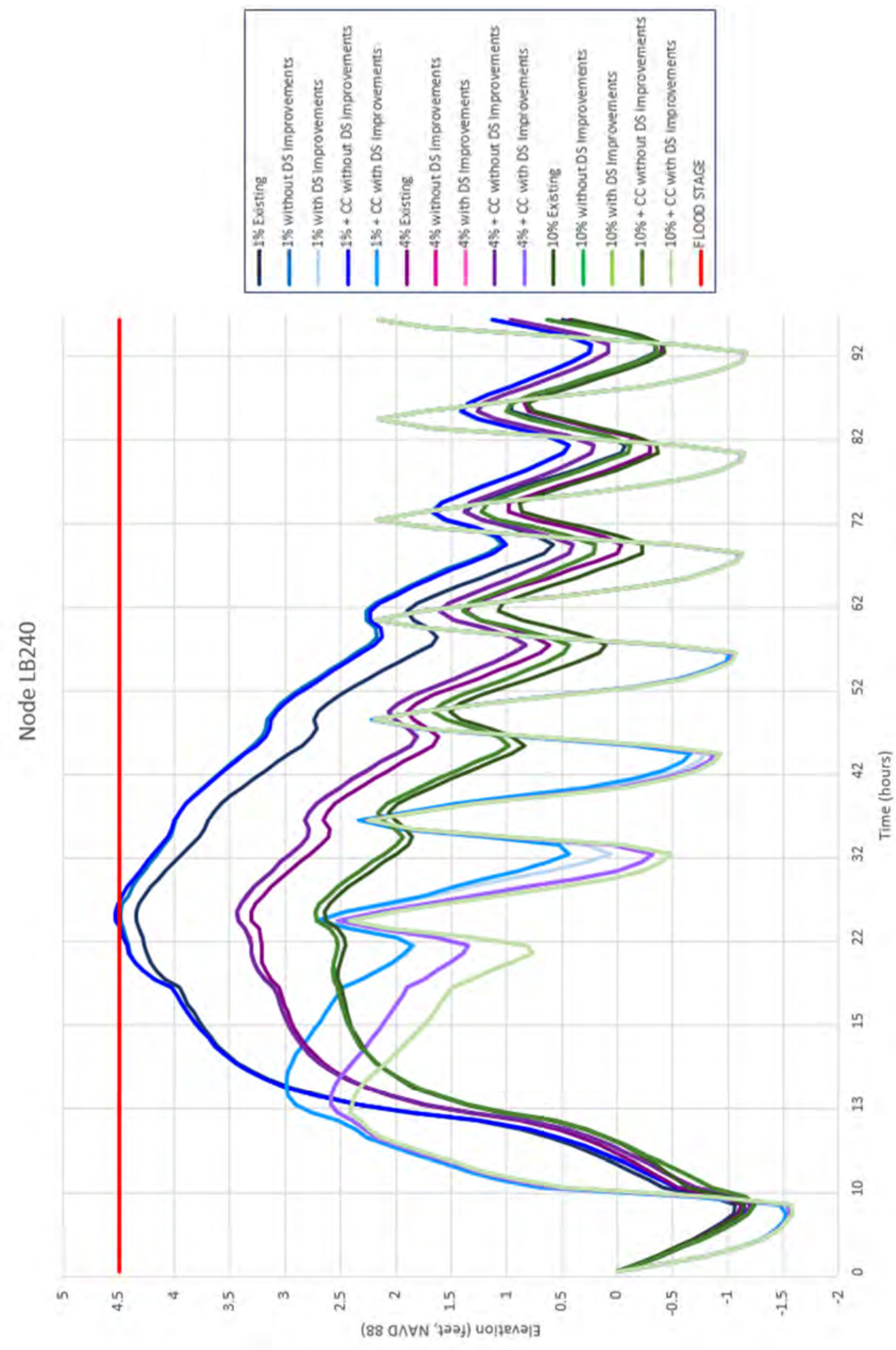

Node A120
Elevation (feet, NAVD 88)
Time (hours)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
0
10
13
15
22
32
42
52
62
72
82
92
1% Existing
1% without DS Improvements
1% with DS Improvements
1% + CC without DS Improvements
1% + CC with DS Improvements
4% Existing
4% without DS Improvements
4% with DS Improvements
4% + CC without DS Improvements
4% + CC with DS Improvements
10% Existing
10% without DS Improvements
10% with DS Improvements
10% + CC without DS Improvements
10% + CC with DS Improvements
FLOOD STAGE

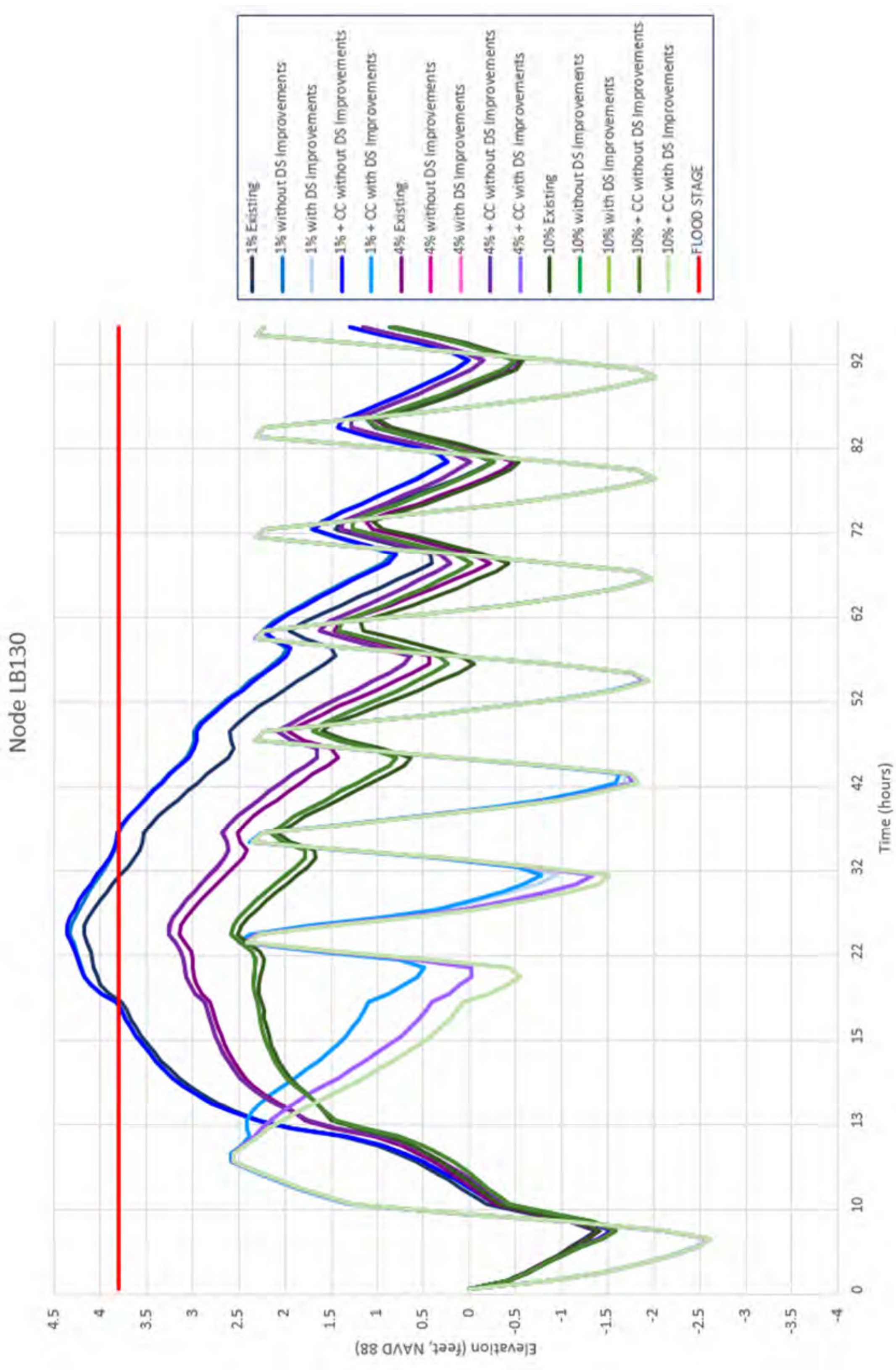

Node 0210
1% Existing
1% without DS Improvements
1% with DS Improvements
1% + CC without DS Improvements
1% + CC with DS Improvements
4% Existing
4% without DS Improvements
4% with DS Improvements
4% + CC without DS Improvements
4% + CC with DS Improvements
10% Existing
10% without DS Improvements
10% with DS Improvements
10% + CC without DS Improvements
10% + CC with DS Improvements
FLOOD STAGE
Elevation (feet, NAVD 88)
Time (hours)
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
10
13
15
22
32
42
52
62
72
82
92

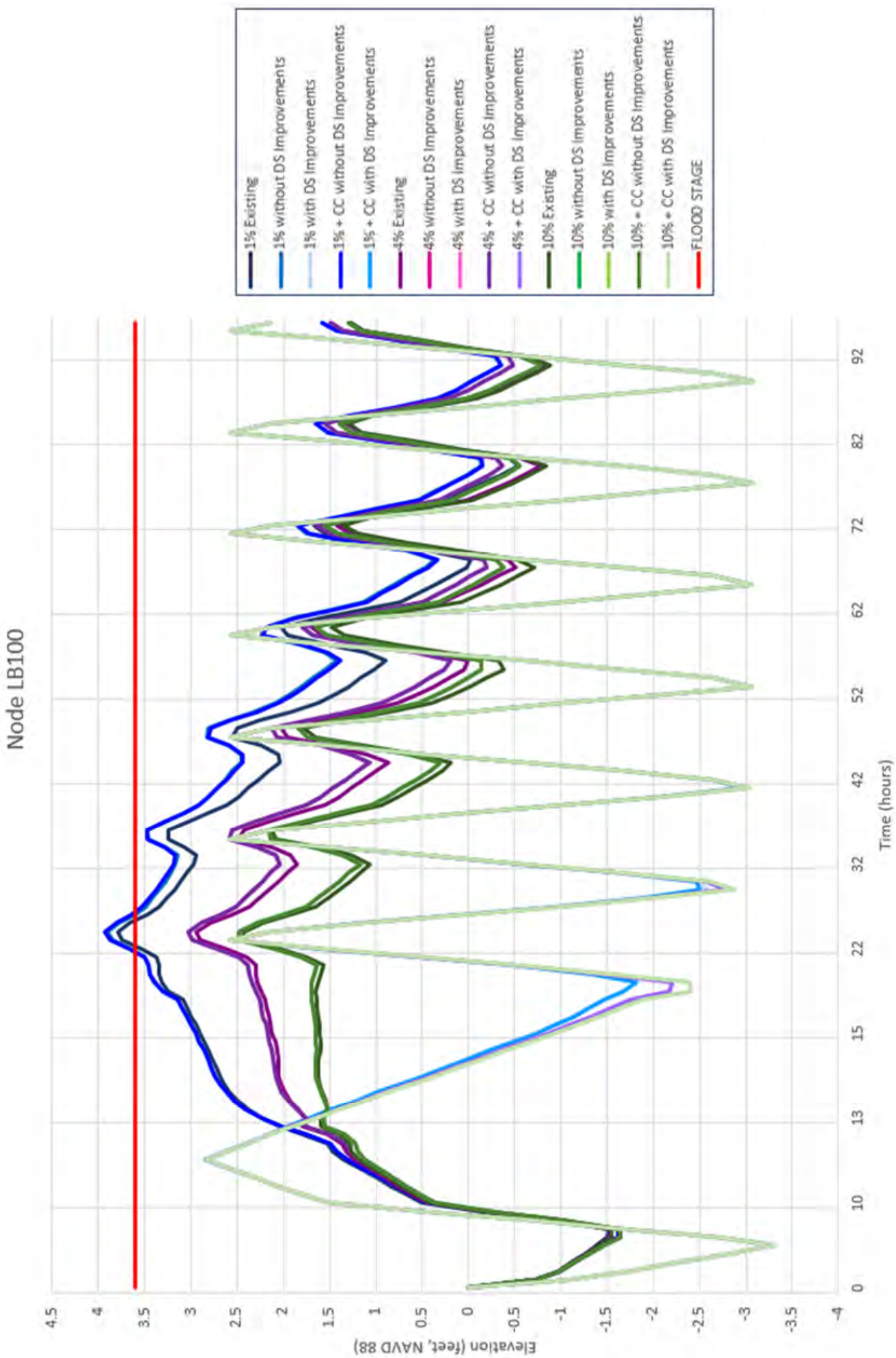

Node 0530
Elevation (feet, NAVD 88)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Time (hours)
0
10
13
15
22
32
42
52
62
72
82
92
1% Existing
1% without DS improvements
1% with DS improvements
1% + CC without DS improvements
1% + CC with DS improvements
4% Existing
4% without DS improvements
4% with DS improvements
4% + CC without DS improvements
4% + CC with DS improvements
10% Existing
10% without DS improvements
10% with DS improvements
10% + CC without DS improvements
10% + CC with DS improvements
FLOOD STAGE


Node LB300
1% Existing
1% without DS Improvements
1% with DS Improvements
1% + CC without DS Improvements
1% + CC with DS Improvements
4% Existing
4% without DS Improvements
4% with DS Improvements
4% + CC without DS Improvements
4% + CC with DS Improvements
10% Existing
10% without DS Improvements
10% with DS Improvements
10% + CC without DS Improvements
10% + CC with DS Improvements
FLOOD STAGE
Elevation (feet, NAVD 88)
Time (hours)


Node LB370
1% Existing
1% without DS Improvements
1% with DS Improvements
1% + CC without DS Improvements
1% + CC with DS Improvements
4% Existing
4% without DS Improvements
4% with DS Improvements
4% + CC without DS Improvements
4% + CC with DS Improvements
10% Existing
10% without DS Improvements
10% with DS Improvements
10% + CC without DS Improvements
10% + CC with DS Improvements
FLOOD STAGE
Elevation (feet, NAVD 88)
Time (hours)
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
10
13
15
22
32
42
52
62
72
82
92

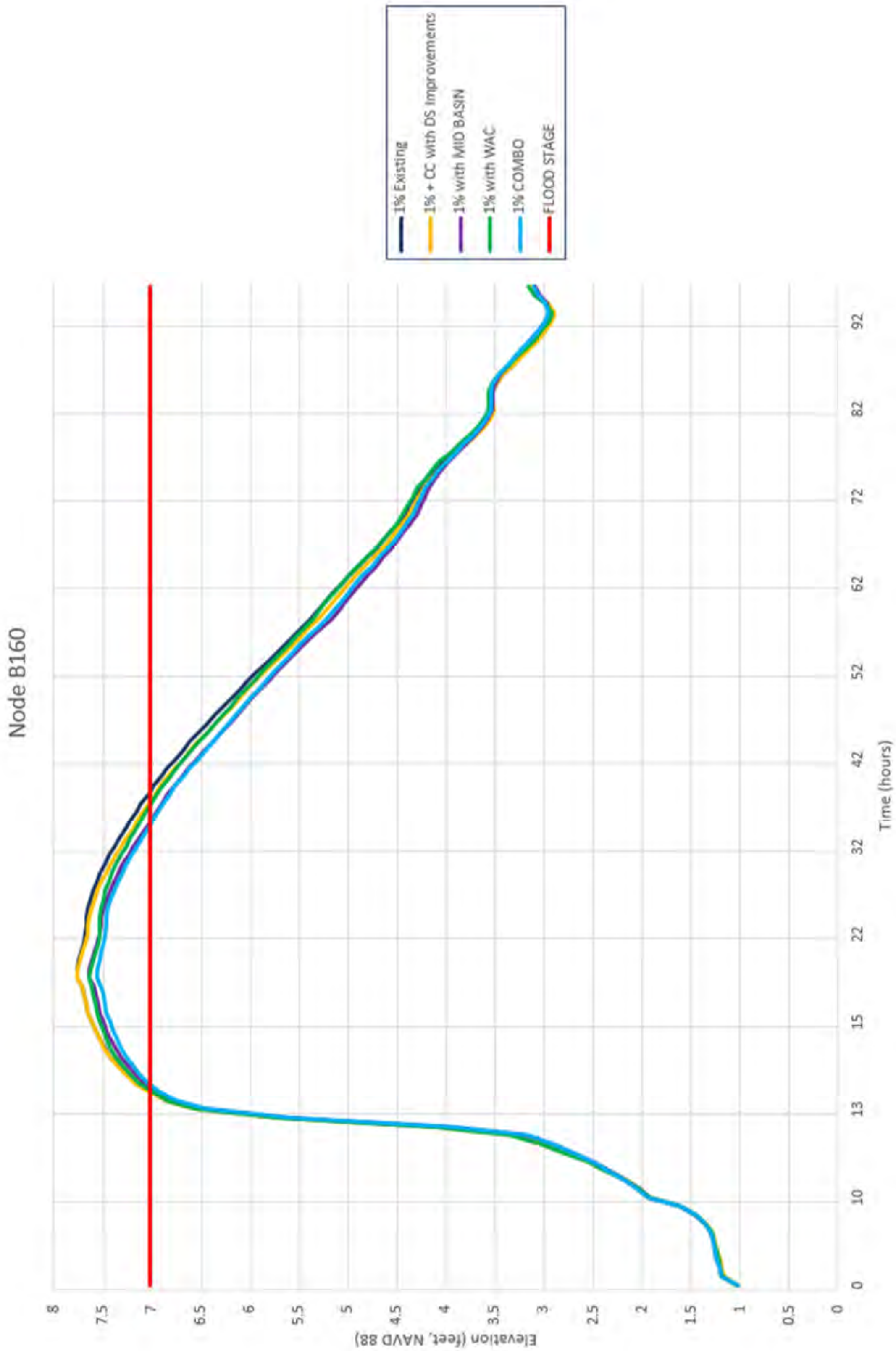

Node LB240
Elevation (feet, NAVD 88)
Time (hours)
1% Existing
1% without DS Improvements
1% with DS Improvements
1% + CC without DS Improvements
1% + CC with DS Improvements
4% Existing
4% without DS Improvements
4% with DS Improvements
4% + CC without DS Improvements
4% + CC with DS Improvements
10% Existing
10% without DS Improvements
10% with DS Improvements
10% + CC without DS Improvements
10% + CC with DS Improvements
FLOOD STAGE

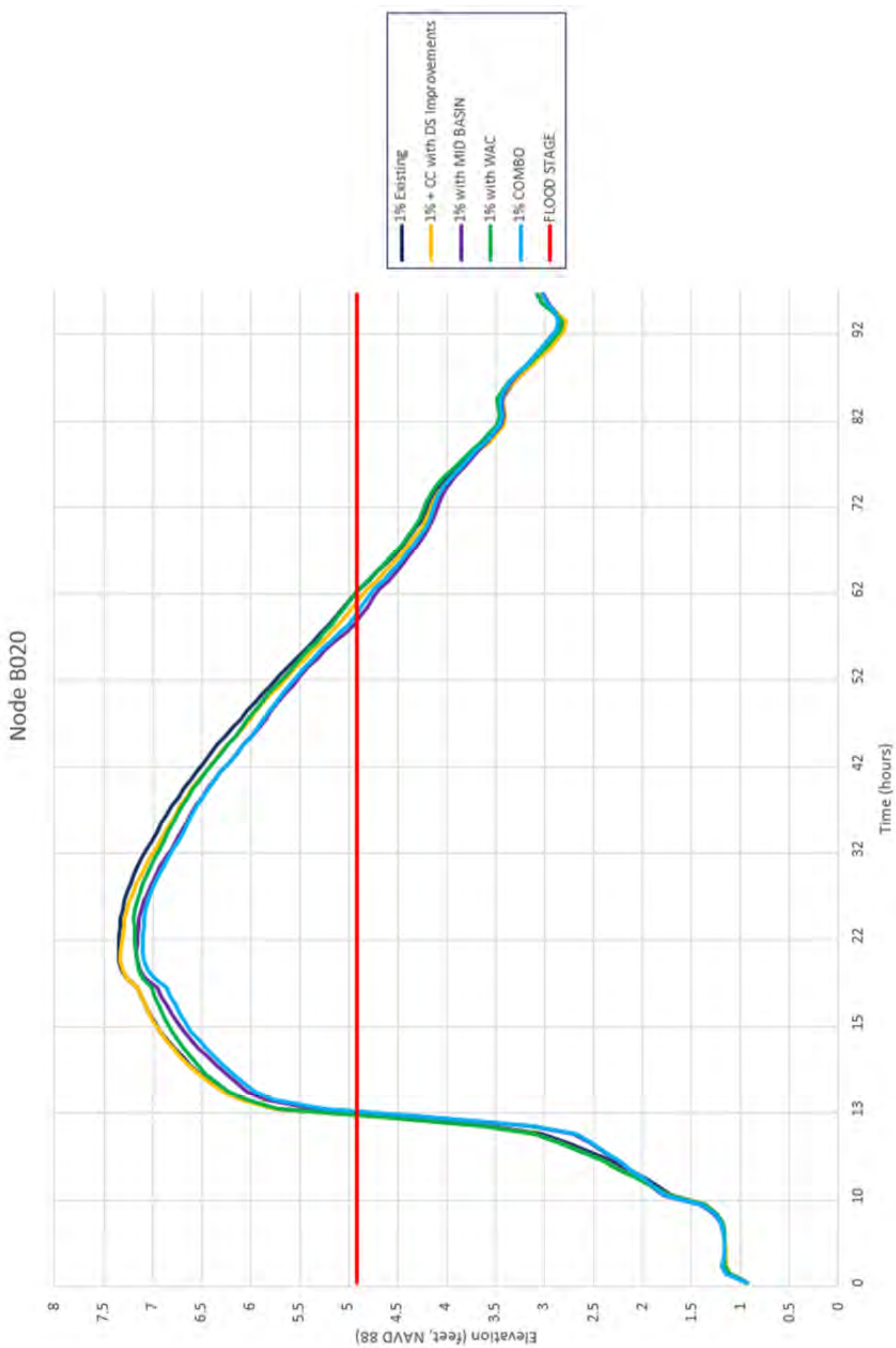

Node LB130
1% Existing
1% without DS Improvements
1% with DS Improvements
1% + CC without DS Improvements
1% + CC with DS Improvements
4% Existing
4% without DS Improvements
4% with DS Improvements
4% + CC without DS Improvements
4% + CC with DS Improvements
10% Existing
10% without DS Improvements
10% with DS Improvements
10% + CC without DS Improvements
10% + CC with DS Improvements
FLOOD STAGE
Elevation (feet, NAVD 88)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
Time (hours)
0
10
13
15
22
32
42
52
62
72
82
92

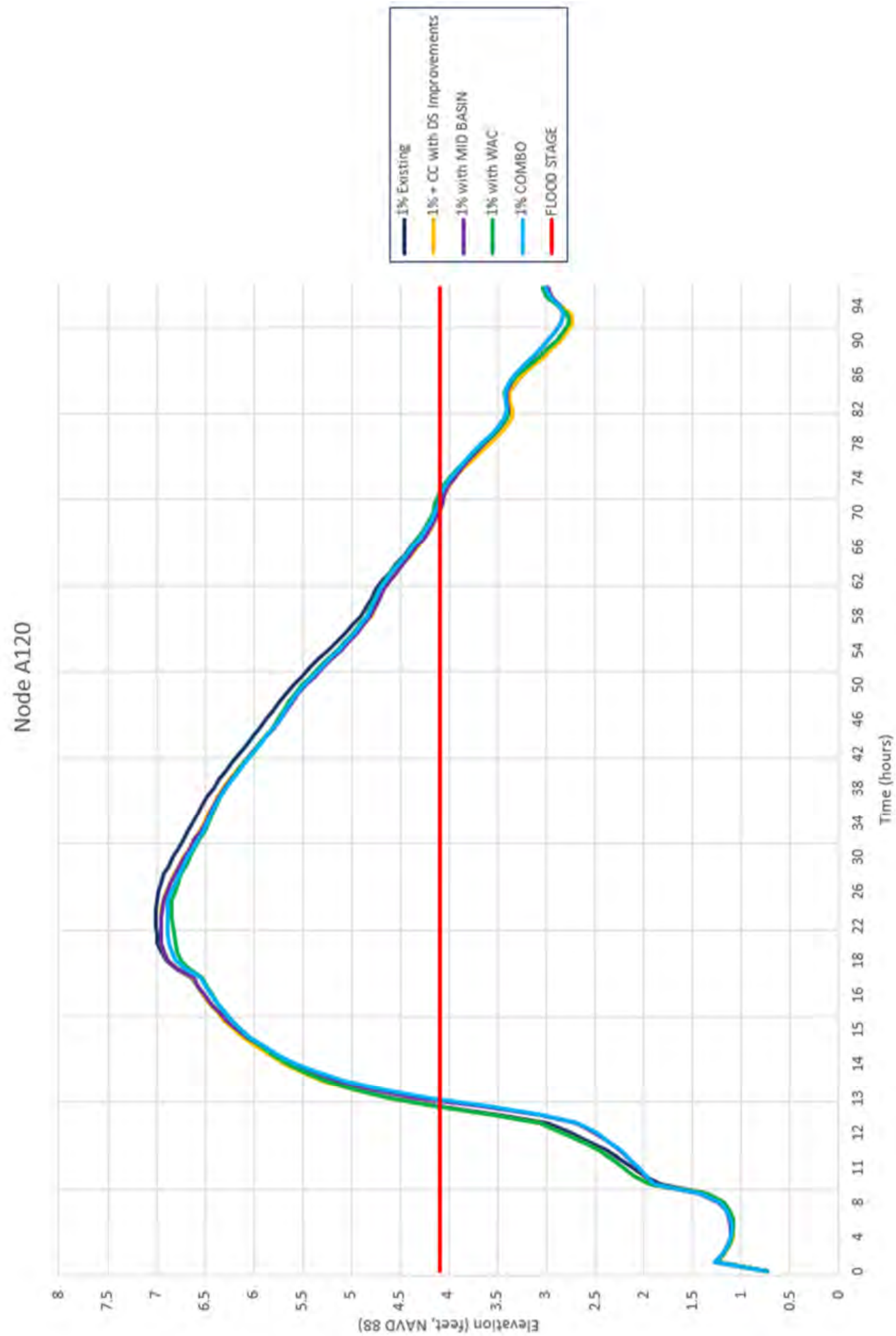

Node LB100
Elevation (feet, NAVD 88)
Time (hours)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
0
10
13
15
22
32
42
52
62
72
82
92
1% Existing
1% without DS Improvements
1% with DS Improvements
1% + CC without DS Improvements
1% + CC with DS Improvements
4% Existing
4% without DS Improvements
4% with DS Improvements
4% + CC without DS Improvements
4% + CC with DS Improvements
10% Existing
10% without DS Improvements
10% with DS Improvements
10% + CC without DS Improvements
10% + CC with DS Improvements
FLOOD STAGE

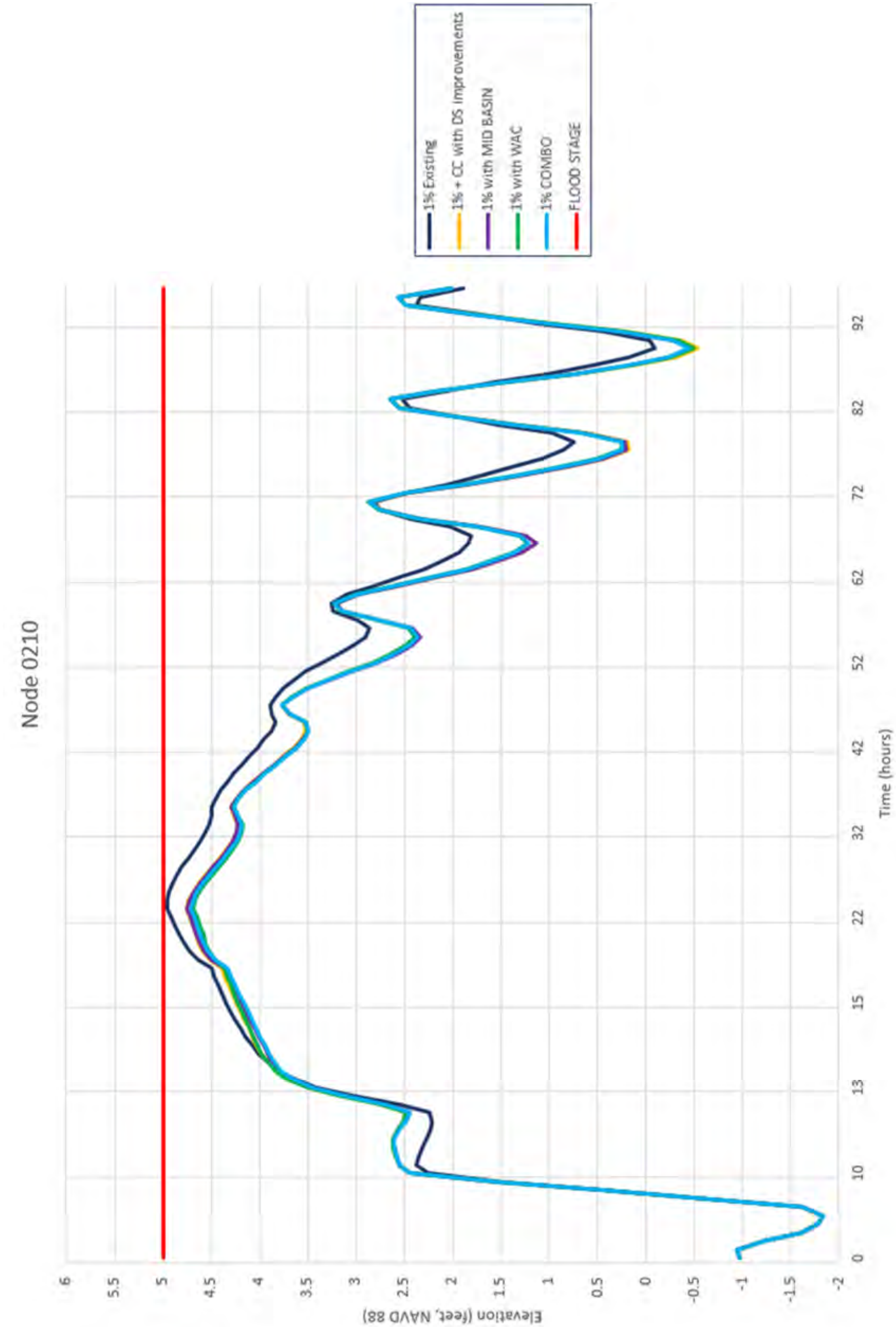
APPENDIX D

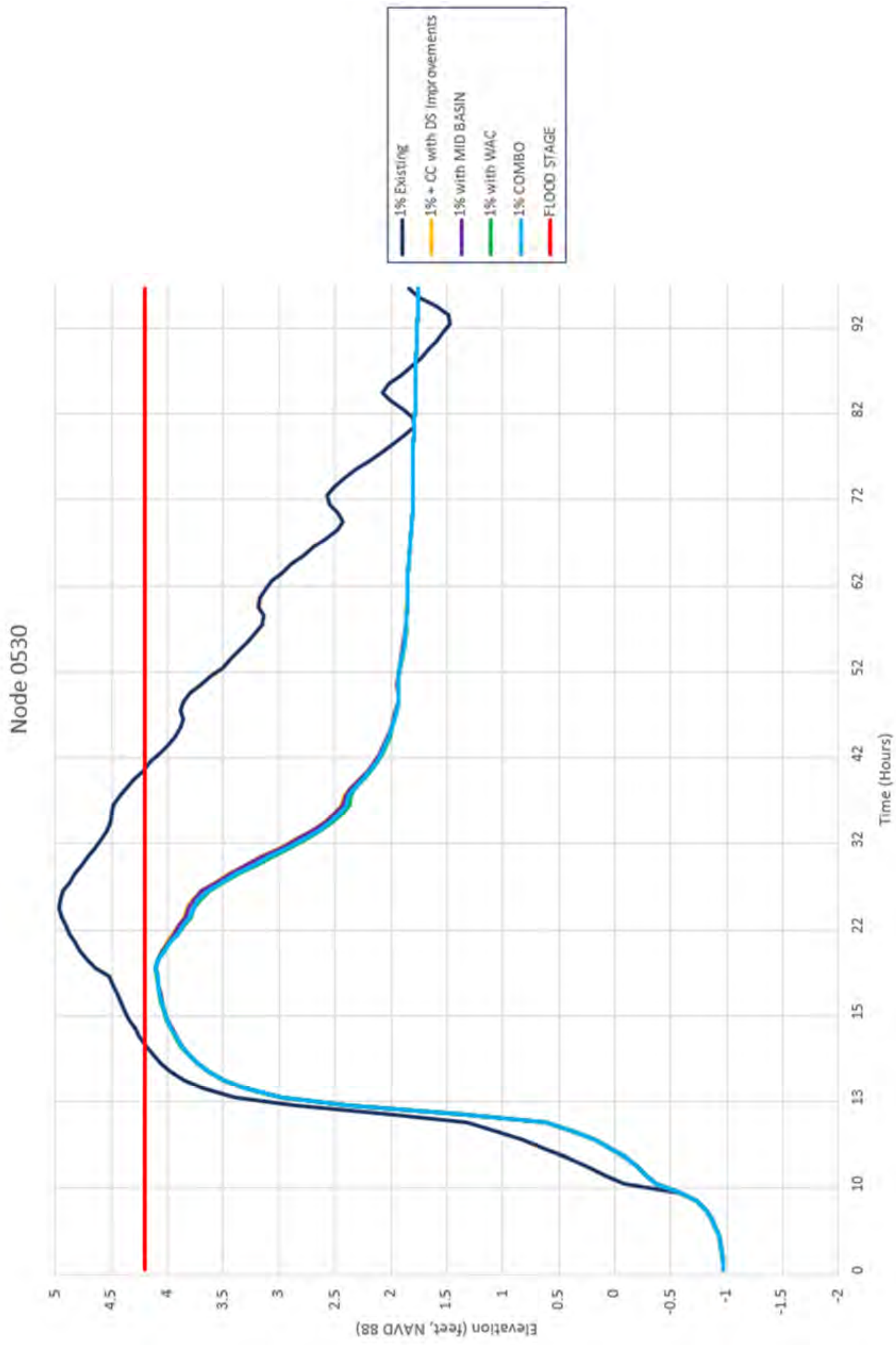
Hydrographs by Node for Combination Scenarios


Node B160
1% Existing
1% + CC with DS Improvements
1% with MID BASIN
1% with WAC
1% COMBO
FLOOD STAGE
Elevation (feet, NAVD 88)
Time (hours)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
0
10
13
15
22
32
42
52
62
72
82
92

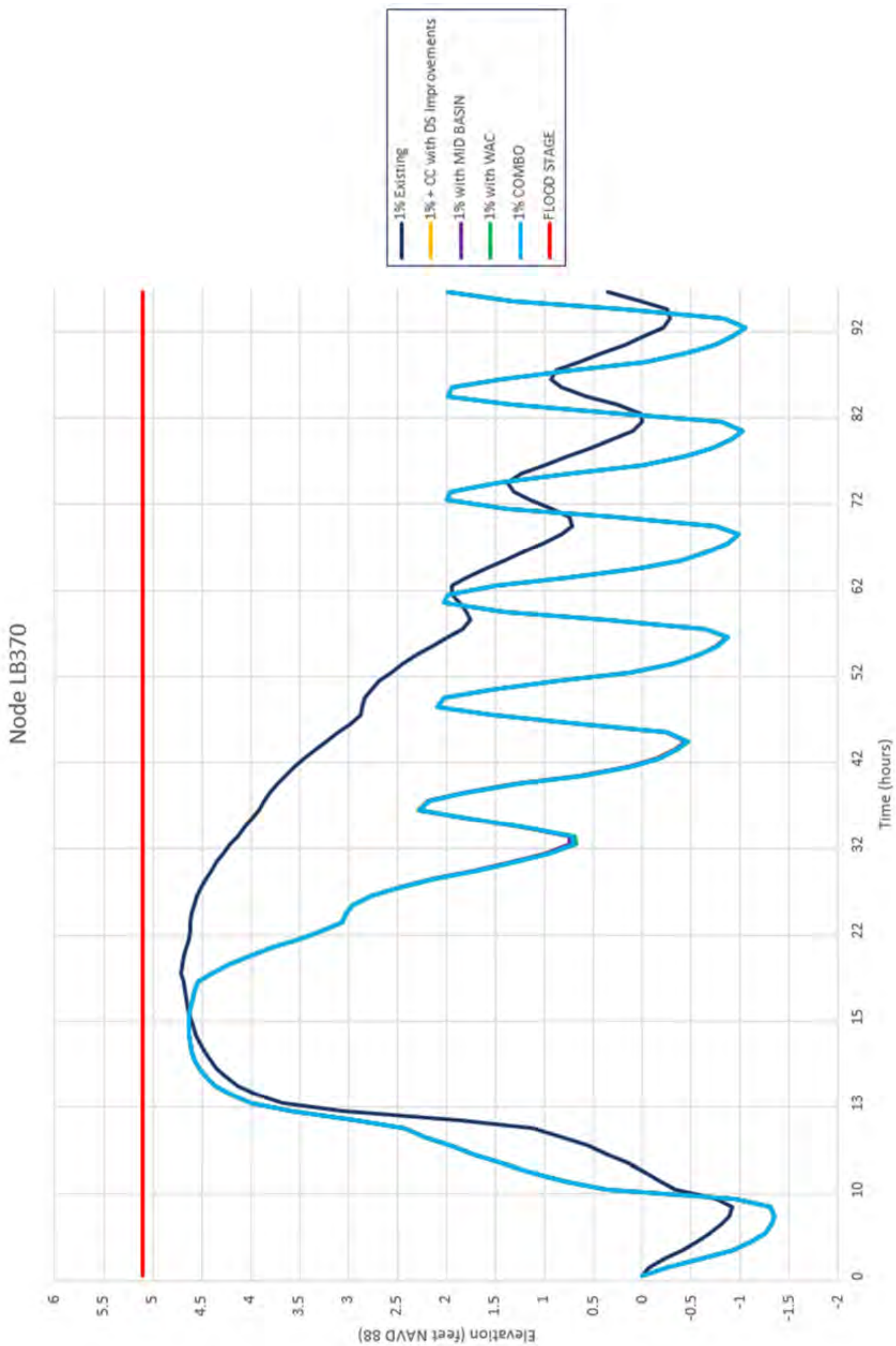

Node B020
1% Existing
1% + CC with DS Improvements
1% with MID BASIN
1% with WAC
1% COMBO
FLOOD STAGE
Elevation (feet, NAVD 88)
Time (hours)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
0
10
13
15
22
32
42
52
62
72
82
92

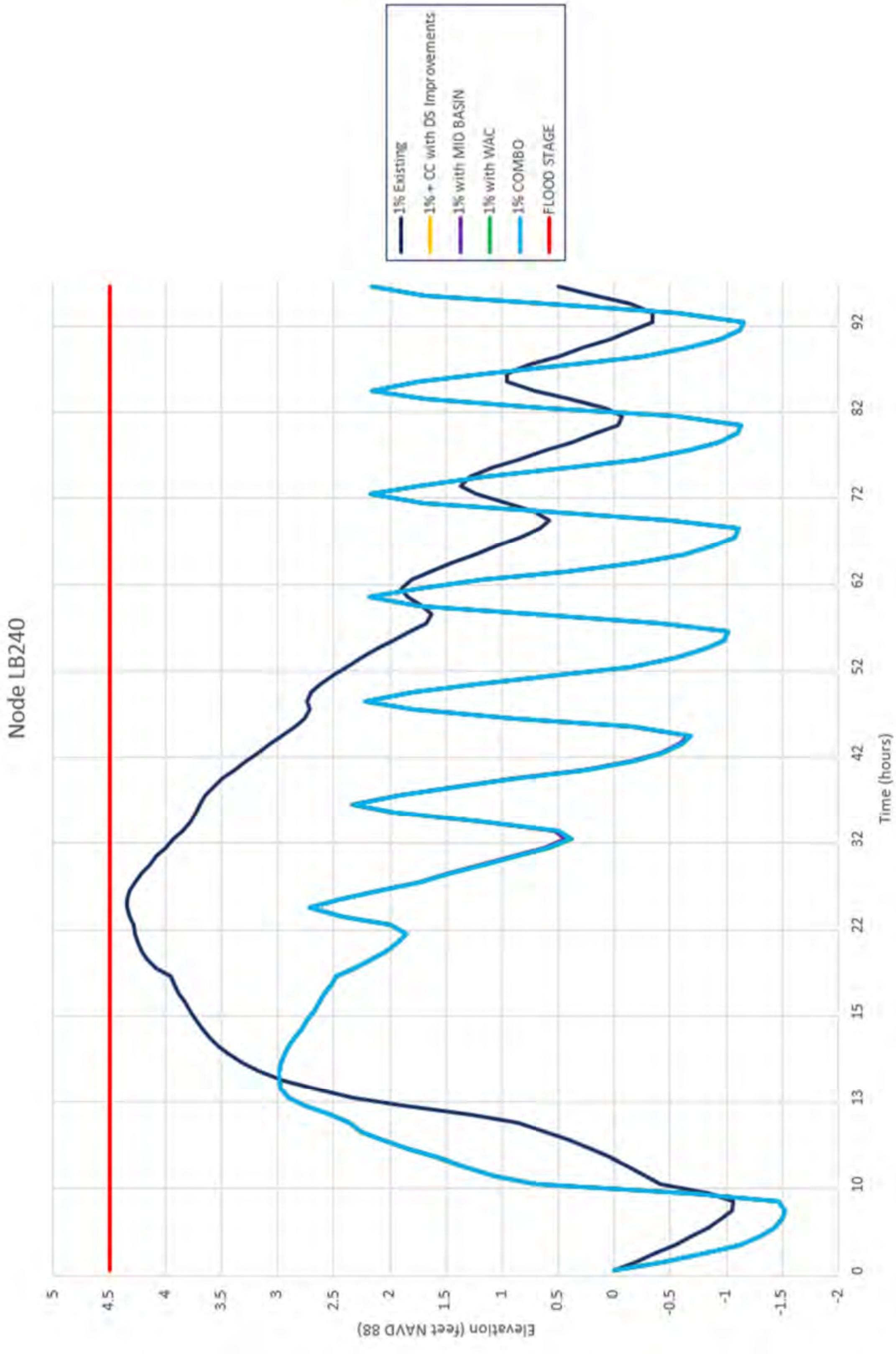

Node A120
1% Existing
1% + CC with DS Improvements
1% with MID BASIN
1% with WAC
1% COMBO
FLOOD STAGE
Elevation (feet, NAVD 88)
Time (hours)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
0 4 8 11 12 13 14 15 16 18 22 26 30 34 38 42 46 50 54 58 62 66 70 74 78 82 86 90 94


Node 0210
1% Existing
1% + CC with DS Improvements
1% with MID BASIN
1% with WAC
1% COMBO
FLOOD STAGE
Elevation (feet, NAVD 88)
Time (hours)
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
10
13
15
22
32
42
52
62
72
82
92

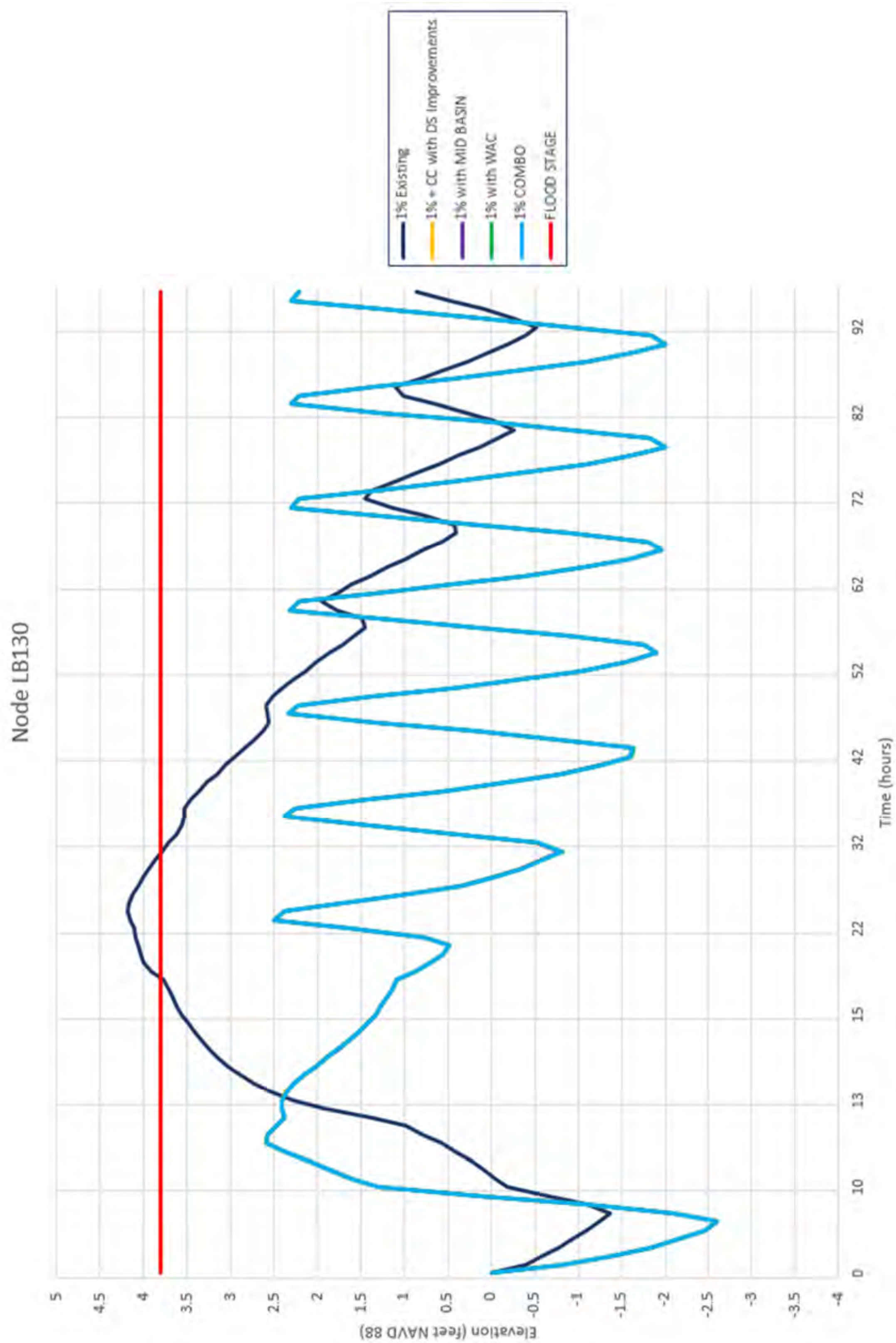

Node 0530
1% Existing
1% + CC with DS Improvements
1% with MID BASIN
1% with WAC
1% COMBO
FLOOD STAGE
Elevation (feet, NAVD 88)
Time (Hours)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
10
13
15
22
32
42
52
62
72
82
92

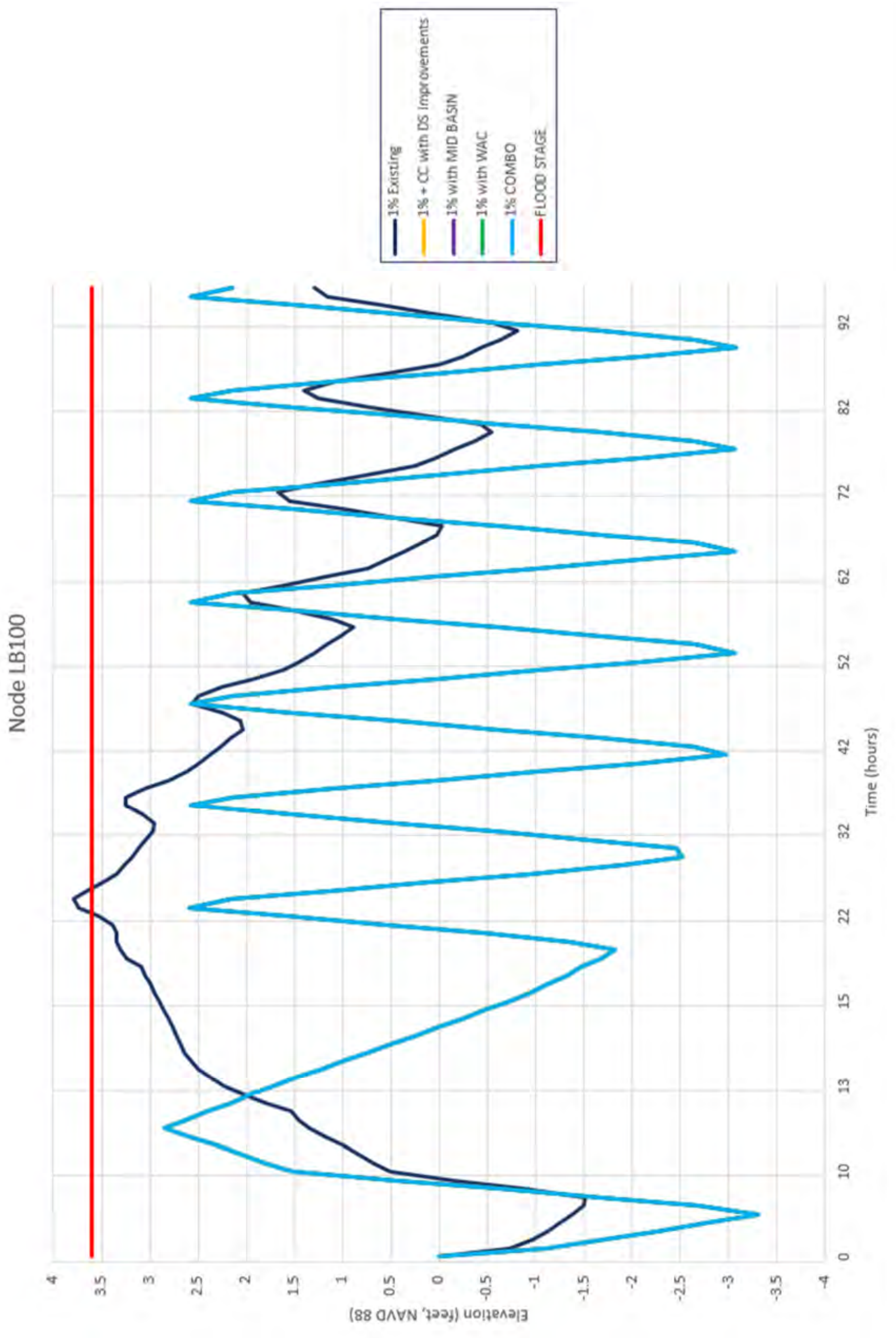
Weston & Sampson


Node LB370
1% Existing
1% + CC with DS Improvements
1% with MID BASIN
1% with WAC
1% COMBO
FLOOD STAGE
Elevation (feet NAVD 88)
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Time (hours)
0
10
13
15
22
32
42
52
62
72
82
92


Node LB240
1% Existing
1% + CC with DS Improvements
1% with MID BASIN
1% with WAC
1% COMBO
FLOOD STAGE
Elevation (feet NAVD 88)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Time (hours)
0
10
13
15
22
32
42
52
62
72
82
92

Lake Dotterer Flow Restoration



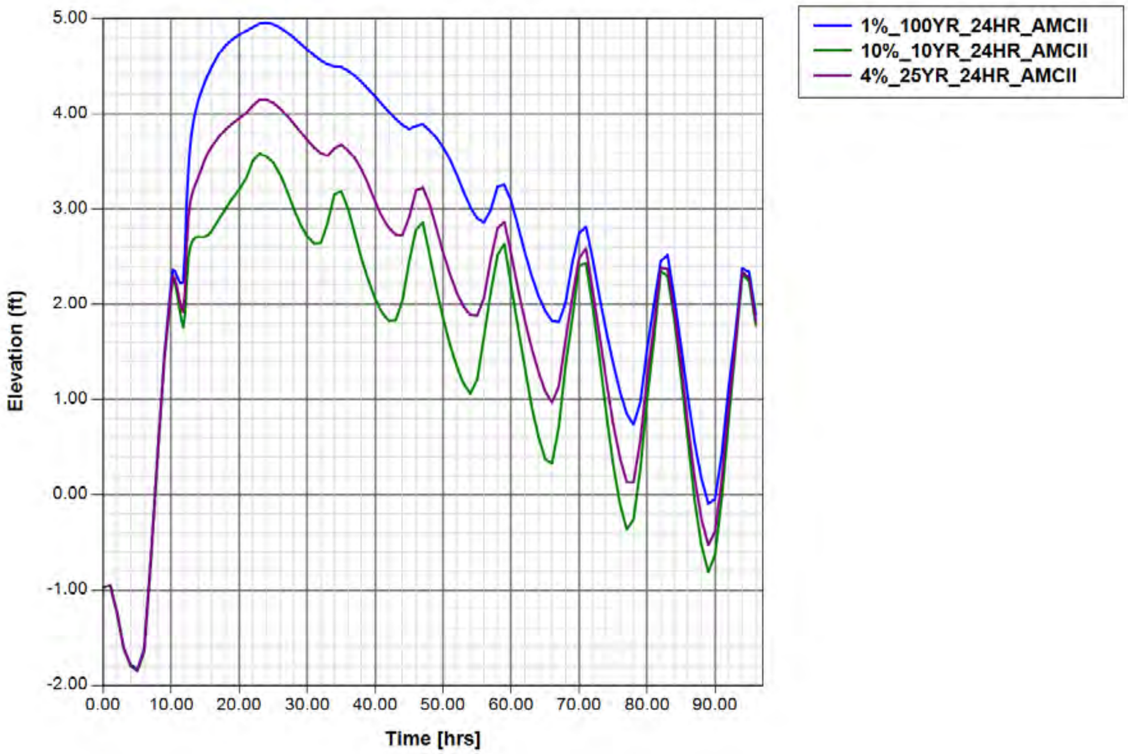

Node LB100
1% Existing
1% + CC with DS Improvements
1% with MID BASIN
1% with WAC
1% COMBO
FLOOD STAGE
Elevation (feet, NAVD 88)
Time (hours)
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
0
10
13
15
22
32
42
52
62
72
82
92

APPENDIX E

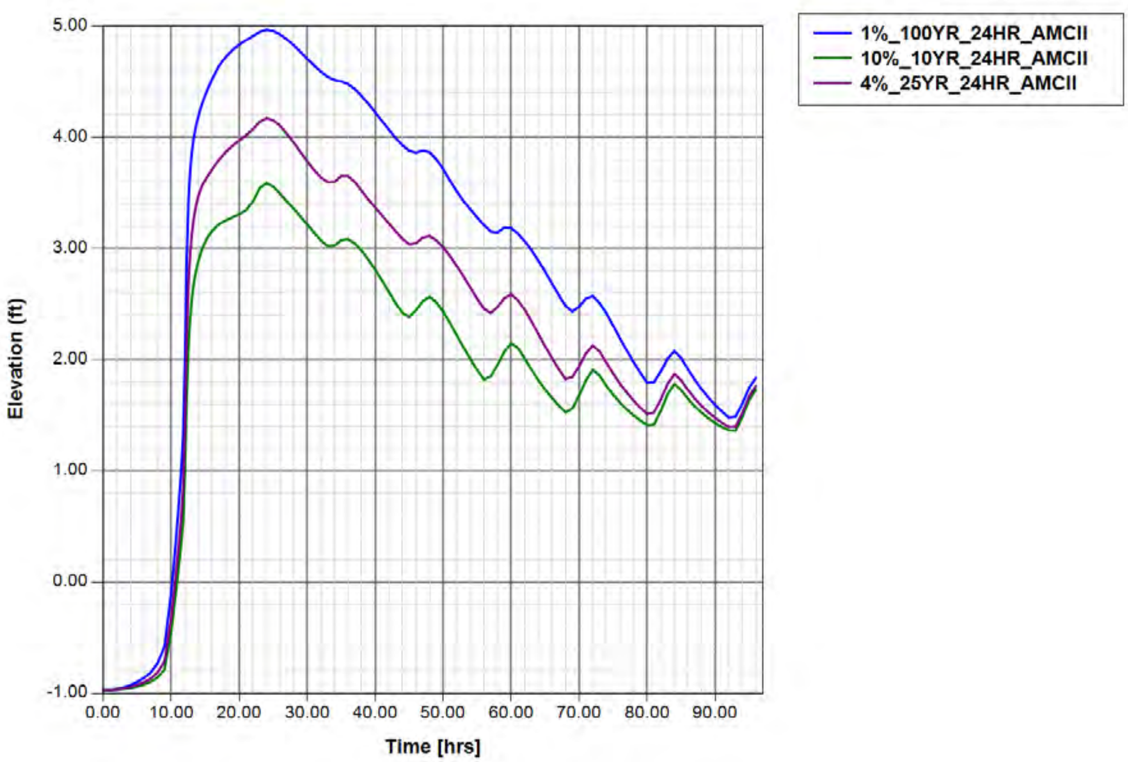
Single Hydrographs Output from Model

Lake Dotterer Diversion EXISTING CONDITIONS 1

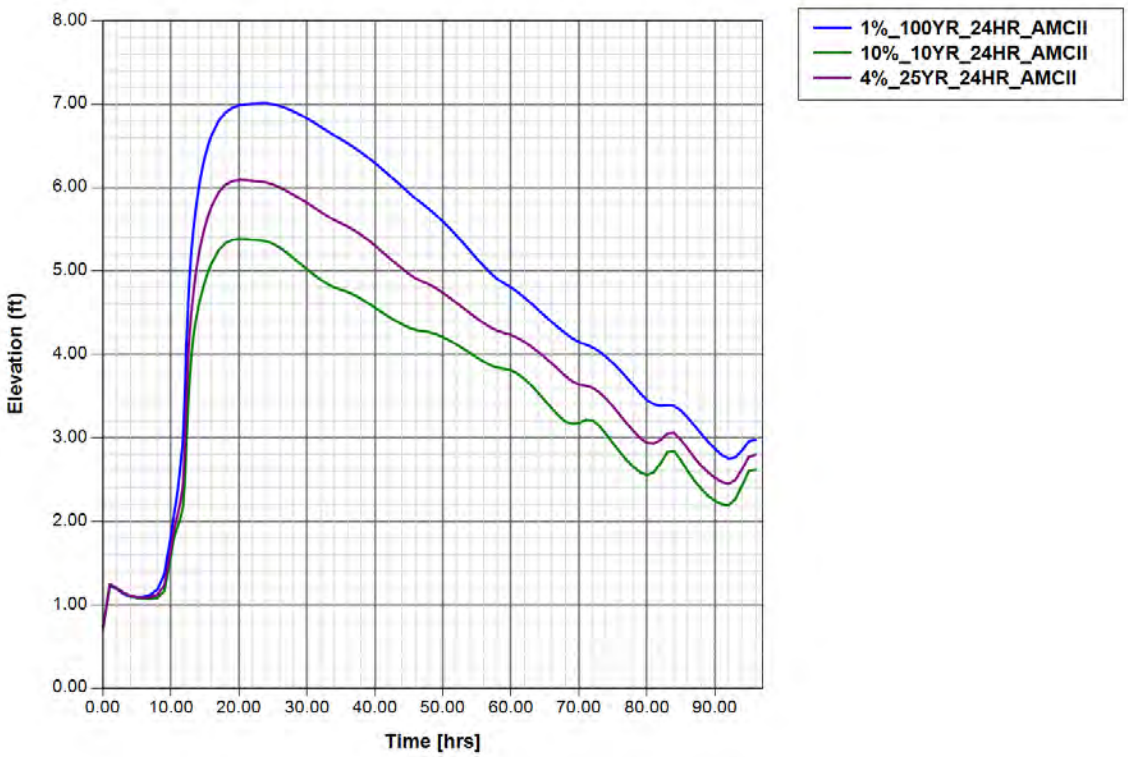
Node Stage: N-0210_SLT [01_Existing_EXP]



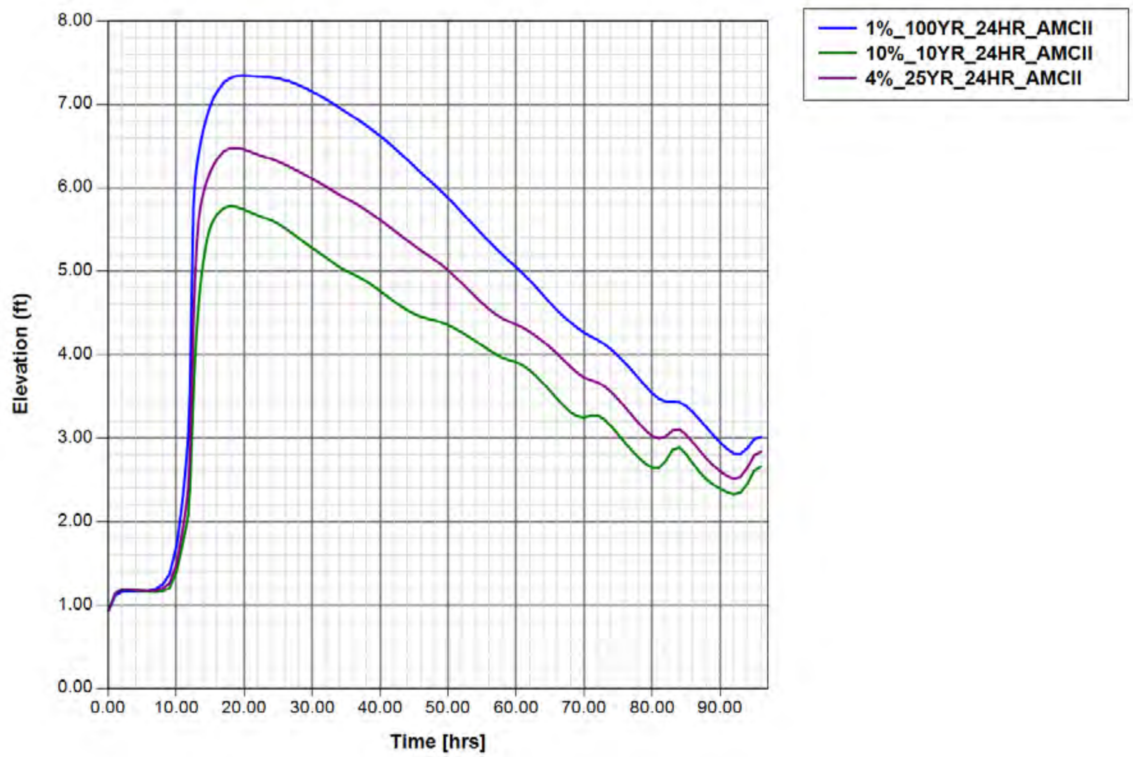
Node Stage: N-0530_SLT [01_Existing_EXP]



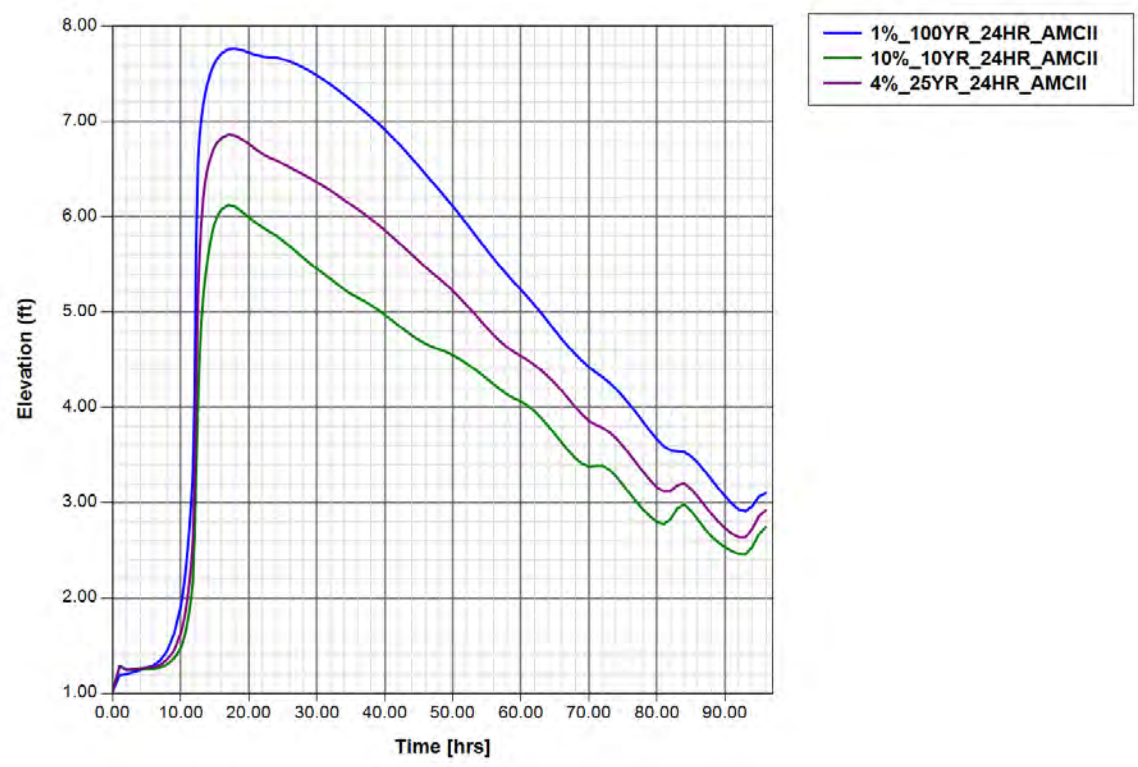
Node Stage: N-A120 [01_Existing_EXP]



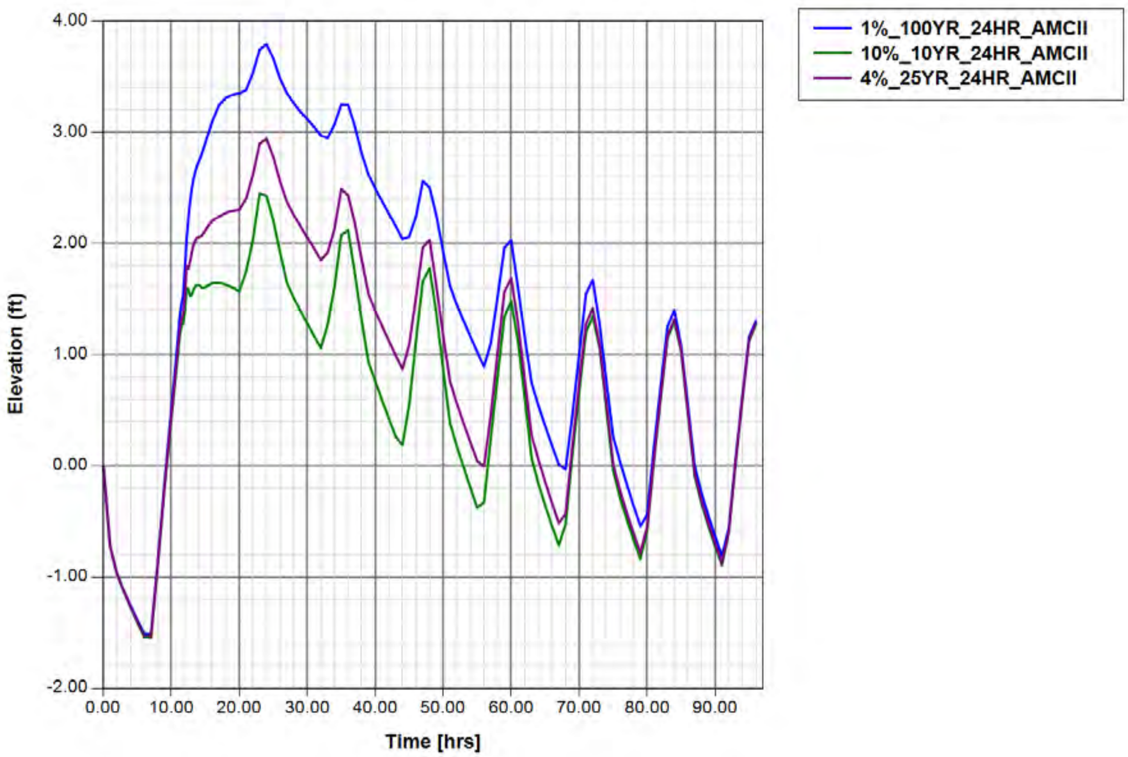
Node Stage: N-B020 [01_Existing_EXP]



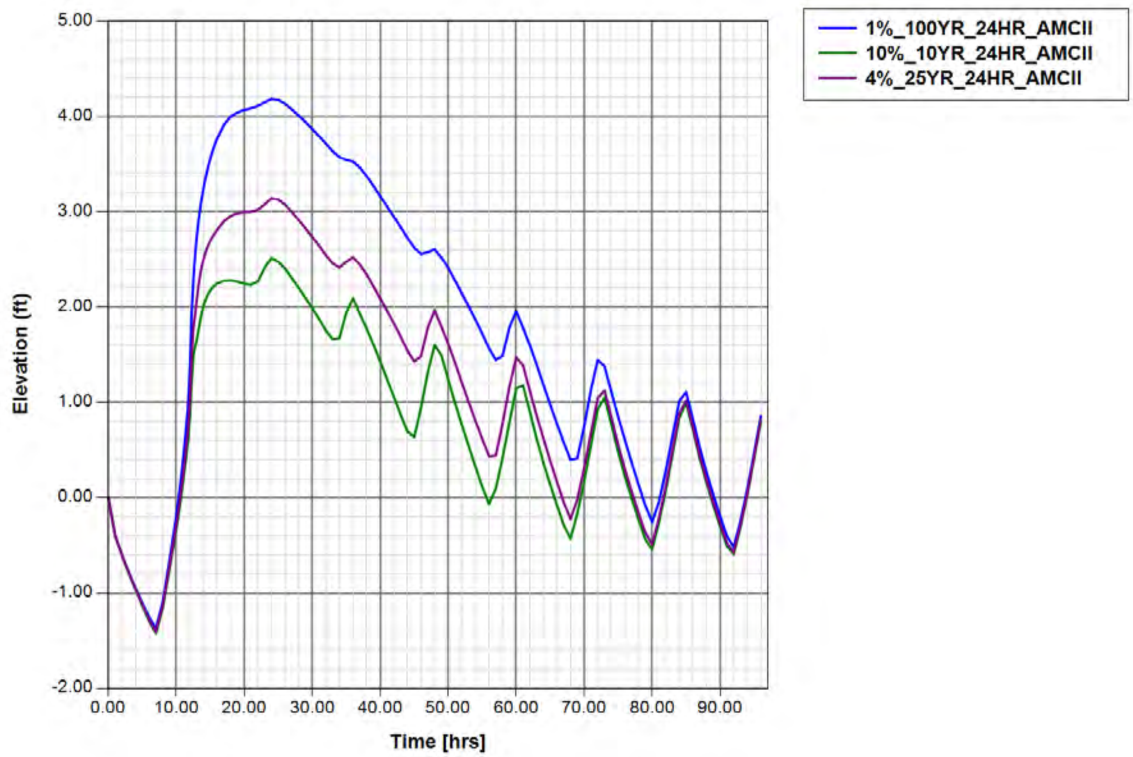
Node Stage: N-B160 [01_Existing_EXP]



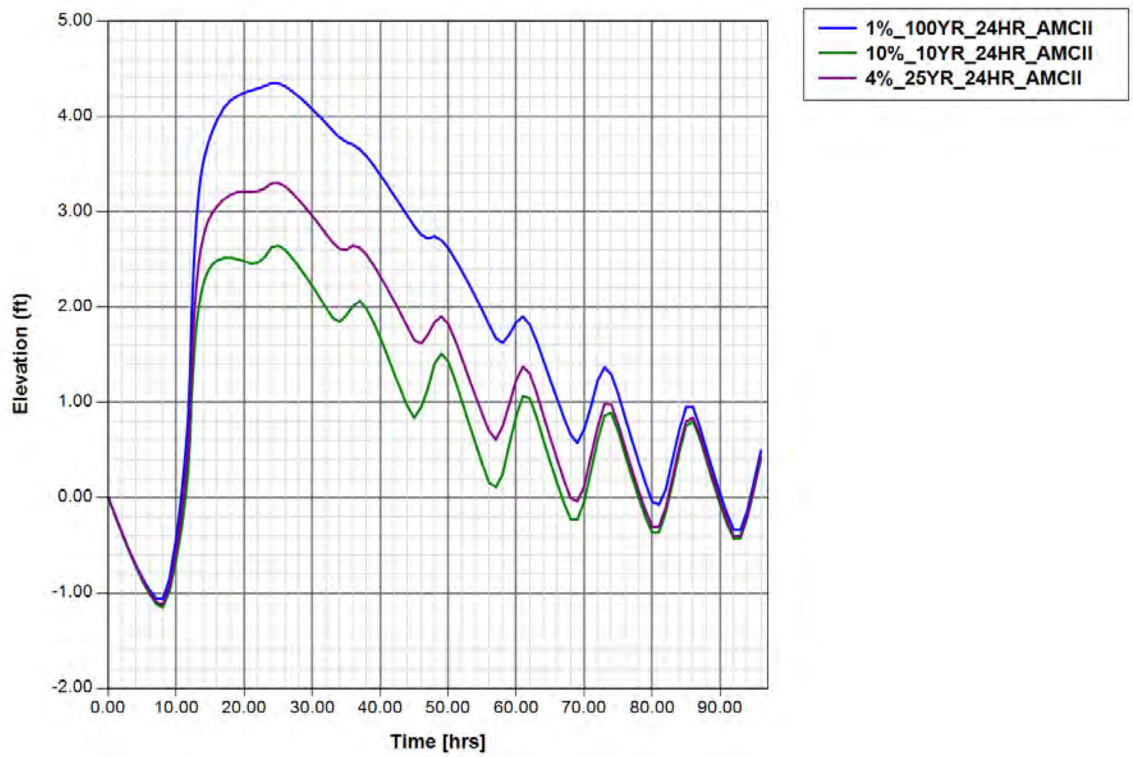
Node Stage: N-LB100 [01_Existing_EXP]



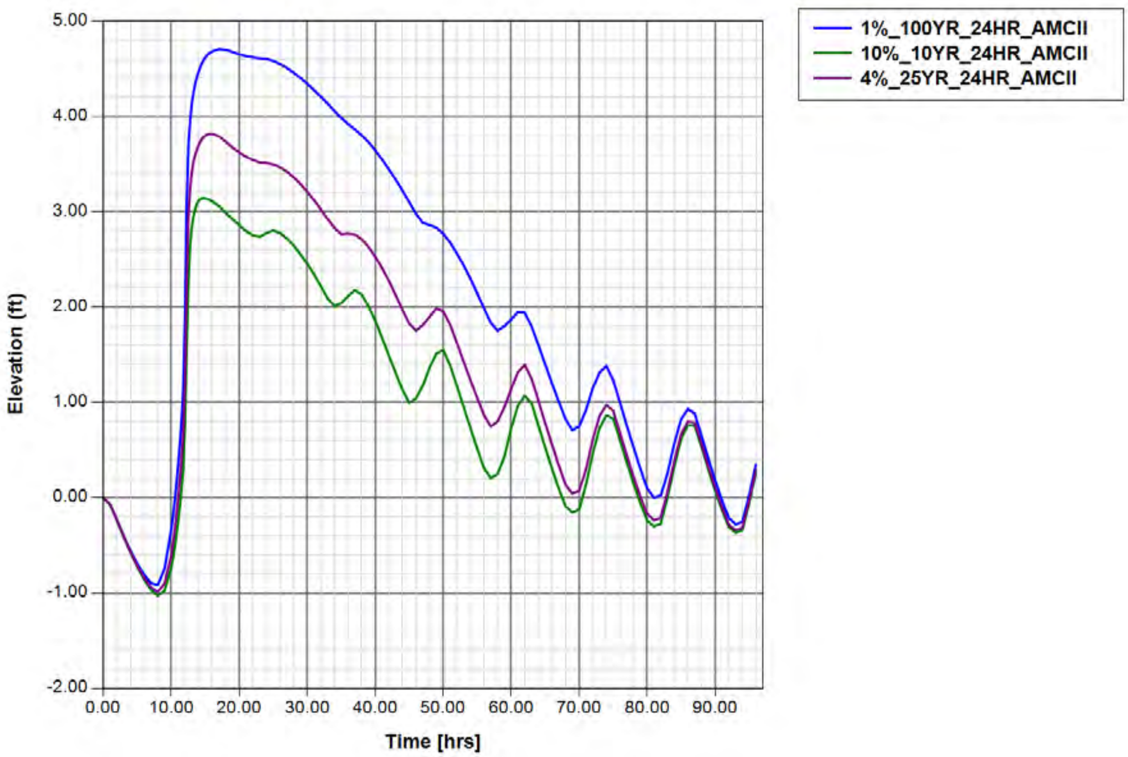
Node Stage: N-LB130 [01_Existing_EXP]



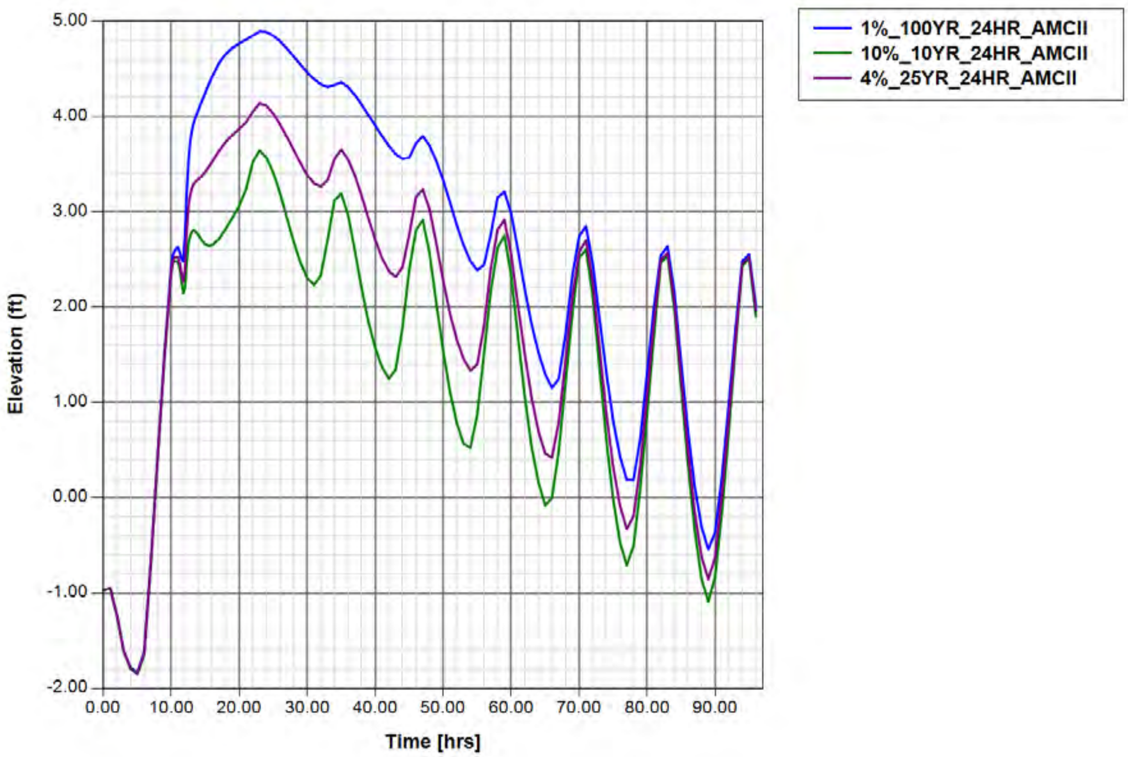
Node Stage: N-LB240 [01_Existing_EXP]



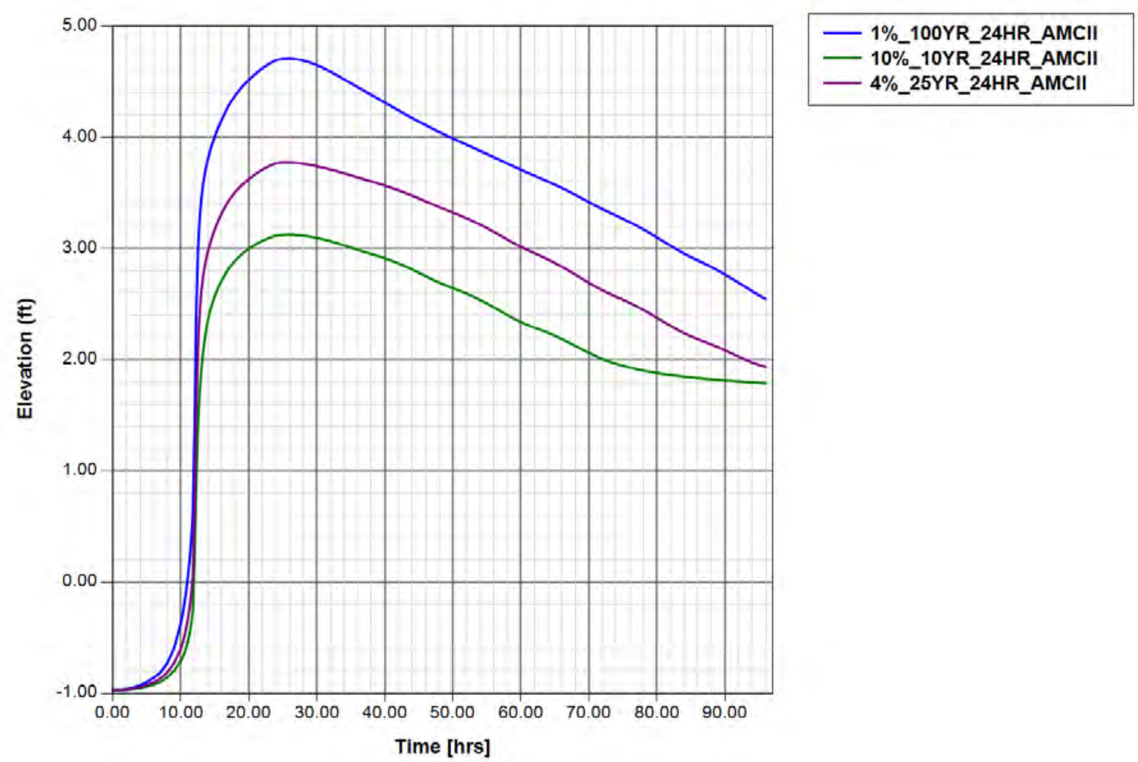
Node Stage: N-LB370 [01_Existing_EXP]



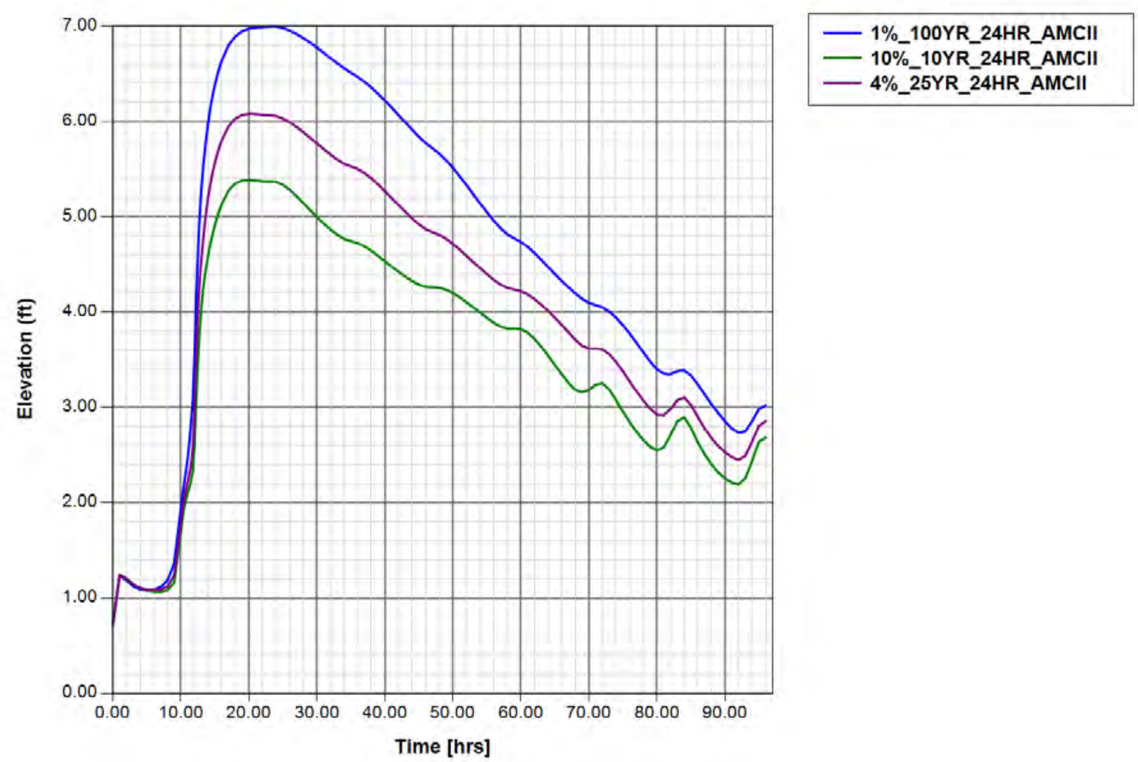
Node Stage: N-0210_SLT [02_LDD]



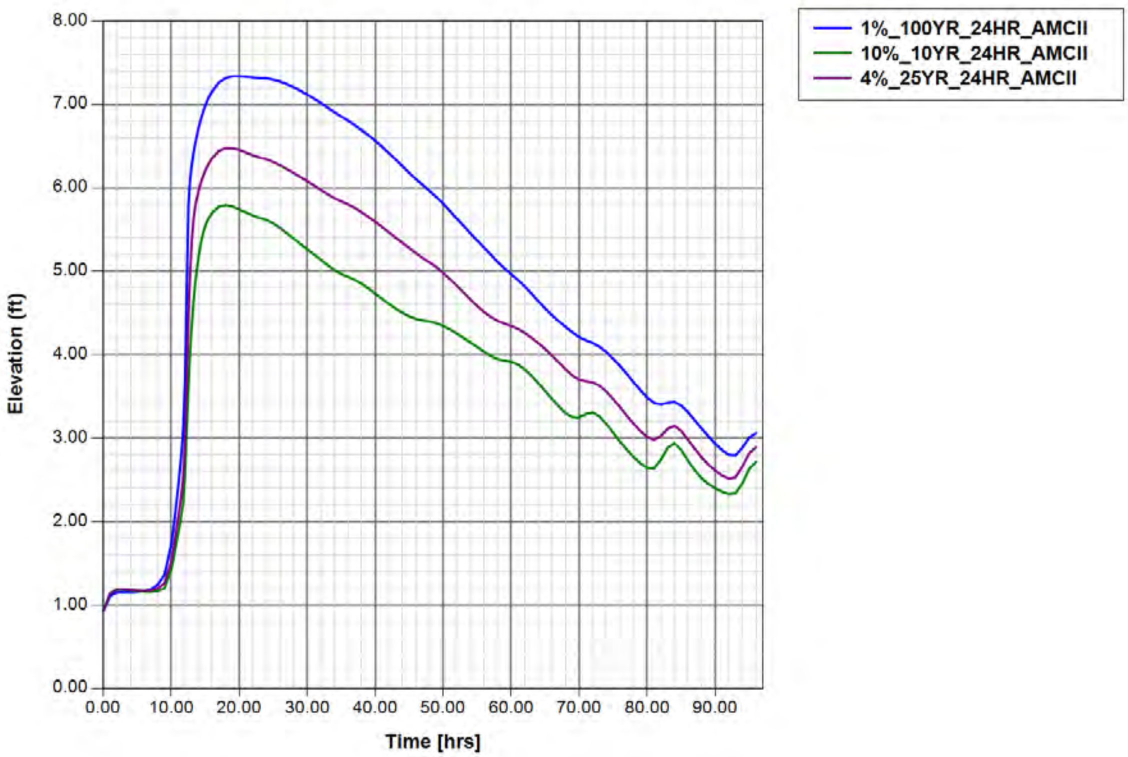
Node Stage: N-0530_SLT [02_LDD]



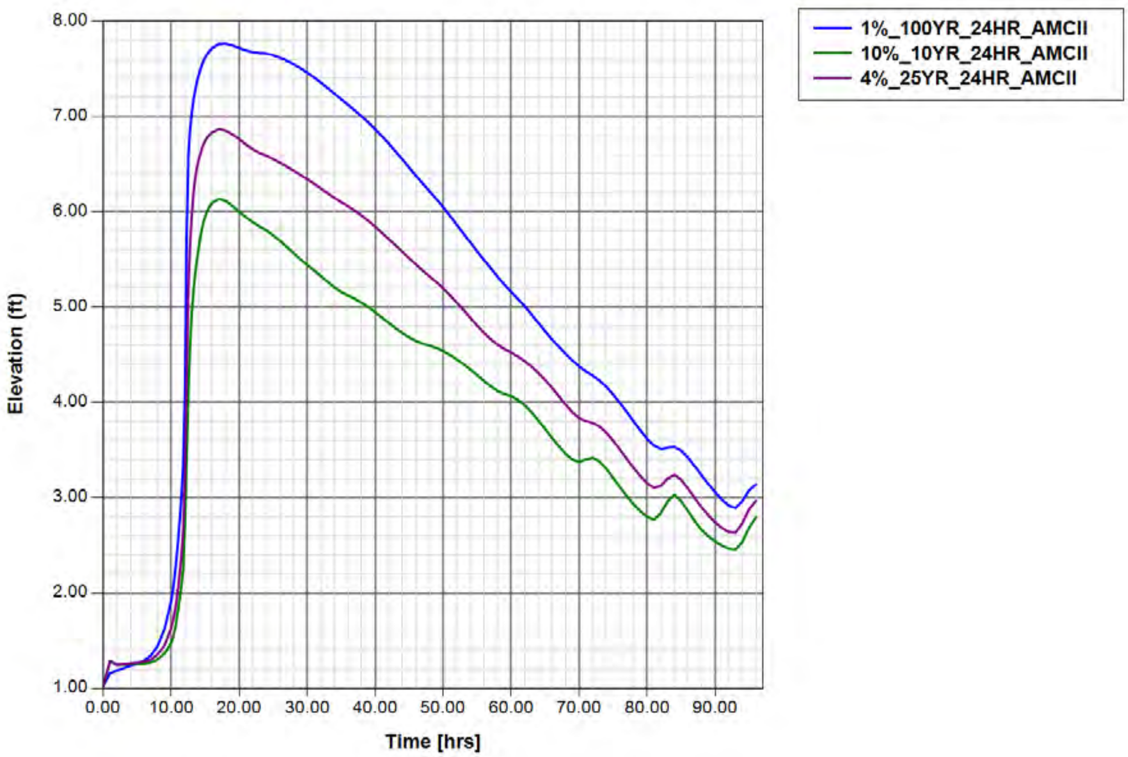
Node Stage: N-A120 [02_LDD]



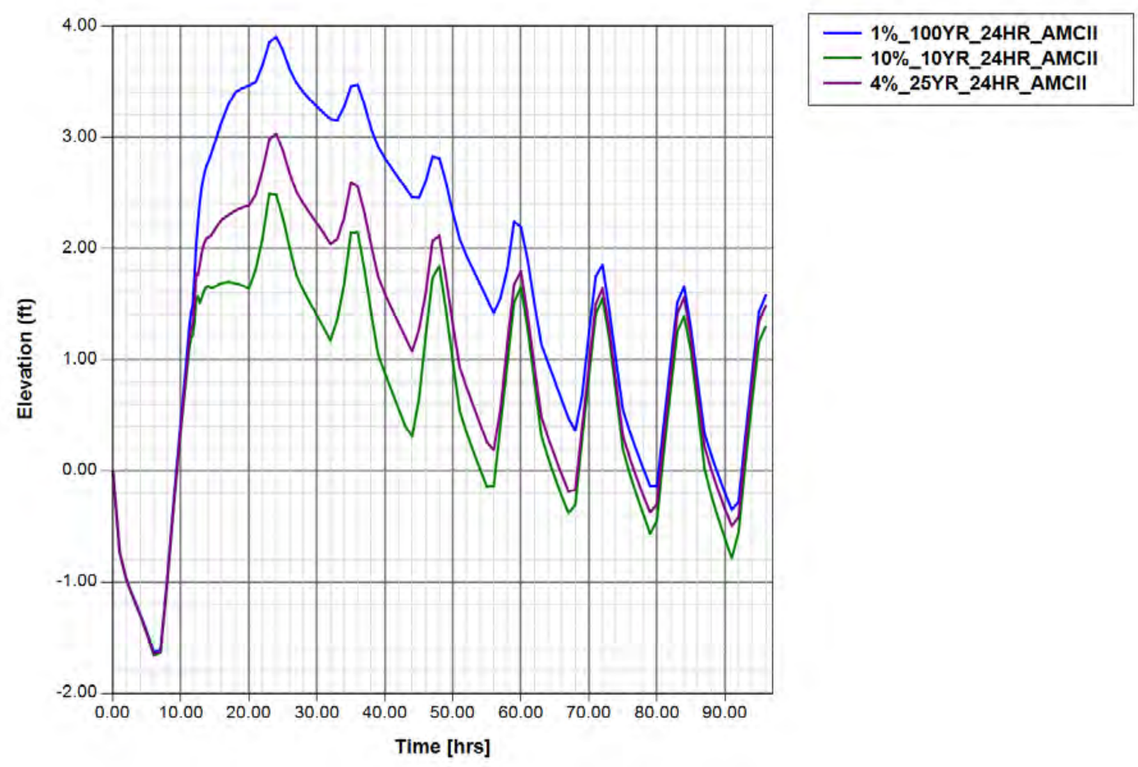
Node Stage: N-B020 [02_LDD]



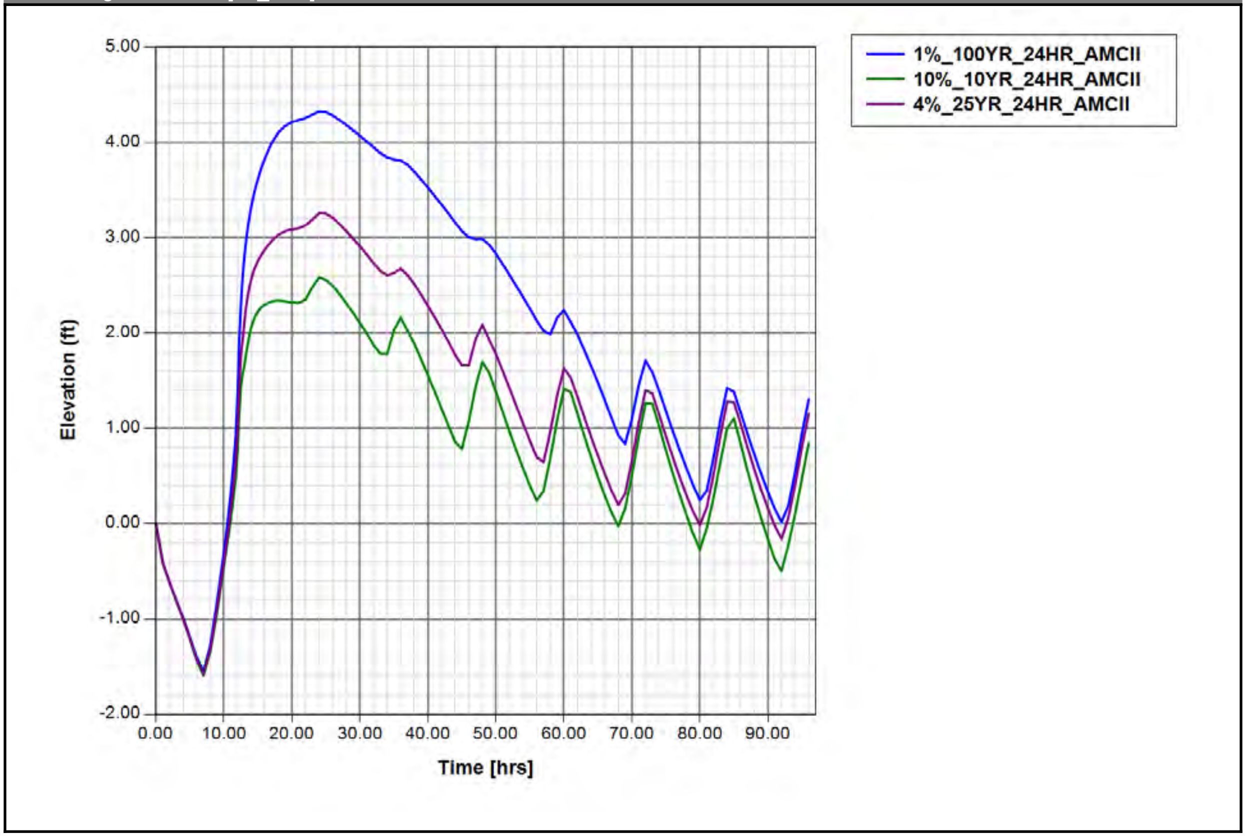
Node Stage: N-B160 [02_LDD]



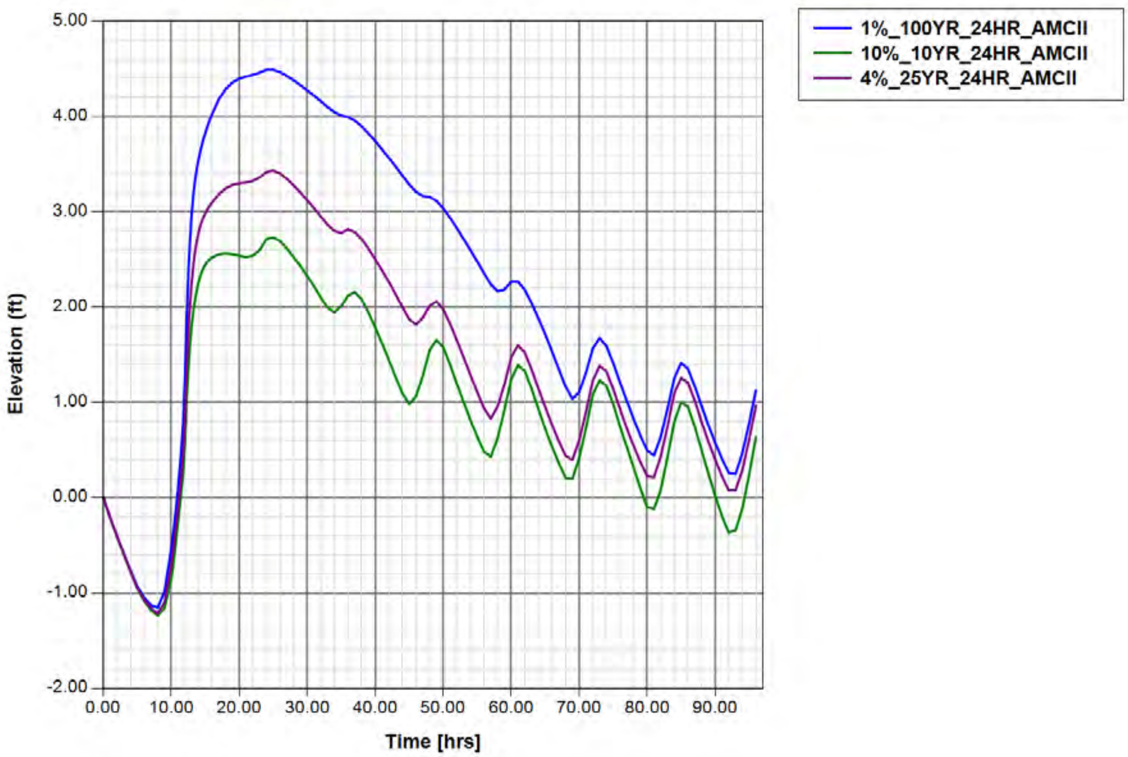
Node Stage: N-LB100 [02_LDD]



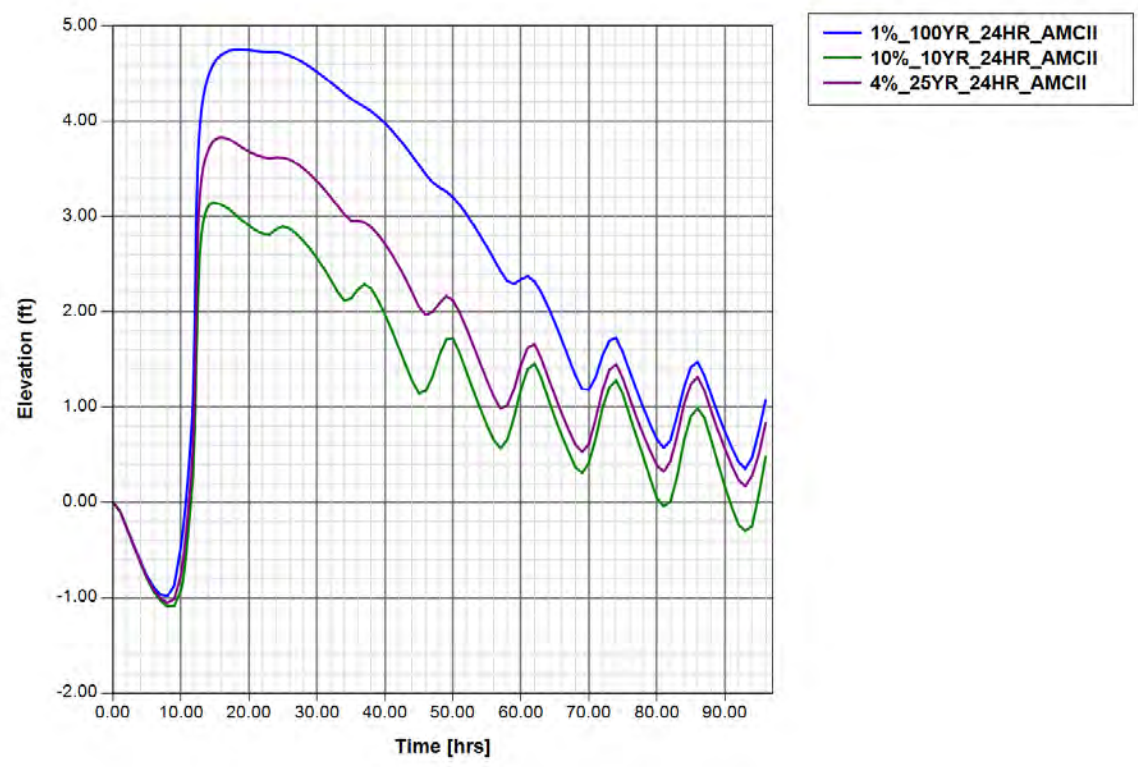
Node Stage: N-LB130 [02_LDD]



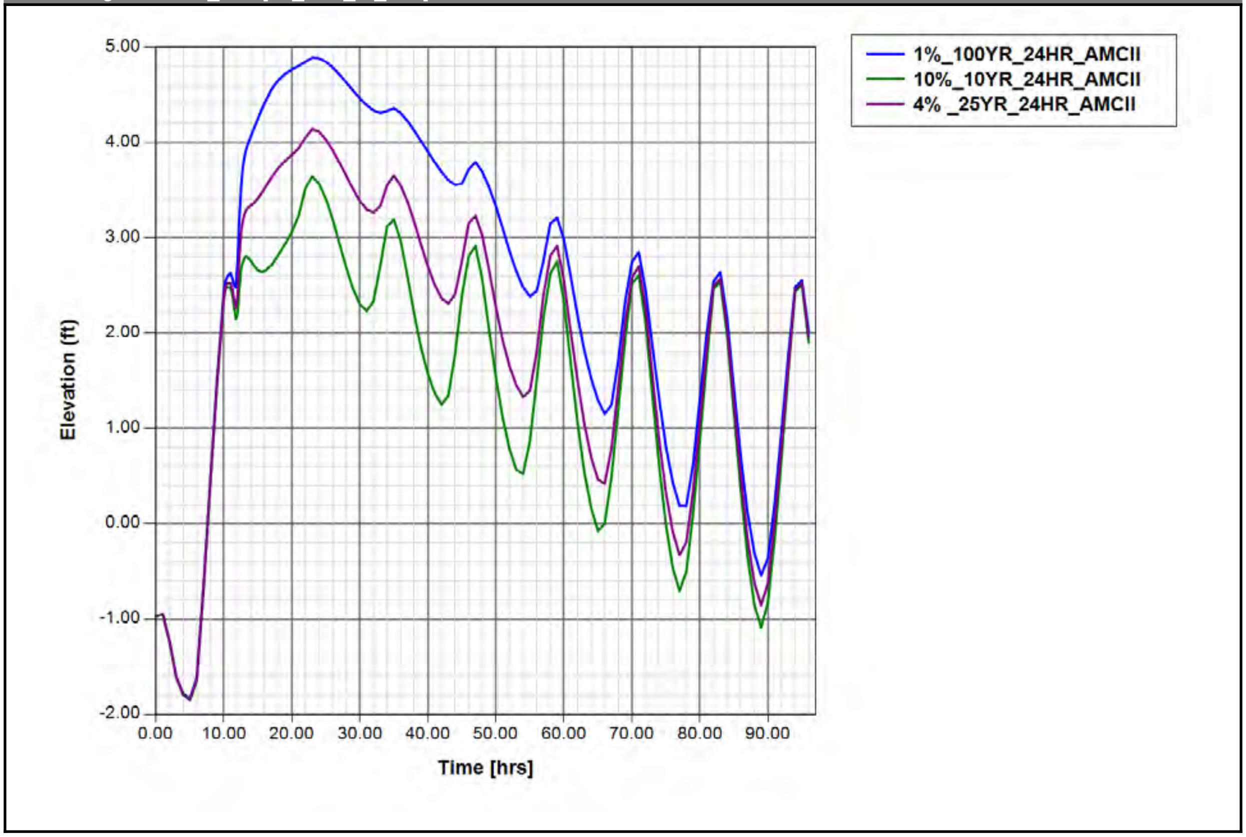
Node Stage: N-LB240 [02_LDD]



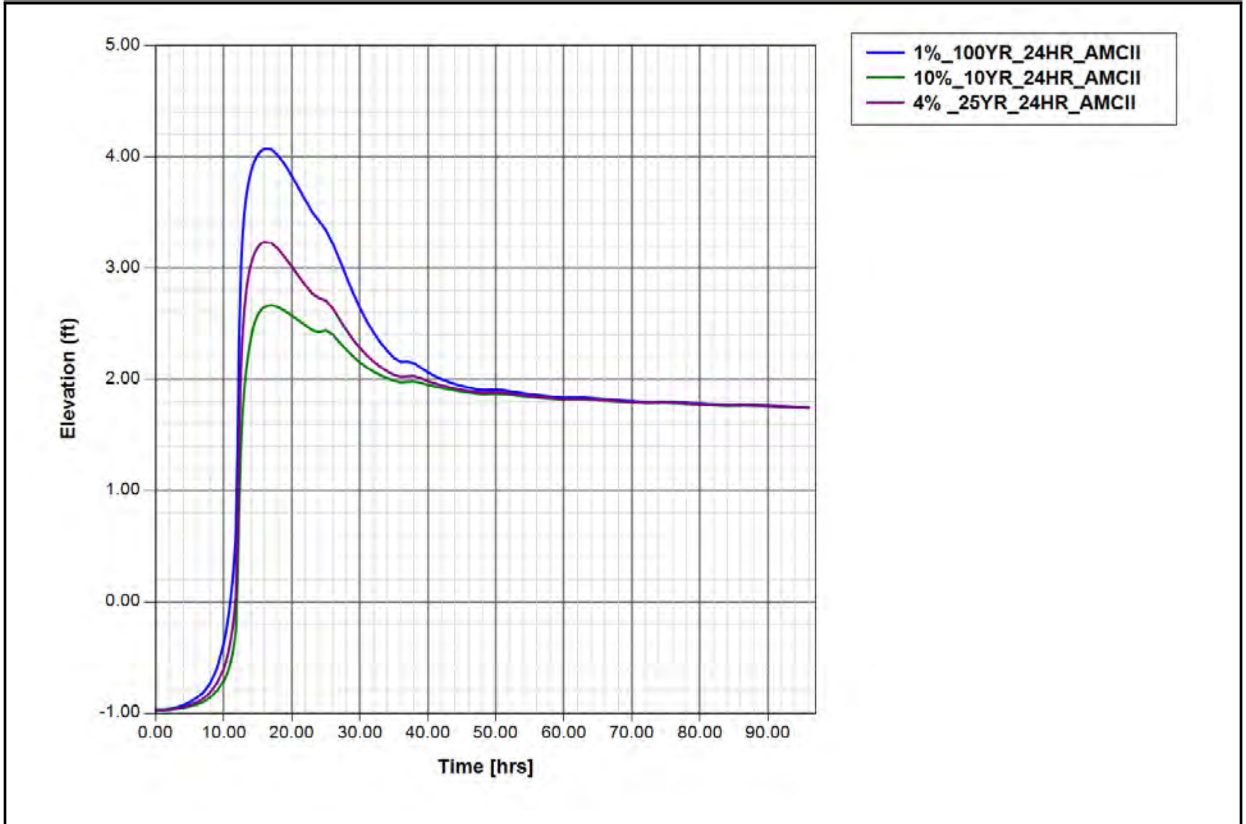
Node Stage: N-LB370 [02_LDD]



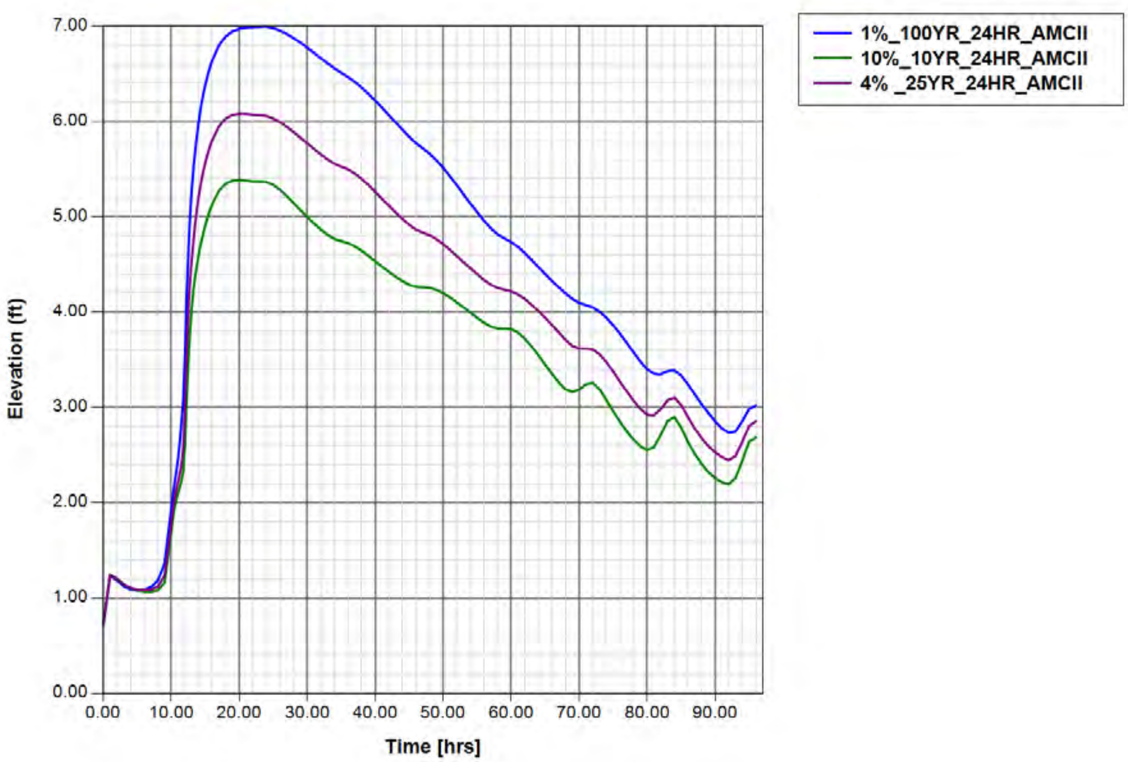
Node Stage: N-0210_SLT [03_LDD_W_IMP]



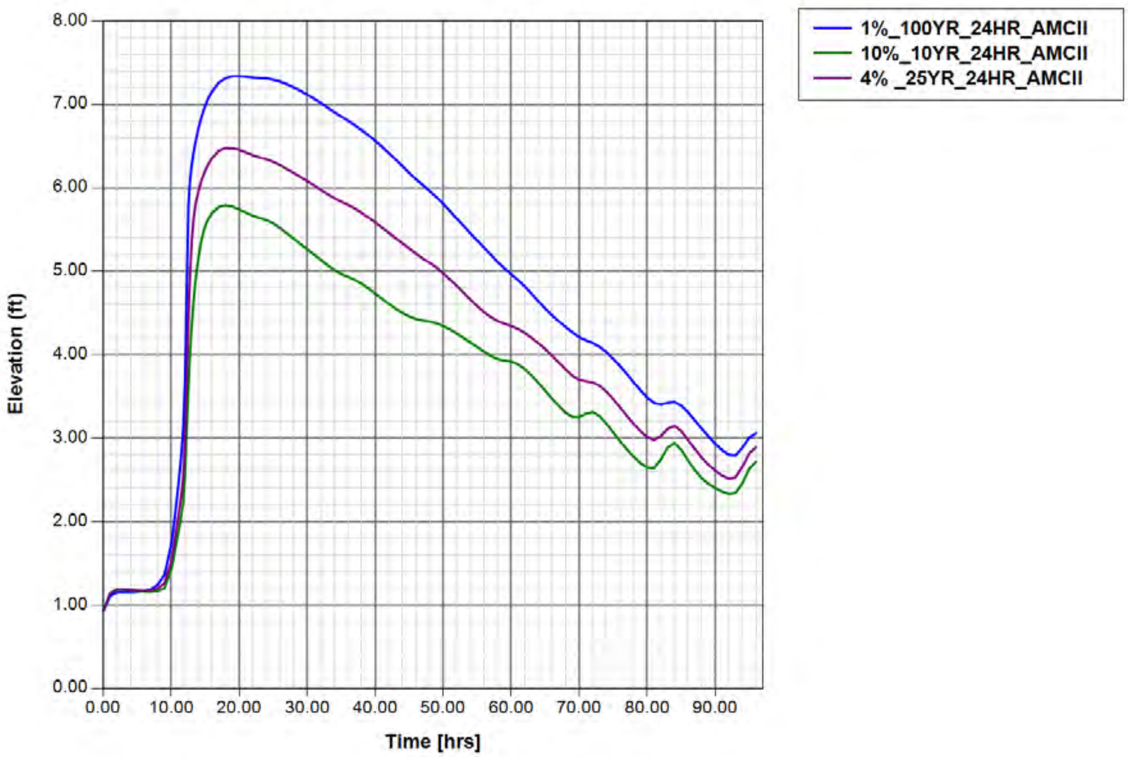
Node Stage: N-0530_SLT [03_LDD_W_IMP]



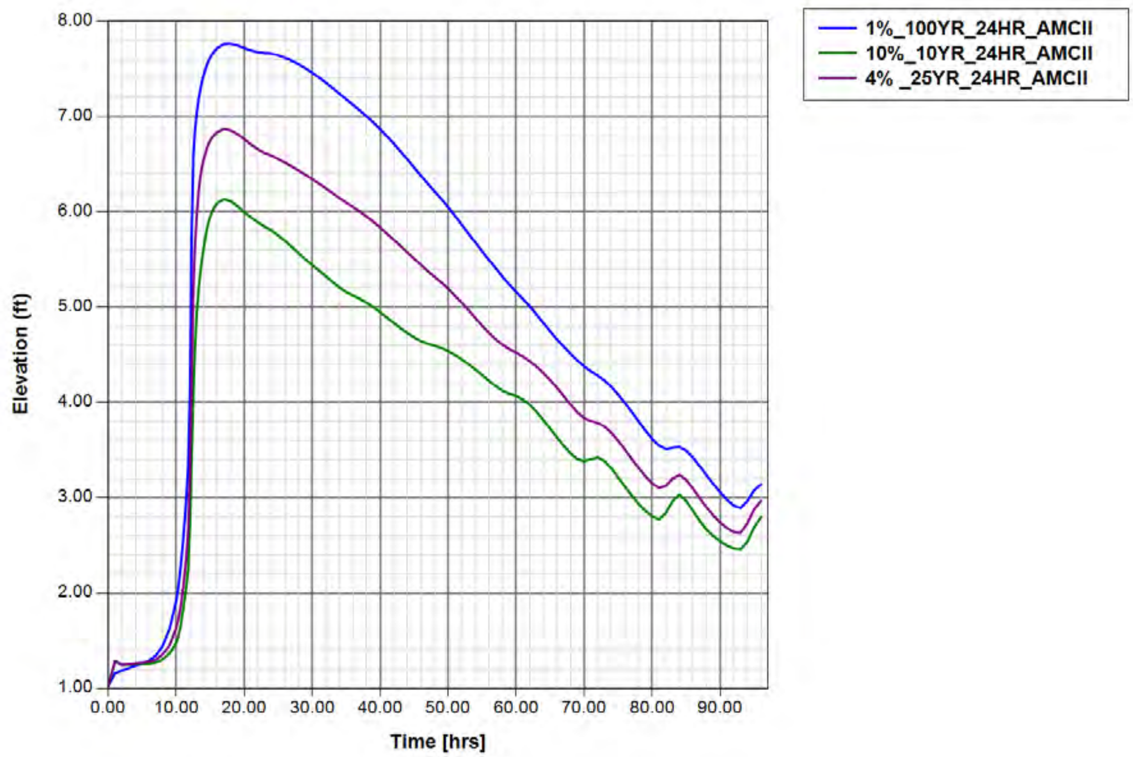
Node Stage: N-A120 [03_LDD_W_IMP]



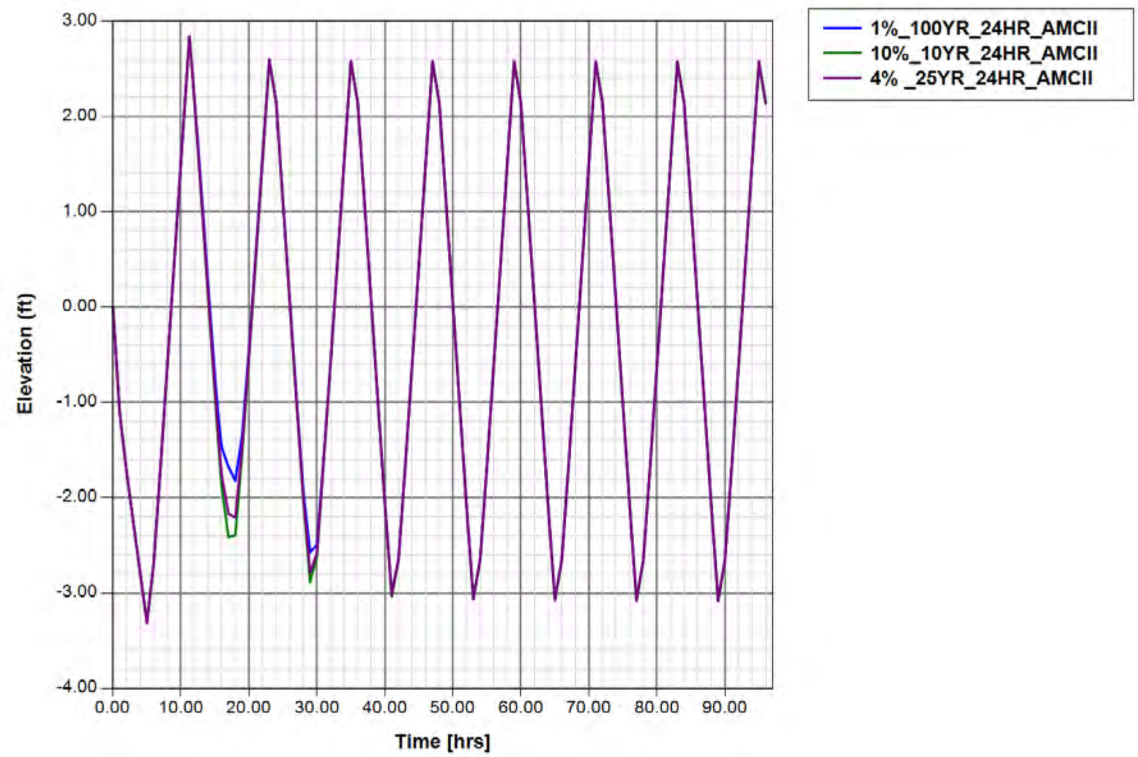
Node Stage: N-B020 [03_LDD_W_IMP]



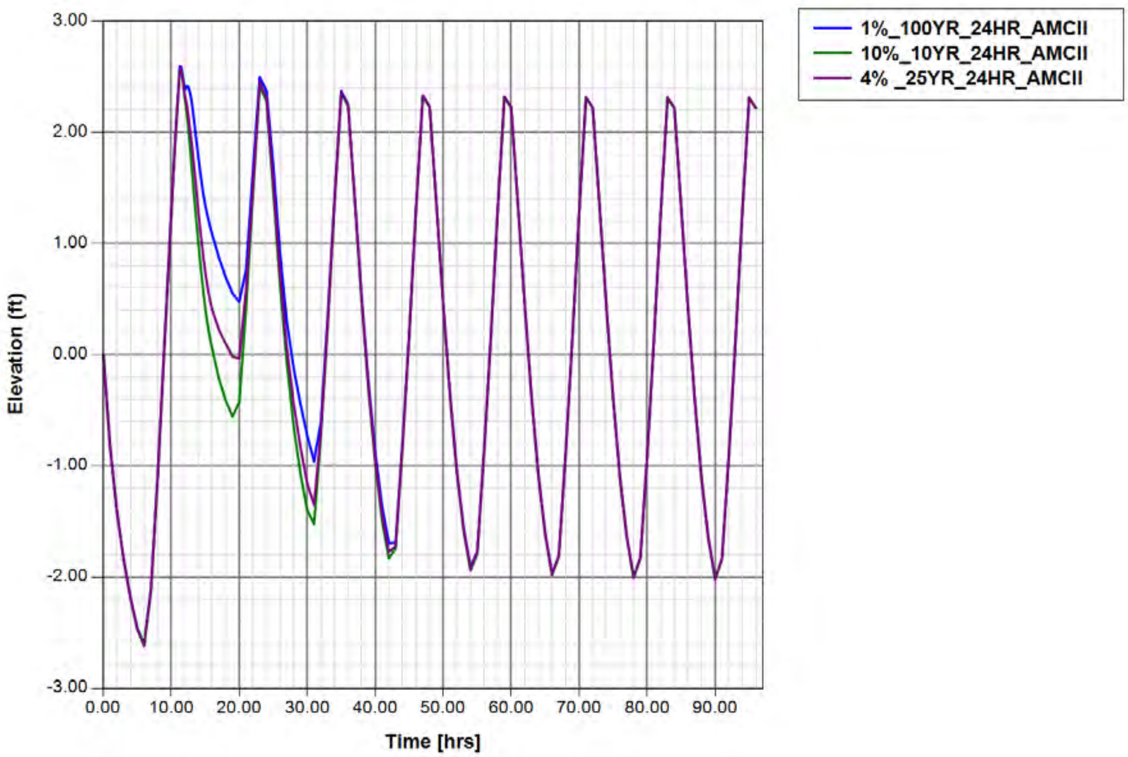
Node Stage: N-B160 [03_LDD_W_IMP]



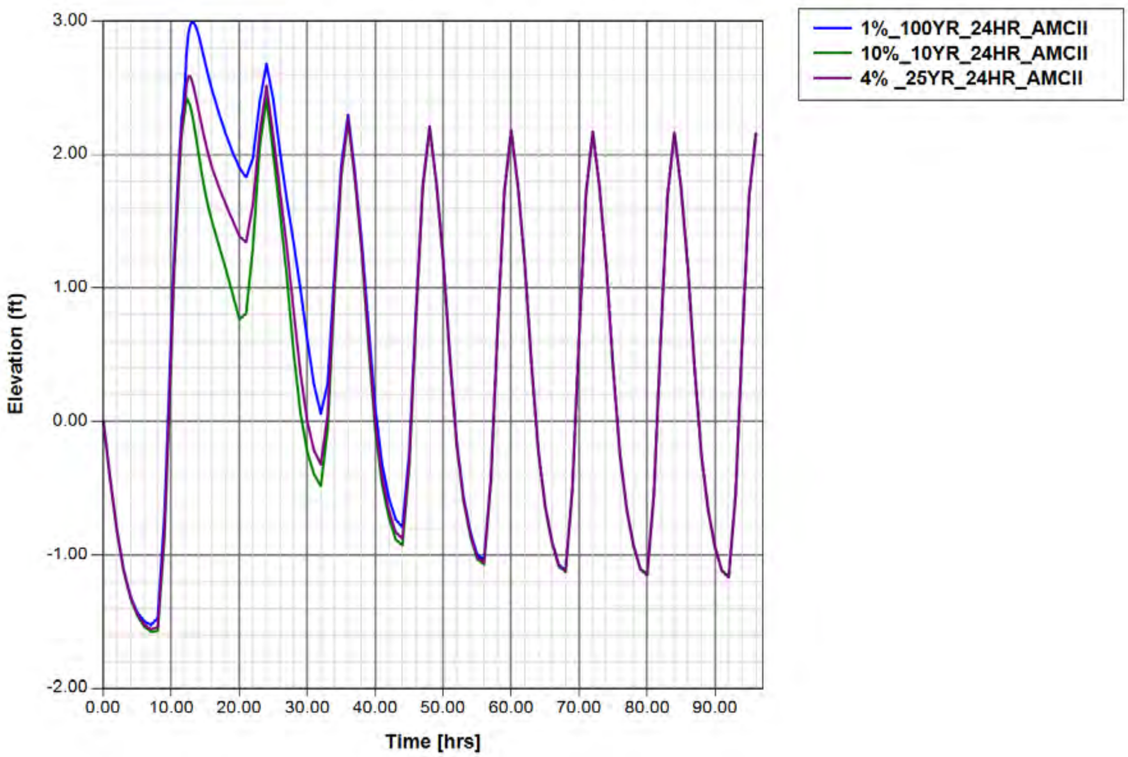
Node Stage: N-LB100 [03_LDD_W_IMP]



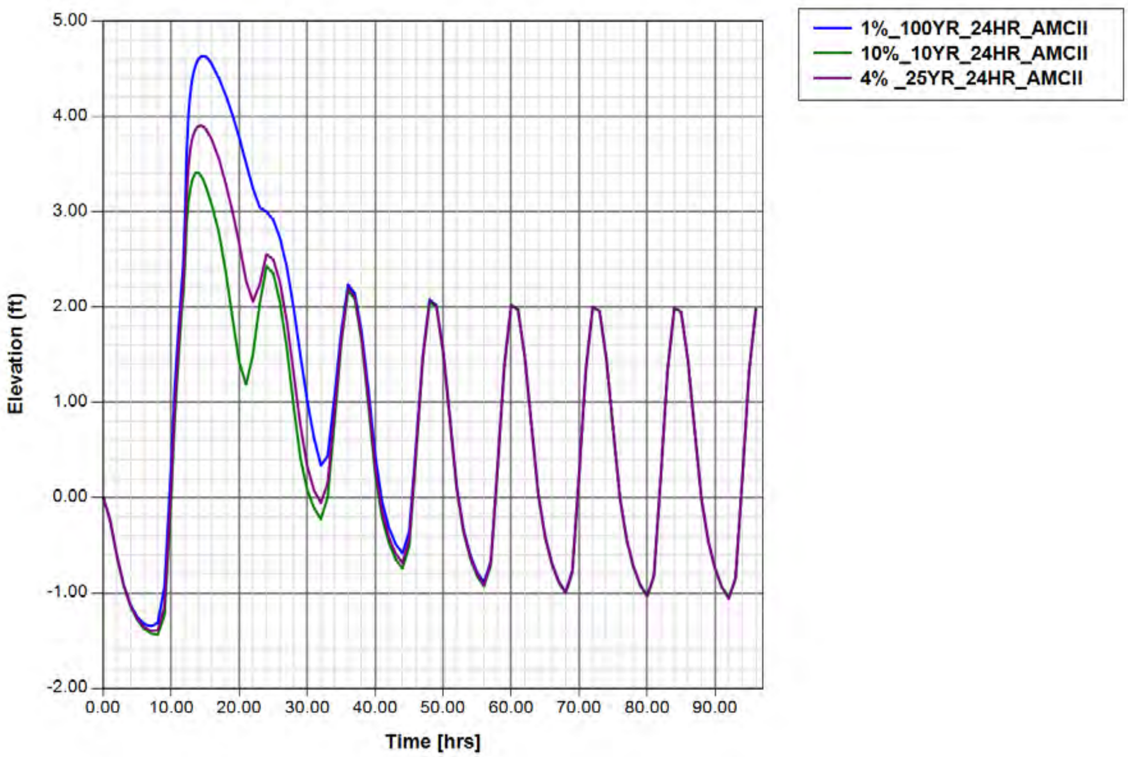
Node Stage: N-LB130 [03_LDD_W_IMP]



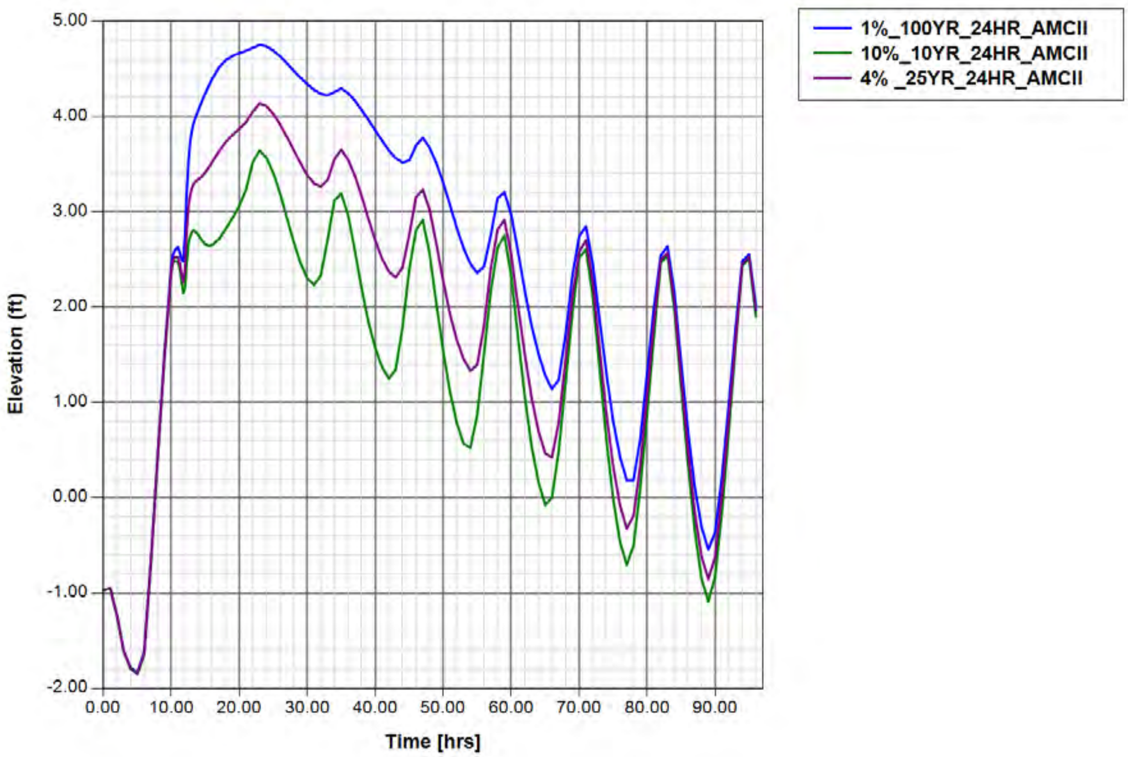
Node Stage: N-LB240 [03_LDD_W_IMP]



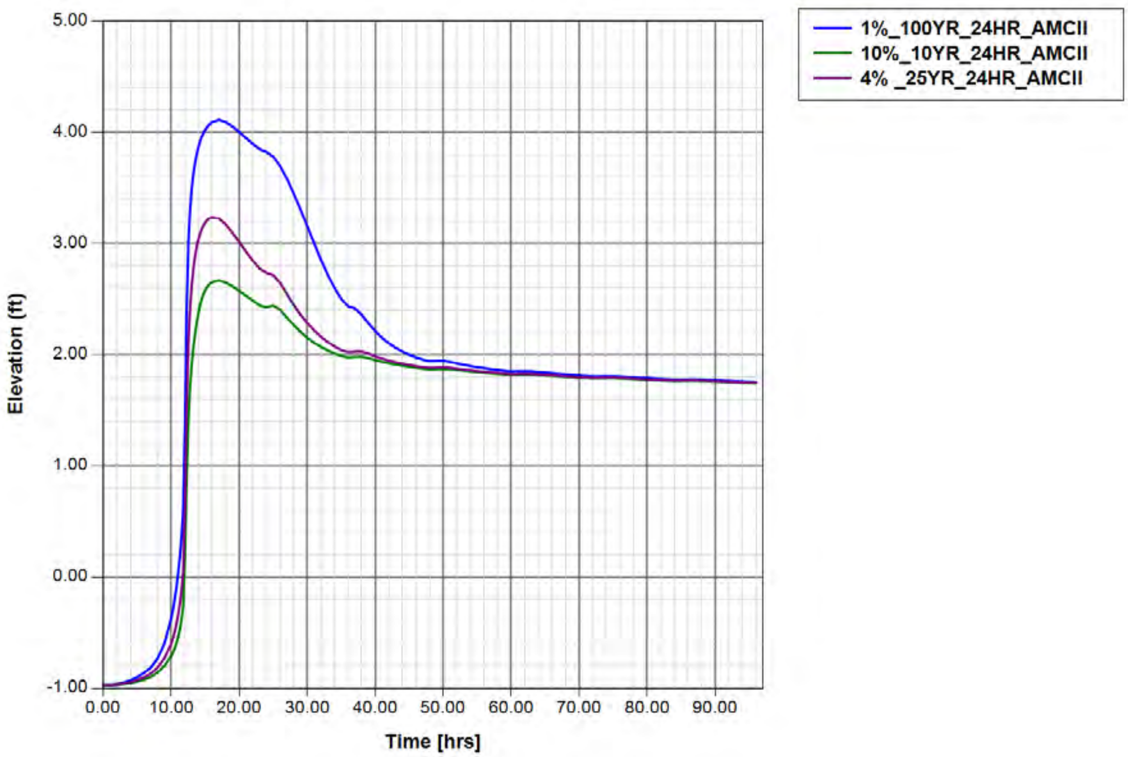
Node Stage: N-LB370 [03_LDD_W_IMP]



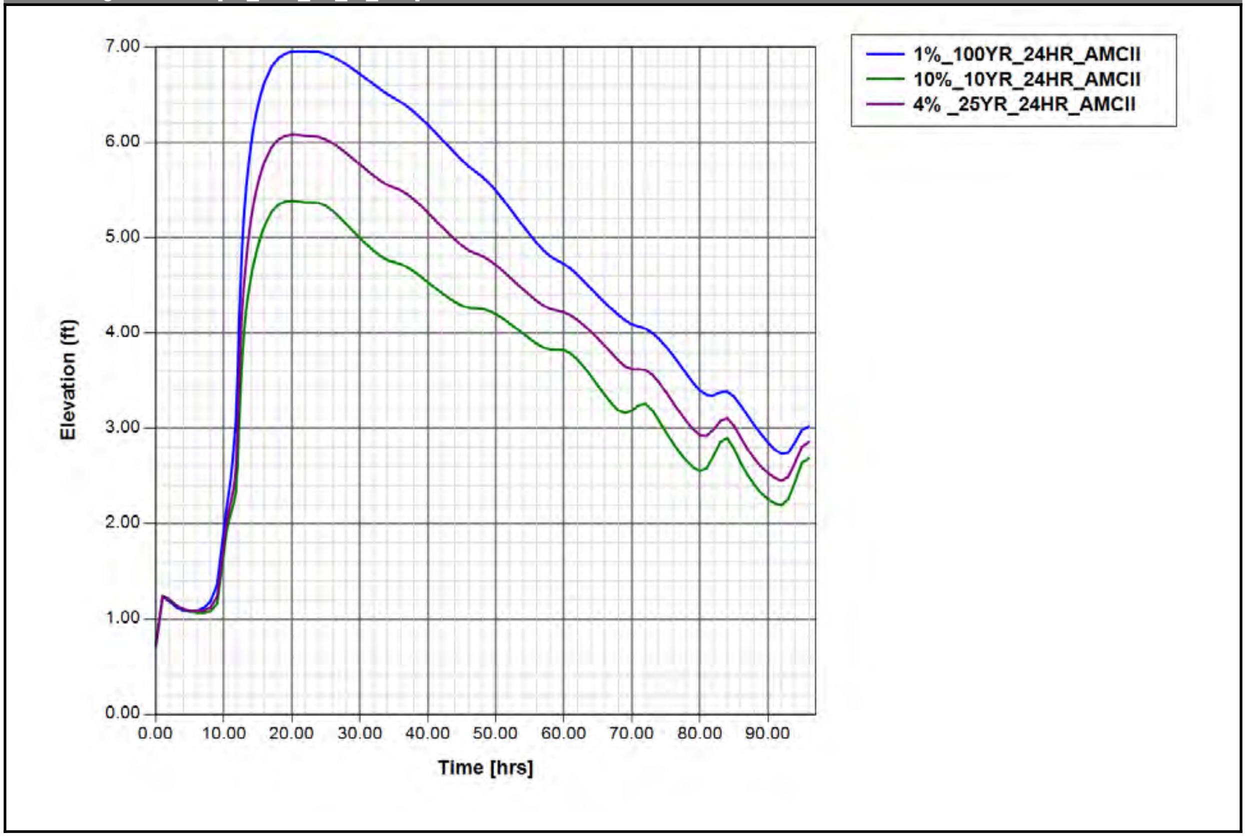
Node Stage: N-0210_SLT [04_LDD_CC_W_IMP]



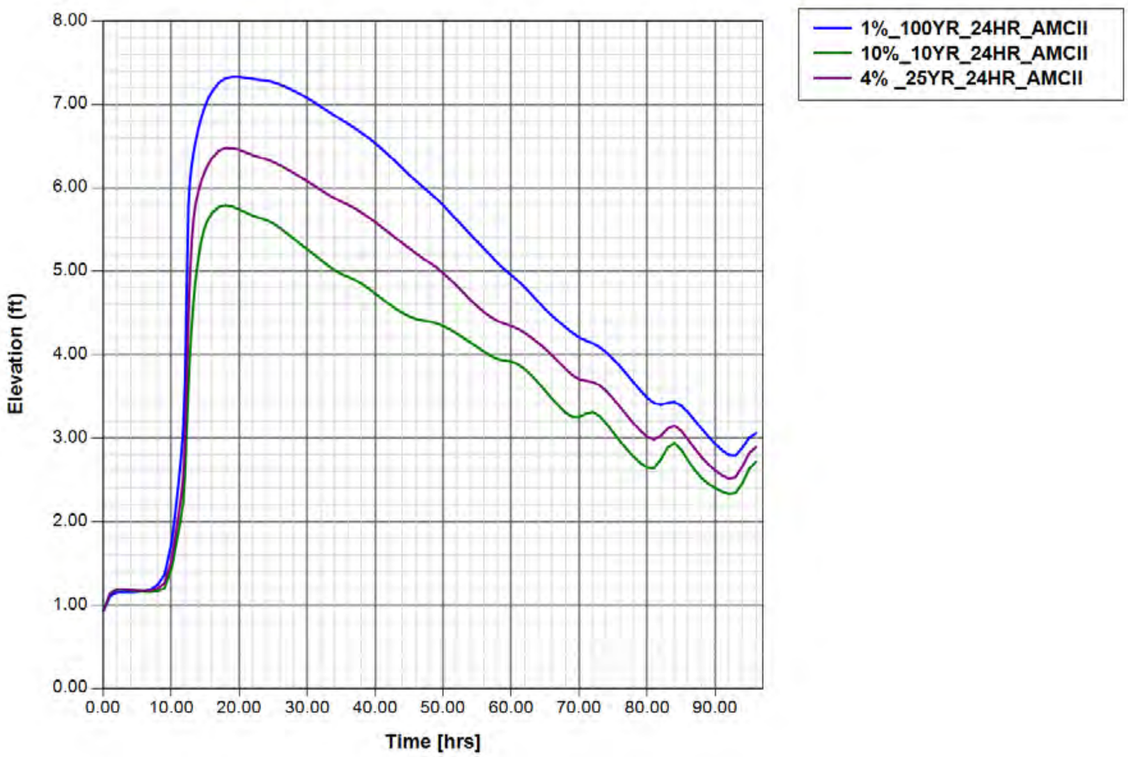
Node Stage: N-0530_SLT [04_LDD_CC_W_IMP]



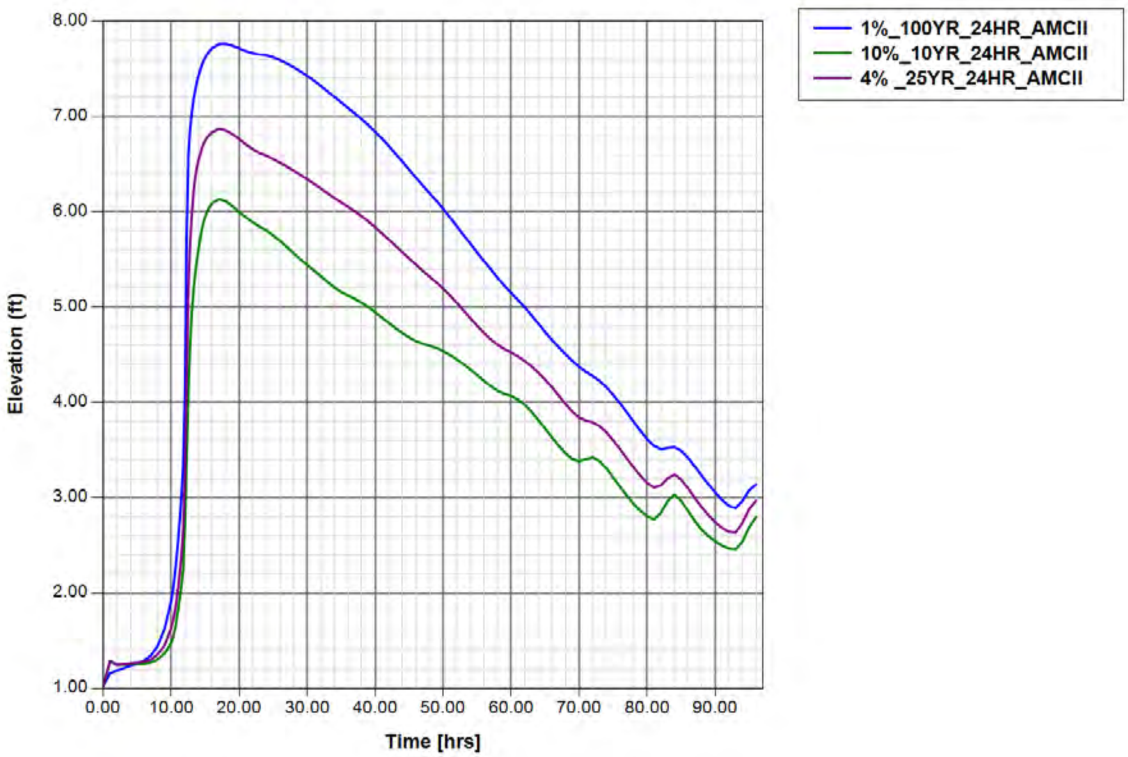
Node Stage: N-A120 [04_LDD_CC_W_IMP]



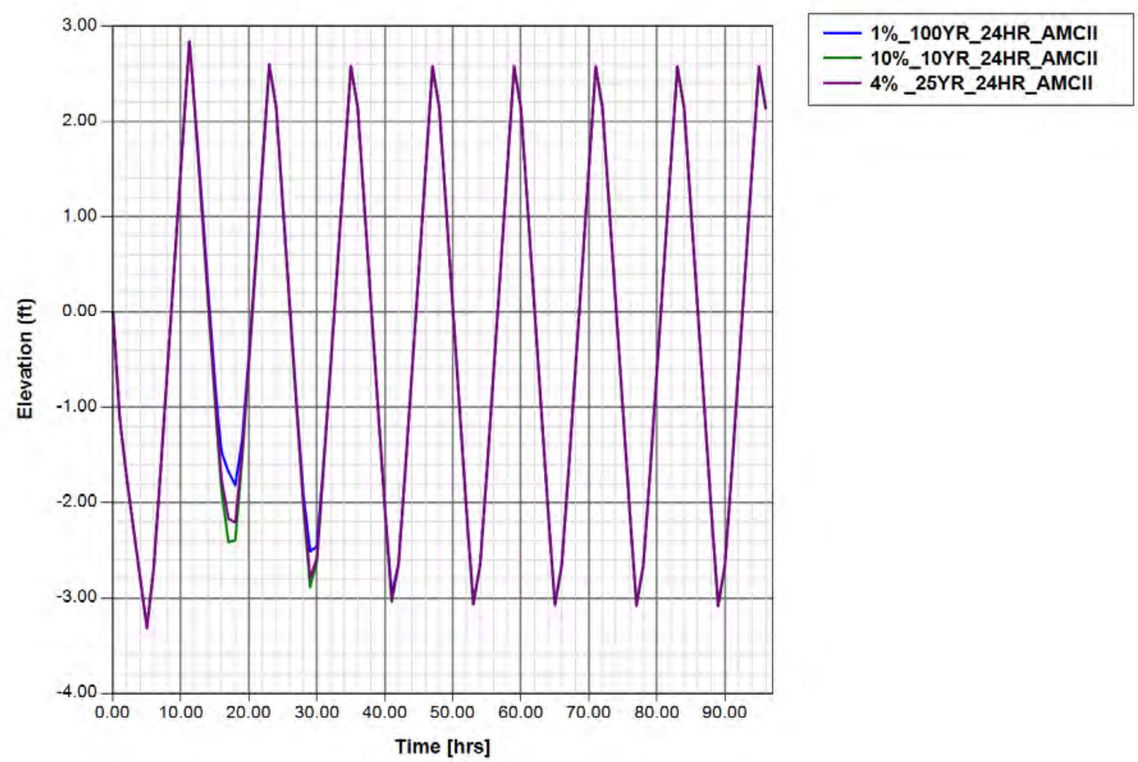
Node Stage: N-B020 [04_LDD_CC_W_IMP]



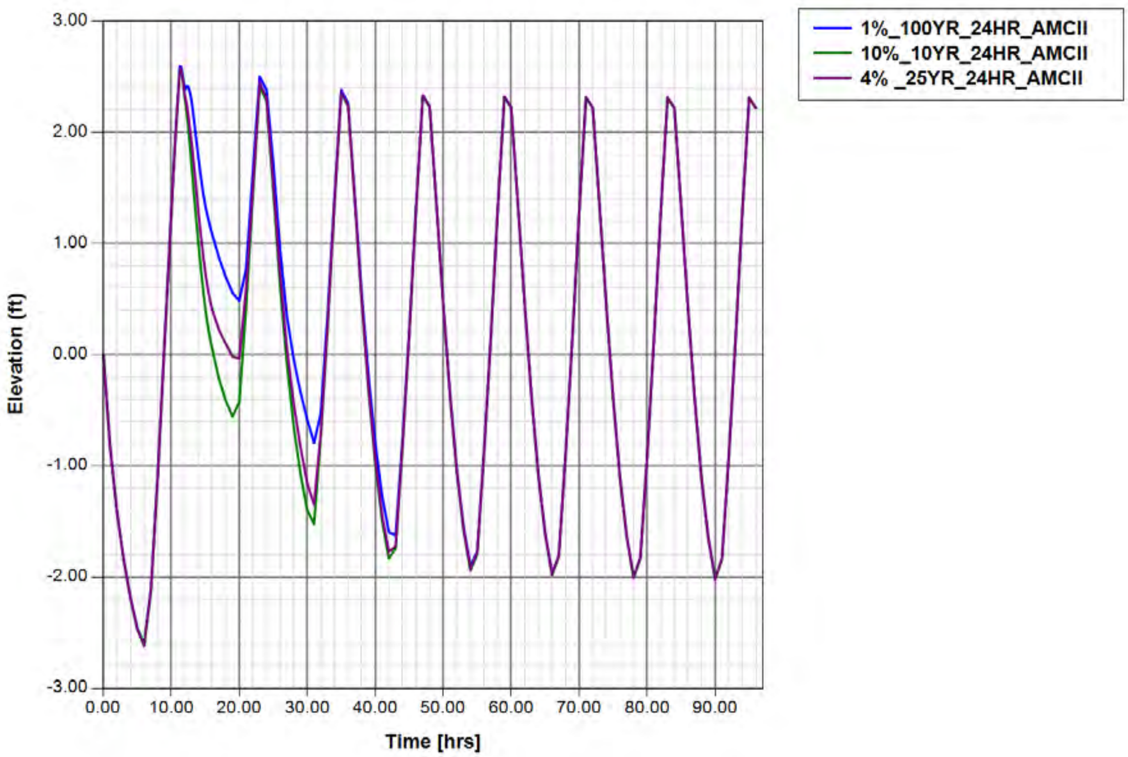
Node Stage: N-B160 [04_LDD_CC_W_IMP]



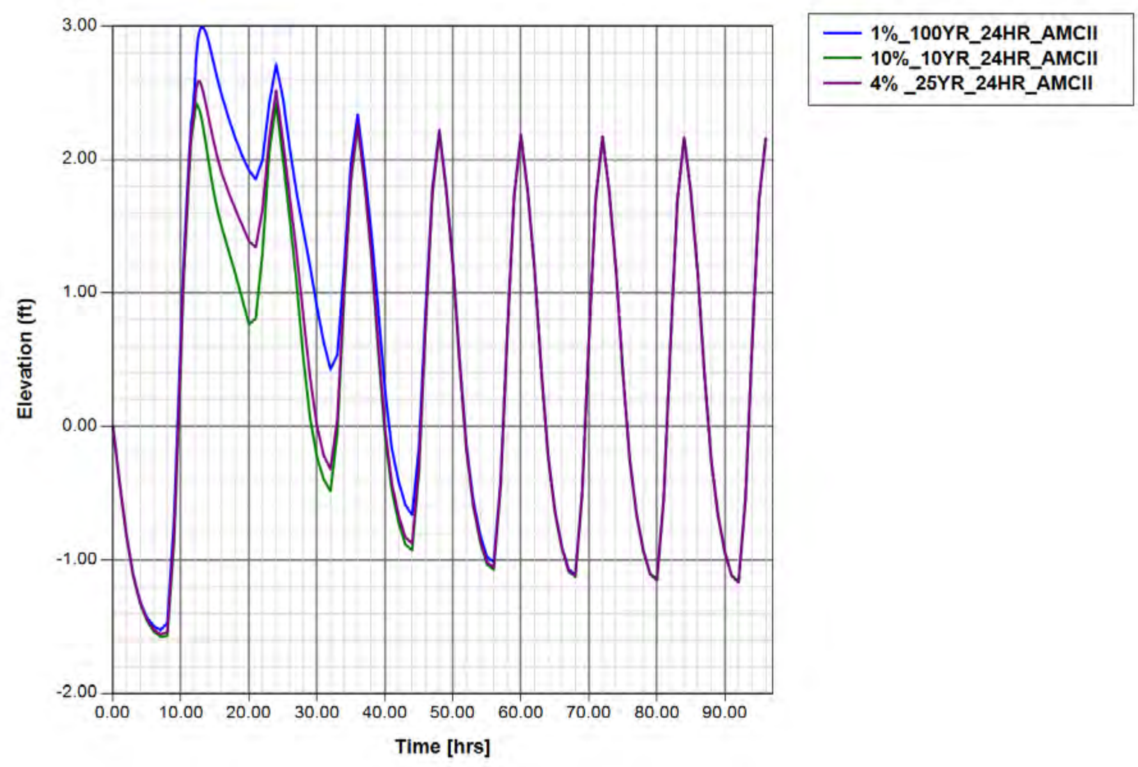
Node Stage: N-LB100 [04_LDD_CC_W_IMP]



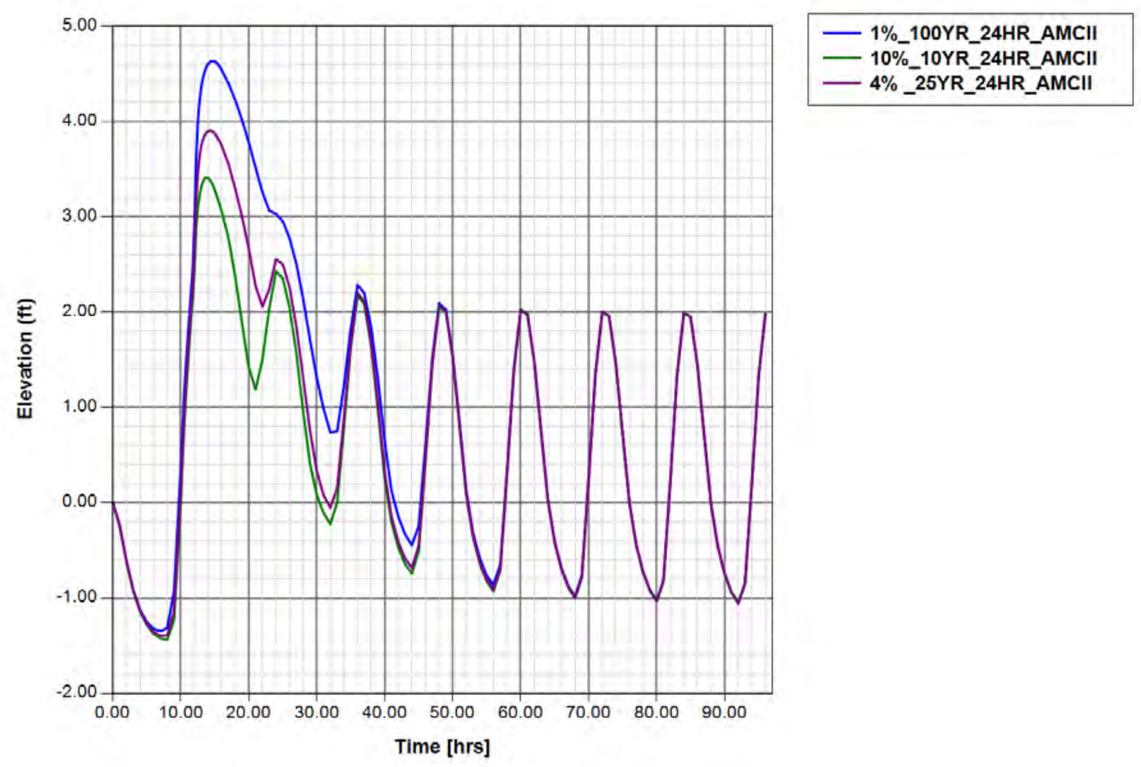
Node Stage: N-LB130 [04_LDD_CC_W_IMP]



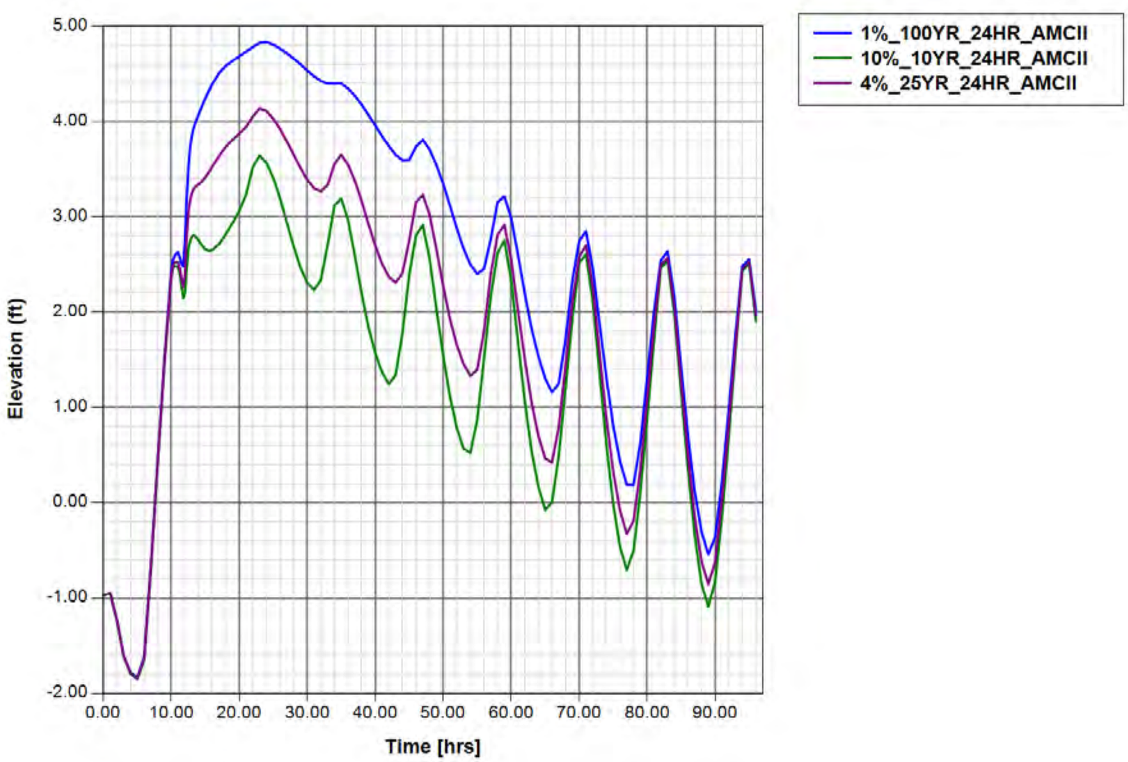
Node Stage: N-LB240 [04_LDD_CC_W_IMP]



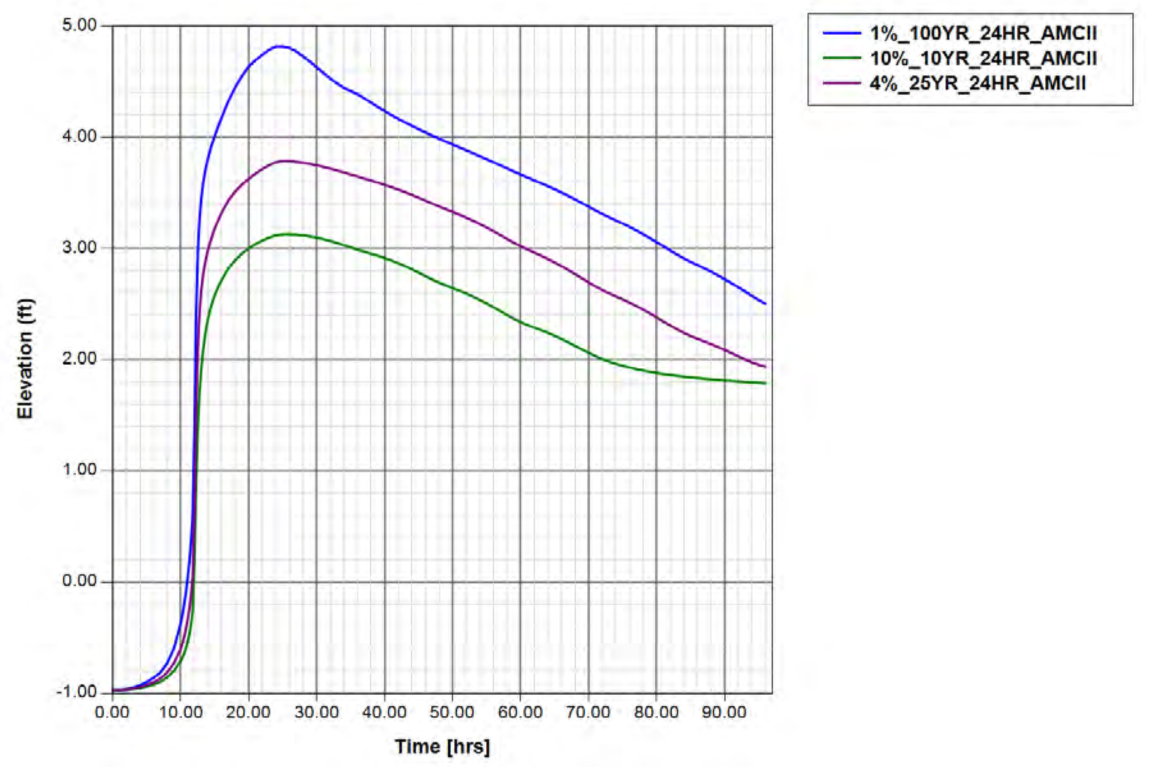
Node Stage: N-LB370 [04_LDD_CC_W_IMP]



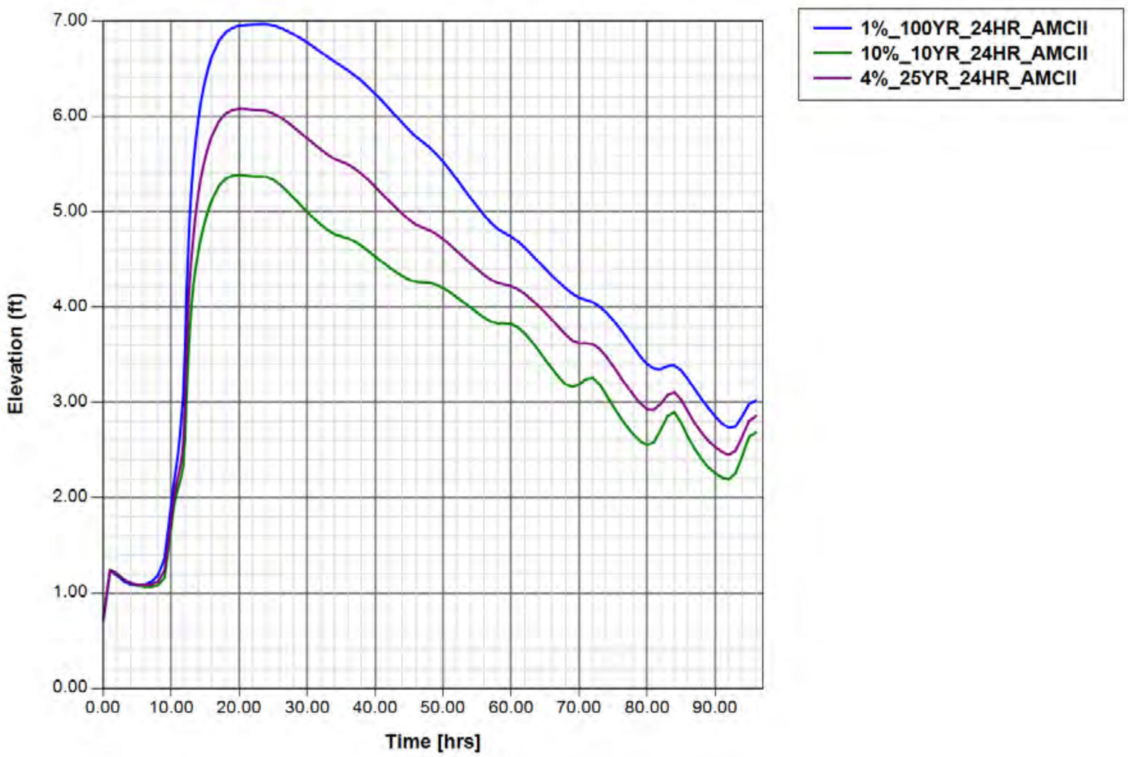
Node Stage: N-0210_SLT [05_LDD_CC]



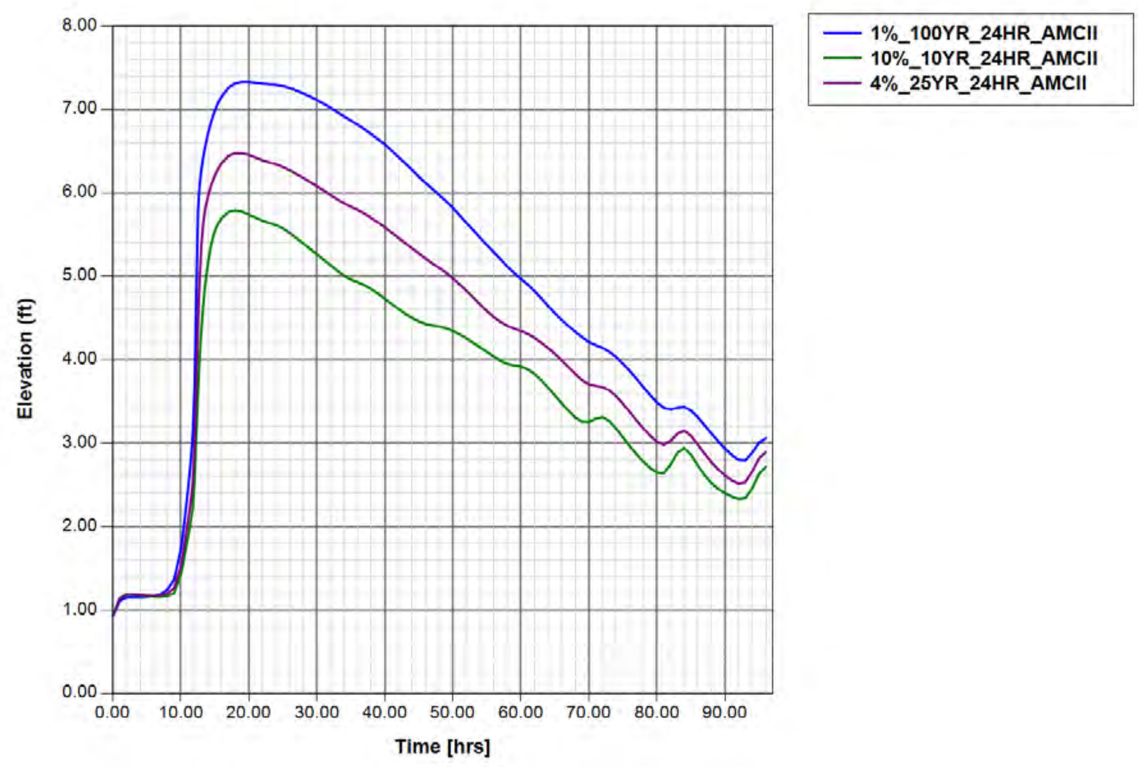
Node Stage: N-0530_SLT [05_LDD_CC]



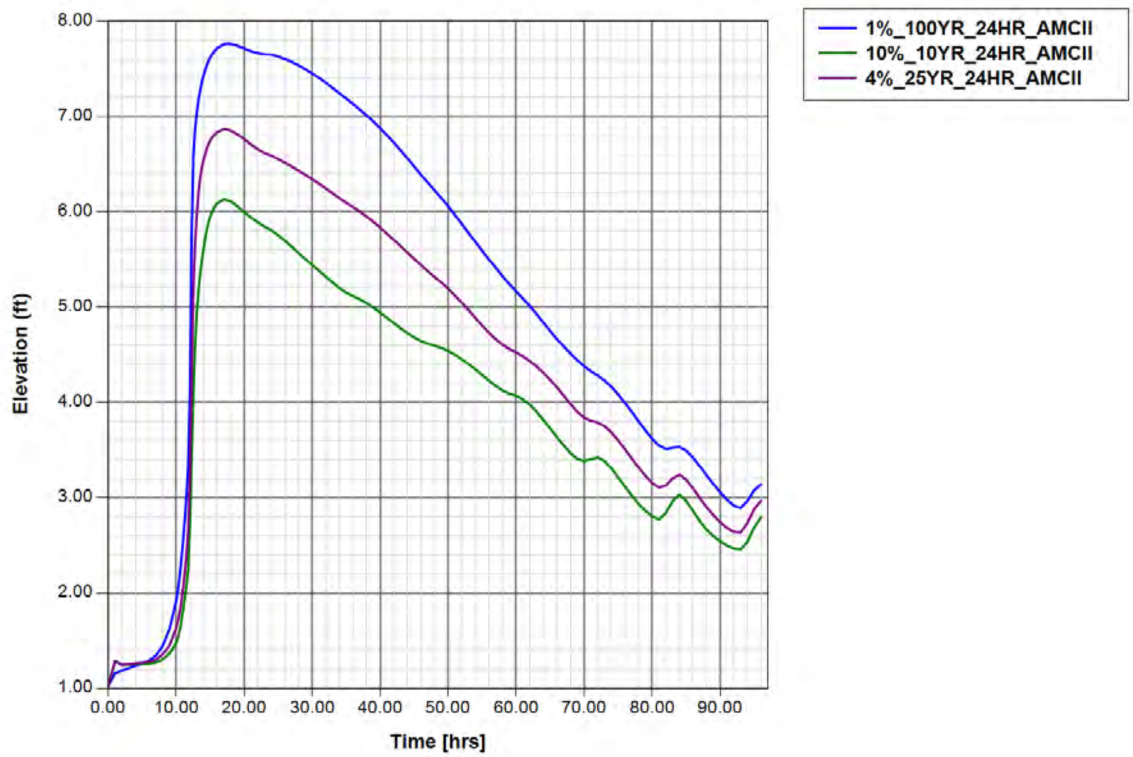
Node Stage: N-A120 [05_LDD_CC]



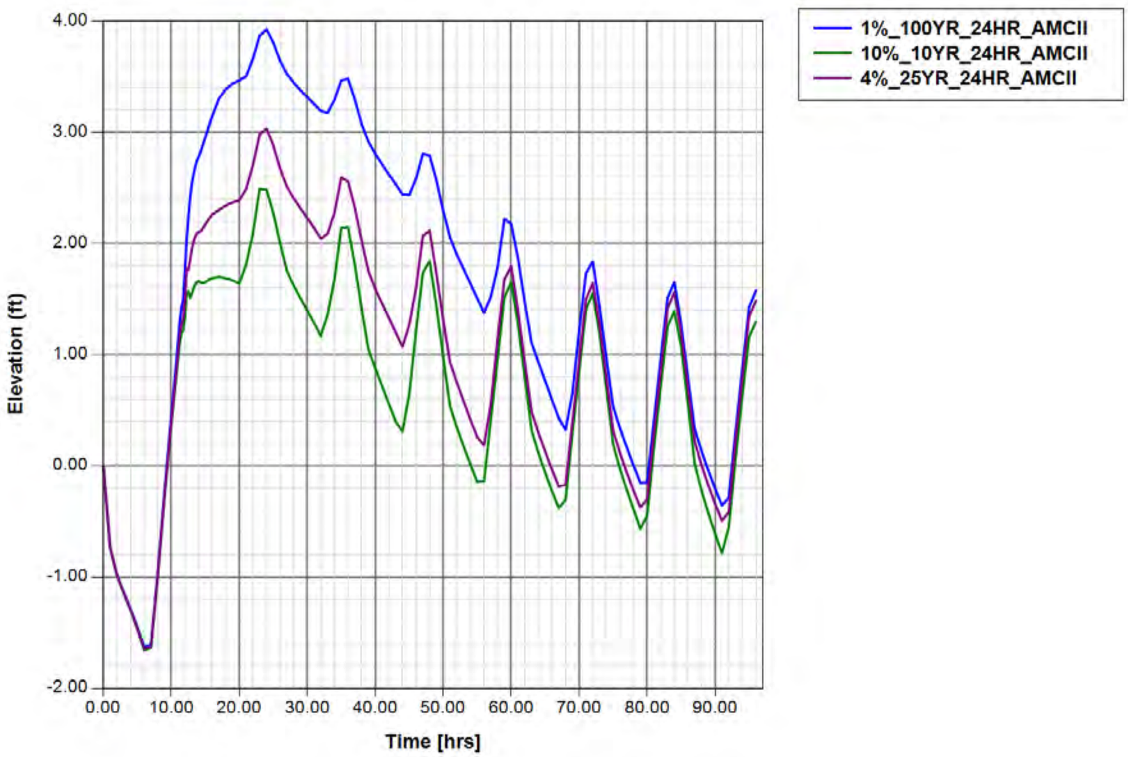
Node Stage: N-B020 [05_LDD_CC]



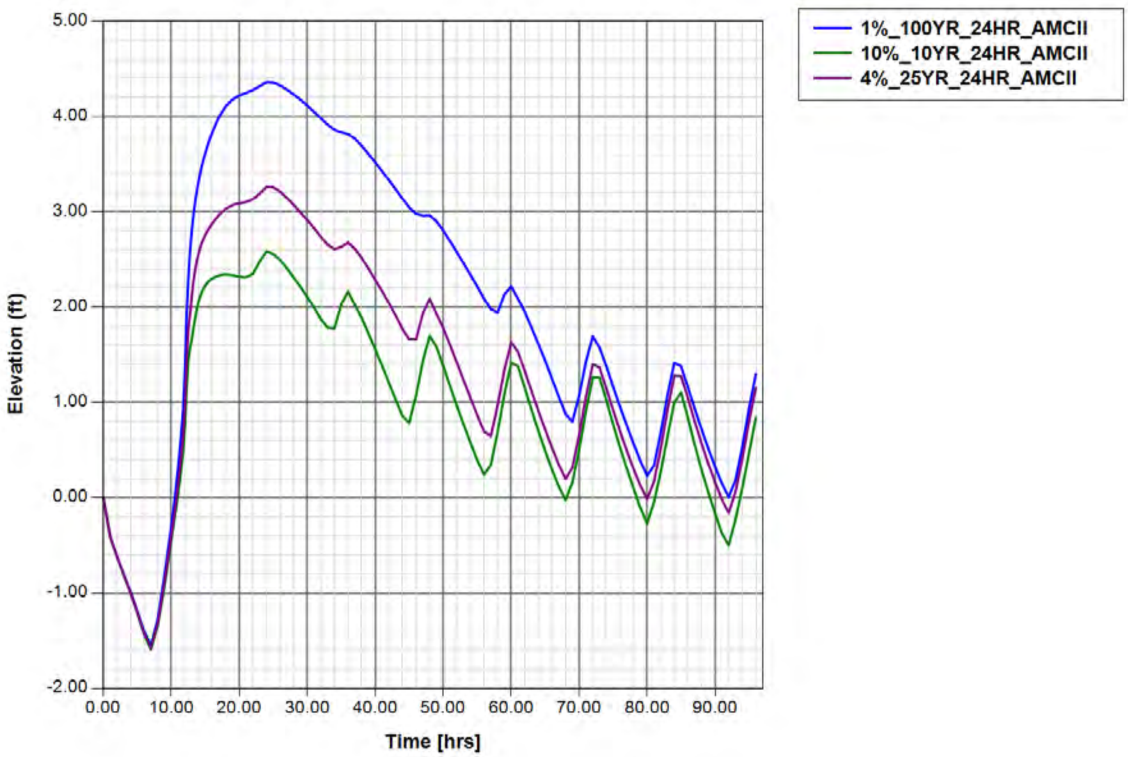
Node Stage: N-B160 [05_LDD_CC]



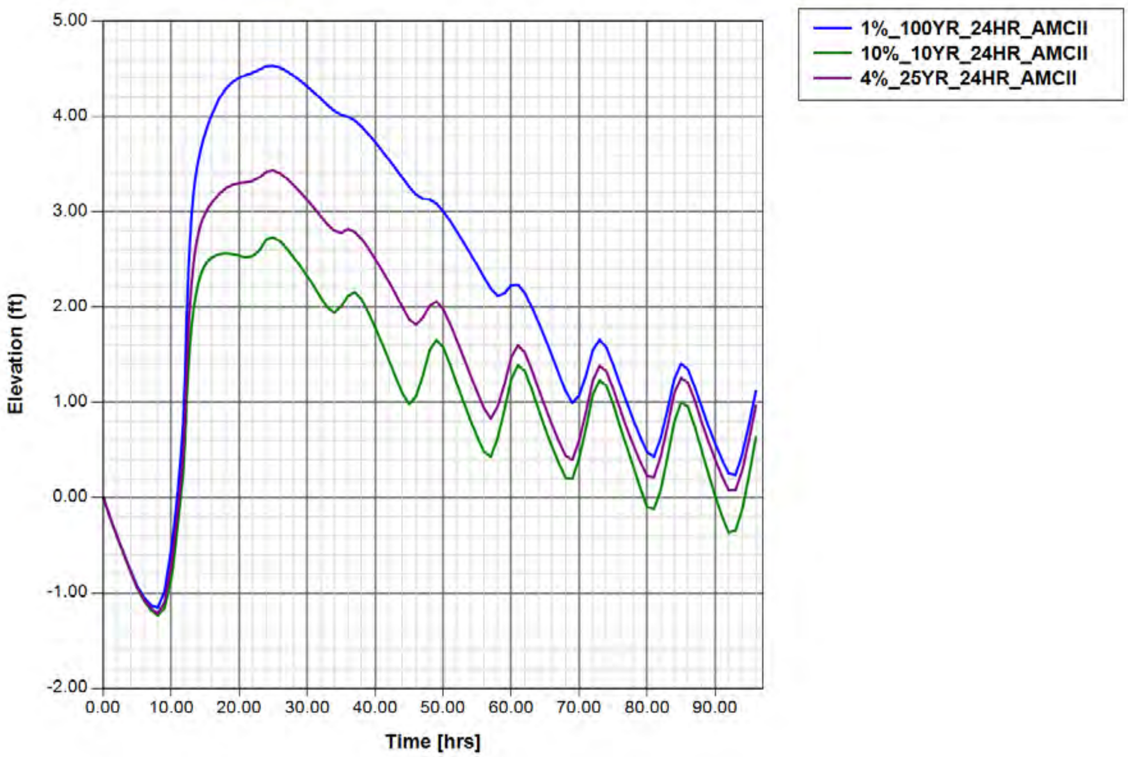
Node Stage: N-LB100 [05_LDD_CC]



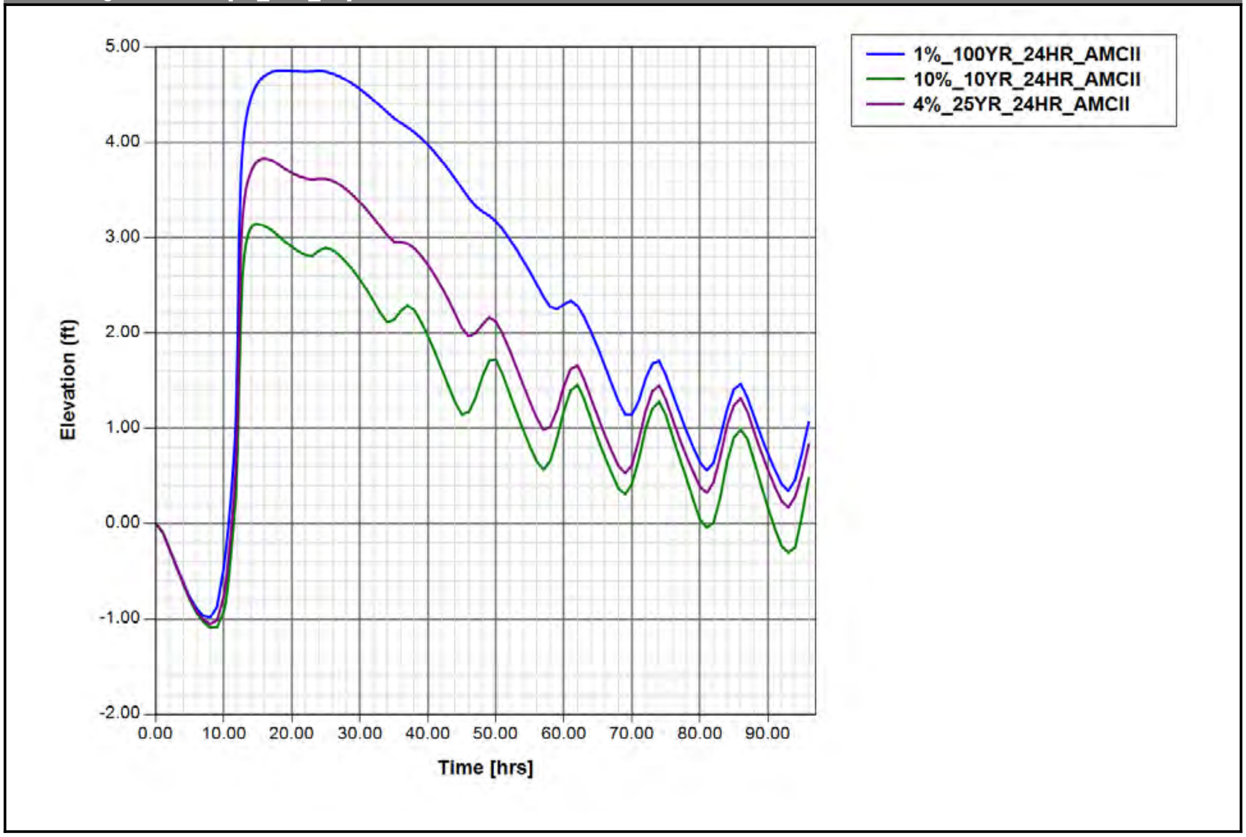
Node Stage: N-LB130 [05_LDD_CC]



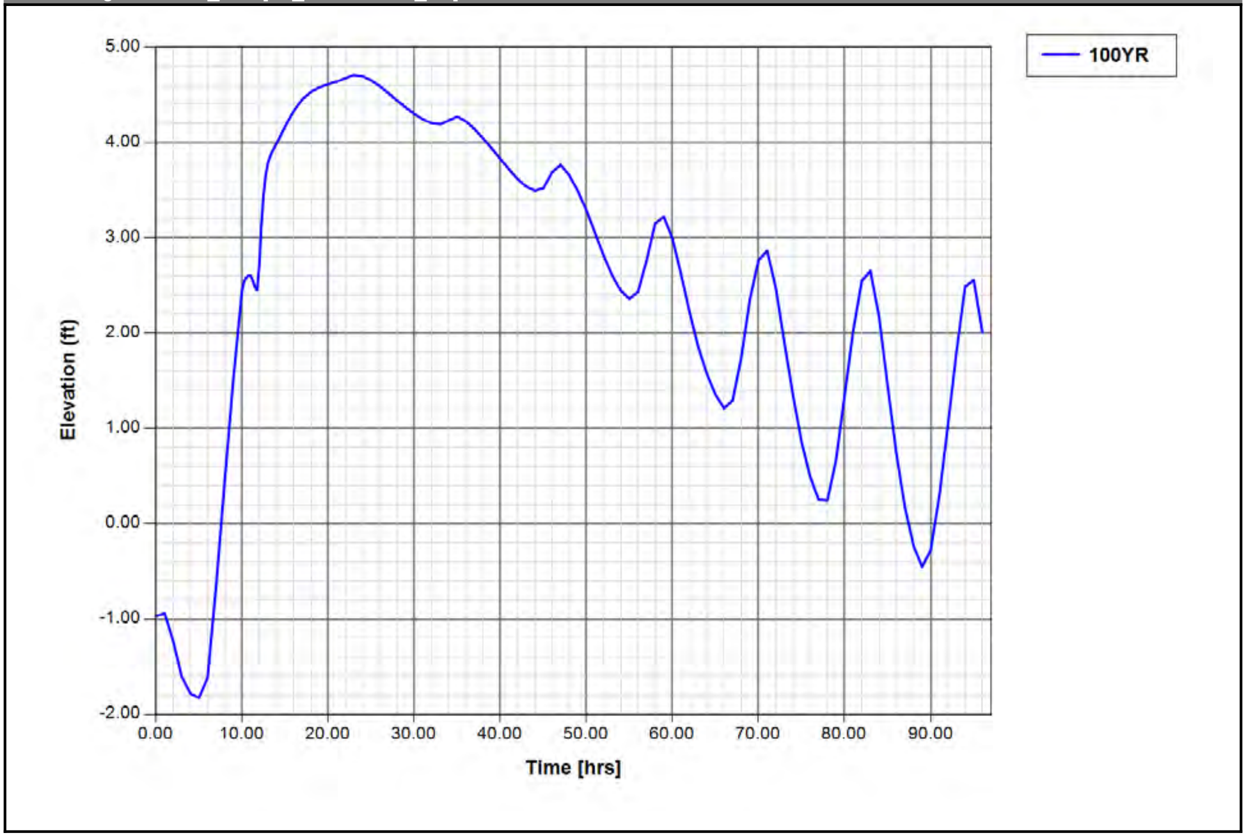
Node Stage: N-LB240 [05_LDD_CC]



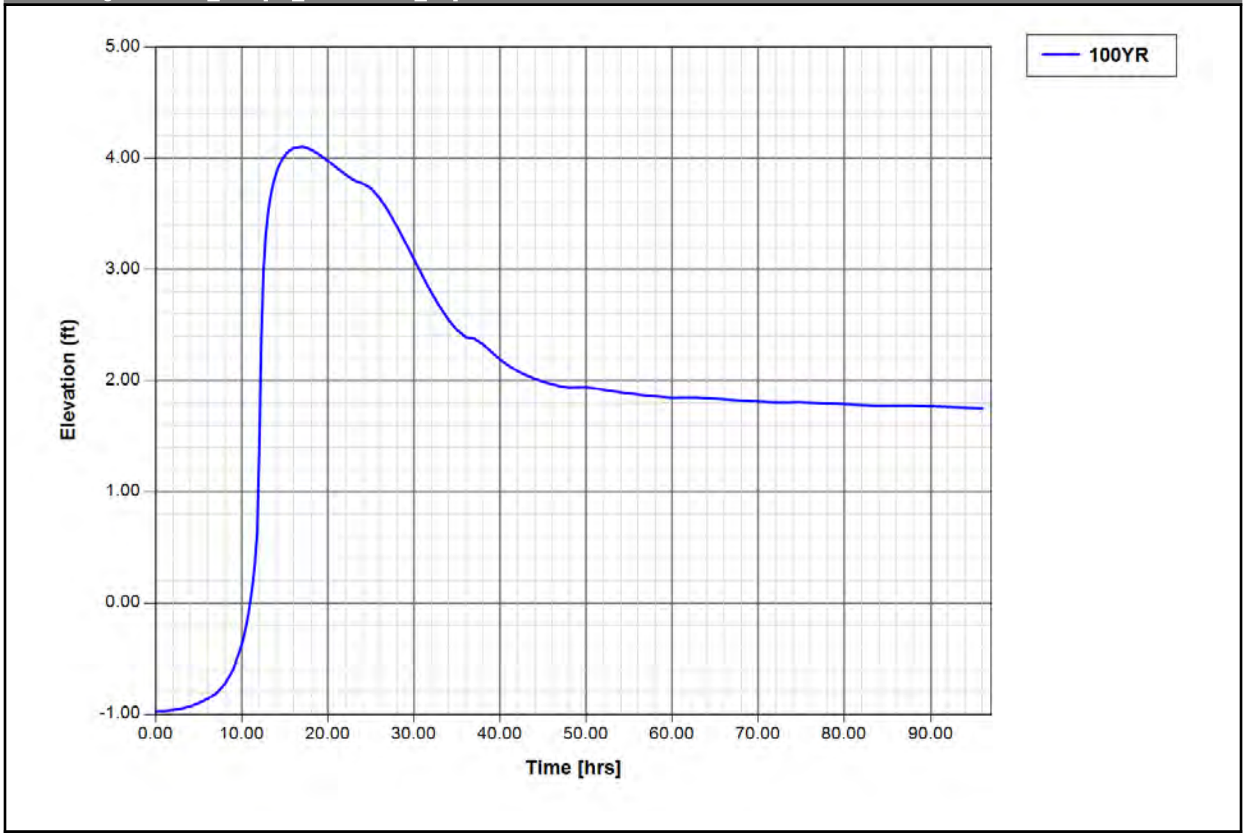
Node Stage: N-LB370 [05_LDD_CC]



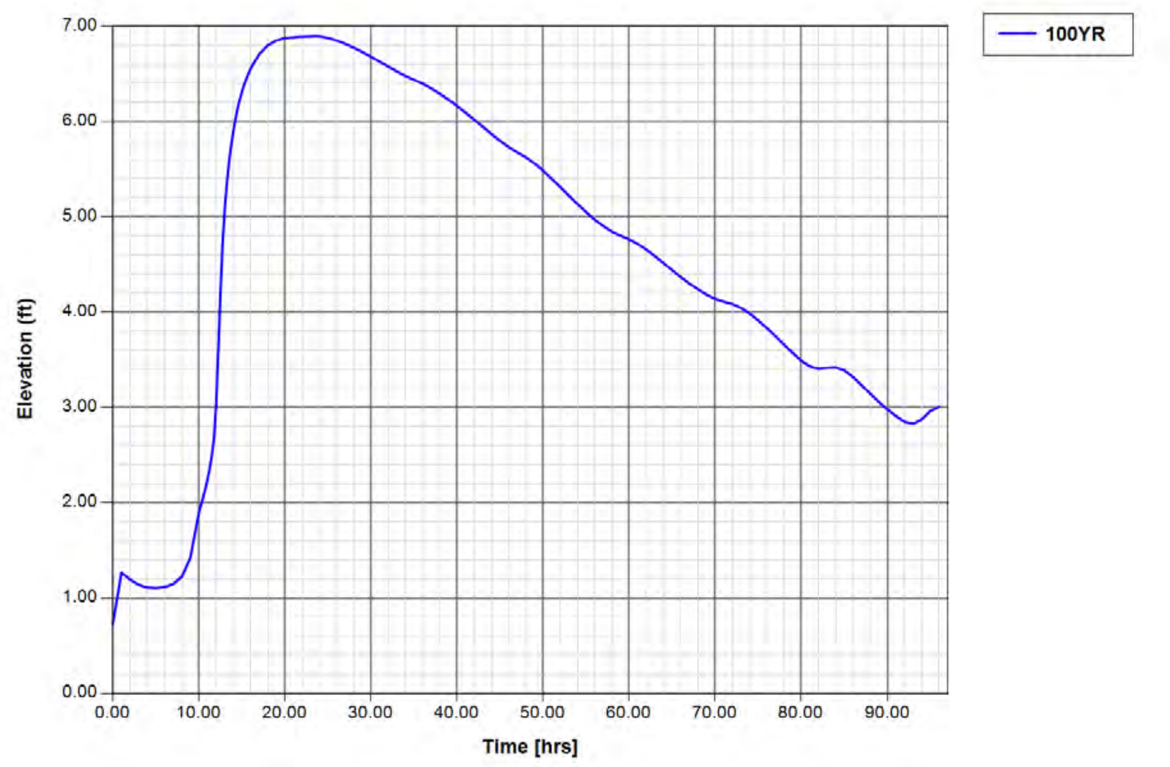
Node Stage: N-0210_SLT [06_FLFR-COMB_CC]



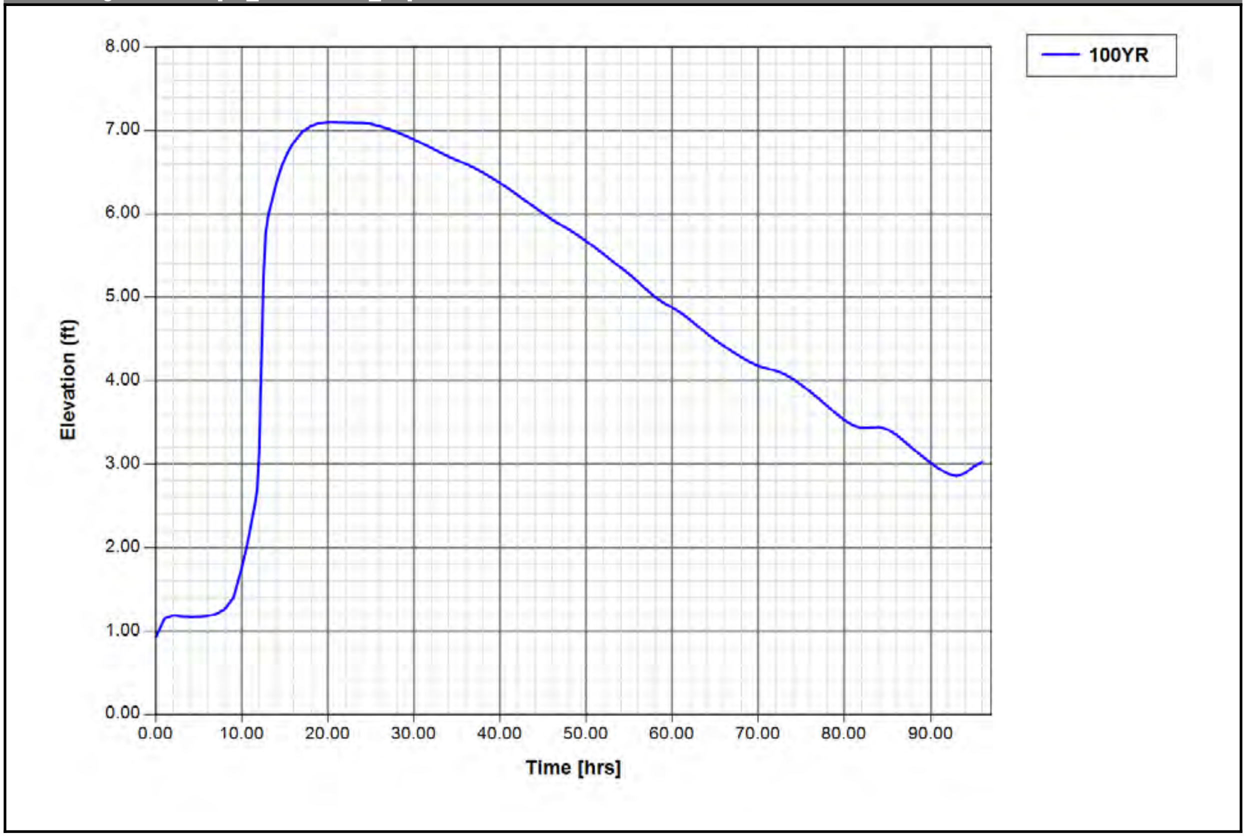
Node Stage: N-0530_SLT [06_FLFR-COMB_CC]



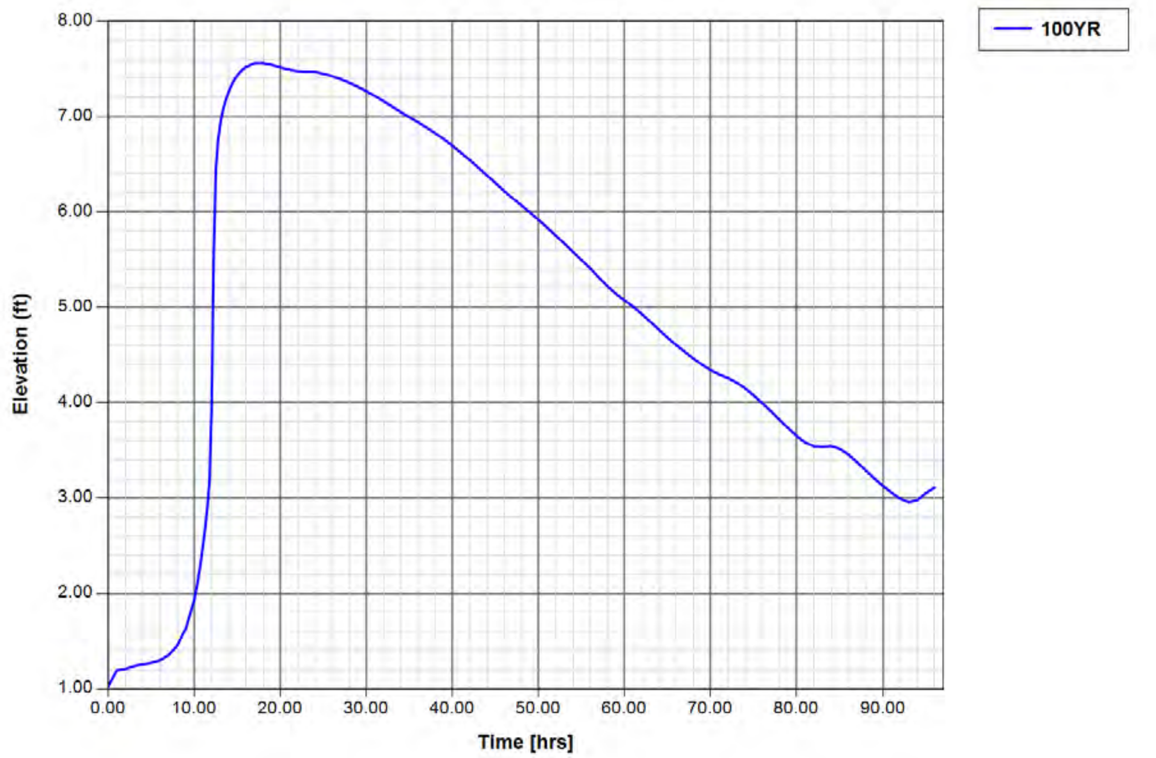
Node Stage: N-A120 [06_FLFR-COMB_CC]



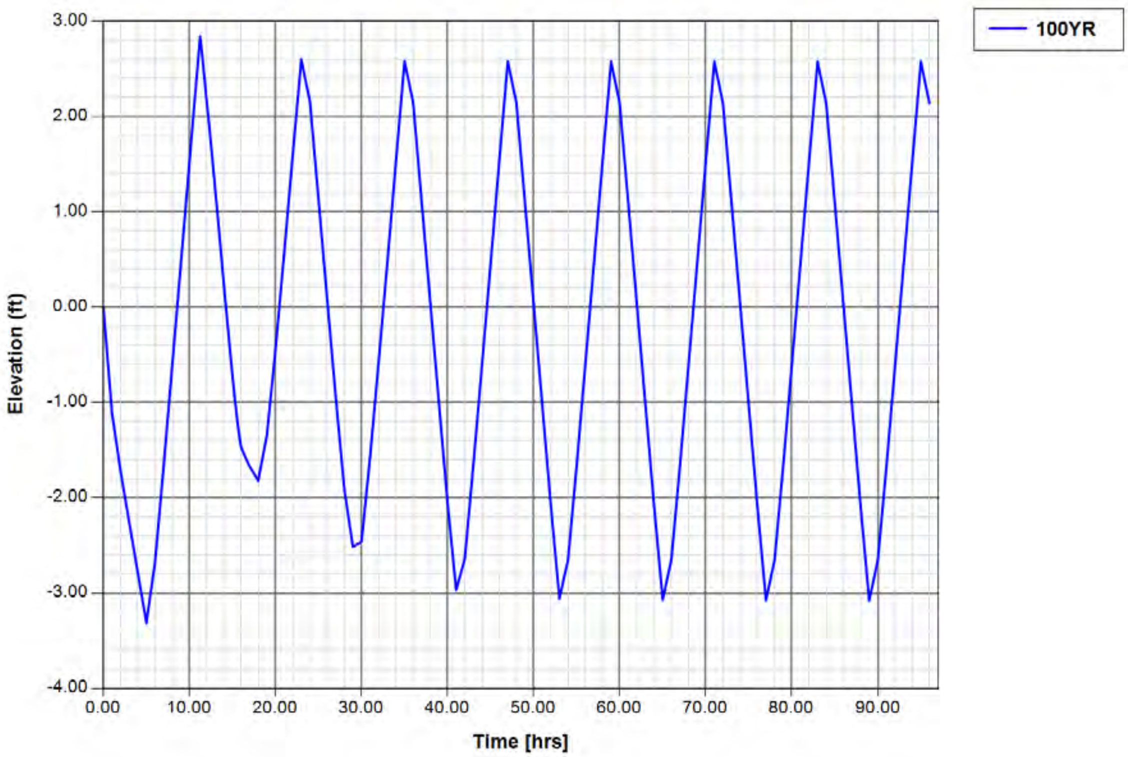
Node Stage: N-B020 [06_FLFR-COMB_CC]



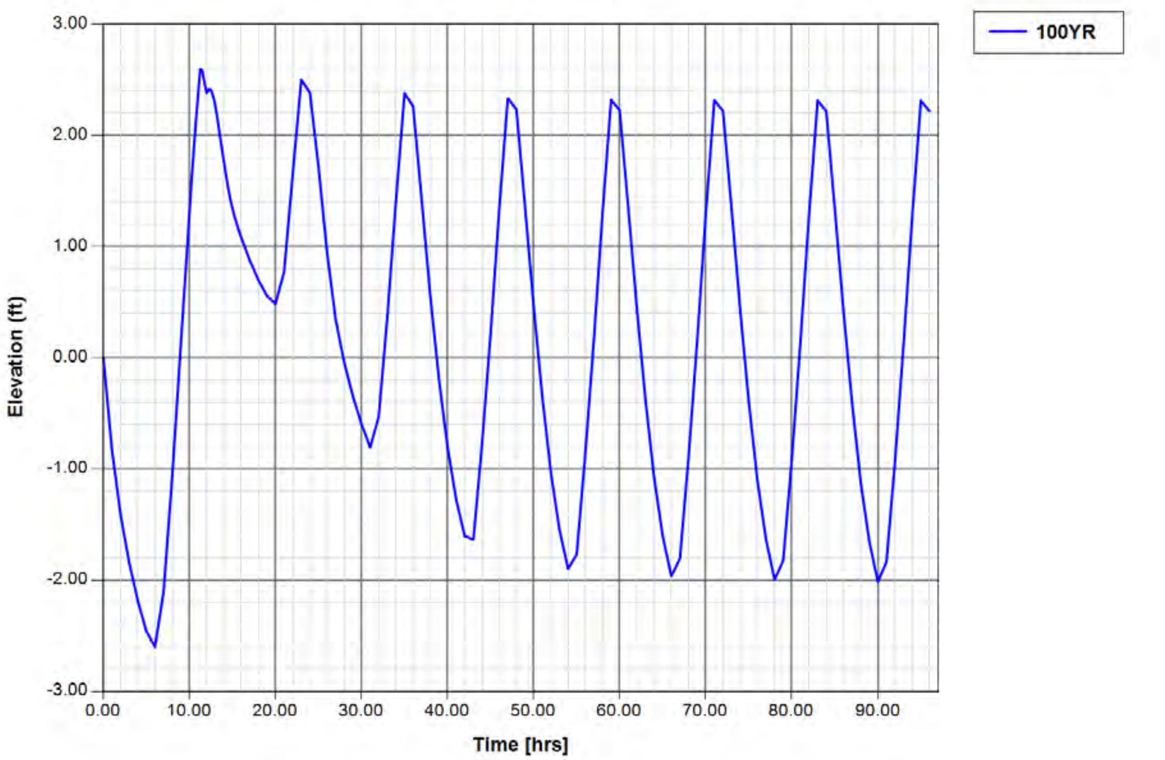
Node Stage: N-B160 [06_FLFR-COMB_CC]



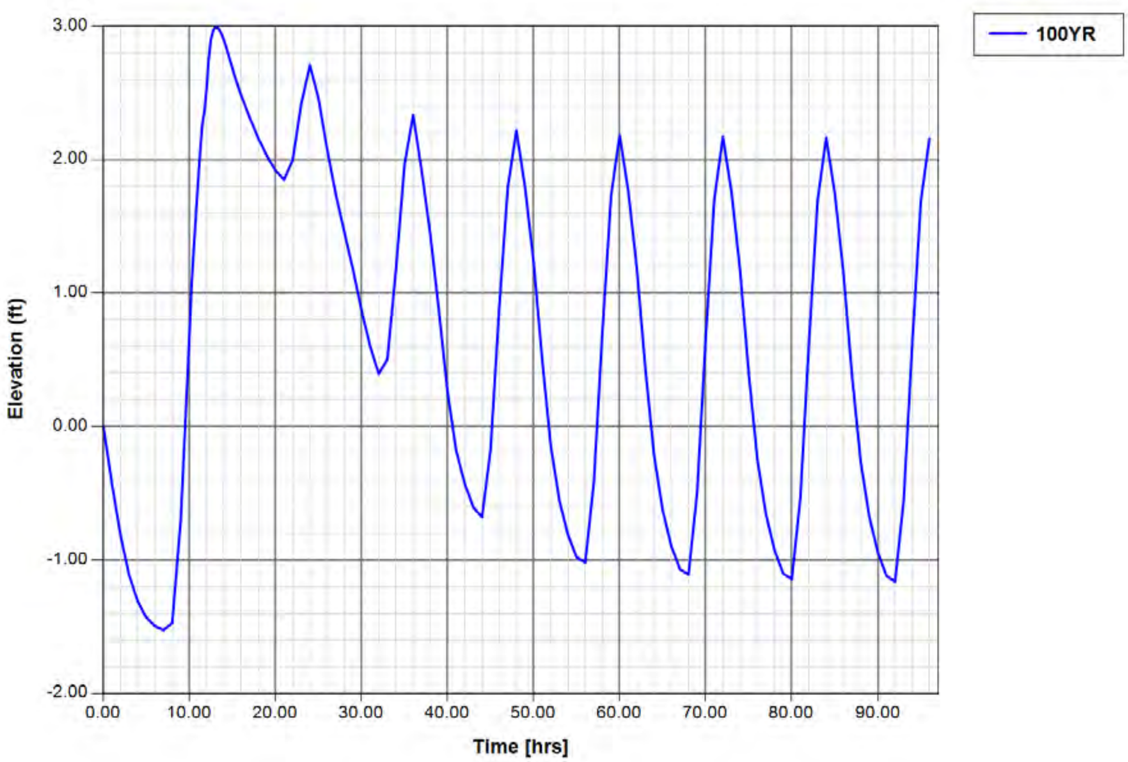
Node Stage: N-LB100 [06_FLFR-COMB_CC]



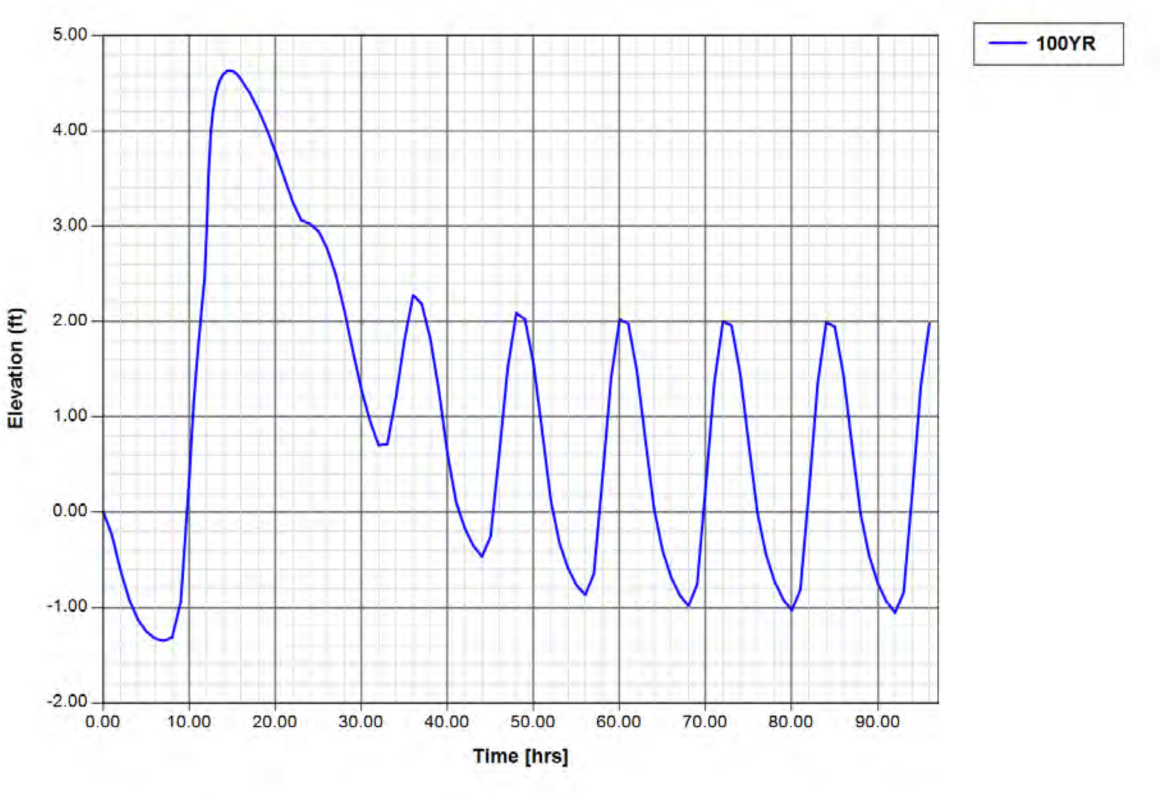
Node Stage: N-LB130 [06_FLFR-COMB_CC]



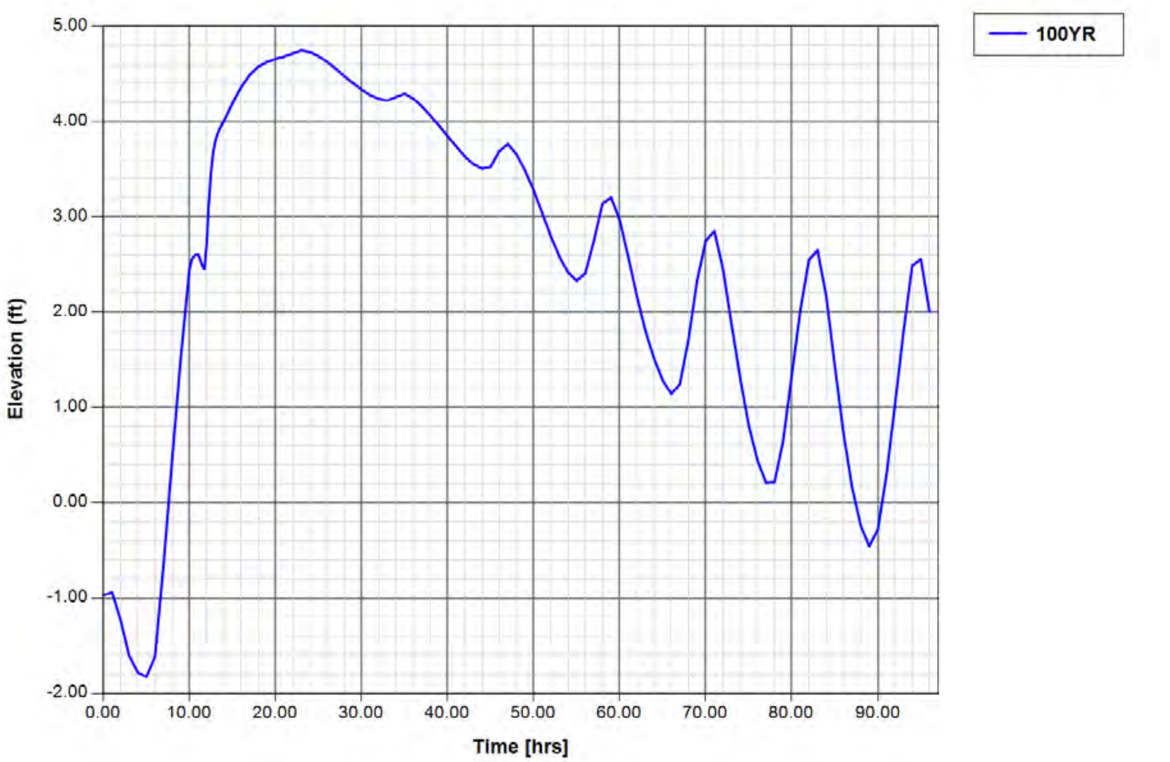
Node Stage: N-LB240 [06_FLFR-COMB_CC]



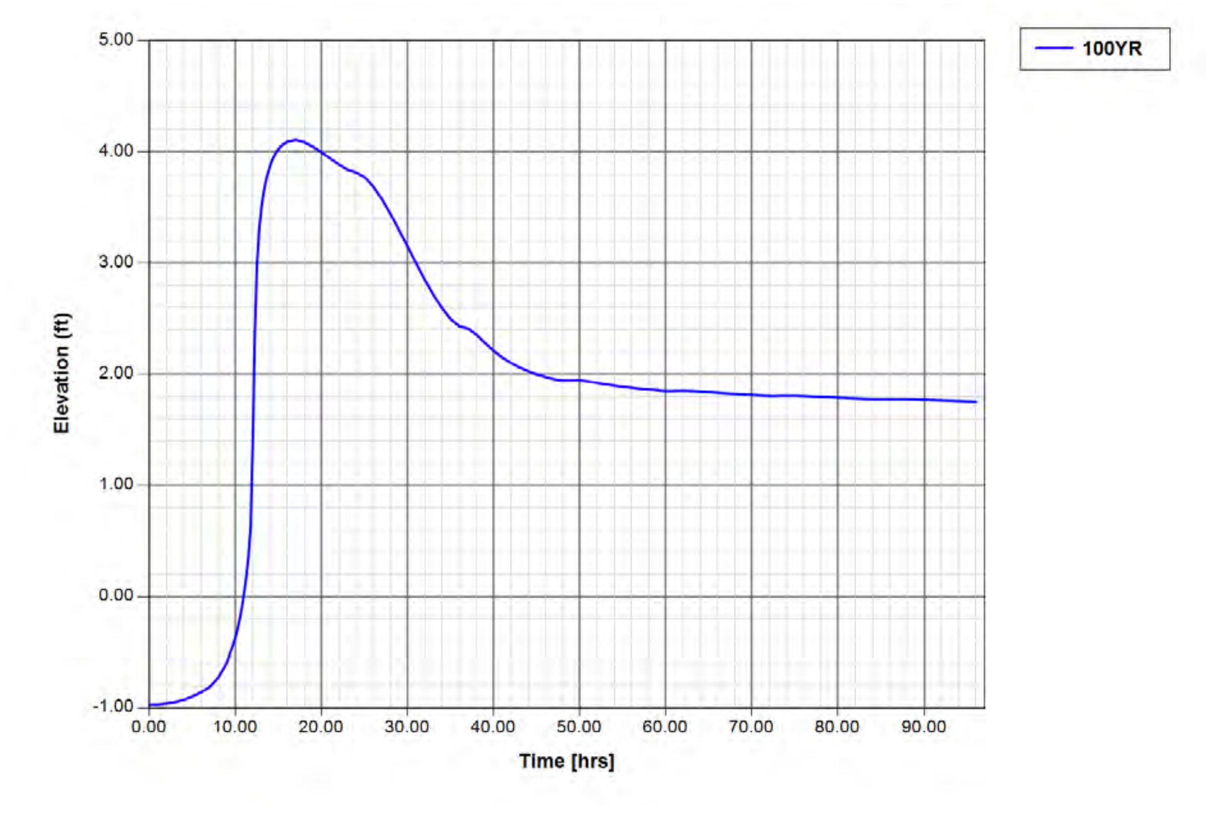
Node Stage: N-LB370 [06_FLFR-COMB_CC]



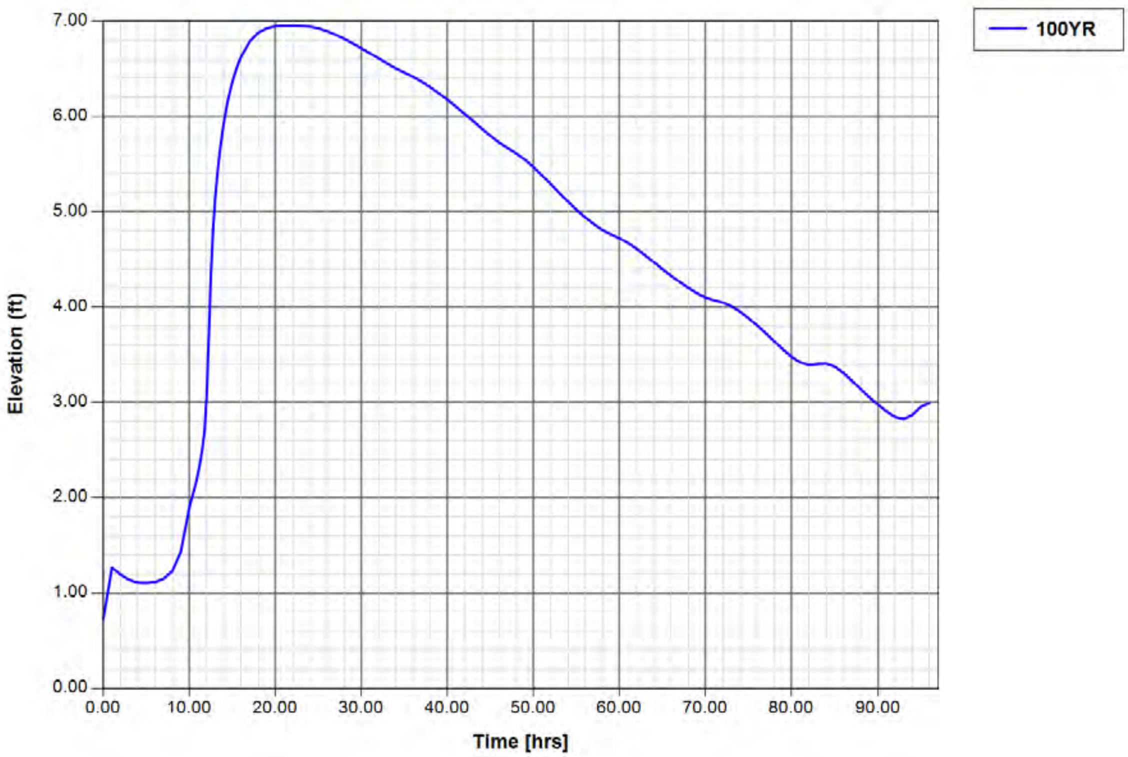
Node Stage: N-0210_SLT [07_FLFR-MidB_CC]



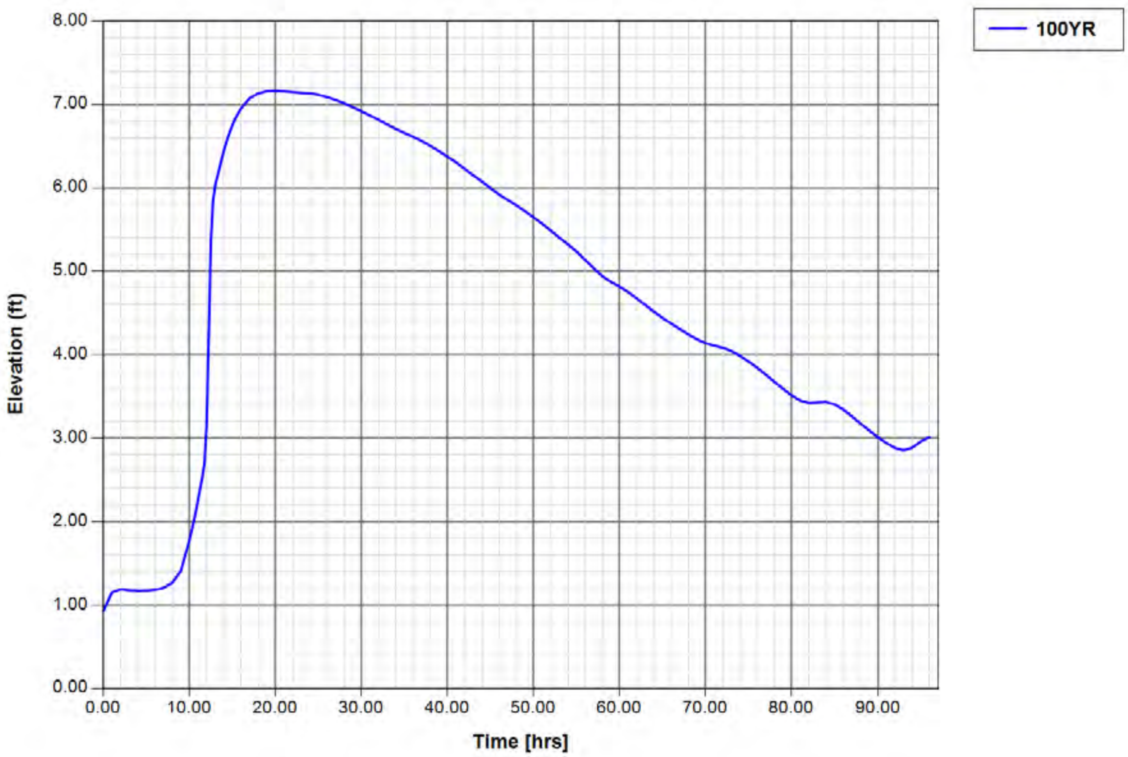
Node Stage: N-0530_SLT [07_FLFR-MidB_CC]



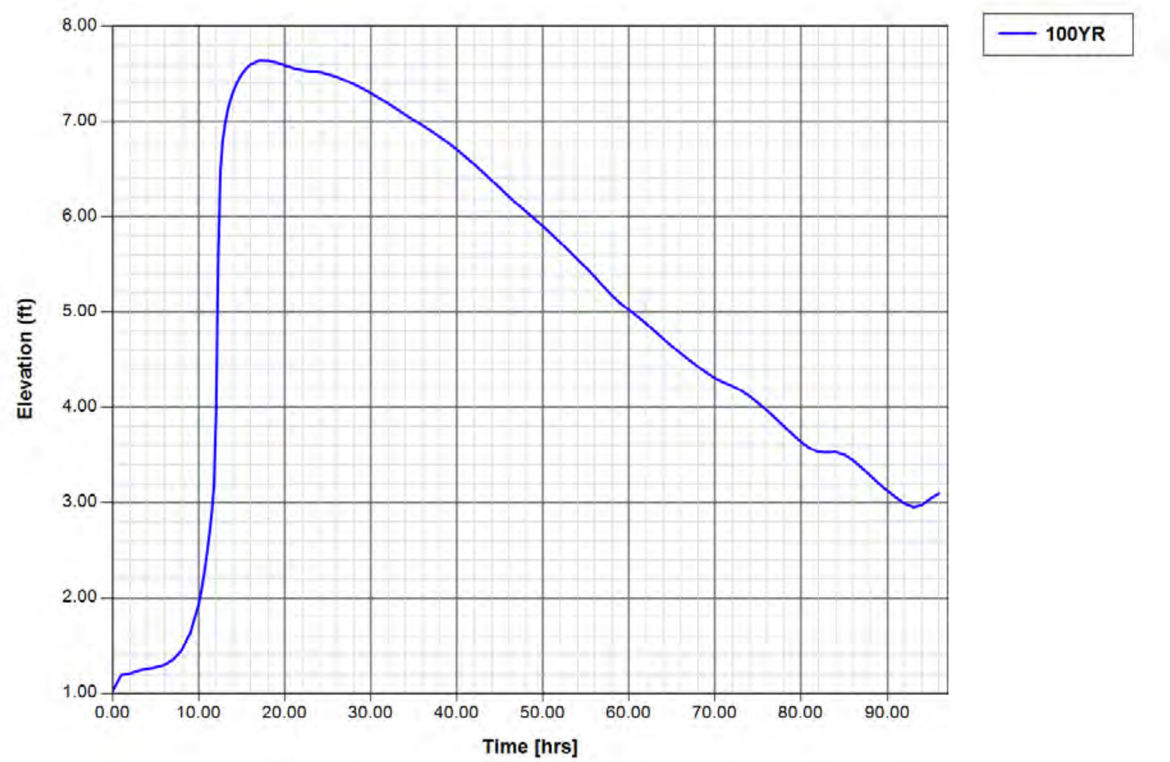
Node Stage: N-A120 [07_FLFR-MidB_CC]



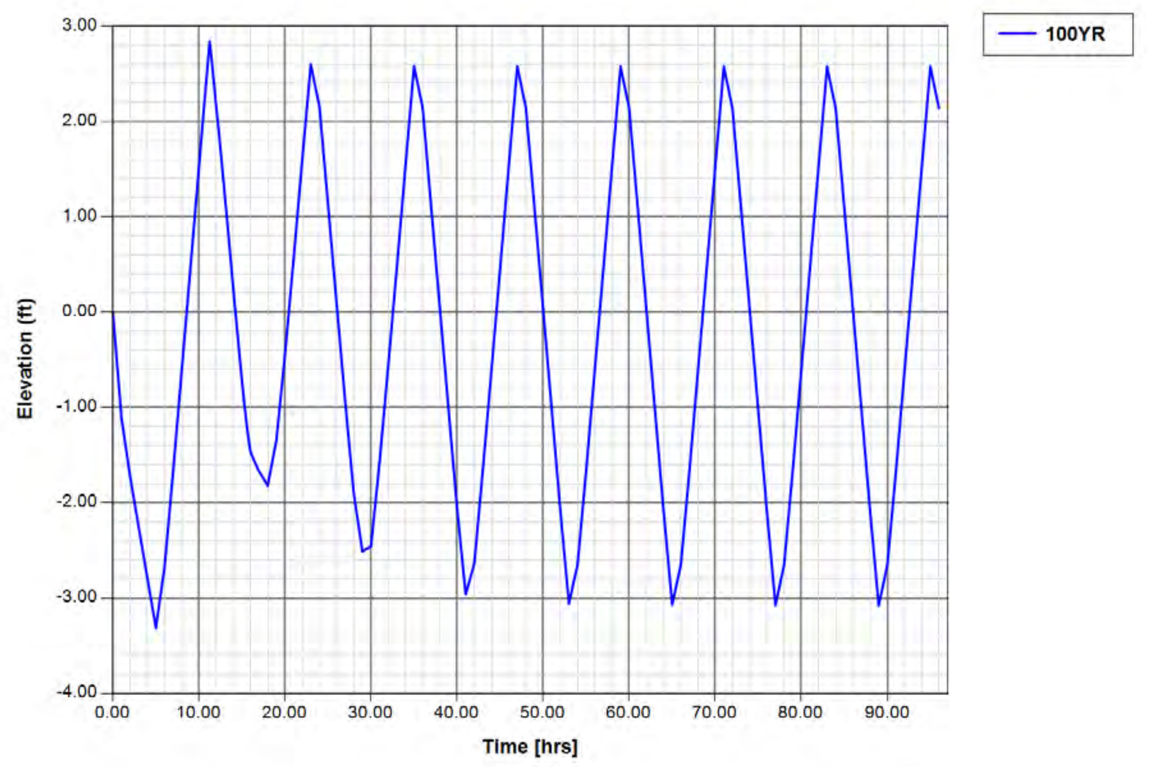
Node Stage: N-B020 [07_FLFR-MidB_CC]



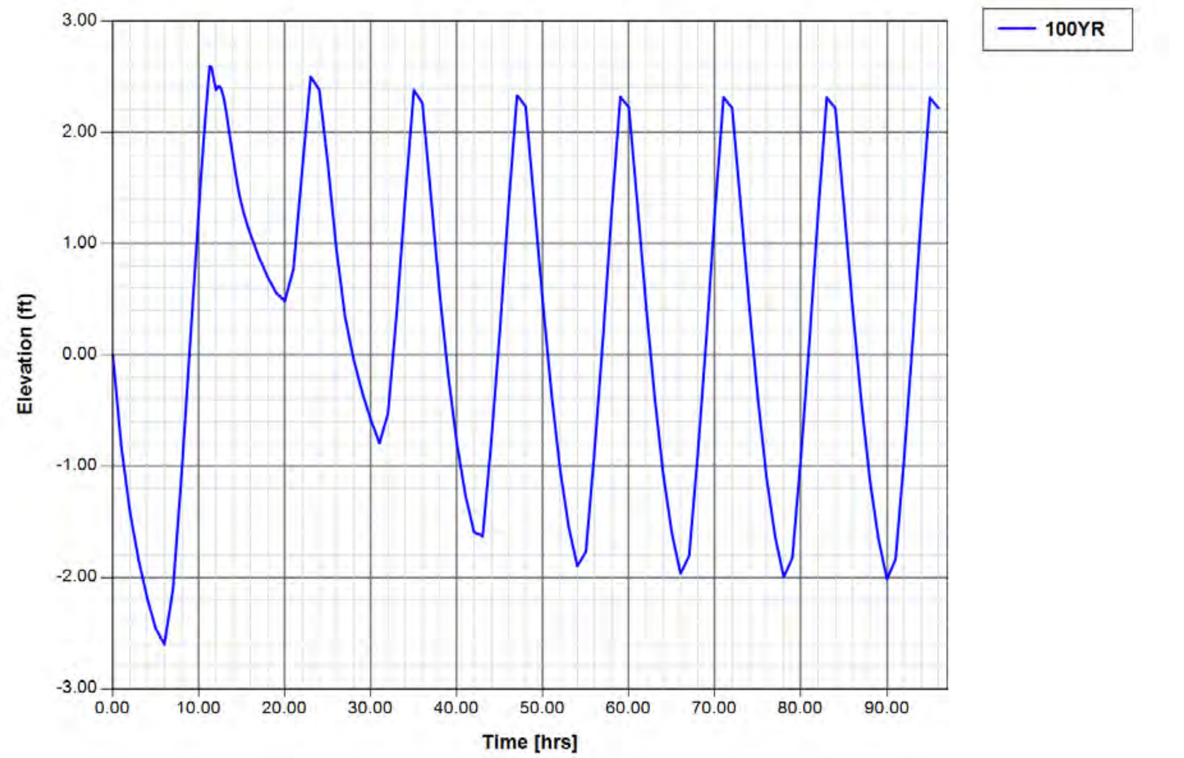
Node Stage: N-B160 [07_FLFR-MidB_CC]



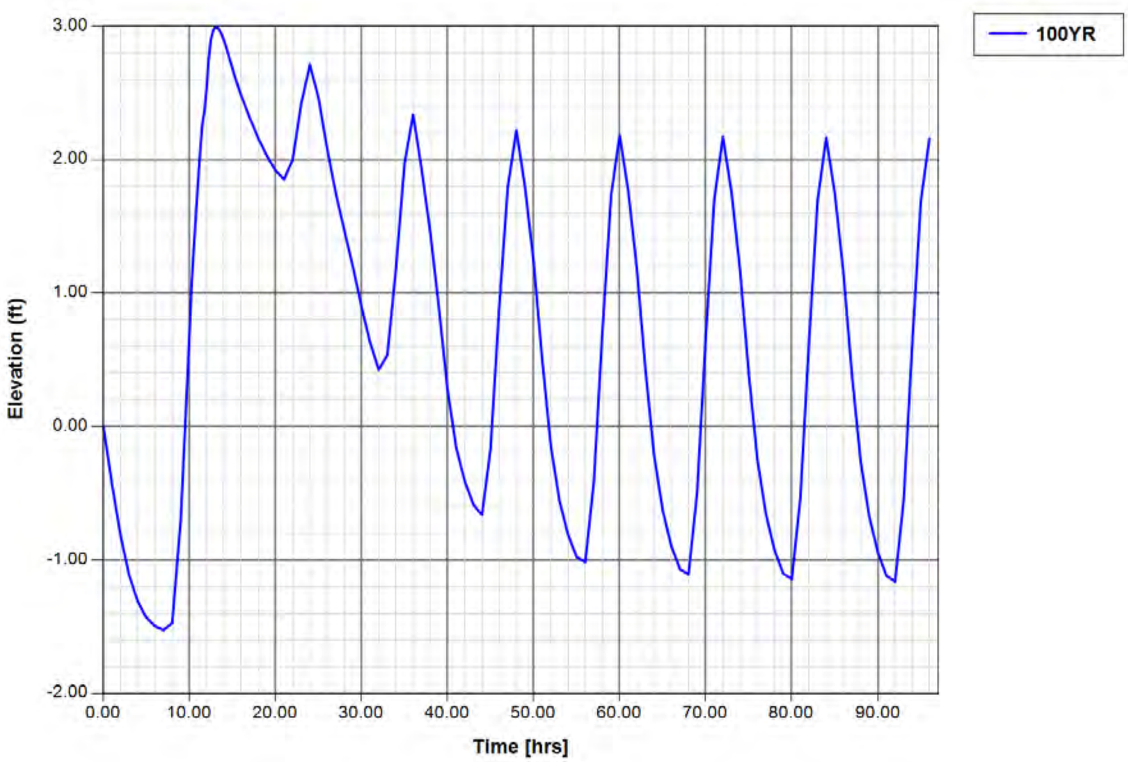
Node Stage: N-LB100 [07_FLFR-MidB_CC]



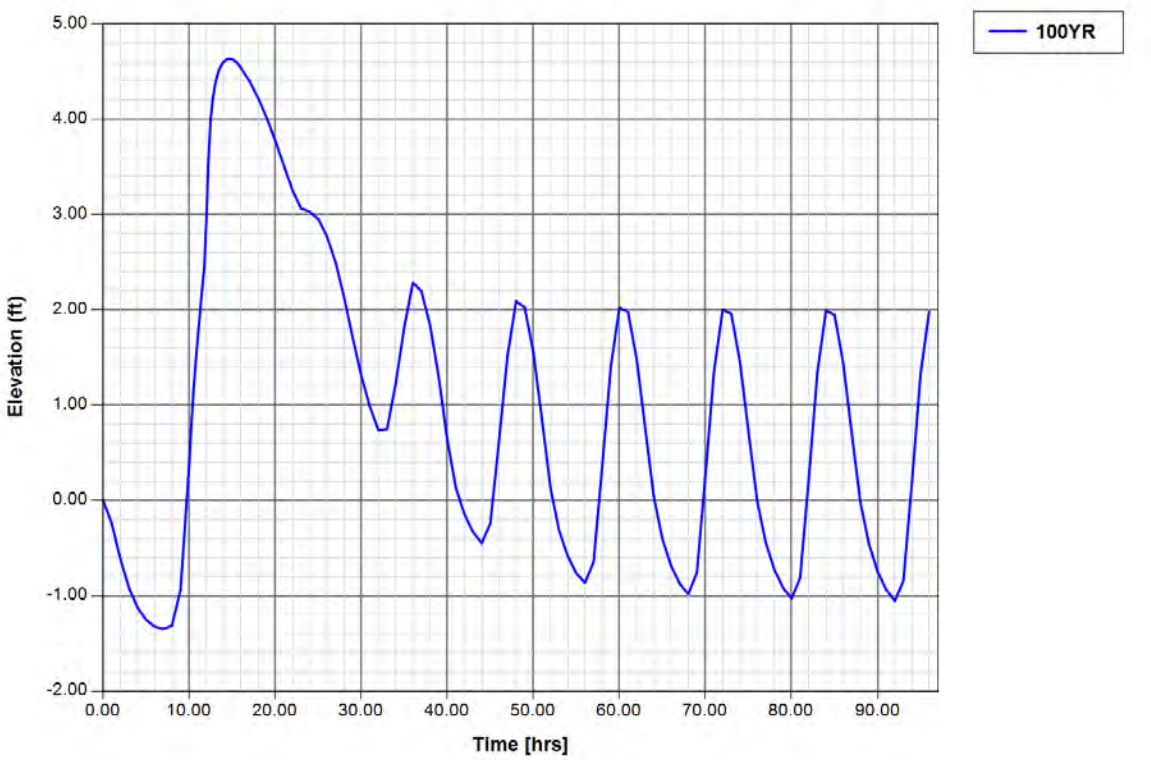
Node Stage: N-LB130 [07_FLFR-MidB_CC]



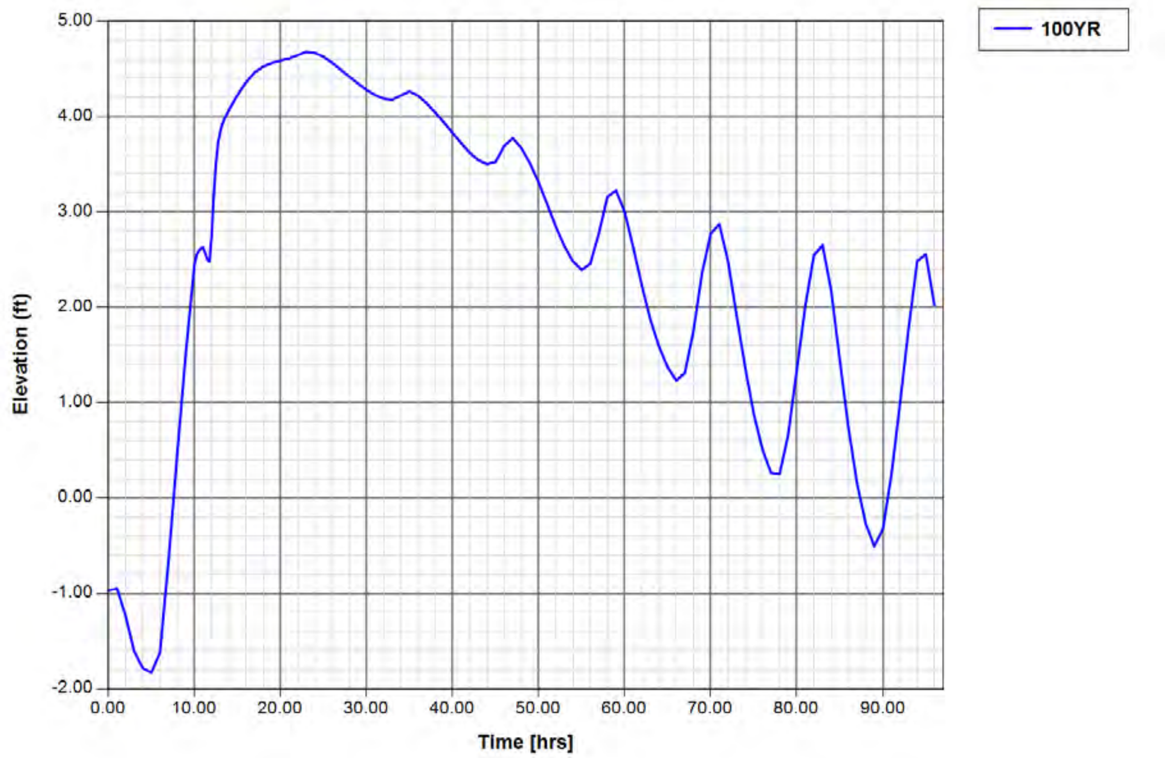
Node Stage: N-LB240 [07_FLFR-MidB_CC]



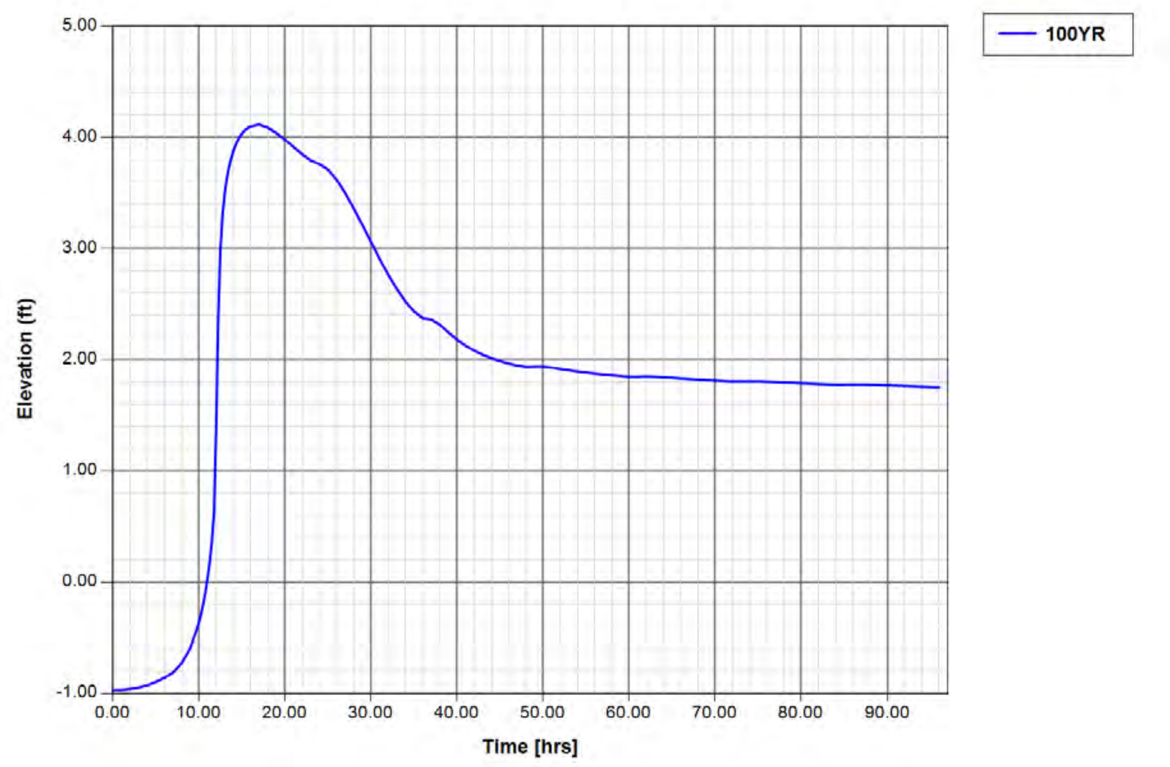
Node Stage: N-LB370 [07_FLFR-MidB_CC]



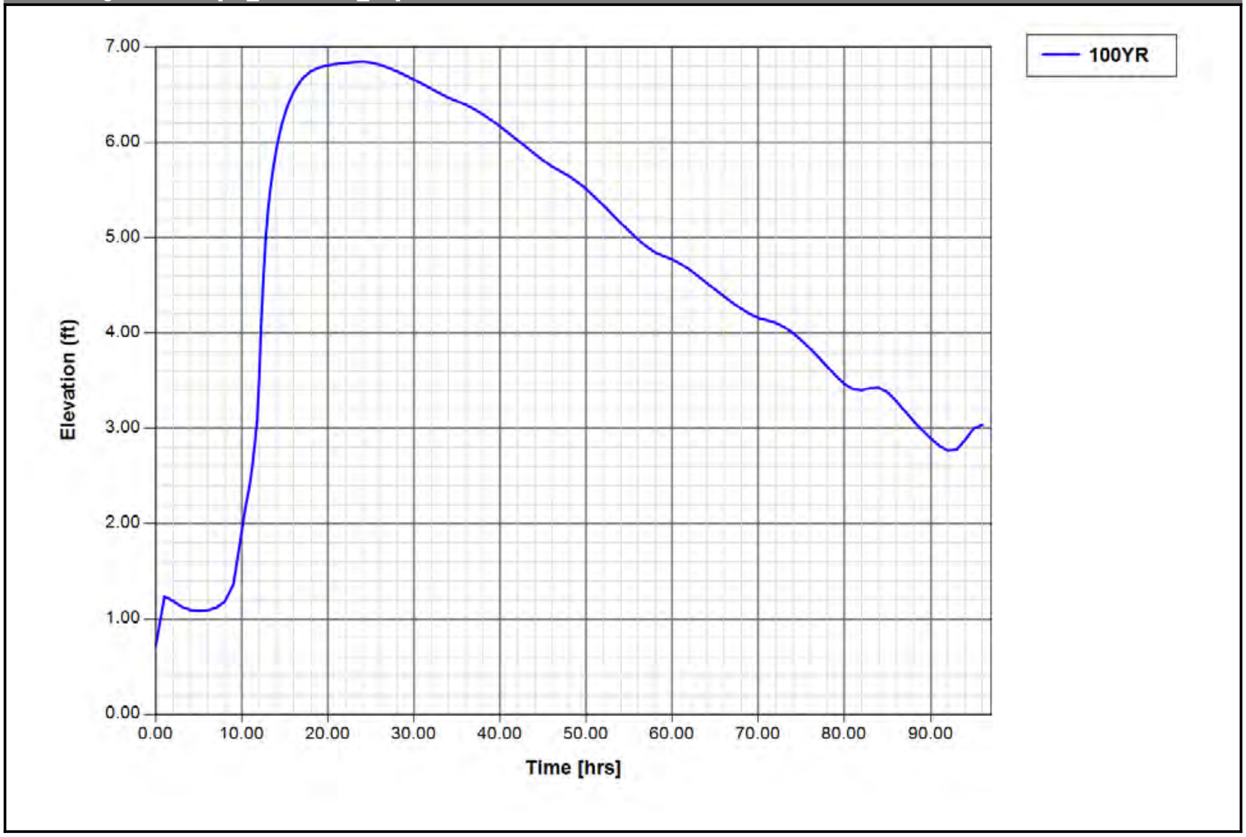
Node Stage: N-0210_SLT [08_FLFR-WAC_CC]



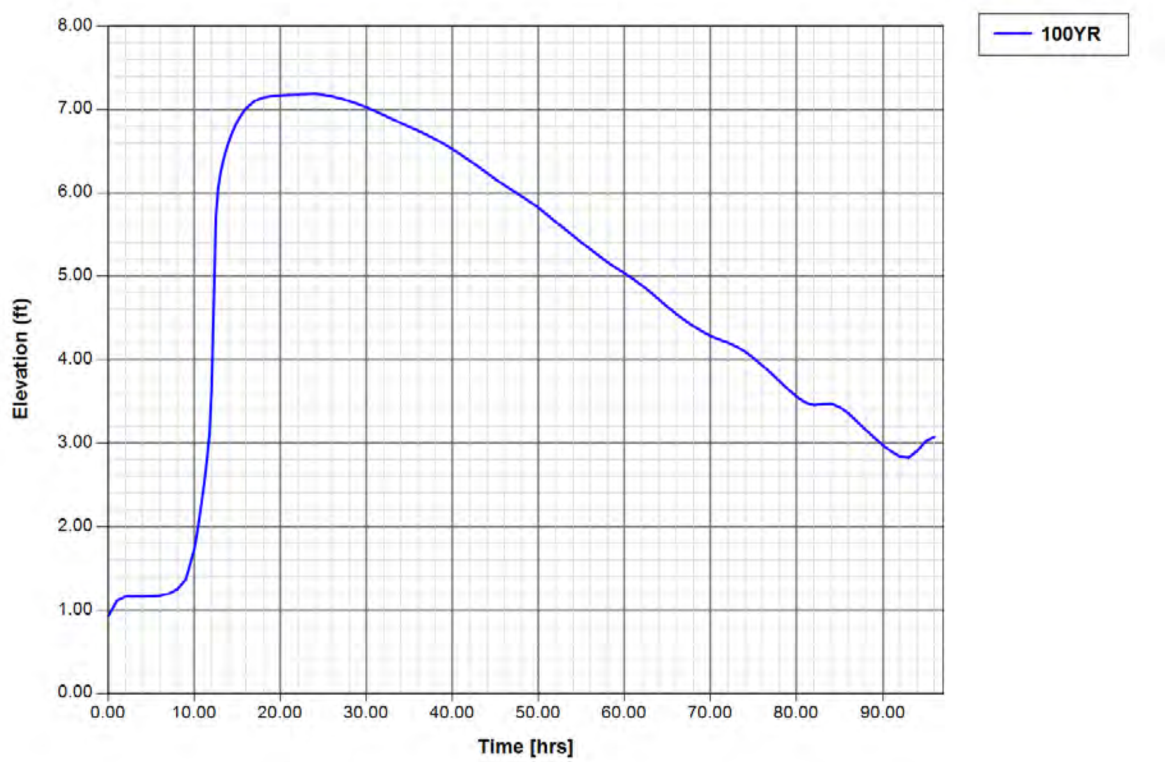
Node Stage: N-0530_SLT [08_FLFR-WAC_CC]



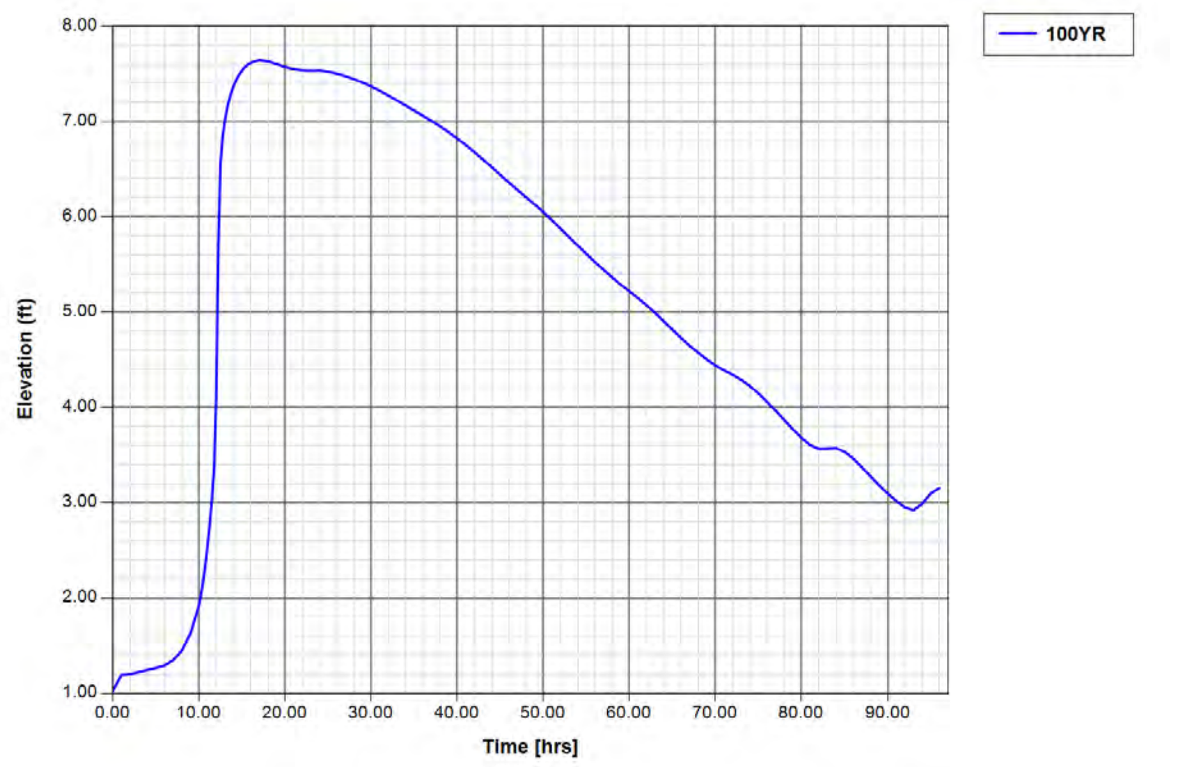
Node Stage: N-A120 [08_FLFR-WAC_CC]



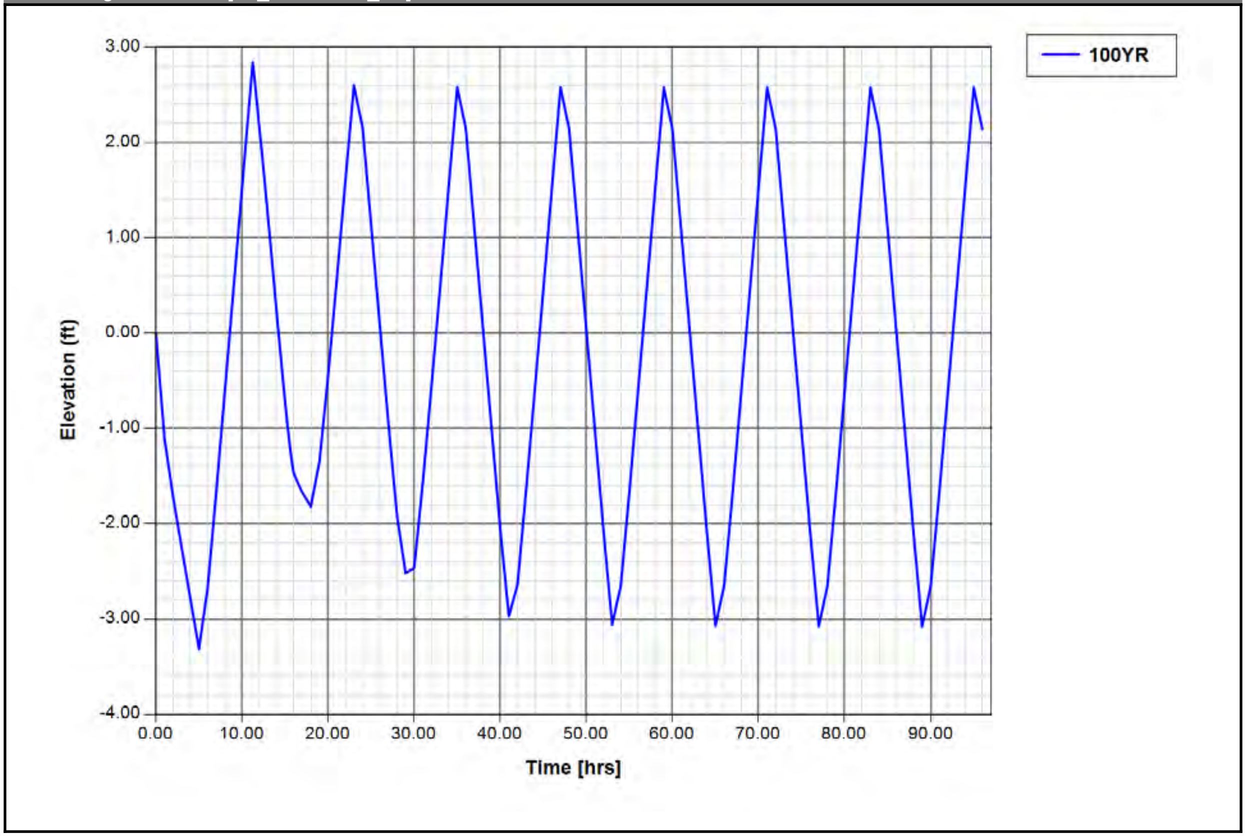
Node Stage: N-B020 [08_FLFR-WAC_CC]



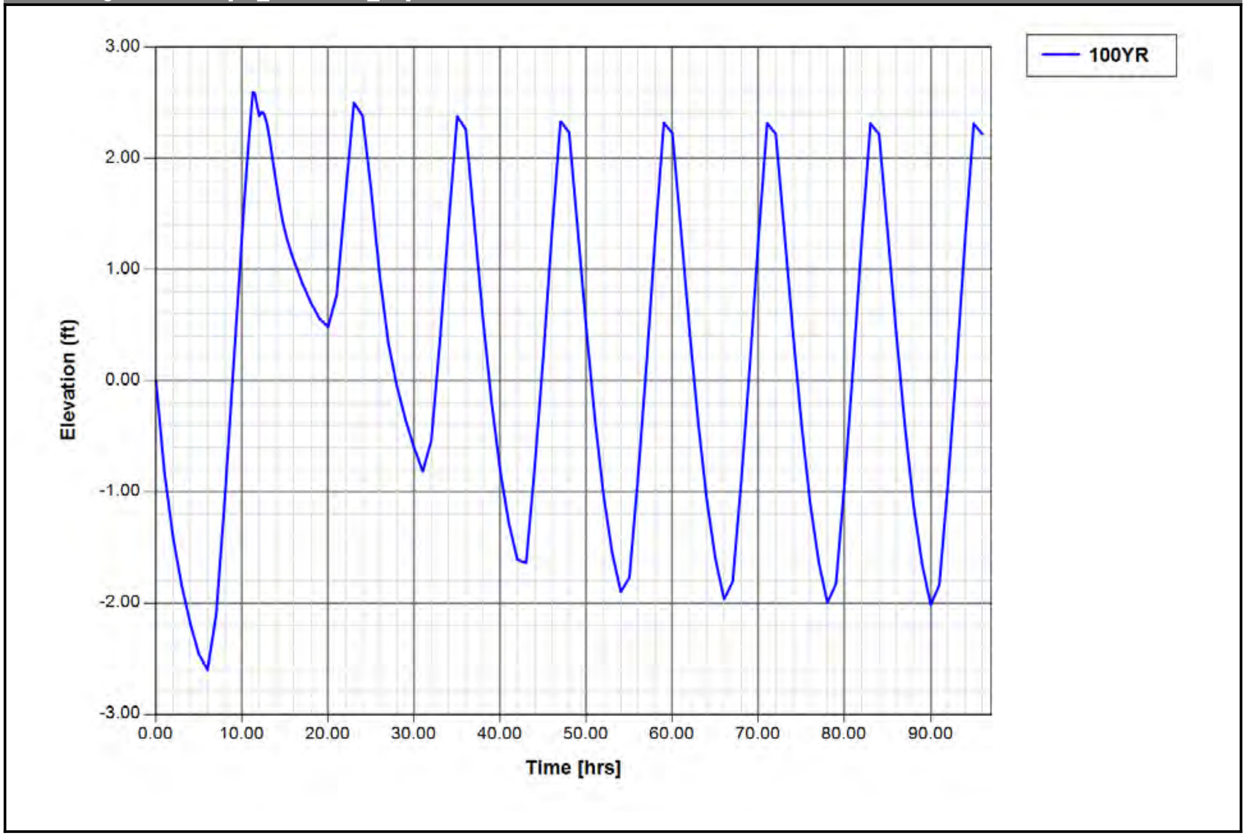
Node Stage: N-B160 [08_FLFR-WAC_CC]



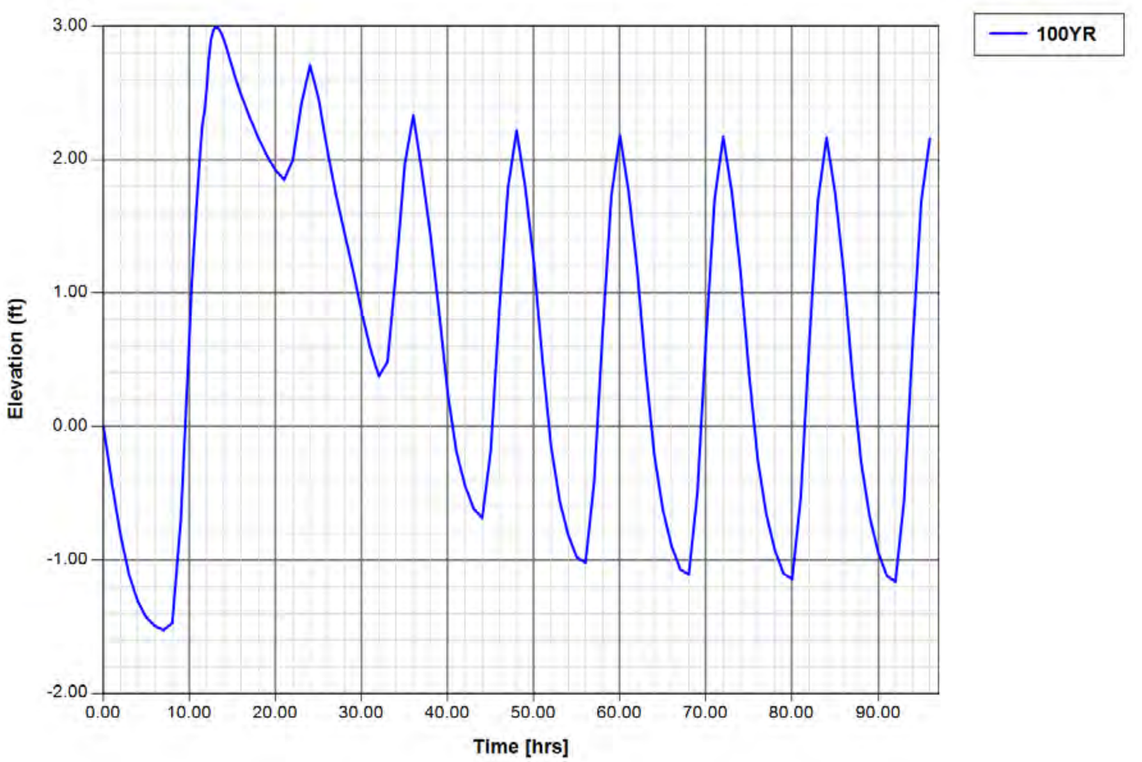
Node Stage: N-LB100 [08_FLFR-WAC_CC]



Node Stage: N-LB130 [08_FLFR-WAC_CC]



Node Stage: N-LB240 [08_FLFR-WAC_CC]



Node Stage: N-LB370 [08_FLFR-WAC_CC]