Mare Brook Culvert and Coffin Ice Pond Dam Conceptual Design

Brunswick, Maine

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1. Introduction

The purpose of this study was to develop conceptual designs at select culverts within the Mare Brook watershed and for Coffin Ice Pond Dam. Based on conversations with the Town of Brunswick, the 100-year annual recurrence interval storm was chosen as the design storm. This design storm aligns with design standards and guidance provided by the Maine Department of Transportation (MaineDOT).

In the development of conceptual designs, GEI Consultants, Inc. consulted the State of Maine Aquatic Resource Management Strategy (ARMS) Forum's Stream Smart Road Crossing Guide for designing the replacement culverts (MaineDOT, 2024). The web-based guide provides information for "installing and replacing crossings in an effective and cost-efficient manner while meeting goals of restoring and maintaining stream habitat connectivity and enhancing the stability of roads and culvert crossings."

As part of this project GEI developed a 2-dimensional (2D) rain-on-grid hydraulic model of the Mare Brook watershed to estimate hydraulic capacity limits at conveyance structures such as culverts and dams. The model was used to size proposed culverts and a conceptual spillway at Coffin Ice Pond Dam. GEI also used the model to evaluate flood conditions, peak water elevations, and peak flows under existing and proposed conditions. GEI performed this evaluation using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center – River Analysis System (HEC-RAS) software, Version 6.4.1 (USACE, 2023). The model was originally developed by GEI during the 2023 Mare Brook Watershed Hydrologic & Hydraulic Study (GEI, 2023).

The North American Vertical Datum of 1988 (NAVD88) was the reference datum for elevations in this report and the hydraulic model.

GEI completed the analysis for the Town of Brunswick in based on GEI's Proposal dated January 31, 2024. The following GEI personnel were primarily responsible for performing the hydraulic analysis for this report:

Project Manager:	Marc Chmura, P.E. (ME)
Consultant Reviewer:	Lissa C. Robinson, P.E. (ME)
Quality Assurance/Control Lead:	Joel Bilodeau, PH

2. Project Background

Mare Brook is a 5.7-mile stream with a 6.02-square-mile drainage area located entirely within the Town of Brunswick (Figure 1). The headwaters of the brook begin in the northwest area of the watershed in a dense residential area. The brook flows east through residential neighborhoods, and into Coffin Ice Pond, which is impounded by a small dam just upstream of Harpswell Road. The brook continues to flow through several culverts, including a more than 3,000-foot-long culvert under the runway of the Brunswick Executive Airport. The brook continues downstream to its confluence with the Merriconeag Stream then travels south for less than a mile through forested land where it discharges to Harpswell Cove.

In February 2022, the Town of Brunswick, with help from the Cumberland County Soil and Water Conservation District (CCSWCD), completed the Mare Brook Watershed Plan (WMP) 2022-2032 (CCSWCD, 2022). Mare Brook is a Maine Class B stream and is currently listed by the Maine Department of Environmental Protection (Maine DEP) as impaired due to poor macroinvertebrate sampling results and habitat (CCSWCD, 2022). Standards for classifications of streams are set under Maine Revised Statutes, Title 38, Section 465. Class B streams must meet minimum dissolved oxygen requirements and discharges may not cause adverse impact to aquatic life indigenous to the receiving water.

The stream is also considered an Urban Impaired Stream under the Maine Stormwater Management Law due its failure to meet water quality standards, primarily as a result of the effects of stormwater runoff from developed land. Land use activities and impervious cover within the watershed are two of several stressors that reportedly contribute to the impairment of Mare Brook. This has led to erosion, sediment imbalances, loss of habitat, and poor water quality.

Maine’s water classification system, in place since the 1950’s, establishes water quality goals for the state and classifies freshwater rivers into four classes (AA, A, B, and C). Streams classified as AA have the lowest risk of ecosystem breakdown and loss of use due to either natural or human-caused events, while streams with classification of C have the highest risk of ecosystem breakdown. The primary goal of the WMP is to bring Mare Brook up to the Maine State-designated Class B standards by 2037.

In March of 2023 GEI performed a Hydrologic and Hydraulic (H&H) analysis on the Mare Brook Watershed to identify existing undersized culverts. The study involved estimating existing flood conditions during the 2-, 10-, and 25-year design storm events. To ensure the model appropriately simulated H&H conditions, GEI calibrated the model using collected water level data and observed precipitation events during the summer of 2022. The results of the study indicated that a majority of the culverts along Mare Brook had insufficient flow capacity. The 2023 H&H Report is provided in Appendix A.

3. Existing Conditions Analysis

3.1. Model Refinements

For this study, we built upon the hydraulic model developed during the 2023 H&H analysis by GEI. The hydraulic model was developed as a 2D rain-on-grid HEC-RAS model and was updated from HEC-RAS version 6.3 to version 6.4.1, the newest version at the onset of this analysis. For details on the model's development and calibration, refer to the 2023 Mare Brook Watershed H&H Study.

GEI revised the model at Sparwell Lane and Richards Drive based on the thalweg survey performed by GEI in September 2023. The field survey was performed by Marc Chmura, P.E. and Sebastian Carvajal, both of GEI. During the survey, GEI recorded the stream channel (horizontal and vertical coordinates) using a Trimble DA2 GNSS Receiver. The receiver uses a real-time kinematic positioning (RTK) system to correct errors and improve accuracy. Updates to the model included modifying the channel minimum elevation to reflect thalweg survey by GEI and inputting the proposed replacement culvert dimensions at Richards Drive and Sparwell Lane based on the design developed by Brunswick and CCSWCD (Brunswick, 2024a & 2024b).

Upon review of the existing model, slight refinements were made to the model to improve accuracy and performance. For example, cell spacing at crossings and within the main stem of the river were reduced to improve the spatial resolution of results. These changes did not significantly change the overall results compared to the previous version of the model but did improve model stability when modeling the larger proposed culverts.

3.2. Annual Recurrence Storm Estimate

GEI modeled the 24-hour 100-year annual recurrence interval precipitation event also referred to as the "design storm." The 100-year design storm has a 1% chance of occurring in any given year. GEI obtained precipitation estimates from the National Oceanic and Atmospheric (NOAA) Atlas 14 Precipitation Frequency Data Server (NOAA PFDS, 2024). Precipitation estimates for durations of 5-minutes through 24-hours are shown in Table 3-1. The 100-year 24-hour storm event has a total precipitation depth 7.43 inches.

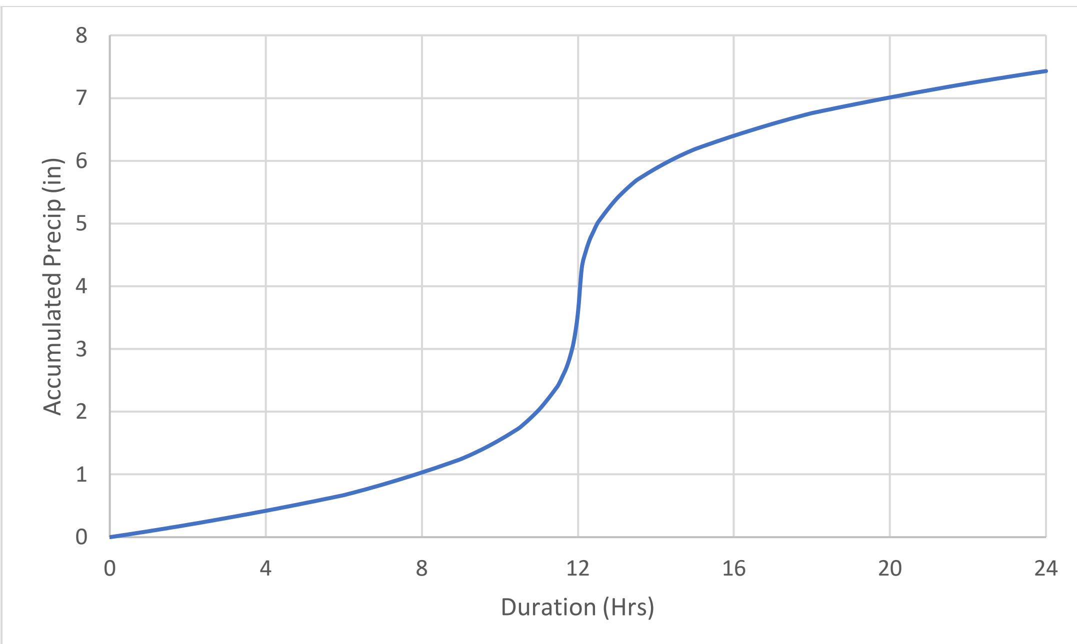
Table 3-1. Precipitation Estimates (inches) for the 100-year Design Storm Event

Duration	Precipitation (in)
5-min	0.83
10-min	1.18
15-min	1.39
30-min	1.88
60-min	2.37
2-hr	3.15
3-hr	3.71
6-hr	4.82

Duration	Precipitation (in)
12-hr	6.10
24-hr	7.43

Using the NOAA precipitation estimates, GEI developed a 24-hour rainfall timeseries by nesting precipitation depths for all durations (5-minutes through 24-hours). The shortest most intense duration (0.83 inches within 5 minutes) was centered at 12 hours. The 100-year 24-hour rainfall time series is shown in Graphic 3.1. It should be noted that nesting the annual recurrence interval precipitation values into the temporal pattern establishes a more conservative rainfall which is expected to provide additional margin of safety in conceptual designs. Further refinement of the temporal pattern maybe warranted during later phases of the design process.

Graphic 3-1. 100-Year Storm Precipitation Timeseries



3.3. 100-Year Existing Condition Analysis

GEI used the model to estimate peak water surface elevations and flows during the 100-year design storm event under existing conditions. The existing condition analysis serves as a baseline to compare changes in water levels and inundation extents expected under proposed conditions. The analysis will also be used to evaluate whether increasing culvert capacity will cause inundation issues downstream particularly at the Brunswick Executive Airport Crossing and at Liberty Crossing. Table 3-2 contains estimated peak water surface elevations and flows at each major culvert along the main branch of Mare Brook including Coffin Ice Pond Dam. The culverts and dam are listed in the table from upstream to downstream. Figure 2 contains a map of major Mare Brook culverts as well as other tributary culverts included in the model.

Table 3-2. 100-Year Design Storm Existing Condition Analysis

Crossing Name	Culvert ID	Peak U/S WSEL (ft, NAVD88)	Peak Discharge (cfs)	Top of Road Elevation/Dam (ft, NAVD88)	Freeboard (+) Overtopping (-) (ft)
Baribeau Drive	Cul04 & Cul05	76.9	86	78.1	1.2
Barrows Street	Cul10	71.6	224	71.3	-0.3
MacMillan Drive	Cul14	70.5	190	69.4	-1.1
Maine Street	Cul16	66.2	332	64.8	-1.4
Meadowbrook Road	Cul17	61.9	294	61.3	-0.6
Coffin Ice Pond Dam	DamCIP	53.3	342	50.5	-4.2
Harpswell Road	Cul23	53.3	208	57.7	4.4
Perimeter Drive	CulPD	42.3	303	44.0	1.7
Samuel Adams Drive	No ID#	35.0	347	43.7	8.7
Runway Culvert	CulAP	31.8	352	57.2	25.4
Eagle Drive	Cul29	23.6	492	28.5	5.0
Liberty Crossing	No ID#	12.9	630	15.9	3.0

WSEL: Water Surface Elevation

Under existing conditions during the 100-year design storm four roadways would be overtopped along the main of branch of Mare Brook. The greatest amount of overtopping would occur at Maine Street with 1.4 ft of overtopping. Other roadways that would be overtopped include Barrows Street, MacMillan Drive, and Meadowbrook Road.

Harpswell Road would not be expected to overtop during the design event; however, the existing culvert is significantly undersized for the design storm and would cause water to backup and pond upstream of the culvert. The backwater conditions caused by the undersized culvert inundates Coffin Ice Pond by as much as 4.2 ft resulting in a peak water elevation of 53.3 ft at both Coffin Ice Pond Dam and Harpswell Road. Another indicator of insufficient hydraulic capacity is revealed in a comparison of peak upstream culvert discharge with peak discharge at Harpswell Road. The peak flow at Harpswell Road is 208 cfs, which is 40% lower than the peak flow at Coffin Ice Pond Dam. The Meadowbrook Road and Manie Street crossings, both located upstream of Harpswell Road, also have higher peak discharge capacity comparatively. Furthermore, the difference between upstream and downstream water elevations at Harpswell Road is approximately 11 ft. In this condition, the roadway acts as a dam and the embankments may be at risk of destabilizing.

Under the 100-year design storm event, the water at Coffin Ice Pond Dam would be expected to rise 4.2 ft above the dam crest. This backwater condition and the rapid wetting and dewatering of the embankment may result in embankment instability. The top of Coffin Ice Pond Dam was considered to be the top of the concrete piers, at elevation 49.1 ft (approximately 2 ft below the bridge walking surface) based on the 2022 Survey by Little River Land Surveying. This elevation represents the lowest non-overflow section of the dam. Increasing capacity at Harpswell Road would decrease the amount of dam overtopping potential; however, as our analysis shows later in this report, resizing Harpswell Road culvert would not completely alleviate dam overtopping potential. Refer to Section 6 for discussion of Coffin Ice Pond Dam spillway capacity and conceptual designs.

Perimeter Drive (also referred to locally as Security Road) is a private road owned by Bowdin College and is reportedly used by the school to access portions of its property on either side of the Mare Brook crossing. The idea of removing the road crossing completely was initially discussed with the Town of Brunswick but that option does not appear to be likely given its present use by the College. The roadway surface would not be expected to overtop during the 100-year storm, but the two 48-inch culverts would be overwhelmed with headwaters estimated to rise about 4 ft above the upstream crown of the culverts. Additionally, the culverts in their current condition may prevent upstream fish passage due to debris and perched culvert outlets (Stantec, 2016).

The Samuel Adams Drive crossing consists of two 6-foot-diameter concrete pipes located on a private access road within the Brunswick Executive Airport. The roadway has approximately 8.7 ft of freeboard and appears to have sufficient capacity under existing conditions.

The Runway Culvert crossing consists of three 65-in-diameter concrete pipes that run under the airport's runway. Due to the long length of the culvert system, they may present a barrier to fish passage. The culverts appear to provide sufficient flow capacity under existing conditions.

Under existing conditions, the culvert at Eagle Drive would have the capacity to pass the 100-year design storm without overtopping the roadway. However, the culvert likely acts as a barrier to fish passage due to the perched downstream outlet. Therefore, the Eagle Drive culvert is recommended to be replaced.

The Liberty Crossing roadway would not be expected to overtop during the 100-year storm. Based on the 2016 Stantec Fish Passage Assessment, Liberty Crossing is capable of passing fish at higher tides during typical instream flows.

Based on the existing condition analysis as well as the WMP and discussions with the Town of Brunswick the following crossings were selected for development of conceptual culvert replacement plans. These culverts were selected because they are located on the main branch of Mare Brook, have poor fish passage potential, and/or poor hydraulic capacity.

1. Baribeau Drive Crossing (Cul04 & Cul05)
2. Barrows Street Crossing (Cul10)
3. Macmillan Drive Crossing (Cul14)
4. Maine Street Crossing (Cul16)
5. Meadowbrook Road Crossing (Cul17)
6. Harpswell Road Crossing (Cul23)
7. Perimeter Drive Crossing (CulPD)
8. Eagle Drive Crossing (Cul29)

Replacing these culverts with larger structures will likely increase downstream flows within Mare Brook. Some downstream culverts in the existing condition analysis were able to pass the 100-year design storm but may fare differently if/when upstream culverts are replaced with higher capacity culverts. Section 5 estimates the minimum culvert size required for each culvert selected above and discusses how the proposed changes may impact other existing culverts.

4. Bankfull Width Estimation

The MaineDOT Stream Smart Crossing Guide recommends culvert structures have a hydraulic opening width of at least 1.2 times the bankfull width (MaineDOT, 2024). Bankfull width is the term used to define the natural width of a stream and is measured perpendicular to flow from the lowest most extent of permanent woody vegetation on either side of the stream. Spanning the natural bank width improves passage of aquatic organisms and other wildlife movement during normal flows while providing increased hydraulic capacity for peak flows during significant storm events. An appropriate culvert width also allows the stream to flow in a natural manner and prevents pinching or constriction of the channel, which can lead to increased velocities, erosion, and scour.

On March 22, 2024, GEI's Marc Chmura, P.E. and Alison Brady performed bankfull width measurements at the eight culverts selected for conceptual design. The measurements are listed in Table 4-1 and the approximate location of where the measurements were taken from are shown in maps within Appendix B.

GEI attempted to measure the natural undisturbed bankfull widths in locations that appeared to be outside of the influence of the existing stream crossings. This proved difficult in some locations particularly in the stretch between Barrows Street and Meadowbrook Road where urban development and undersized culverts appeared to have altered the stream's natural channel. To account for variances in channel width, three or more measurements were taken at each culvert to estimate an overall average bankfull width.

Descriptions of each culvert are also included in Table 4-1. Information for each culvert such as size, material, and other data relevant to hydraulic modeling was compiled from the WMP, the 2022 survey by Little River Land Surveying, Inc, GEI's own field investigations, and data provided by others.

Table 4-1. Bank Full Width Estimation

Crossing Name	Culvert ID	Bankfull Width (ft)	Existing Culvert Description
Baribeau Drive	Cul04 & Cul05	11	Twin 30-inch CMP and one 30-inch RCP
Barrows Street	Cul10	11	One 42-inch CMP and one 24-inch CMP
MacMillan Drive	Cul14	10	One 42-inch CMP and one 24-inch CMP
Maine Street	Cul16	10	42-inch by 84-inch Elliptical CMP
Meadowbrook Road	Cul17	10	48-inch CMP
Harpswell Road	Cul23	13	60-inch CMP
Perimeter Drive	CulPD	15	Twin 48-inch CPP
Eagle Drive	Cul29	16	120-inch CMP

CMP: Corrugated Metal Pipe, RCP: Reinforced Concrete Pipe, CPP: Corrugated Plastic Pipe

5. Conceptual Culvert Design

5.1. Methodology

GEI developed conceptual culvert designs based on the minimum culvert size required to pass the 100-year storm. A total of 8 crossings were selected for conceptual design as listed in Section 3.3.

Culvert design typically depends on whether a culvert is inlet controlled or outlet controlled. A culvert is inlet controlled if water can flow through and out of a culvert faster than it can enter. A culvert is outlet controlled if water can flow into the culvert faster than it can flow through and out. In this scenario, flow through the culvert is limited by downstream topography and tailwater conditions and not necessarily the size of the culvert.

If a crossing was inlet controlled, GEI estimated the minimum culvert size required to pass the 100-year design storm at 90% culvert capacity. For outlet-controlled crossings, GEI estimated the size required to pass the 100-year design storm with a minimum of 1-foot of freeboard to the upstream roadway surface. This criterion is based in part on the MaineDOT Bridge Design Guide for minor spans and culvert-type structures (MaineDOT, 2003).

GEI assumed conceptual crossings were rectangular culverts with natural streambed material along the channel bottom. GEI also added 45-degree headwalls to reduce culvert length and improve hydraulic efficiency. The hydraulic width of each crossing was set to a minimum of 1.2 times the natural bankfull width as measured by GEI in Section 4. The height of each culvert was dependent on required hydraulic capacity, location restraints such as utility crossings, and roadway elevations.

Culverts were sized to account for increases in flow resulting from the replacement of upstream culverts and changes in the tailwater conditions. If increasing the width or height did not significantly alter upstream water elevations (downstream conditions controlled) the smallest culvert dimensions were chosen while meeting minimum width and freeboard requirements.

The slope and alignment of each culvert was selected by approximating the natural slope and orientation of the stream as determined by aerial imagery, LiDAR data, and existing survey information. No bathymetry data was available for the brook nor was bathymetric survey part of this project's scope of work. In final design the channel thalweg should be surveyed to better estimate the brook's natural slope before setting final inlet and outlet elevations.

5.2. Utility Information

Brunswick provided available utility information at each crossing from the following sources:

- Brunswick Topsham Sewer District
- Brunswick Topsham Water District
- Central Maine Power

- Maine Natural Gas
- Consolidated Communications
- The Midcoast Regional Redevelopment Authority

GEI compiled the utility data for each crossing and included the approximate locations on the Conceptual Design Plans (Appendix C). The buried depths of utilities were not known and field locating utilities was outside this project's scope of work. During final design Dig Safe should be contacted and ground penetrating radar, test pits, or other appropriate utility location methods should be performed to confirm the exact location, size, depth, and material of the existing utilities. Findings from utility location may have implications for the conceptual design presented in this study.

Due to limited cover at certain roadway crossings, increasing culvert size may require modifications to utilities and roads such as relocating, insulating, or possibly raising the road's elevation. The conceptual designs attempted to limit utility interferences; however, there may be situations where this is unavoidable. Detailing utility modifications are considered outside this project's scope of work.

5.3. 100-Year Concept Results

Table 5-1 contains a summary of replacement culvert dimensions and estimated 100-year peak water surface elevations, peak flows, and freeboard (upstream water surface to top of roadway) under proposed conditions. Note that these proposed dimensions represent the size of the flow conveyance and do not include the culvert's buried depths. Actual culvert sizes would need to be taller to accommodate instream substrate. Conceptual drawings for the proposed culverts are provided in Appendix C. Additional details such as culvert elevations, slope, length and other culvert information for the 24-hour 100-year storm event are provided in Appendix D.

Table 5-1. Conceptual Culvert Dimensions and 100-Year Design Storm Results

Crossing Name	Proposed Dimensions		Peak U/S WSEL (ft, NAVD88)	Peak Discharge (cfs)	Flow Capacity (%)	Freeboard (ft)
	Rise (ft)	Span (ft)				
Baribeau Drive	3.0	14	74.6	100	88%	3.5
Barrows Street	3.5	16	66.8	236	93%	4.5
MacMillan Drive	5.0	14	63.8	258	98%	5.6
Maine Street	4.0	16	62.7	382	100%	2.1
Meadowbrook Road	6.5	14	54.2	500	89%	7.1
Harpswell Road	8.0	16	45.3	763	88%	12.4
Perimeter Drive	7.5	18	41.4	639	100%	2.6
Eagle Drive	8.0	20	17.2	854	86%	11.4

WSEL: Water Surface Elevation

Table 5-2 compares existing and proposed 100-year peak water surface elevations and peak flows for culverts along the main branch of Mare Brook.

Table 5-2. 100-Year Design Storm Existing vs Proposed Conditions

Crossing Name	Peak U/S WSEL (NAVD88, ft)			Peak Discharge (cfs)		
	Existing	Proposed	Change	Existing	Proposed	Change
Baribeau Drive	76.9	74.6	-2.3	86	100	+13.0
Barrows Street	71.6	66.8	-4.8	224	236	+11.8
MacMillan Drive	70.5	63.8	-6.7	190	258	+67.5
Maine Street	66.2	62.7	-3.4	332	382	+50.4
Meadowbrook Road	61.9	54.2	-7.7	294	500	+205.8
Coffin Ice Pond Dam	53.3	51.1	-2.2	342	672	+329.8
Harpswell Road	53.3	45.3	-8.0	208	782	+574.3
Perimeter Drive	42.3	41.4	-0.9	211	763	+551.5
*Samuel Adams Drive	35.0	40.7	+5.7	347	639	+291.6
*Runway Culvert	31.8	37.4	+5.6	352	656	+304.1
Eagle Drive	23.6	17.2	-6.4	429	854	+425.5
*Liberty Crossing	12.9	15.4	+2.6	630	910	+280.1

*Denotes culvert was not modified from its existing condition.

The model results indicated the larger conceptual culverts would significantly reduce peak water elevations within Mare Brook from Baribeau Drive to Perimeter Drive. Notably, upstream water elevations were reduced at Meadowbrook Road and Harpswell Road by up to about 8 ft. The larger proposed culverts also significantly increased peak discharge at most existing culverts. Culverts that were not modified from their existing condition in the model experienced increases in peak upstream water elevations, further discussion on these culverts is provided in Section 5.4.

It's important the culvert streambeds are designed in a way that supports passage during a range of flows. The wider culverts could reduce flow depth and make the culverts unpassable during times of low flow. Therefore, a low flow channel should be incorporated that provides sufficient depth of flow during low flow conditions.

The conceptual designs are based on available information at the time of this report and are not intended to be final. The culverts depicted on the drawings are pre-cast three-sided open bottom concrete culverts with concrete footings. The exact elevations, dimensions, and materials used for construction should be determined during final design. It’s likely that survey and utility investigation may alter the designs presented in this report. The conceptual designs are intended to be informational and for planning purposes only.

5.4. Downstream Impacts

Increasing culvert sizes is expected to increase peak flows within Mare Brook, especially in the downstream sections of the stream. In the proposed model run, three crossings were not modified from their existing condition: Samuel Adams Drive, the Airport Runway Culverts, and Liberty Crossing. These three culverts are located in the bottom third of the watershed. The proposed model showed all three would experience greater flows and higher water surface elevations. However, simulation results indicated that the three culverts were still able to pass 100-year storm event without overtopping.

Additionally, Samuel Adams Drive and Liberty Crossing were given a fish passage rating of “good” in the 2016 Stantec Fish Passage Report. Therefore, these culverts are not considered to be a high priority for replacement based on the findings of this study.

The runway culvert is not considered passible by aquatic organisms and may be inhibited due to compounding factors related to length and persistent darkness. Obstructions and shallow high-speed flow conditions may also exist within the culvert creating barriers to passage (Stantec, 2016). One potential solution suggested in the WMP was to daylight the existing culvert channel in place. This is likely unfeasible due to several critical factors. Implementing such a solution would require substantial changes to the airports land, potentially affecting airport operations due to a significant loss of the runway. It may also require the removal of legacy pollutants or “forever chemicals,” and involve significant time and resources.

From a hydraulic capacity perspective, performing modifications to the existing runaway culverts does not need to be performed prior to replacing the upstream culverts. The proposed conditions model indicated the existing runway culverts could pass the 100-year storm with a peak upstream elevation of 37.4. This is an increase of 5.6 ft over existing conditions, but there would be an estimated freeboard of approximately 20 ft to the surface of the runway.

6. Coffin Ice Pond Dam Conceptual Design and Fish Passage Feasibility Analysis

In the existing 100-year analysis Coffin Ice Pond Dam would be overtopped by 4.2 ft due to backwater conditions created by the Harpswell Road crossing. To determine whether replacing the Harpswell Road culvert with a larger structure could reduce water levels upstream of the dam, GEI conducted a new 100-year simulation. This simulation maintained Coffin Ice Pond Dam in its current condition while upstream and downstream culverts, including Harpswell Road were replaced with their respective proposed conceptual designs.

The results of this simulation indicated that Harpswell Road would no longer act as a downstream restriction. However, the dam would still be expected to overtop during the 100-year storm by approximately 1.9 ft. This is a reduction in pond elevation of 2.3 ft compared to the simulation with the existing culverts.

Portions of the existing dam are in relatively poor condition; at the time of this study, the dam's concrete piers were deteriorating and undermined from spillway discharge. Additionally, the dam currently provides limited means for fish passage. Therefore, a "do-nothing" alternative (i.e. take no action and leave the dam as is) would not be recommended due to its poor condition, inadequate fish passage, and risk of overtopping.

Dam breach due to overtopping and erosion is possible given the dams earthen construction. Such a breach could result in an uncontrolled release of impounded water and sediment, potentially impacting downstream areas and road crossings such as Harpswell Road. However, due to its small size, dam failure is not expected to cause loss of life. Note, dam breach analysis has not been performed to confirm consequences of dam failure. Per our proposal, GEI has developed a conceptual dam repair alternative with the goal of passing the 100-year design storm.

6.1. 100-Year Coffin Ice Pond Dam Model Results

To pass the 100-year design storm, the conceptual design involved lengthening the spillway to 30 ft, maintaining the existing spillway elevation of 47.4 ft, and grading portions of the dam's embankment to a uniform elevation of 51.1 ft. The resulting spillway results in a peak 100-year water surface elevation that would be equal to the top of dam elevation (51.1 ft). A summary of model results for Coffin Ice Pond Dam are provided in Table 6-1.

Table 6-1. Coffin Ice Pond Dam 100-Year Design Storm Analysis

Crossing Name	Peak WSEL (NAVD88, ft)		Peak Discharge (cfs)	
	Existing	Proposed	Existing	Proposed
Coffin Ice Pond Dam	53.3	51.1	342	672

Increasing the size of the spillway will also increase flows to downstream structures. Therefore, downstream culverts were sized assuming Coffin Ice Pond Dam had been rebuilt to the conceptual design described above.

A sketch of the conceptual dam rehabilitation is provided in Appendix E. The drawing includes a new pedestrian bridge across the dam's spillway to maintain public access. The designs also show a 4-foot-wide stoplog bay that could be used to drawdown the impoundment for future repairs and maintenance. Based on GEI's engineering judgment and experience with similar projects, construction cost of rehabilitating the dam as described above and as shown in Appendix E is estimated to be approximately $1,100,000. This cost estimate should be considered a Class 5 to Class 4 estimate for the purposes of concept/feasibility screening purposes. Actual costs may range from $750,000 to $1,500,000. This cost range is based on the U.S. Department of Energy's (USDOE) Cost Estimating Guide, which states expected accuracy for a Class 4 estimate is between -30% and +50% (USDOE, 2018).

Based on communications with the Town of Brunswick staff (as well as the Town attorney), GEI understands that complete dam removal is not feasible due to legal conditions currently specified in the deed. While dam removal would allow for improved fish passage, prevent sediment accumulation, reduce risk of failure, and likely be less costly than rehabilitation, the aforementioned legal constraints preclude full removal as an option. Consequently, removal of the dam was not considered in this study. As an alternative, Brunswick has expressed interest in installing a fish ladder or a "nature-like fishway" at the dam. A discussion on the feasibility of installing fish passage at the dam is discussed in the following section.

6.2. Fish Passage Feasibility

Coffin Ice Pond Dam and several culverts act as barriers to fish passage along Mare Brook. Despite these barriers, portions of the Brook have historically supported several species of fish. In 2015, a fish survey conducted by the Maine Department of Inland Fisheries and Wildlife (IFW) identified native brook trout, American eel, lake chub, ninespine stickleback, and sea-run brook trout in portions of Mare Brook and Merriconeag Stream. Brook trout were documented as far upstream as the Baribeau Drive Crossing.

Given the amount of time since the last survey, the current status of fish populations in Mare Brook is uncertain. Follow-up surveys are recommended to assess the present populations and compare them to previous findings.

Based on communications with James Pellerin, regional biologist for IFW, Mare Brook supports a relatively robust population of wild brook trout. IFW considers the Brook an important resource worthy of protection, conservation, and restoration with connectivity being an important part of its restoration.

A brief alternatives analysis was conducted by GEI to compare technical fishways to nature-like fishway (NLF) designs and to estimate fish passage feasibility at Coffin Ice Pond Dam.

There are several types of technical fishways such as pool-weir fish ladders, vertical slot, Denil, and Alaska Steeppass. Technical fishways require detailed engineered designs and can be constructed of concrete, aluminum, polymer, and wood (USFW, 2019). Engineered fishways can be prefabricated, which reduces construction costs. However, the hydraulics in engineered fishways are typically different than those observed in nature, and generally few species and sizes of fish are able to negotiate passage. Traditional engineered fishways are generally ineffective at passing eels. Specialized eel passage structures (e.g., climbing ramps) are more commonly used for passing eels compared to conventional fish ladders and lifts (USGS, 2019). This is one reason why we recommend NLFs, as they better mimic natural river conditions and are more effective for a wider range of species.

NLFs are typically constructed of boulders, cobble, and other natural materials to mimic natural rapids that dissipate energy and provide efficient passage of multiple species and age classes (USFW, 2019). NLFs mainly take the form of a rock ramp that span the channel width or can be built to act as a bypass channel around an existing barrier. The fishways involve a series of rock weirs placed perpendicular to flow at different elevations. These fishways may incorporate resting areas or pools for fish to rest and recover during assent. NLFs are a relatively new fish passage technology and although they mimic nature, they do require detailed engineering design. 2D and sometimes 3D hydraulic models are used to help design the intricate rock weirs. Construction of the weirs can also be a delicate process that requires careful selection and placement of boulders to ensure proper spacing and flow velocities.

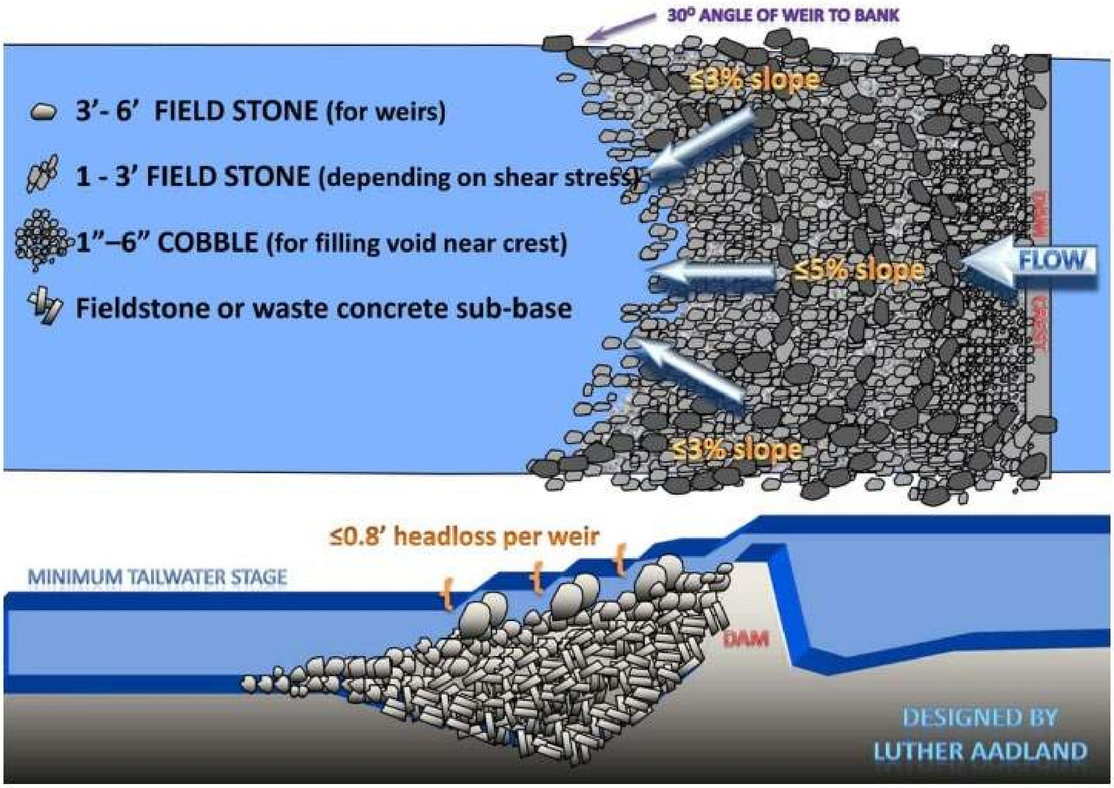
Because of their ability to pass multiple species and age classes under varying flow conditions and migratory run periods, an NLF would be the preferred option for Coffin Ice Pond Dam. NLFs are also believed to be more effective and IFW has indicated a rock ramp would be preferable to a fish ladder. NLFs also generally require less maintenance than engineered fishways because they do not have small slots or features that can trap debris.

Further review was conducted on the *Federal Interagency Nature-like Fishway Passage Design Guidelines for Atlantic Coast Diadromous Fishes* (Turek, 2016). These guidelines provide recommended dimensions for NLFs based on swimming capabilities for Atlantic coast diadromous fish species. For passing multiple species, fishways are typically designed to accommodate the weakest swimmer or the species with the most restrictive design criteria. The guidelines recommend a maximum water velocity between boulders for sea run brook trout and American eel of 3.25 fps and 1fps, respectively. Maximum fishway channel slope of for both fish species is 5%, in general fishways are more successful with slopes less than 5%.

Construction of an NLF at Coffin Ice Pond Dam would likely involve demolition of the existing spillway structure and temporary demolition of the foot bridge. The rock ramp fishway could be constructed in the spillway's current location and be built to maintain the existing water elevation in the pond. The existing dam has an approximate hydraulic head of 4 ft based on LiDAR data; therefore, at a 5% slope the fishway would need to be a minimum of 80 ft in length. The width of the fishway would need to be sufficiently long enough to pass the design storm. The dam's earthen embankment may also need to be raised or graded to a uniform elevation to prevent dam overtopping during the design storm. A pedestrian bridge would be reestablished to provide access across the fishway to conclude construction efforts.

Based on monthly flow estimates from StreamStats average flow at Coffin Ice Pond dam is about 2 to 5 cfs during the summer months. To maintain sufficient depth of flows during low flow conditions a narrow low flow channel could be constructed in the center of the fishway. A conceptual drawing of an NLF at Coffin Ice Pond Dam is provided in Appendix E.

A conceptual design of a typical rock rapid fishway is provided in *Reconnecting Rivers: Natural Channel Design in Dam Removals and Fish Passage* as shown below (Luther P. Adland, 2010).



An example of a nature like fishway with pedestrian bridge is shown in the image below. The photo was taken by GEI personnel at Dunton Locks County Park in Detroit Lakes Minnesota.

The costs of constructing a nature like fishway at Coffin Ice Pond Dam are expected to be similar to those of a complete dam rehabilitation. Both projects would involve similar work, such as demolishing the existing spillway and construction of a new pedestrian bridge with concrete abutments. Cost differences would likely depend on the quantity and unit costs of concrete versus rock, with boulder and rock placement typically being cheaper per cubic yard compared to concrete placement. Costs will also vary depending on the exact details of final design. For example, adjusting the slope of the rock ramp from 5% to 2.5% would double the amount boulder and rock required to construct. GEI has provided conceptual designs for both alternatives; however, the exact scale and scope of both alternatives is subject to change.

7. Culvert Cost Estimate and Replacement Schedule

GEI compiled construction bid estimates from eight similar culvert replacement projects. Seven of the eight projects were put out to bid by MaineDOT and are publicly available from https://www.maine.gov/mdot/contractors/archives/. The other project was the culvert replacement at Richards Drive put out to bid by the Town of Brunswick. Each project involved replacing an existing culvert with a prefabricated box culvert designed to Stream Smart Crossing Guidelines. The designs included an engineered natural bed channel along the bottom of the culvert to promote fish passage. The projects included all incidental work including earthwork, road reconstruction, and scour protection.

A bid estimate summary table of each reviewed project is provided in Appendix F, the summary includes the dimensions of each culvert, bid date, lowest bid, average bid and other details. Of the eight culverts reviewed four had a span of 16 ft or less and the other four had spans greater than 16 ft.

For the culverts spanning 16 ft or less the average bid was approximately $681,000 and the approximate average low bid was $476,000. The average cost (low bid) per square foot for culverts with 16-foot spans or less was approximately $379.

For the culverts spanning more than 16 ft the average bid was approximately $1,467,000 and the approximate average low bid was $1,216,000. The average cost (low bid) per square foot for culverts with spans larger than 16 ft was approximately $476.

GEI developed cost estimates for each conceptual Mare Brook culvert replacement. The estimates were based on our review of similar culvert replacement projects, our knowledge of existing site constrains, and our engineering judgment. Engineering costs are estimated to be approximately 10% of the construction cost.

GEI also prepared an approximate replacement schedule with the goal of completing construction at each of the eight culverts and at Coffin Ice Pond Dam by 2032 as indicated in the Mare Brook Watershed Management Plan. The schedule (Table 7-1) includes approximate construction start dates assuming one to two structures can be completed per year.

Table 7-1. Culvert and Ice Pond Dam Construction Schedule and Cost Estimates

Crossing Name	Const. Start	Const. End	Const. Cost Estimate	Engr. Cost Estimate	Total Cost Estimate	Low Estimate	High Estimate
Eagle Drive	Spring 2026	Fall 2026	$960,000	$96,000	$1,056,000	$739,000	$1,584,000
Perimeter Drive	Spring 2027	Fall 2027	$360,000	$36,000	$396,000	$277,000	$594,000
Harpswell Road	Spring 2028	Fall 2028	$686,000	$69,000	$755,000	$529,000	$1,133,000
Coffin Ice Pond Dam	Spring 2029	Fall 2029	$1,100,000	$110,000	$1,210,000	$750,000	$1,500,000
Meadowbrook Road	Spring 2030	Fall 2030	$428,000	$43,000	$471,000	$330,000	$707,000
Maine Street	Spring 2031	Fall 2031	$518,000	$52,000	$570,000	$399,000	$855,000
MacMillan Drive	Spring 2031	Fall 2031	$403,000	$40,000	$443,000	$310,000	$665,000
Barrows Street	Spring 2032	Fall 2032	$408,000	$41,000	$449,000	$314,000	$674,000
Baribeau Drive	Spring 2032	Fall 2032	$620,000	$62,000	$682,000	$477,000	$1,023,000

The cost estimates are prepared for planning purposes only, actual construction and engineering costs will vary and may change over the lifespan of the project. Low cost and high cost estimates are based on ranges provided by the USDOE for Class 4 estimates; -30% for the low range and +50% for the high range (USDOE, 2018). Cost estimates were made at the current dollar value (2025 dollars) and were not adjusted for future inflation.

8. Recommendations

Based on our review of available documents, the results of the H&H analysis, and discussions with the Town of Brunswick, we recommend the following:

- Culverts should be replaced in an order that does not cause increased flooding downstream. Therefore, culvert replacement should generally progress from downstream to upstream starting with Eagle Drive as indicated in the Construction Schedule (Table 7.1). While Eagle Drive may be one of the more costly upgrades, improving fish passage here would open up approximately 2,000 ft of stream, one the longest uninterrupted reaches in the system.
- Results showed that Harpswell Road was one of the more severely underperforming culverts. We would recommend replacing the Harpswell Road culvert (and other downstream culverts) prior to rehabilitating Coffin Ice Pond Dam.
- GEI recommends that the Town of Brunswick discuss the analyses completed for Coffin Ice Pond Dam with relevant stakeholder groups and select the preferred alternative for further evaluation and design (assuming compliance with CIP Deed is achieved). If fish passage is a priority, GEI recommends incorporating an NLF design. The costs of constructing an NLF are expected to be similar to those of a complete dam rehabilitation. Additionally, an NLF would provide greater ecological benefits and likely attract more grant and funding opportunities.
- The WMP suggests “day lighting” the more than 3,000-foot-long culvert that runs under the airport runways. Though this action would have significant benefit to the overall ecological health of the stream, daylighting the culverts would likely be the most challenging and costly modification in the culvert portfolio. While it is recommended that culvert replacement take place starting from downstream and moving upstream, prioritizing the runway culvert, and associated remedial options suggested within the WMP, may not be immediately necessary. The 100-year proposed condition analysis indicated the runway culvers were able to pass 100-year storm event without overtopping.
- GEI recommends the Town perform exploration (test pits, ground penetrating radar, other) to locate and identify utility crossings at each culvert location. The depth of certain utilities may impact the design of select culverts especially where there is limited cover from road surface to top of proposed culvert. Ideally culverts should be tall enough to limit debris buildup and allow for worker access.
- When performing final design, the culverts streambed should be designed with a low flow channel that provides sufficient depth of flow for fish passage during times of low flow. Additionally, the larger culverts will likely impact the stream morphology; therefore, GEI recommends performing additional stream restoration measures described in the WMP such as performing chop and drops and removing artificial fill.
- GEI recommends the Town perform follow up fish surveys in coordination with IFW. The previous survey was performed in 2015.

The conclusions and recommendations presented in this section are based on GEI's engineering judgment and their interpretation of the study's results. The recommendations in this section are meant to provide Brunswick with possible options for restoring the Mare Brook watershed. The recommendations made are considered suggestions and, in some cases, further analysis may be necessary to determine the best action moving forward.

9. Limitation of Liability

This report presents analyses and results of a site-specific hydrologic and hydraulic study of the Mare Brook watershed. GEI developed a hydrologic and hydraulic model of the Mare Brook watershed to access flood conditions during the 100-year annual recurrence interval storm event. The hydrologic and hydraulic model was created using GEI's best judgment and to be comprehensive and conservative in the development of infiltration rates, design storm precipitation, and other parameters presented in this study. The assumptions are consistent with methods for developing information on design storms and for sizing hydraulic structures.

For modeling of design storms, antecedent moisture conditions were assumed to be fully saturated (i.e. the ground was assumed to be fully wet prior to the storm event). Initial loss, the amount of precipitation lost to ground infiltration at the start of the storm event, was assumed to be 0. This is a conservative assumption that results in greater runoff. If a storm event occurs in the watershed, actual conditions, peak flows, and peak water surface elevations will vary from those presented in this report.

This study included limited hydraulic analysis and does not include an evaluation of the structural integrity of culverts, bridges, dams, and other appurtenances. Because the methods, procedures, and assumptions used to develop the analysis are approximate, the results should be used only as guidance.

The HEC-RAS model was developed to provide reasonably accurate results along the main branch of Mare Brook, Picnic Pond Dam, Coffin Ice Pond Dam. With any complex hydraulic model, a balance must be struck between model stability, accuracy, and run-time speed. GEI structured the model so that flood conditions could be estimated with reasonable accuracy in locations where needed while still maintaining optimal model performance. Use of the model to extrapolate results from locations not prioritized in this study including Mare Brook's tributaries and un-surveyed culverts may provide comparatively less accurate results.

The hydraulic model was developed and calibrated to evaluate watershed characteristics and approximate hydraulic capacity of river crossings and dams for the storm events presented. Assessing Mare Brook and its tributaries under low flow conditions was not the objective of this study. Evaluation of the Mare Brook under low flow conditions would require calibration and additional analyses.

Reuse of this report for any other purposes, in part or in whole, is at the sole risk of the user.

10. References

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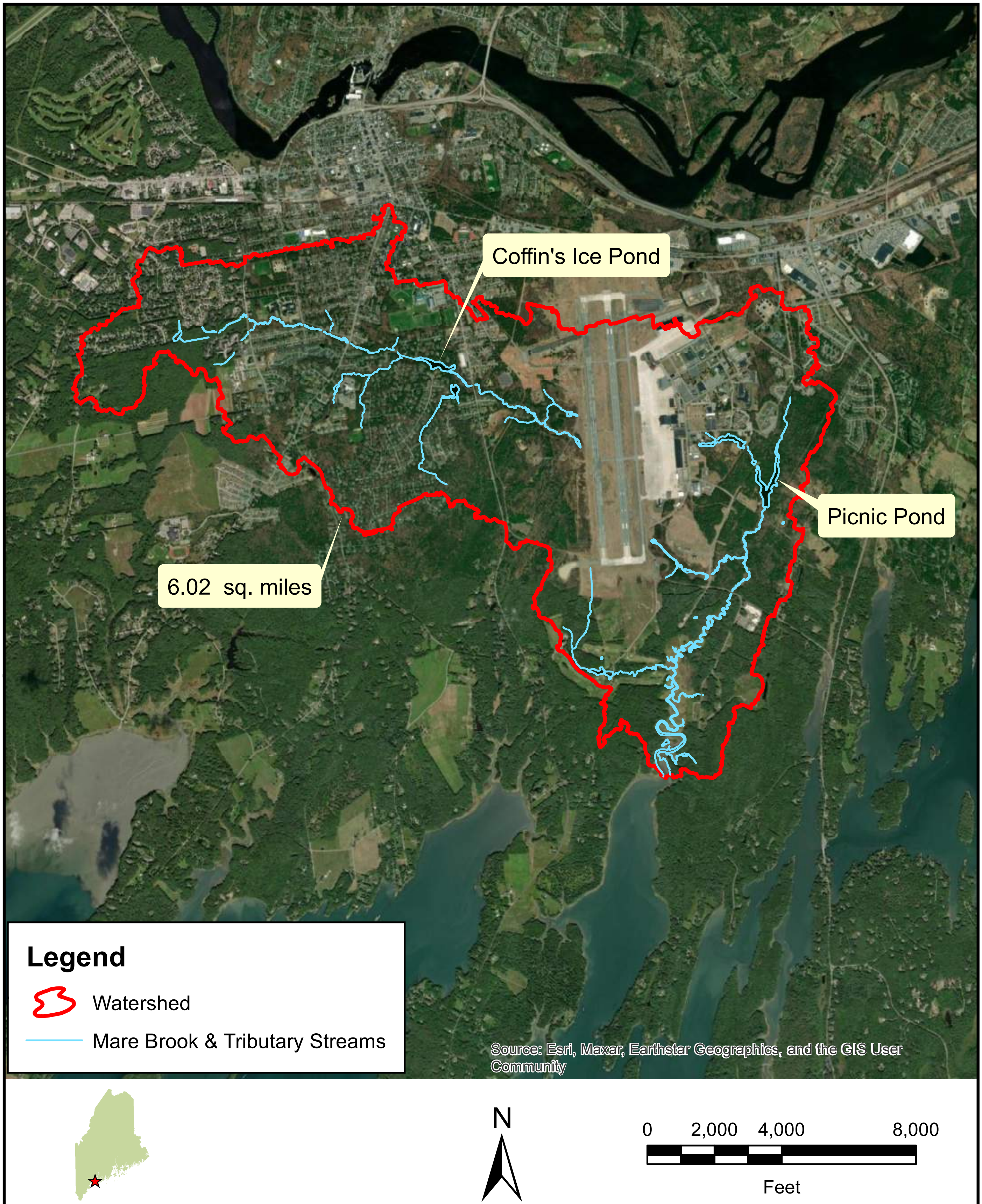
Figures



Mare Brook Culvert and Coffin Ice Pond Dam Conceptual Design Brunswick, Maine	GEI Consultants	WATERSHED AREA MAP
Town of Brunswick, Maine Department of Planning and Development	Project 2202137	January 2025 Fig. 1

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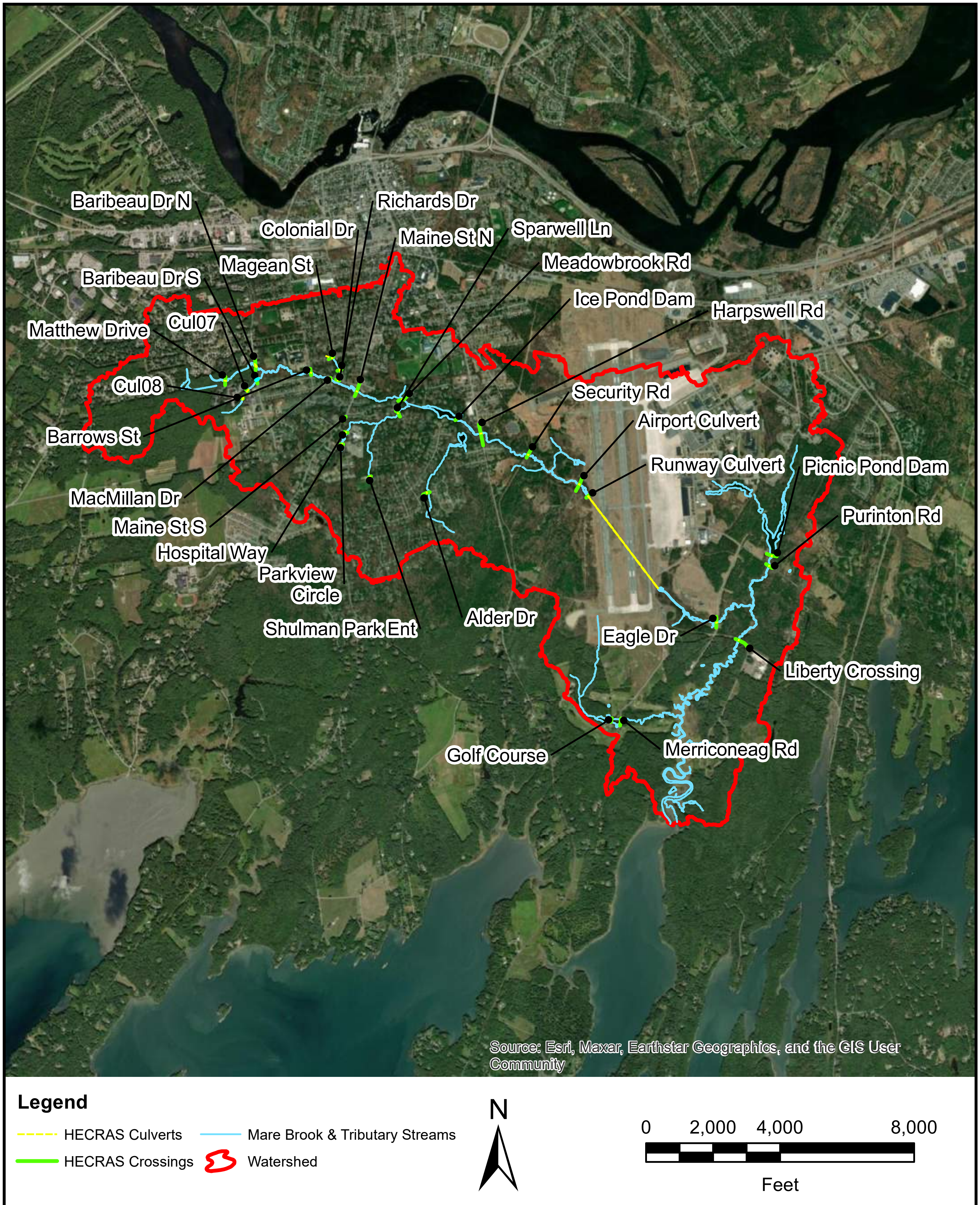

Mare Brook Culvert and Coffin Ice Pond Dam Conceptual Design Brunswick, Maine	GEI Consultants	MODELED STREAM CROSSINGS
Town of Brunswick, Maine Department of Planning and Development	Project 2202137	January 2025 Fig. 2

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Appendix A GEI Mare Brook Watershed Hydrologic & Hydraulic Study, 2023

Consulting
Engineers and
Scientists

Mare Brook Watershed Hydrologic & Hydraulic Study

Brunswick, Maine

Submitted to:
Town of Brunswick, Maine
Department of Planning and Development
85 Union Street
Brunswick, ME 04011

Submitted by:
GEI Consultants, Inc.
5 Milk Street
Portland, ME 04101
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March 2023
Project 2202137

STATE OF MAINE
ELIZABETH C. ROBINSON
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LICENSED
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Senior Water Resources Engineer

Marc Chmura, E.I.T. (MA)
Water Resources Engineer

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Executive Summary

The Town of Brunswick retained GEI Consultants, Inc., to perform a hydrologic and hydraulic (H&H) study of the Mare Brook Watershed. The purpose of this work was to provide the Town with information to help prioritize a sequence of culvert replacements and geomorphic stream restoration projects recommended in the Mare Brook Watershed Management Plan 2022-2032 (WMP).

The WMP was prepared by the Cumberland County Soil and Water Conservation District with input from WMP Steering Committee members. Funding for the plan was provided in part by the U.S. Environmental Protection Agency under Section 604B of the Clean Water Act. In February 2022, Brunswick Town Council voted to adopt the WMP. The plan included a series of recommended stream restoration projects to improve the ecological health of the brook and reduce inland flooding. The plan also identified several specific culverts in need of hydrologic and hydraulic (H&H) analyses to inform culvert replacement options.

GEI's work on this project included the development of a 2-dimensional (2D) rain-on-grid hydraulic model of the Mare Brook watershed to simulate the 2-, 10- and 25-year annual recurrence interval design storms. The model was developed to represent the watershed's existing conditions based on detailed information from survey of existing culverts, dams, and GEI's temporary monitoring equipment. The model was used to estimate flood conditions, peak water elevations, and peak flow at several key stream crossings for the design storm events. GEI performed the H&H modeling using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center - River Analysis System (HEC-RAS) (USACE, 2022a).

The model was calibrated/validated to three observed precipitation events. Adequate comparison between observed and simulated results confirmed the model is suitable in providing reasonable estimates of peak water levels and peak flows during the design storm events (i.e., 2-, 10-, 25-year storms) at key stream crossings within the watershed.

To evaluate the vulnerability of the watershed under climate change and sea level rise conditions and to ensure stream restoration projects provide a healthier, more resilient ecosystem, GEI offers a few possible areas of additional analysis for Brunswick's consideration:

- The Town may want to consider performing a climate change vulnerability analysis to assess impacts to the watershed caused by rising sea levels and increased frequency, depth, and intensity of precipitation events.

- GEI recommends performing an H&H analysis for the 50-year and 100-year annual recurrence interval storm events. The Maine Bridge Design Guide (MaineDOT, 2003) indicates that bridges and minor spans should be designed for the 50-year event and checked for the 100-year event. In certain cases, analysis of the 500-year flood event may be warranted. For culvert design, MaineDOT indicates that the ratio of headwater (depth above the invert) to structure depth (culvert diameter) should be approximately equal to or less than 0.9 (i.e., flow depth at 90% full) for the 50-year event.

  When outlet conditions control culvert flow, a minimum of 1 foot of freeboard is required for the 100-year event. Performing H&H analysis under the 50-year and 100-year flood conditions will provide the Town of Brunswick with an understanding of culvert design relative to the state guidelines.

- GEI created the HEC-RAS model to facilitate design of future culvert replacements. Proposed culverts may be added to the model to assess flood conditions and downstream impacts under proposed designs. GEI recommends consideration of the State of Maine Aquatic Resource Management Strategy (ARMS) Stream Smart Road Crossing Guide when designing replacement and new culverts (MaineDOT, 2023). The web-based guide provides information for "installing and replacing crossings in an effective and cost-efficient manner while meeting goals of restoring and maintaining stream habitat connectivity and enhancing the stability of roads and culvert crossings."

- The hydraulic model was developed for use in evaluating extreme events (i.e., 2-, 10- and 25-year events) and was calibrated to three observed storms on the order of 1- to 2-year annual recurrence interval. Analyzing channel velocities and water depths under low flow conditions may be of interest for the design of future stream restoration projects. If the Town is interested in evaluating low flow conditions, additional work may be required to refine the model such as the collection of detailed stream channel bathymetry (to supplement the detailed LiDAR terrain data), water level monitoring, calibration during low flows, and evaluation of ground water discharge to the brook during low flow periods.

1. Introduction

The purpose of the H&H study was to provide the Town of Brunswick with information to prioritize culvert replacements and geomorphic stream restoration projects recommended within the Mare Brook Watershed Management Plan (WMP) 2022–2032 (CCSWCD, 2022).

Work on this project included the development of a 2-dimensional (2D) rain-on-grid hydraulic model of the Mare Brook watershed to simulate the 2-, 10- and 25-year annual recurrence interval design storm events. The model was used to estimate flood conditions, peak water elevations, and peak flows at several key stream crossings during the design storm events. GEI performed this evaluation using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center – River Analysis System (HEC-RAS) software, Version 6.3.0 (USACE, 2022a). GEI deployed five water level sensors within the watershed from July to October 2022 to capture changes in water elevations during significant precipitation events. The water level data was used for model calibration to demonstrate that the hydraulic model was a reasonable characterization of observed conditions.

Critical to model development was the compilation of terrain data to represent topographic features of the watershed. The model terrain was compiled from three 1-meter digital elevation models (USGS, 2021a, b, and c). GEI also subcontracted Little River Land Surveying, Inc. to collect elevation data at key river crossings.

The North American Vertical Datum of 1988 (NAVD88) was the reference datum for elevations in this report and the hydraulic model.

GEI completed the analysis for the Town of Brunswick in accordance with GEI's Proposal dated April 29, 2022. The following GEI personnel were primarily responsible for performing the hydraulic analysis for this report:

Project Manager:	Lissa Robinson, P.E. (ME)
Water Resource Engineer:	Marc Chmura, E.I.T (MA)
Quality Assurance/Control Lead:	Amanda Barnett, E.I. (ME)
Engineering Field Lead:	Dan Pelletier, E.I., (ME)

2. Project Background

In February 2022, the Town of Brunswick with help from the Cumberland County Soil and Water Conservation District completed the Mare Brook Watershed Plan 2022-2032 (WMP). Mare Brook, a Maine Class B stream, is currently listed by the Maine Department of Environmental Protection (Maine DEP) as impaired due to poor macroinvertebrate sampling results and habitat (CCSWCD, 2022). Maine's water classification system, in place since the 1950's, establishes water quality goals for the state. Mare Brook is also considered an Urban Impaired Stream under Maine's Stormwater Management Law.

The primary goal of the WMP is to meet the Maine State-designated Class B standards by 2037. Land use activities and impervious cover within the watershed are two of several stressors that reportedly contribute to the impairment of Mare Brook. This has led to erosion, loss of habitat, and poor water quality. GEI conducted this H&H study to help the Town of Brunswick evaluate the existing stream system and to provide the Town with a tool for assessing future culvert replacement and stream restoration projects.

Mare Brook is a 5.7-mile stream with a 6.02-square-mile drainage area located entirely within the Town of Brunswick (Fig. 1). The headwaters of the brook begin in the northwest area of the watershed in a dense residential area. The brook flows east through neighborhoods, and into Coffin's Ice Pond, which is impounded by a small dam just upstream of Harpswell Road. The brook continues to flow past several culverts including a more than 3,000-foot-long culvert under the runway of the Brunswick Executive Airport and continues downstream to its confluence with the Merriconeag Stream, Mare Brook's main tributary.

Merriconeag Stream begins in the northeast area of the watershed and flows into Picnic Pond, which is impounded by a small dam just upstream of Purington Road. Downstream of the confluence with Merriconeag Stream, Mare Brook continues south for less than a mile through forested land where it discharges to Harpswell Cove.

3. Field Survey

The GEI Team performed several field visits throughout the watershed to confirm existing conditions, observe road crossings and associated culverts, measure culvert and dam dimensions, observe potential obstructions to flow, and record approximate channel widths and depths. The information gathered during GEI's site visits was used to develop the HEC-RAS model and ensured that the model would reasonably represent conditions at the time of the study.

To further improve model accuracy, GEI retained Little River Land Surveying, Inc. to collect elevation data at key river crossings. The survey was focused on locations critical for the accuracy of the H&H model such as culverts, water level sensor elevations, bank locations, weir elevations at dams, and top of road elevations at culvert crossings. This site-specific survey data was used to supplement the publicly available digital elevation model (DEM) at the critical hydraulic structure locations. Locations of surveyed structures are shown in Fig. 2.

The crossings selected for the survey were based on the following: (1) location along the main stem of Mare Brook, (2) importance to hydraulic conveyance, and (3) identification in the WMP as requiring an H&H model to inform culvert replacement design.

4. Water Level Sensor Installation and Monitoring

GEI installed water level sensors to collect depth measurements at key locations during rainfall events in summer and fall of 2022. This information was critical for calibration of the hydraulic model to ensure the model was appropriate for use in simulating flows for the design storms identified for the study (2-, 10-, and 25-year events). To GEI's knowledge, no prior streamflow or water level data exist for Mare Brook or its tributaries.

GEI deployed five water level sensors upstream of the following five structures:

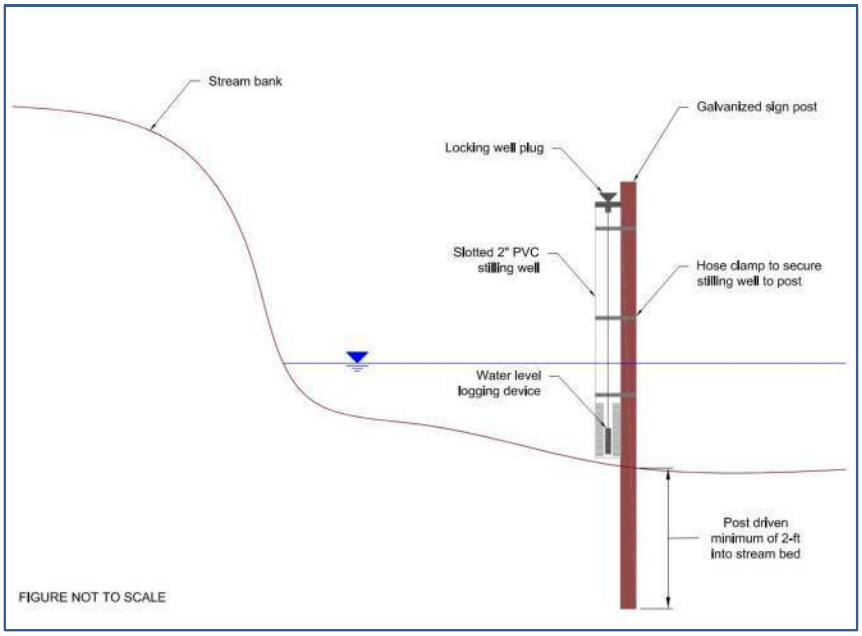
1. Meadowbrook Road Culvert
2. Picnic Pond Dam
3. Airport Runway Culvert
4. Coffin's Ice Pond Dam
5. Liberty Crossing Culvert

The locations of these water level sensors are shown in Fig. 2. Graphs of water depth at each sensor are provided in Appendix A. Consistent with water level logging practices, the sensors were set above the channel bottom and therefore "depth" represents the depth of water above the sensor. GEI converted water depth measurements to elevations (NAVD88) by adding the recorded depth to the known sensor elevation surveyed by Little River Land Surveying, Inc.

Water level loggers require adjustment to account for changes in barometric pressure. GEI recorded atmospheric pressure at a barometer installed upstream of the Meadowbrook Road Culvert. The barometric data was used to adjust water level readings using Solinst Levelogger Software. Water level and barometric data was continuously collected from July 9, 2022 to October 28, 2022 at 5-minute intervals.

To estimate streamflow, GEI developed stage discharge rating curves for the culverts and dams located immediately downstream of the sensors. The rating curves for culverts were created using HY-8 Culvert Hydraulic Analysis software published by the Federal Highway Administration (FHWA, 2021). Rating curves at the two dams were developed using standard weir equations. Using the rating curves, GEI was able to estimate streamflow for each recorded water elevation. The estimated streamflow data was used to support model calibration.

The water level monitoring equipment consisted of a water level logger in the form of a pressure transducer installed within a 2-inch-diameter slotted PVC stilling well that was secured to a driven galvanized post. The monitoring equipment included five (5) Solinst Levelogger 5 sensors and one (1) Solinst Barologger 5 barometer. Graphic 1 shows a schematic of GEI's temporary stilling well and water level logger installation. GEI field personnel periodically checked the water level loggers to download data and perform maintenance. The equipment was removed on October 28, 2022.



Graphic 1. Water Level Logger Installation Schematic

5. Hydraulic Model Setup

To perform the hydrologic and hydraulic analysis, GEI developed a 2-dimensional (2D) rain-on-grid HEC-RAS model of the Mare Brook watershed. GEI developed this model using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center – River Analysis System (HEC-RAS) software, Version 6.3.0 (USACE, 2022a).

The model was used to simulate watershed conditions for the 2-, 10- and 25-year annual recurrence interval design storm events. The focus of this study was to evaluate crossings on the main stem of the Mare Brook River that were previously identified as needing a H&H analysis in the WMP.

The model was developed to represent existing conditions in the watershed. Modifications may be made to the model to facilitate design and analysis of future stream modification projects, dam rehabilitation or removal, land use build-out, and/or culvert replacement projects. A spreadsheet will be provided containing water depths recorded by GEI.

5.1 Terrain

A terrain model is a 3-D representation of the watershed's topography that affects the movement of water through the floodplain. The terrain was based on one-meter resolution Digital Elevation Models (DEMs) available from the USGS 3D Elevation Program (USGS 2021a, b, and c). The DEMs were merged, converted from meters to feet, and projected to Maine State Plane West Zone NAD83. The files used to create the DEM reference a publish date of January 21, 2021.

5.2 Watershed Delineation

GEI used the terrain and ArcGIS watershed analysis tools (ESRI, 2020) to delineate the Mare Brook watershed boundary. GEI also reviewed stormwater infrastructure data provided by Brunswick and refined the watershed boundary where existing stormwater infrastructure diverts surface runoff out of Mare Brook's natural watershed. Brunswick also provided a previous watershed delineation performed by Maine DEP in the form of a GIS shapefile. This prior watershed delineation was used to verify and amend the watershed limits estimated by GEI, as applicable and appropriate. In general, GEI found good agreement between the Maine DEP watershed and the GEI watershed. Differences between the two may be due to GEI's use of a more recent and higher resolution DEM. Fig. 1 presents the GEI-delineated watershed.

5.3 2D Flow Area

Using the HEC-RAS 2D flow area editor, GEI generated a computational mesh to represent the 6.02 square-mile watershed. The cell size, shape, and orientation were input to describe the terrain and changes in water surface slope in the 2D areas. A cell size of 100 ft by 100 ft was selected as the default cell size. Smaller cell sizes were input for model stability and additional detail along the main channel and at key geometric features such as culverts, reservoirs, and dams. Breaklines were added to the 2D flow area mesh to reduce cell size, re-orient the cells to align with geometric features and the primary direction of flow, and to capture “high” features in the terrain.

5.4 Land Cover and Manning’s n-value

Land cover data for the watershed was obtained from the Maine Land Cover Dataset (MLCD), downloaded from Maine GeoLibrary (2004) as a GIS shapefile. A map of the land cover for the watershed, as classified in the MLCD, is provided in Fig. 3. The land cover categories include types of development for urbanized areas and natural vegetation cover types for undeveloped areas. The distribution of land cover as a percent of total watershed area is presented in Table 1.

Table 1. Distribution of Land Cover

Land Cover	Area (Square miles)	Area Percentage
Developed, High Intensity	0.55	9.05%
Developed, Medium Intensity	0.48	7.93%
Developed, Low Intensity	0.80	13.33%
Developed, Open Space	1.36	22.51%
Cultivated Crops	0.01	0.15%
Pasture/Hay	0.10	1.63%
Grassland/Herbaceous	0.03	0.51%
Deciduous Forest	0.16	2.64%
Evergreen Forest	0.92	15.21%
Mixed Forest	1.00	16.53%
Shrub/Scrub	0.05	0.80%
Wetland Forest	0.20	3.25%
Wetlands	0.13	2.09%
Roads – Runway	0.21	3.50%
Unconsolidated Shore	0.01	0.13%
Open Water	0.03	0.51%
Blueberry Field	0.00	0.00%
Light Partial Cut	0.01	0.15%
Heavy Partial Cut	<0.01	0.05%
Forest Regeneration	<0.01	0.02%

Land cover within the 2D model was associated with Manning's n-values to establish roughness coefficients in the model. GEI assigned Manning's n-values to land cover groups based on Chow (1959), NRCS (2010), and our engineering judgement. A high-resolution GIS shapefile representing impervious areas including roads, sidewalks, buildings, runways, and parking lots was provided by the Town of Brunswick. This detailed shapefile was superimposed over the MLCD so that Manning's n-values could be refined in areas containing impervious surfaces.

5.5 Infiltration

GEI used the deficit and constant loss method in HEC-RAS to estimate surface runoff volume and precipitation loss due to soil infiltration. In this method, precipitation is stored within the soil layer until the soil becomes fully saturated and can no longer accept water. Once the soil is fully saturated, additional precipitation loss due to percolation out of the bottom of the soil layer can occur. The rate of percolation is modeled as a constant rate and is determined by the properties of the soil and landcover. In general, soils consisting of clay and silt have lower percolation rates compared to sand and gravel soils. The amount of rainfall that occurs in excess of the percolation rate represents the volume of direct surface runoff. Total runoff in areas with impervious surfaces are reduced based on the average percent of impervious area within a model cell.

The parameters required to use the deficit and constant loss method within HEC-RAS include:

- Initial Deficit (inches)
- Constant Rate (in/hr)
- Maximum Deficit (inches)

5.5.1 Initial Deficit

Initial deficit represents the "initial loss" and is the amount of water required to bring the soil layer from a dry state to full saturation. In other words, it is the portion of precipitation that is immediately lost to the unsaturated voids or openings in the subsurface soil/rock before precipitation contributes to surface runoff. For modeling of design storms, the initial loss was assumed to be 0. This is a conservative assumption (produces more runoff) and represents fully saturated conditions prior to a design storm event.

For modeling of actual observed storm events, the initial loss was input based on precipitation observations leading up to the selected storm and refined based on model calibration. Further discussion of initial loss calibration is included in Section 6.

5.5.2 Constant Rate

When the soil is fully saturated, the amount of loss (i.e., infiltration) is defined by a constant rate. This rate was estimated based on published information for the watershed including soil type, land cover, drainage classification, depth to ground water table, and hydrologic soil group (HSG). HSG is a published classification that provides an estimate of runoff potential for a given soil type. The Natural Resources Conservation Service (NRCS) defines four hydrologic soil groups (HSGs) of A, B, C, or D. Minimum infiltration rates for each soil group are show in Table 2 reproduced by the USACE (2022b) from Skaggs and Khaleel (1982). The ranges provided represent minimum infiltration rates and actual observed rates may be and often are higher than these minimum published values.

Table 2. Hydrologic Soil Group Minimum Infiltration Rates

Hydrologic Soil Group	Description	Minimum Loss Rate (in/hr)
A	Deep sand, deep loess, aggregated silts	0.30 – 0.45
B	Shallow loess, sandy lam	0.15 – 0.30
C	Clay loams, shallow sandy loam, soils low in organic content, and soils usually high in clay	0.30 – 0.15
D	Soils that swell significantly when wet, heavy plastic clays, and certain saline soils	0.00 – 0.05

Soil data including soil classification, soil texture, drainage classification, HSGs and other parameters were downloaded from the U.S. Department of Agriculture (USDA) website (USDA, 2022). The data obtained for this project represents information compiled in the Soil Survey for Cumberland County, Maine.

The percent distribution of hydrologic soil groups across the Mare Brook watershed are shown in Table 3. A map of the watershed displaying hydrologic soil groups is provided in Fig. 4. GEI used engineering judgment to select an appropriate HSG in areas where the soil survey did not assign a HSG classification or areas that were assigned dual classifications (A/D, C/D, etc.). GEI also consulted Maine Geological Survey Surficial Geology Maps (MGS, 1999) for additional information regarding the presence and extent of significant sand and gravel aquifers in the Mare Brook watershed.

Table 3. Percent Distribution of Hydrologic Soil Groups

Hydrologic Soil Group	Area (Square miles)	Area Percentage
A	3.84	63.9%
B	<0.00	0.04%
C	0.79	13.2%
D	1.38	22.9%

Most of the watershed (63.9%) was estimated to fall under HSG A, indicating the watershed consists mostly of soils that provide relatively high infiltration rates.

5.5.3 Maximum Deficit

The maximum deficit determines the total amount of water the soil layer can hold. Unlike initial deficit, this value is not affected by antecedent moisture conditions. Instead, the maximum deficit represents the driest the soil can become under the influence of gravity, evaporation, and transpiration. This parameter is a function of effective porosity, wilting point, and an assumed active layer depth (Rawls, Brakensiek, and Miller, 1983). GEI performed sensitivity testing by varying the maximum deficit estimate and found that the parameter had no measurable effect on model results. This is because maximum deficit is typically used to account for evapotranspiration that happens between storm events and sets a limit on the amount of water that is required to bring the soil from a dry state to a fully saturated condition. Because the model is used to simulate single storm events under saturated conditions, the maximum deficit does not influence the results. Therefore, the maximum deficit was set to zero (0) during design storm simulations or was set equal to the estimated initial deficit during simulation of observed storms.

5.6 Boundary Conditions

The boundary condition downstream of the watershed was set using a stage hydrograph to represent fluctuations of tides in Harpswell Cove. Tide data was obtained from the NOAA Portland ME Tide Station (Station ID 8418150) and downloaded from tidesandcurrents.noaa.gov (NOAA, 2022). The downstream boundary was placed at the confluence of Mare Brook and Harpswell Cove. For modeling of design storms, average high tide was set to occur when flow through the Liberty Crossing culvert (the most downstream culvert) was at its peak. This is a conservative measure resulting in higher water surface elevations in the downstream areas of the model.

Inflow hydrographs were used as upstream boundary conditions in various areas of the model to represent base flow. Water levels recorded during dry weather conditions were converted to flow using GEI's estimated rating curves. Base flows were then adjusted as necessary during model calibration to best match recorded initial river and pond levels.

Detailed bathymetric data in ponds and deeper sections of the brook were not available and a bathymetric survey was outside the scope of work. For storm event modeling the bathymetric data is not as critical as it would be for low flow modeling. Initial reservoir elevations of Coffin's Ice Pond Dam and Picnic Pond Dam were set to the average normal pool water elevations recorded by GEI's water sensors (47.6 ft and 23.3 ft, respectively) for the period of monitoring from July 2022 through October 2022.

5.7 Culvert Crossings and Control Structures

Structures were built within the model to represent the geometry of culverts and other stream crossings. Culvert invert elevations recorded during survey were directly input into the model. Other culvert input parameters included culvert length, material, slope, Manning's n-value, and entrance and exit loss coefficients. If a culvert was observed in the field to be clogged with debris or partially collapsed, GEI used the depth blocked parameter in HEC-RAS to account for the flow restriction. For culverts that were not surveyed either due to access restrictions or because they were less critical to model development, culvert geometry was based on documented information in the culvert and outfall inspection datasheets provided in Appendix B of the Mare Brook WMP. Inverts of culverts not surveyed were estimated based on photographs and the LiDAR surface in the area of the culvert.

GEI also modeled the geometry of Picnic Pond Dam and Coffin's Ice Pond Dam. The model includes elevations and lengths of embankments, spillways, and other hydraulic controls. The dimensions and elevations were based off measurements recorded during site-survey and GEI's field observations. Fig. 5 contains a map identifying stream crossings and culverts included in the 2-D hydraulic model.

6. HEC-RAS Model Calibration

Model calibration was performed to demonstrate the model can reasonably replicate observed stream and pond conditions. The process involved comparing simulated model results with observed conditions and refining inputs to optimize the model's replication of observed data. The goal of calibration was to achieve an overall "best match" to the observed data by replicating the timing, water level elevation, and discharge in the model.

6.1 Selection of Calibration and Validation Storms

GEI reviewed observed water level data and chose two calibration storms based on dates when high water levels were recorded by GEI's water level sensors. Two separate storms were selected for calibration to account for possible anomalies in the observed precipitation or water level data. The first storm of interest occurred on October 14, 2022. This storm produced the greatest amount of rainfall and the highest water levels compared with other events during the monitoring period from July to October 2022. On average about 2.7 inches of rainfall fell across the watershed in 24 hours. A review of historic rainfall data indicated the October storm would be on the order of a 1- to 2-year annual recurrence interval storm event. The second storm of interest occurred on July 25, 2022 when an average of 1.2 inches of rain fell over the watershed within 10 hours.

To verify the model would produce repeatable results, a third event was selected to serve as the model's validation storm. The third storm occurred over three days from September 18 to September 20, 2022 when an average of 2.3 inches of rain fell over the watershed. The September storm resulted in the second highest water levels recorded by GEI's water level sensors.

6.2 Precipitation Data

To accurately model observed storm events, it is critical to have reliable, high resolution precipitation data. During a storm event, rainfall intensity and duration can vary significantly from one end of a watershed to the other. Therefore, it's helpful to obtain rain gage data from multiple points within the watershed to capture the storm's path and timing.

Rainfall modeling methods typically guide selection of precipitation data. GEI elected to use the more detailed direct rainfall method included in the HEC-RAS software, referred to as "rain-on-grid." This method allowed for the simulation of the temporal and spatial variability of the observed storms allowing for more accurate results compared to average basin methods, where rainfall would typically be averaged across the entire watershed.

GEI consulted two precipitation data sources, Multi-Radar Multi-Sensor, and Weather Underground, to develop the gridded rainfall data.

(1) Multi-Radar Multi-Sensor (MRMS) – a system originally developed by NOAA's National Severe Storms Laboratory that produces gridded precipitation data as a time series. The automated system compiles data from Next Generation Weather Radar (NEXRAD) stations, satellite observations, and numerical weather prediction models to generate gridded data records for the United States.

    The MRMS data for this project was downloaded from Iowa State University's Iowa Environmental Mesonet (IEM) as Multi-Sensor Quantitative Precipitation Estimation (QPE) Pass 2 data (NOAA NSSL, 2022). The data set was downloaded in GRIB file format and represented 1-hour precipitation estimates at an approximate 1100x800 meter grid resolution. GEI used the U.S. Army Corps of Engineers HEC Hydrologic Modeling System (HEC-HMS) version 4.10.0 (USACE, 2022b) to convert the raw gridded precipitation data into a DSS file for input to HEC-RAS. The precipitation files were projected to align with the hydraulic model's coordinate system and time zone, and were clipped to the Mare Brook watershed boundary.

(2) Weather Underground (wunderground.com) – is website containing meteorological data from a network of weather stations maintained by meteorologists and members with personal weather stations. The site provides access to recorded weather data including 5-minute incremental precipitation. Rainfall data was obtained from 10 weather stations located within and around the Mare Brook watershed. A map of the selected weather stations is provided in Fig. 6.

    The precipitation data from each station along with the station's respective coordinates were entered into the HEC-RAS program. GEI used HEC-RAS to create an interpolated precipitation grid using a two-step process. First, the Thiessen Polygon method was used to determine which rain gage should be used as the representative storm pattern for a give cell within the 2D grid. Next, the Inverse Square of the Distance method was used to estimate the weighted rainfall total for each individual cell. This approach resulted in the compilation of precipitation data representing the spatial and temporal distribution of the given storms at 5-minute intervals.

Precipitation data from MRMS and Weather Underground were compared to determine an appropriate precipitation estimate for each storm event. GEI used engineering judgment to determine which source provided the most appropriate data for the three storms under consideration for this study. In general, MRMS data can provide higher resolution precipitation estimates in areas of low weather station density. While there were several weather stations located around the watershed, only one station was within the watershed boundary (See Fig. 6). Therefore, the MRMS data was the preferred option because the data provided relatively higher spatial resolution. For the July calibration model run, the MRMS precipitation estimates compared favorably with Weather Underground rain gage measurements in both magnitude and timing, thus, the MRMS data was chosen as the precipitation estimate for this storm.

While MRMS can produce higher resolution precipitation estimates, the NEXRAD data used to develop the estimates can be prone to error. These errors can stem from beam blockages, improper algorithms, range degradation and other mechanisms inherent in the process of estimating precipitation. Thus, NEXRAD data benefits from comparison with point gage data to verify the magnitude and timing of a rainfall event. Upon GEI's review, it was determined the MRMS data significantly overestimated the depth of rainfall during the October and September storms when compared to rain gage measurements from Weather Underground. Therefore, Weather Underground was used as the precipitation data source for the October calibration and the September validation model runs.

6.3 Calibration Adjustments

Several refinements were made to the HEC-RAS model inputs until the simulated model results compared favorably with the observed data. The "time step" (the frequency at which the model's calculations are performed) was tested for sensitivity. GEI determined a "variable" 5 second timestep (i.e., an automatically adjusted time step based on the Courant Condition) provided the best combination of runtime speed and stability. The model's sensitivity to Manning's n-values was also evaluated. However, modifying the Manning's n-values did not result in significant variations to model flows or water surface elevations. Therefore, initial values were determined to be appropriate. Initial base flows were also adjusted until water levels in the model matched recorded water elevations observed prior to the storm events. Other modifications included adding breaklines, adjusting impervious area infiltration percentages, and decreasing cell size in high flow areas. By performing these refinements, GEI was able to develop optimum inputs and model configurations that improved the agreement between observed and simulated model results.

6.4 Infiltration Rate Calibration

GEI's model sensitivity testing revealed that soil infiltration rates had the greatest influence on model results. Infiltration directly affects the amount of surface runoff calculated by the model. After making preliminary calibration runs, it became apparent that the volume of water flowing in the stream was too high compared to observed measurements. GEI determined that initial infiltration estimates were too low causing excessive runoff. The need for higher infiltration rates was attributed to two primary factors: drought conditions and soil types.

6.4.1 Drought Conditions

Cumberland County, Maine experienced drought conditions during the monitoring period from July through October 2022 (NOAA, 2023). NOAA and the U.S. Drought Monitor use a

5-category system to classify drought: abnormally dry, moderate drought, severe drought, extreme drought, and exceptional drought. Cumberland County was classified as abnormally dry in May and June, moderate drought in July, severe drought in August and September, and moderate drought in October.

These conditions likely resulted in high infiltration potential reducing the volume of direct runoff compared to rain events during periods when soils are saturated prior to the onset of a storm event. While the drought resulted in potentially increased short term infiltration potential, it is likely that the drought conditions in Maine in the summer of 2022 were not so severe as to result in "hydrophobic" conditions where the soil would repel precipitation and infiltration. This assumption is based on the observation of no significant vegetation die-off during the stream monitoring period suggesting the presence of moisture in the soil.

6.4.2 Soil Types

In addition to a review of NRCS soil characteristics, GEI reviewed published geology maps to further evaluate infiltration potential. Maine Geological Survey maps show that sand and gravel aquifers cover a significant area of the watershed (MGS, 1999). Research by Gerber and Hebson (Gerber and Hebson, 1997) indicate sand and gravel materials in Maine exhibit the greatest recharge potential (50% to 60% of average annual precipitation) when compared with other geologic materials like till, clay, and bedrock, which range from 2% (clay and bedrock) to 20% (sandy till) of average annual precipitation. In *Introduction to Soil Physics* (Hillel, 1982) the infiltration rate for sand and gravel is estimated to be 0.8 inches/hour or greater, loams 0.2 to 0.4 inches/hour, and clays 0.04 to 0.2 inches/hour. These infiltration rates are nearly twice the minimum infiltration rates reproduced by USACE (2022b) based on Skaggs and Khaleel (1982) which were used in GEI's preliminary model runs (see Table 2). In GEI's opinion, increasing the infiltration rates within the model was appropriate based on the available soil information, published maps, research on Maine soils, and the water level data recorded during significant storm events.

The July and October storms were independently calibrated. To achieve reasonable model accuracy, the July storm required a slightly lower infiltration rate to achieve a best match compared to the October storm. The average calibrated infiltration rates between the October and July storms were used in model validation and final design storm model runs.

6.5 Model Calibration Results

GEI compared observed water level data with the water levels simulated by the model at each of the five sensor locations. Peak observed and simulated water levels for the October and July storm events are shown in Table 4 and Table 5, respectively. Graphs summarizing simulated and observed results are included in Appendix B.

Table 4. October 14, 2022 Model Calibration Results

Location	Peak Water Surface Elevation (ft, NAVD88)		
	Observed	Simulated	Difference
U/S of Meadow Brook Rd. Culvert	50.8	51.0	+0.2
Coffin's Ice Pond	48.4	48.5	+0.1
U/S of Runway Culvert	27.8	28.1	+0.3
Picnic Pond	25.4	25.2	-0.2
U/S of Liberty Crossing Culvert	6.0	6.2	+0.2

Note: "U/S" indicates "upstream."

Table 5. July 25, 2022 Model Calibration Results

Location	Peak Water Surface Elevation (ft, NAVD88)		
	Observed	Simulated	Difference
U/S of Meadow Brook Rd. Culvert	51.3	50.6	-0.8
Coffin's Ice Pond	48.3	48.1	-0.2
U/S of Runway Culvert	27.4	27.3	-0.1
Picnic Pond	24.0	24.0	0.0
U/S of Liberty Crossing Culvert	5.1	4.9	-0.2

Note: "U/S" indicates "upstream."

Modeled peak water surface elevations during the October event were within 0.3 ft or less of observed levels. For the July calibration storm event, modeled results were within 0.2 feet or less at four out of five sensors. These results indicate very good agreement between the observed data and simulated results.

At the Meadowbrook Road culvert, the model results for the July calibration event were 0.8 ft lower than the observed peak water elevation of 51.3 ft. This event produced the highest recorded water level at the Meadowbrook sensor during the observation period. The peak recorded during the July storm (51.3 ft) was about half of a foot higher than the peak recorded during the larger October storm (50.8 ft). This result for Meadowbrook Road culvert was somewhat unexpected because nearly half as much rain fell during the July storm compared to the October storm. One possible explanation for the high water surface is that the culvert may have become blocked from debris during the July storm event reducing flow and causing water levels upstream of the culvert to rise. Another possibility is an intense but short microburst may have passed over the area upstream of the Meadowbrook culvert which may not have been captured in the observed precipitation data.

Aside from the minor anomaly identified at the Meadowbrook Road culvert in July, these results indicate that the model provided an accurate estimation of peak water levels for both calibration storm events. Also, the graphs provided in Appendix B show the model accurately simulates the timing of peak water surface, arriving at about the same time as the GEI observed peak water levels.

6.6 Model Validation Results

To validate the model, a third storm was compared with observed water levels. The third storm occurred over three days from September 18 to September 20, 2022. The September storm resulted in the second highest water levels recorded by GEI's water level sensors.

Peak simulated and observed water levels for the September storm event are shown in Table 6. Graphs summarizing the simulated and observed results are included in Appendix C.

Table 6. September 18 – 20, 2022 Model Validation Results

Location	Peak Water Surface Elevation (ft, NAVD88)		
	Observed	Simulated	Difference
U/S of Meadow Brook Rd. Culvert	50.7	50.6	-0.1
Coffin's Ice Pond	48.4	48.3	-0.1
U/S of Runway Culvert	27.7	27.8	+0.1
Picnic Pond	24.8	24.7	-0.1
U/S of Liberty Crossing Culvert	5.2	5.7	+0.5

Again, the model showed accurate results compared to observed conditions with four out of five sensors coming within 0.1 feet of observed elevations. The graphs in Appendix C also show very good timing of peak water elevation and flow volume.

The model accurately simulated observed conditions for three separate storm events. In GEI's opinion, the model is suitable for its intended use in providing reasonable estimates of peak water levels and peak flows during the design storm events (i.e., 2-, 10-, 25-year storms) at key stream crossings within the watershed.

7. Design Storm Analysis

7.1 Annual Recurrence Storm Estimation

GEI modeled the 24-hour 2-, 10-, and 25-year annual recurrence interval precipitation events also referred to as "design storms." Respectively, these events have a 50%, 10%, and 4% chance of occurring in any given year. To select the precipitation associated with these recurrence intervals, GEI compared precipitation estimates from the National Oceanic and Atmospheric (NOAA) Atlas 14 Precipitation Frequency Data Server (PFDS) with precipitation estimates published by Northeast Regional Climate Center (NRCC) Extreme Precipitation in New York and New England (NOAA PFDS, 2022 and NRCC, 2022). Estimates from each source are presented in Table 7.

Table 7. Precipitation Estimates (inches) for Design Storm Events

	2-Year		10-Year		25-Year	
Duration	Atlas 14	NRCC	Atlas 14	NRCC	Atlas 14	NRCC
5-min	0.351	0.32	0.54	0.43	0.654	0.51
10-min	0.497	0.49	0.76	0.67	0.926	0.81
15-min	0.584	0.61	0.90	0.85	1.09	1.04
30-min	0.790	0.80	1.21	1.16	1.47	1.43
60-min	0.995	1.01	1.53	1.51	1.86	1.89
2-hr	1.33	1.28	2.04	1.94	2.48	2.45
3-hr	1.57	1.49	2.40	2.26	2.91	2.86
6-hr	2.05	1.90	3.12	2.86	3.79	3.61
12-hr	2.62	2.42	3.96	3.60	4.81	4.52
24-hr	3.16	3.10	4.81	4.51	5.84	5.60

The 24-hour precipitation estimates from NOAA Atlas 14 were greater than estimates from NRCC for each of the three design storm events. As a conservative measure, GEI used the greater precipitation estimates from NOAA Atlas 14.

GEI estimated rainfall distribution curves using the NRCC web tool (NRCC, 2022). The tool develops a dimensionless 24-hour hyetograph and incorporates storms of smaller duration from 5-minutes through 24-hours that have a consistent exceedance probability. The dimensionless 24-hour hyetograph is represented as cumulative rainfall at 6-minute intervals. GEI multiplied the 24-hour NOAA Atlas 14 precipitation estimate by the by the dimensionless hyetograph to create cumulative precipitation curves for each design storm event.

7.2 Results

Results for the 24-hour 2-, 10-, and 25-year annual recurrence interval precipitation events are provided in Appendix D. The results include peak upstream water elevation, peak flow, and headwater depth versus structure depth ratio (HW/D). Results are provided for Coffin's Ice Pond Dam, Picnic Pond Dam, and the culverts identified in the Mare Brook WMP as needing an H&H analysis. These culverts are included in Table 8, listed from upstream to downstream.

Table 8. Key Culverts listed in MWP

Location	Culvert ID	Total Cross Sectional Flow Area (ft^2)	WMP Recommendation
Baribeau Drive	Cul04 & Cul05	15	1) Remove culverts, 2) Restore channel 3) Replace with open bottom culvert
Barrows Street	Cul10	16	1) Remove undersized culverts, restore channel 2) Replace with larger opening
Macmillan Drive	Cul14	16	1) Remove culverts, restore channel 2) Replace open bottom culvert
Maine Street	Cul16	19	1) Remove culverts, restore channel 2) Replace open bottom culvert
Meadowbrook Road	Cul17	13	1) Remove culvert, restore channel 2) Upsize culvert
Harpswell Road	Cul23	20	1) Remove culvert, restore channel 2) Replace with open bottom culvert
*Sparwell Lane	Cul18	5	1) Upsize culvert 2) Rebuild road
• *Sparwell Lane crossing is located on a tributary of Mare Brook between Meadowbrook Road and Harpswell Road			

The majority of these culverts were identified in the WMP as undersized and nearing the end of their design lives. The WMP also indicated these culverts offered little opportunity for aquatic organism passage. In general, the culverts were recommended to be replaced with a larger, open bottom culvert or bridge.

GEI's H&H model indicated significant ponding upstream of the culverts listed in Table 8. Road crossings at the culvert locations were not overtopped in GEI's 25-year design storm analysis. However, each culvert barrel was fully submerged for the 25-year storm, and debris carried by flood water could restrict flow increasing the risk of roadway overtopping during future storm events.

The model also identified limitations in the existing capacity of other hydraulic structures within the watershed. Several culverts were overtopped along the tributary at the Mid Coast Senior Health Center. The WMP identified these culverts as Cul09, Cul08 and Cul07. The WMP indicated these culverts were undersized and/or partially blocked with debris.

Culvert Cul28 located downstream of Picnic Pond Dam was overtopped during the 10 and 25-year storm events. This road was closed to the public at the time of preparing this report and may not be critical to Brunswick's restoration plan. It is not clear if road overtopping at this location from the low recurrence interval storm would result in instability and/or potential failure of the road. Stability analysis was not performed for this study.

Based on GEI's H&H analysis, Coffin's Ice Pond Dam and Picnic Pond Dam would be at risk of overtopping for storm events of similar order of magnitude as the 2-year storm or greater. Table 9 presents estimates of overtopping/freeboard depth at the non-overflow embankment sections during the modeled design storm events.

Table 9. Overtopping/Freeboard Depth at Picnic Pond and Coffin's Ice Pond Dams

Dam	Freeboard (-), Overtopping (+), (ft)		
	2-yr	10-yr	25-yr
Coffin's Ice Pond Dam	-0.1	+0.5	+1.4
Picnic Pond Dam	0.0	+1.0	+1.5

The dams appeared to be earthen embankments, which are highly susceptible to erosion from overtopping. Loss of Coffin's Ice Pond Dam would likely have ecological and social repercussions, though consideration for either is beyond the scope of this analysis and requires further consideration by the Town of Brunswick.

The Environmental Protection Agency (EPA) placed the Picnic Pond area on the Superfund program's National Priorities List in 1987. Wastes generated by the U.S. Navy when the base was active have contaminated soil and ground water in areas upstream of the pond. The Navy has and continues to perform cleanup in the Picnic Pond area, which is closed to the public. Loss of Picnic Pond Dam could potentially cause a release of contaminated sediment into the downstream reach of Mare Brook.

7.3 Conclusions

The conclusions and recommendations presented in this section are based on GEI's engineering judgment and their interpretation of the study's results. The recommendations in this section are meant to assist Brunswick develop a strategy for restoring the Mare Brook watershed. The recommendations made are considered suggestions and, in some cases, further analysis and public outreach may be necessary to determine the best action moving forward. In Section 8, Next Steps, GEI includes specific recommended studies that will further help Brunswick make decisions to meet their goals in accordance with published state guidelines.

Mare Brook, a Maine Class B stream, is currently listed by the Maine Department of Environmental Protection as impaired due to poor macroinvertebrate sampling results and habitat. Brunswick's WMP has a goal to meet the State-designated Class B standards in Mare Brook by 2037 by performing stream restoration and culvert replacement projects. These projects seek to improve stream health while reducing risk of inland flooding. Several of the existing culverts are undersized and in poor condition as indicated in the WMP. Most of the culverts will likely need to be replaced prior to 2037.

GEI recommends Brunswick identify design storms to use in culvert replacements and dam rehabilitation based on an appropriate level of risk and consistent with state guidelines while also considering potential effects of climate change and sea level rise.

It is critical that culverts/dams be replaced/rehabilitated in an order that does not cause increased flooding downstream. Therefore, culvert replacement should generally progress from downstream to upstream especially for culvert replacements that are proposed to increase capacity. The 2D hydraulic model created by GEI is capable of analyzing the culverts as a system rather than individually. This allows future modeling efforts to analyze the effects a new culvert will have on the watershed as whole. Ideally, all culverts proposed for replacement should be designed concurrently. This is done so that each culvert is designed to account for the increased flow expected once all upstream culverts are replaced.

GEI recommends the Town of Brunswick address spillway capacity at Coffin's Ice Pond Dam prior to replacing culverts upstream of the dam. Coffin's Ice Pond Dam is at risk of overtopping during storm events greater than the 2-year annual recurrence interval and overtopping of the earthen embankment could lead to failure. The WMP suggests exploring removal as a possible remedial action, though it acknowledges this action would require further consideration and analysis of potential ecological and social impacts prior to implementation. Regarding the pond's social value, the WMP suggests establishing a "Coffin's Ice Pond Stakeholder Working Group, [tasked with establishing] a definitive charge and timeline to weigh [the] benefit of dam removal and/or restoration to stream health versus community and ecological benefits to provide a [final] recommendation to the Mare Brook Leadership Team." While GEI would be able to provide assistance as it pertains to modeling the effect of removal versus non removal, final determination as to how to mitigate stressors in either scenario would require further analysis and consideration by the Mare Brook Leadership Team, as would establishing a public outreach program to educate the community on the possible rehabilitation or removal of dam before taking action.

The WMP suggests "day lighting" the more than 3,000-ft-long culverts that run under the airport runways. Though this action would have significant benefit to the overall ecological health of the stream, daylighting the culverts would likely be the most challenging and costly modification in the culvert portfolio. While it is recommended that culvert replacement take place starting from downstream and moving upstream, prioritizing the runway culvert, and associated remedial options suggested within the WMP, may not be immediately necessary. Currently, the runway's existing culvert system has significantly more conveyance capacity compared to other culverts in the watershed; further analysis would be required to confirm airport culvert capacity relative to that of anticipated remediation efforts further upstream, with the need for further analysis contingent on design storms selected by the Town. Given the challenges associated with this culvert, time and more calculated effort concerning planning and securing funding would be necessary in the event of such an undertaking; as such, while the system does not appear to require immediate attention, additional modeling efforts to assess shifts in the collective impact of (a) suggested remedial actions within the WMP, and (b) replacements and updates implemented, would be beneficial for the purpose of evaluating the performance of this culvert in relation to the overall systems flow and hydrology.

8. Next Steps

To help evaluate the vulnerability of the watershed under potential climate change and sea level rise impacts and to ensure stream restoration projects provide a healthier more resilient ecosystem, GEI offers a few possible areas of additional analysis for Brunswick's consideration. These suggested analyses are model-based scenarios by which Brunswick may examine the impact of potential policy changes, construction efforts and improvements, or other climate-based scenarios as they pertain to the WMP and the betterment of Mare Brook. These suggestions are as follows:

- The Town may want to consider performing a climate change vulnerability analysis to assess impacts to the watershed caused by rising sea levels and increased frequency, depth, and intensity of precipitation events.

- GEI recommends performing an H&H analysis for the 50-year and 100-year annual recurrence interval storm events. The Maine Bridge Design Guide (MaineDOT, 2003) indicates that bridges and minor spans should be designed for the 50-year event and checked for the 100-year event. In certain cases, analysis of the 500-year flood event may be warranted. For culvert design, MaineDOT indicates that the ratio of headwater (depth above the invert) to the structure depth (culvert diameter) should be approximately equal to or less than 0.9 (i.e., flow depth at 90% full) for the 50-year event.

  When outlet conditions control culvert flow, a minimum of 1 foot of freeboard is required for the 100-year event. Performing H&H analysis under the 50-year and 100-year flood conditions will provide the Town of Brunswick with an understanding of culvert design relative to the state guidelines.

- GEI created the HEC-RAS model to facilitate design of future culvert replacements. Proposed culverts may be added to the model to assess flood conditions and downstream impacts under proposed designs. GEI recommends consideration of the State of Maine Aquatic Resource Management Strategy (ARMS) Stream Smart Road Crossing Guide when designing replacement and new culverts (MaineDOT, 2023). The web-based guide provides information for "installing and replacing crossings in an effective and cost-efficient manner while meeting goals of restoring and maintaining stream habitat connectivity and enhancing the stability of roads and culvert crossings."

- The hydraulic model was developed for use in evaluating extreme events (i.e., 2-, 10- and 25-year events) and was calibrated to three observed storms on the order of 1- to 2-year annual recurrence interval. Analyzing channel velocities and water depths under low flow conditions may be of interest for the design of future stream restoration projects. If the Town is interested in evaluating low flow conditions, additional work may be required to refine the model such as the collection of detailed stream channel bathymetry (to supplement the detailed LiDAR terrain data), water level monitoring, calibration during low flows, and evaluation of ground water discharge to the brook during low flow periods.

9. Limitation of Liability

This report presents analyses and results of a site-specific hydrologic and hydraulic study of the Mare Brook watershed. GEI developed a hydrologic and hydraulic model of the Mare Brook watershed to access flood conditions during the 2-, 10- and 25-year annual recurrence interval storm events. The hydrologic and hydraulic model was created using GEI's best judgment and to be comprehensive and conservative in the development of infiltration rates, design storm precipitation, and other parameters presented in this study. This study also relied on data developed by others.

This study included limited hydraulic analysis and does not include an evaluation of the structural integrity of culverts, bridges, dams, and other appurtenances. If a storm event occurs in the watershed, actual conditions, peak flows, and peak water surface elevations will vary from those presented in this report. Because the methods, procedures, and assumptions used to develop the analysis are approximate, the results should be used only as guidance. Actual flood inflow volumes, water surface elevations, and flood timing may differ from the results presented in this report.

The HEC-RAS model was developed to provide reasonably accurate results along the main branch of Mare Brook, Picnic Pond Dam, Coffin's Ice Pond Dam, and at crossings identified in the Mare Brook Management Plan as needing a H&H analysis. With any complex hydraulic model, a balance must be struck between model stability, accuracy, and run-time speed. GEI structured the model so that flood conditions could be estimated with reasonable accuracy in locations where needed while still maintaining optimal model performance. Use of the model to extrapolate results from locations not prioritized in this study including Mare Brook's tributaries and un-surveyed culverts may provide comparatively less accurate results.

The hydraulic model was developed and calibrated to evaluate watershed characteristics and approximate hydraulic capacity of river crossings and dams for the storm events presented. Assessing Mare Brook and its tributaries under low flow conditions was not the objective of this study. Evaluation of the Mare Brook under low flow conditions would require calibration and additional analyses.

Reuse of this report for any other purposes, in part or in whole, is at the sole risk of the user.

10. References

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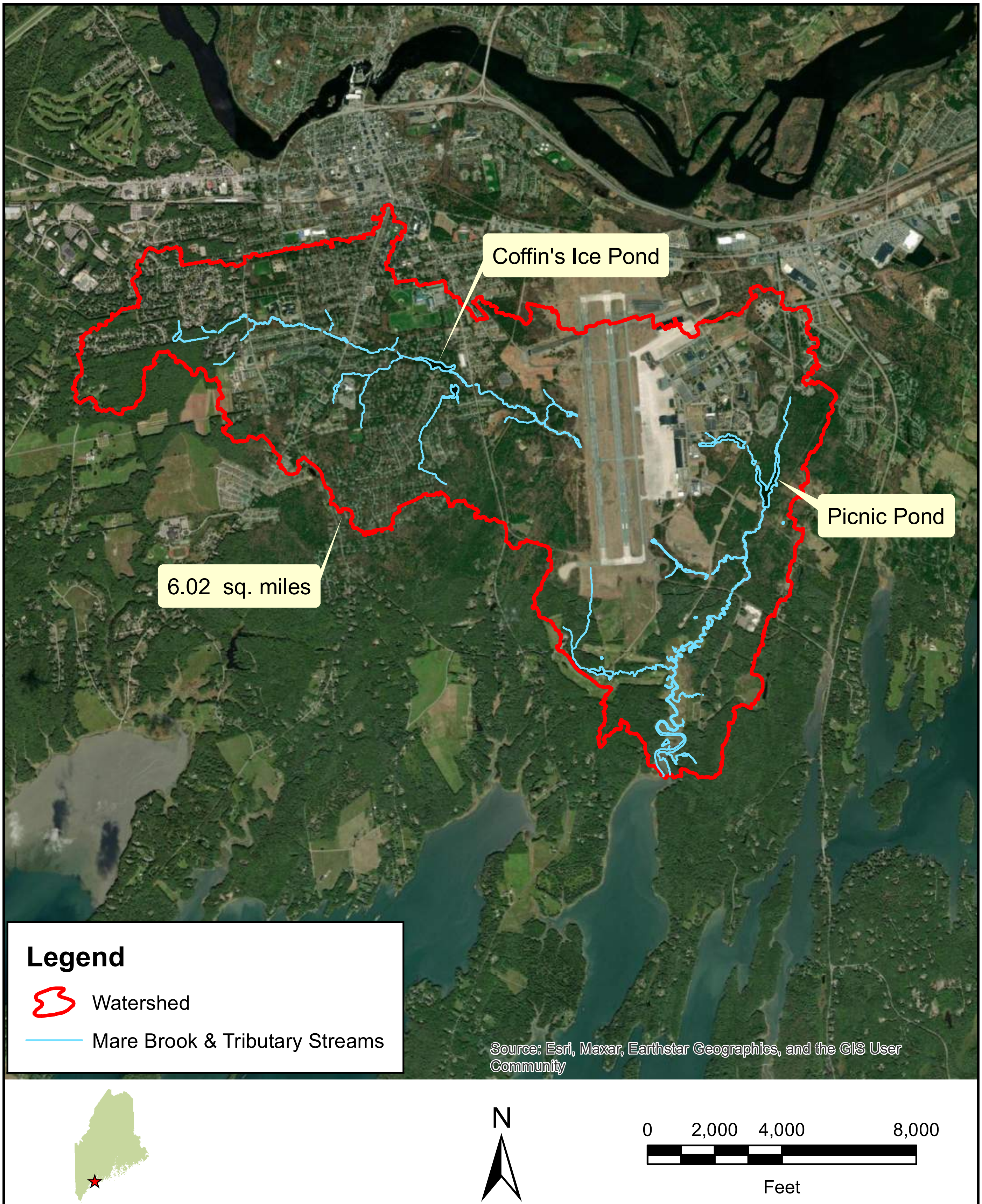
Figures



Mare Brook Watershed Hydrologic & Hydraulic Study Brunswick, Maine	GEI Consultants	WATERSHED AREA MAP
Town of Brunswick, Maine Department of Planning and Development	Project 2202137	March 2023 Fig. 1

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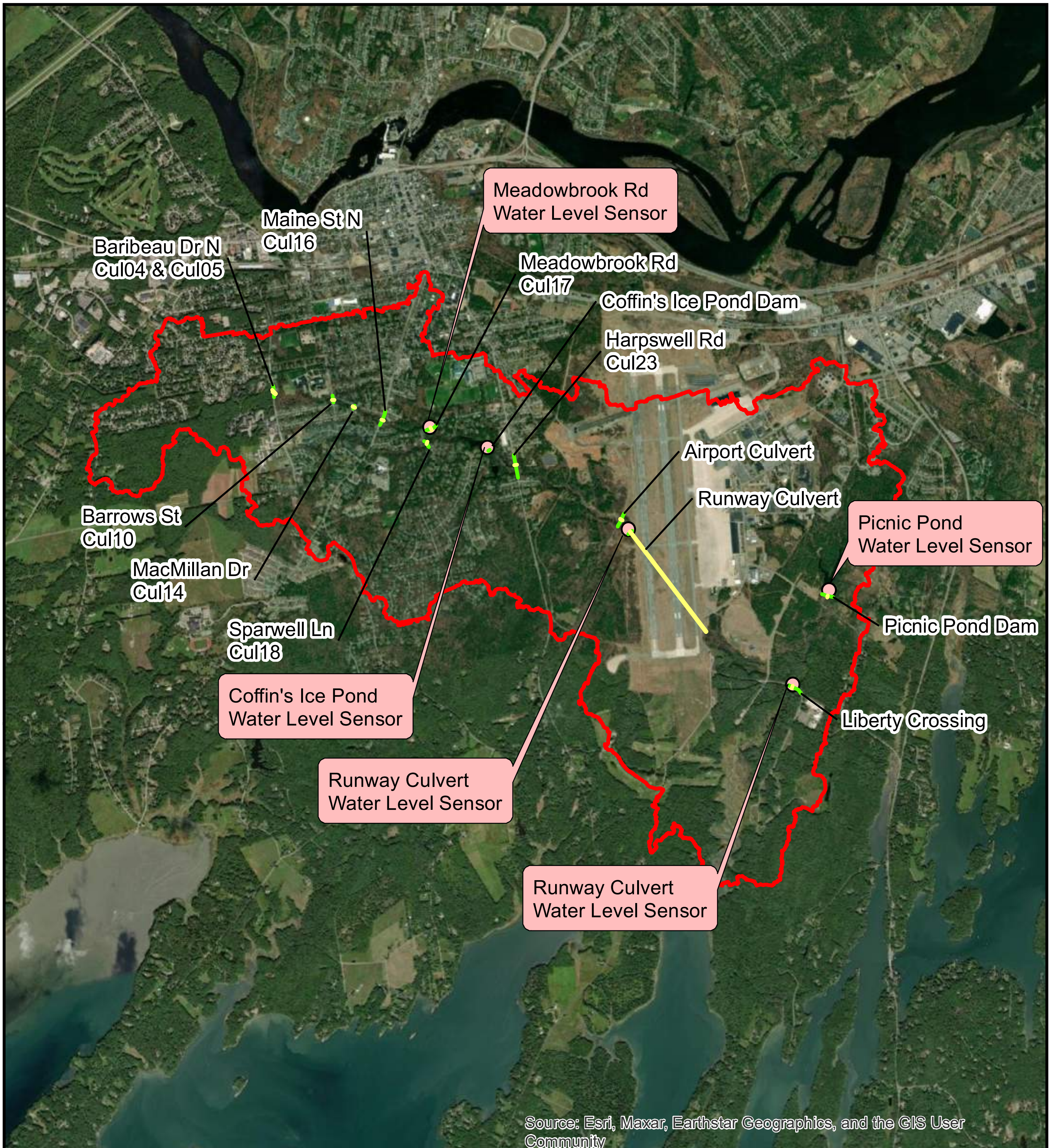

Legend

Cuvert Surveyed

Crossing Surveyed

Water Level Sensor

Watershed

N

0 2,000 4,000 8,000

Feet

Mare Brook Watershed Hydrologic & Hydraulic Study Brunswick, Maine	GEI Consultants	SURVEYED CROSSINGS AND WATER LEVEL SENSOR LOCATIONS
Town of Brunswick, Maine Department of Planning and Development	Project 2202137	March 2023 Fig. 2

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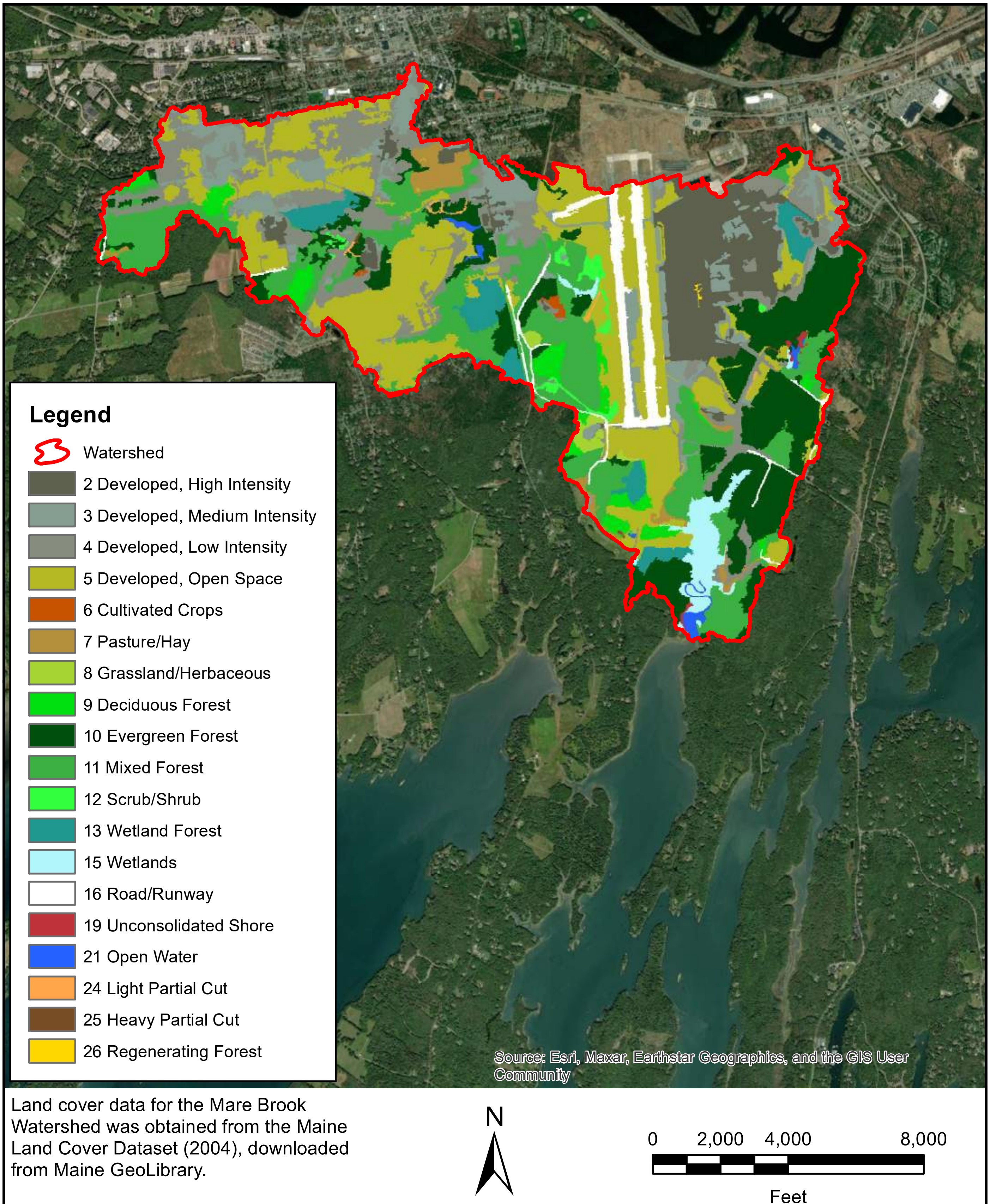

Land cover data for the Mare Brook Watershed was obtained from the Maine Land Cover Dataset (2004), downloaded from Maine GeoLibrary.

Mare Brook Watershed Hydrologic & Hydraulic Study Brunswick, Maine	GEI Consultants	LAND COVER MAP
Town of Brunswick, Maine Department of Planning and Development	Project 2202137	March 2023 Fig. 3

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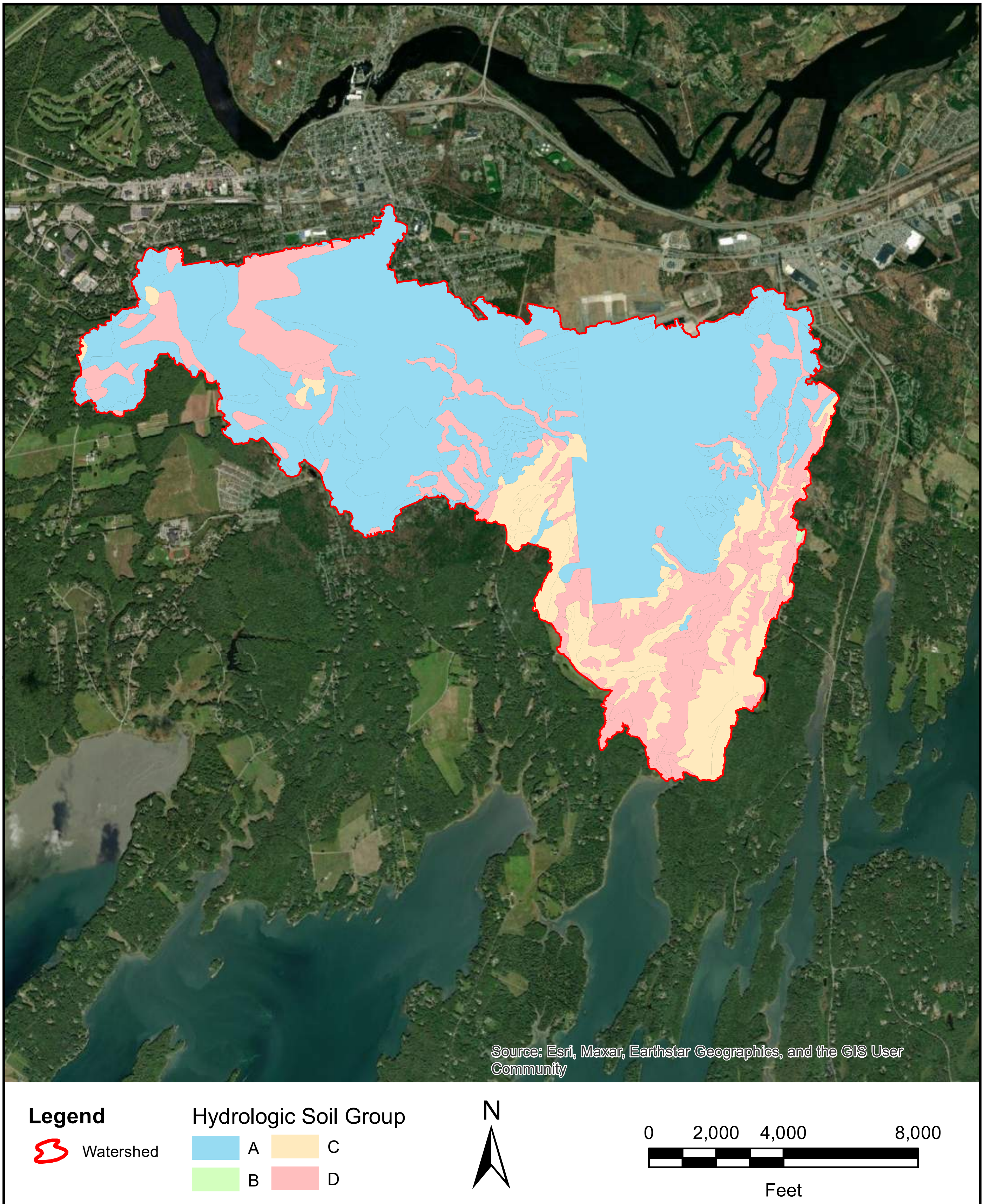

Mare Brook
Watershed Hydrologic & Hydraulic Study
Brunswick, Maine

Town of Brunswick, Maine
Department of Planning and Development

GEI Consultants

HYDROLOGIC SOIL GROUP MAP

Project 2202137

March 2023

Fig. 4

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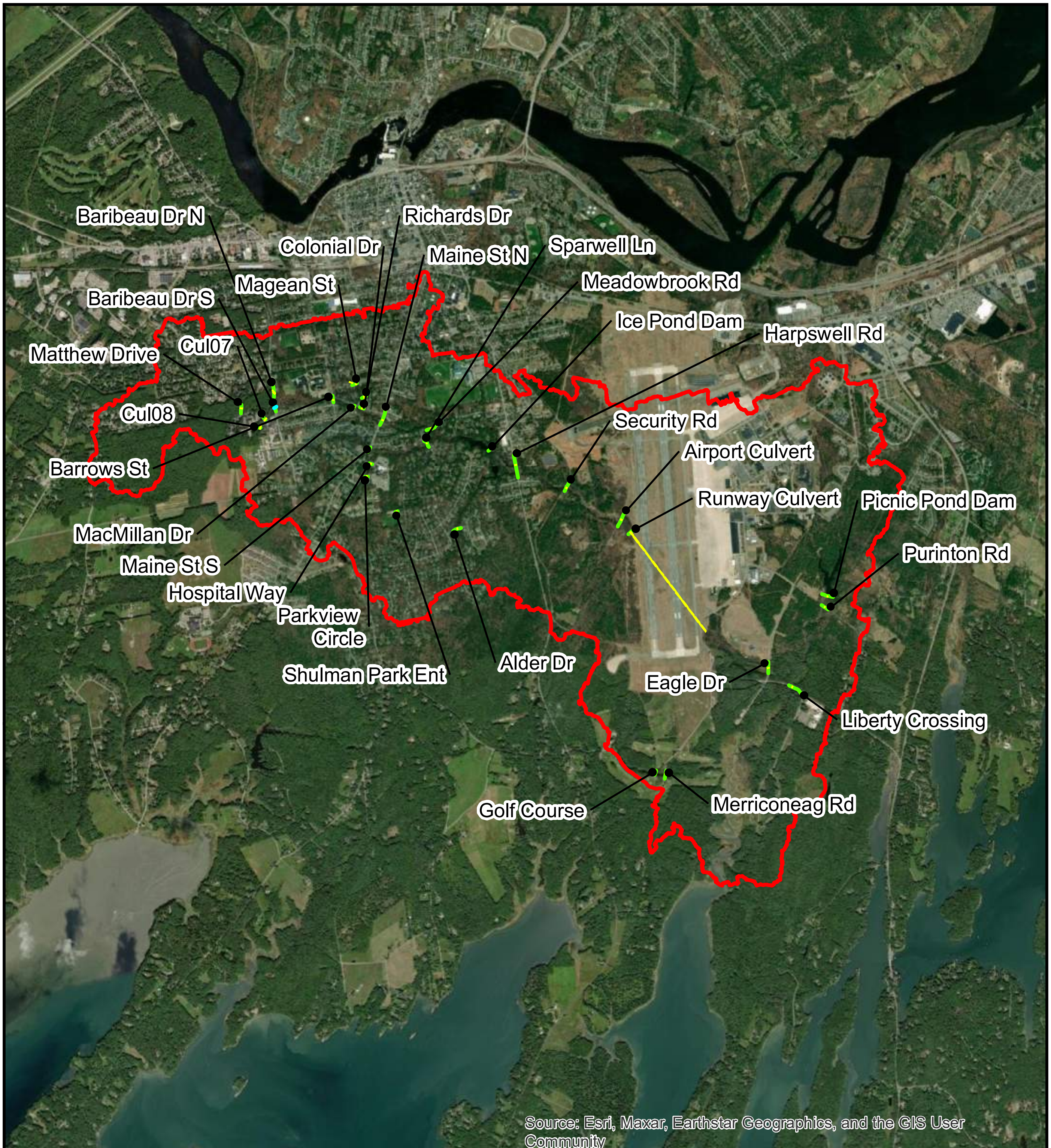

Legend

HECRAS Culverts

HECRAS Crossings

Watershed

N

0 2,000 4,000 8,000

Feet

Mare Brook
Watershed Hydrologic & Hydraulic Study
Brunswick, Maine

Town of Brunswick, Maine
Department of Planning and Development

GEI Consultants

MODELED STREAM CROSSINGS

Project 2202137

March 2023

Fig. 5

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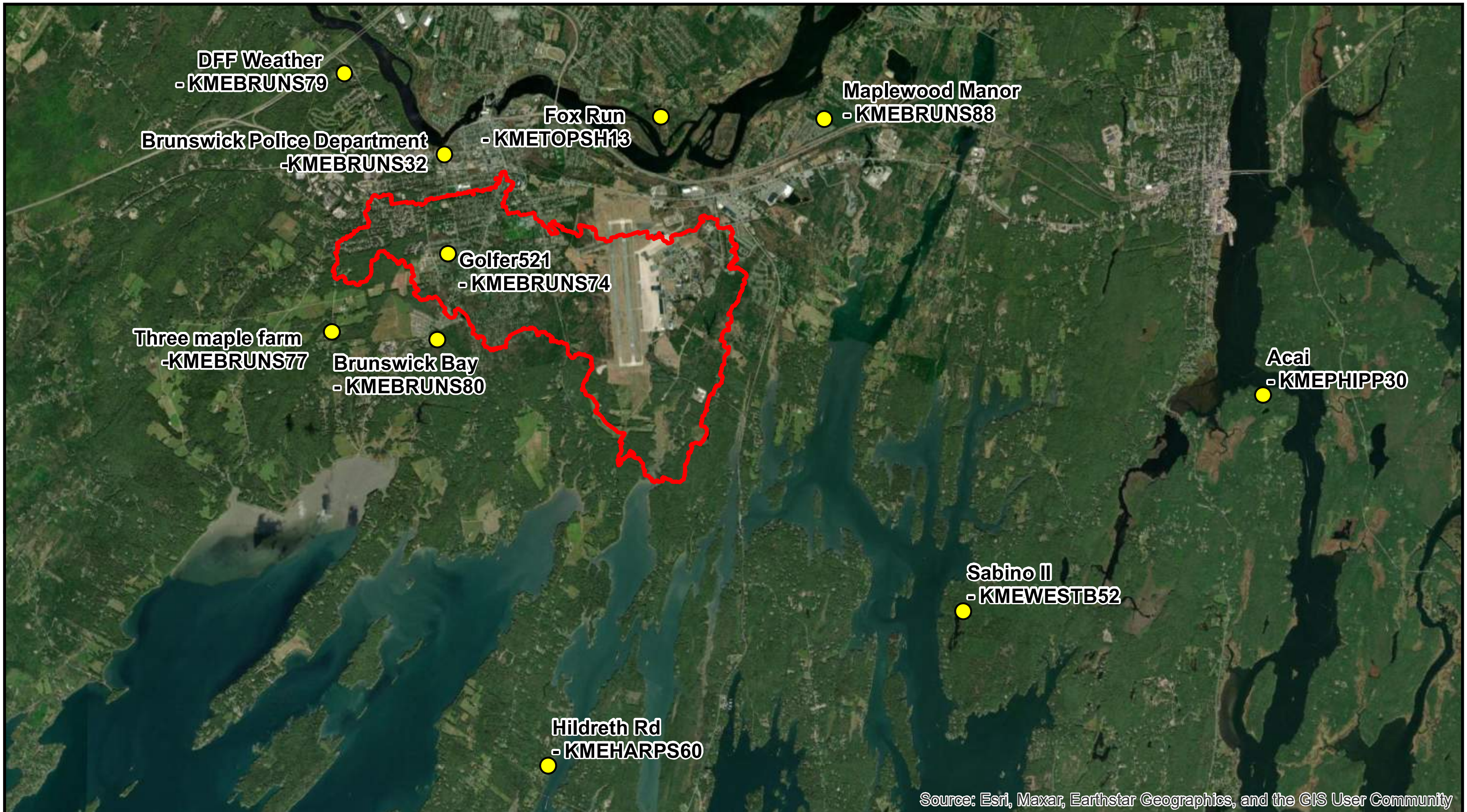

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Watershed

Precipitation Gages

N

0 4,000 8,000 16,000

Feet

Mare Brook Watershed Hydrologic & Hydraulic Study Brunswick, Maine	GEI Consultants	WEATHER STATION MAP	
Town of Brunswick, Maine Department of Planning and Development	Project 2202137	March 2023	Fig. 6

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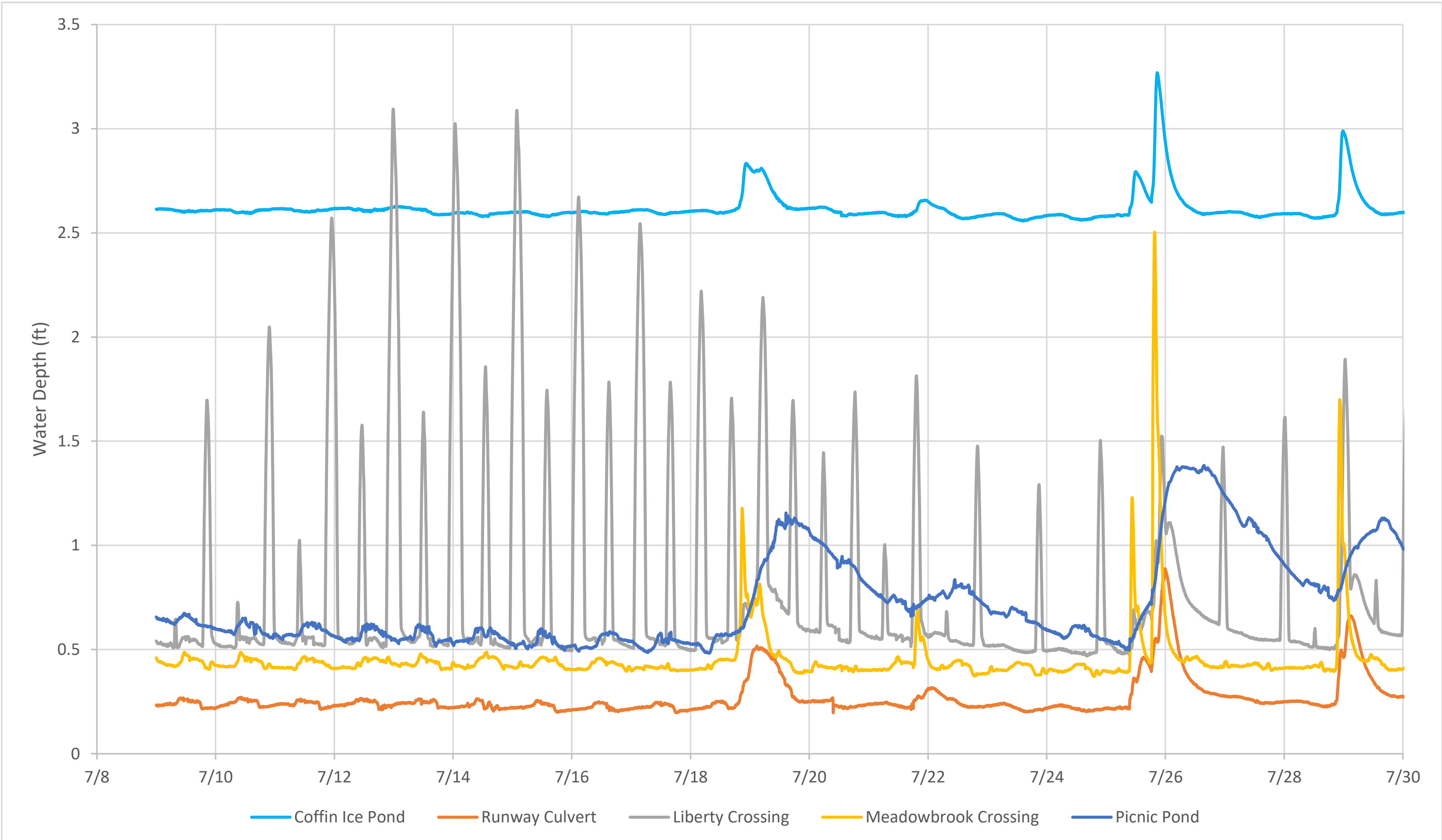
Appendix A

Mare Brook Water Depth Graphs



Note:

Water level data recorded by GEI. "Depth" represents water depth as measured from the bottom of sensor to water level and does not represent actual depth of water. Provided data compensates for barometric pressure at time of measurement.

Mare Brook Watershed
Hydrologic & Hydraulic Study

GEI Consultants

MARE BROOK WATER DEPTHS
July 2022

Town of Brunswick, Maine
Department of Planning and Development

Project 2202137

December 2022

Appx. A
Fig. 1

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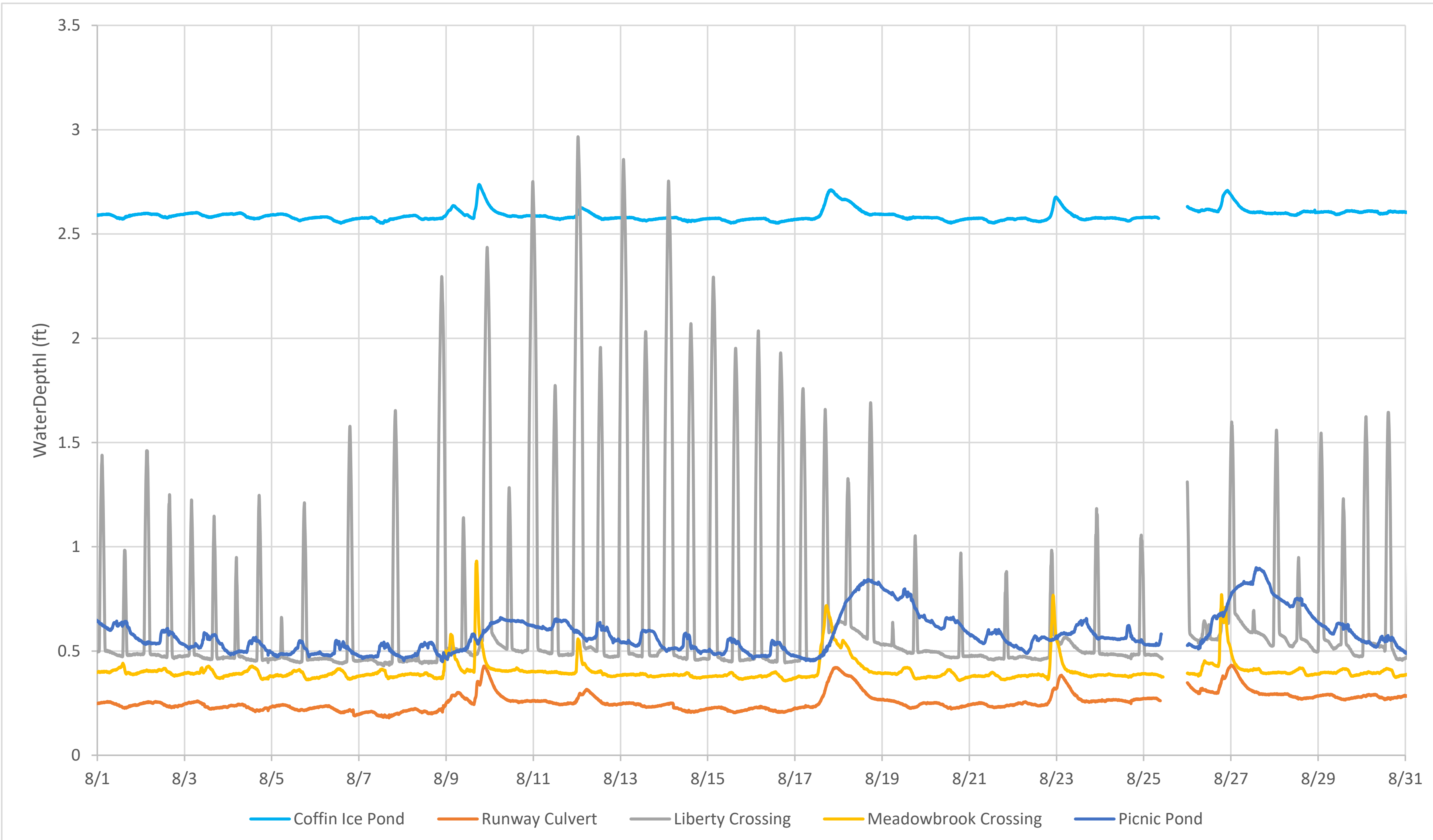

Note:			
Water level data recorded by GEI. "Depth" represents water depth as measured from the bottom of sensor to water level and does not represent actual depth of water. Provided data compensates for barometric pressure at time of measurement.	**Mare Brook Watershed** **Hydrologic & Hydraulic Study**	GEI Consultants	**MARE BROOK WATER DEPTHS** **August 2022**
	Town of Brunswick, Maine **Department of Planning and Development**	**Project 2202137**	**December 2022** **Appx. A Fig. 2**

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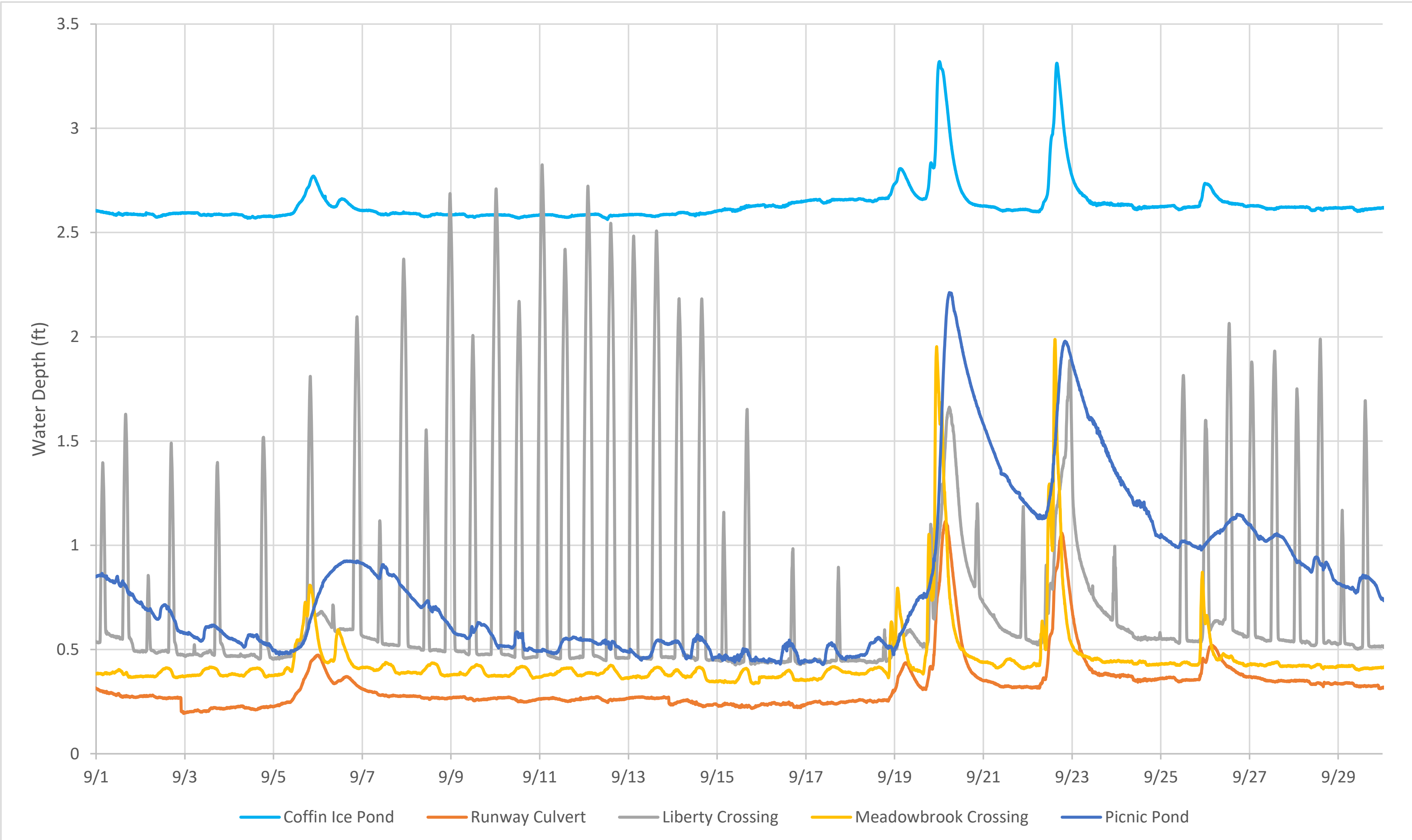

<u>Note:</u>

Water level data recorded by GEI. "Depth" represents water depth as measured from the bottom of sensor to water level and does not represent actual depth of water. Provided data compensates for barometric pressure at time of measurement.

Mare Brook Watershed
Hydrologic & Hydraulic Study

GEI Consultants

MARE BROOK WATER DEPTHS
September 2022

Town of Brunswick, Maine
Department of Planning and Development

Project 2202137

December 2022

Appx. A
Fig. 3

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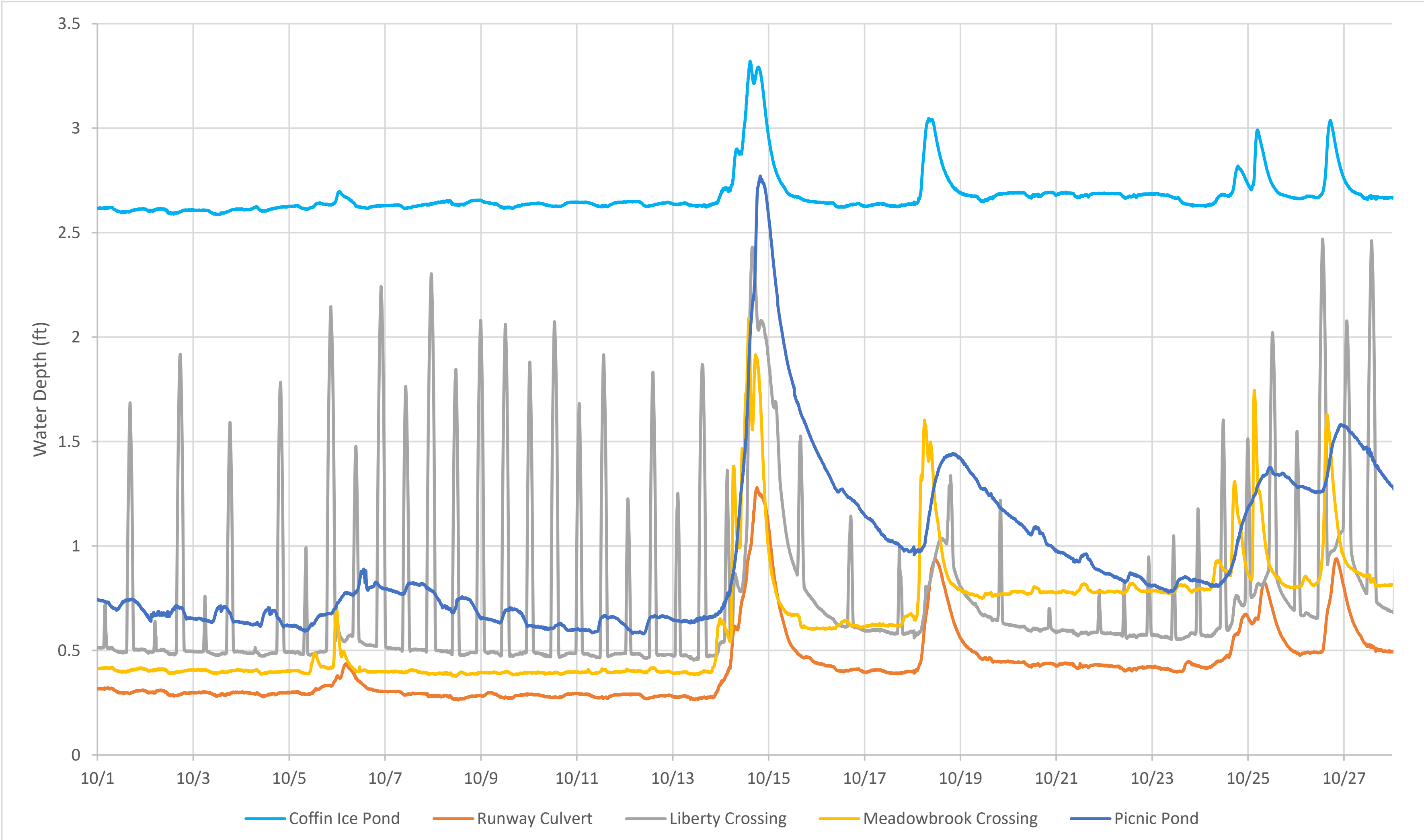

Note: Water level data recorded by GEI. "Depth" represents water depth as measured from the bottom of sensor to water level and does not represent actual depth of water. Provided data compensates for barometric pressure at time of measurement.	**Mare Brook Watershed Hydrologic & Hydraulic Study**	GEI Consultants	**MARE BROOK WATER DEPTHS October 2022**
	Town of Brunswick, Maine Department of Planning and Development	**Project 2202137**	**December 2022** **Appx. A Fig. 4**

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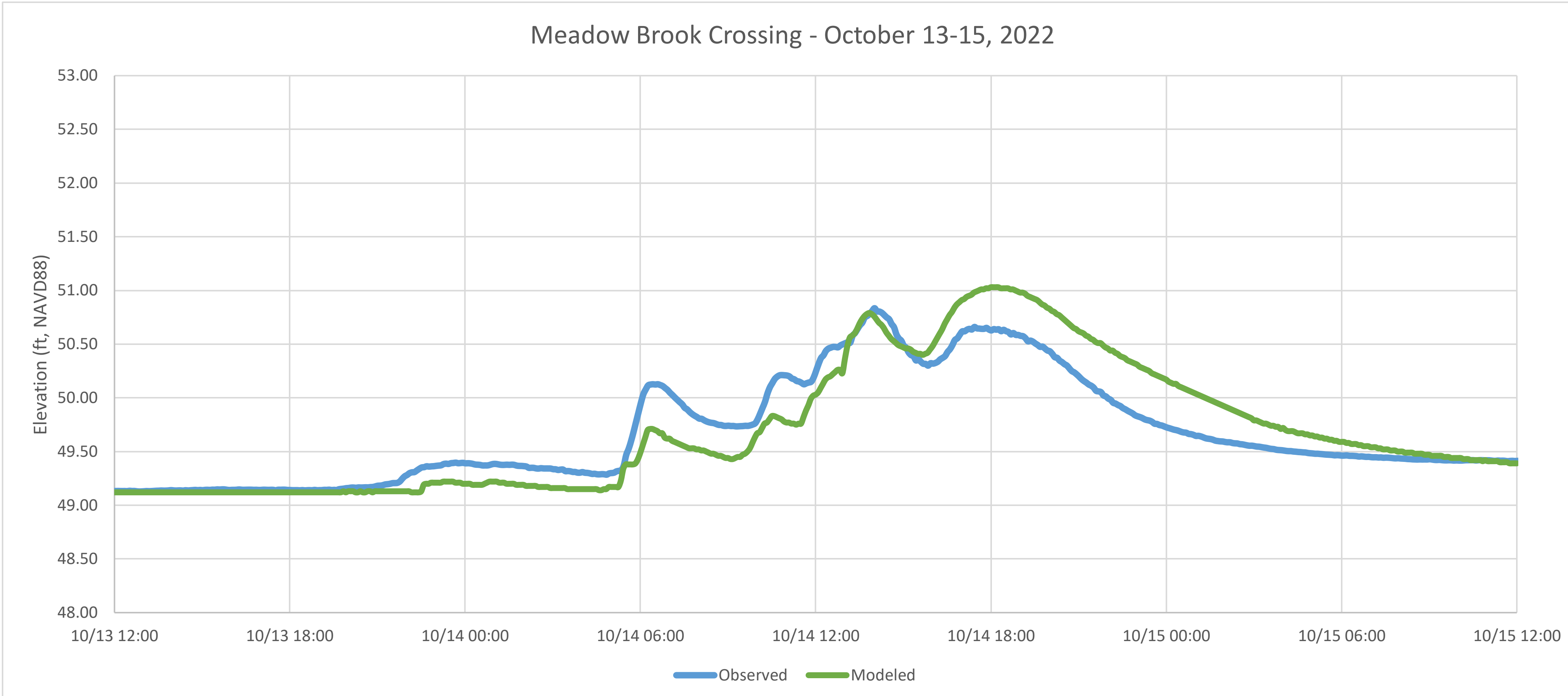
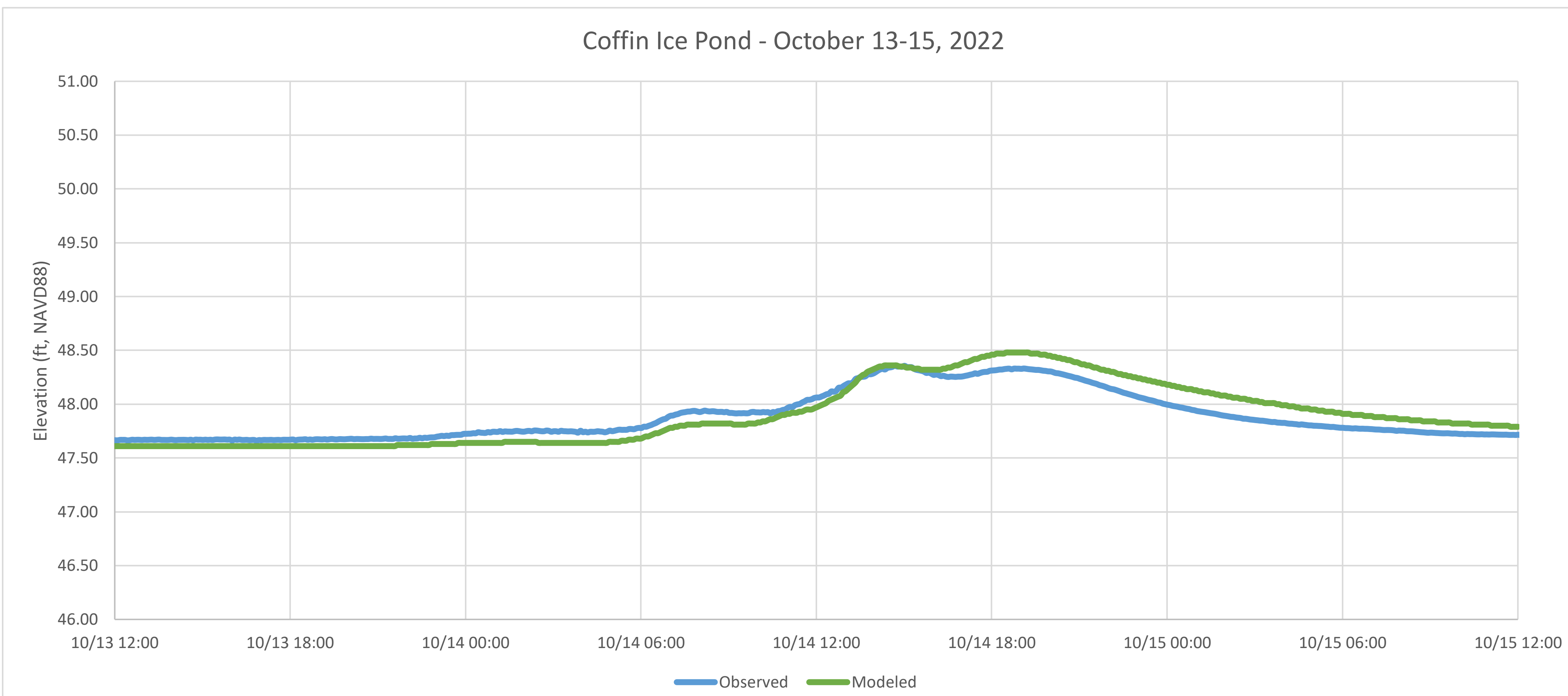
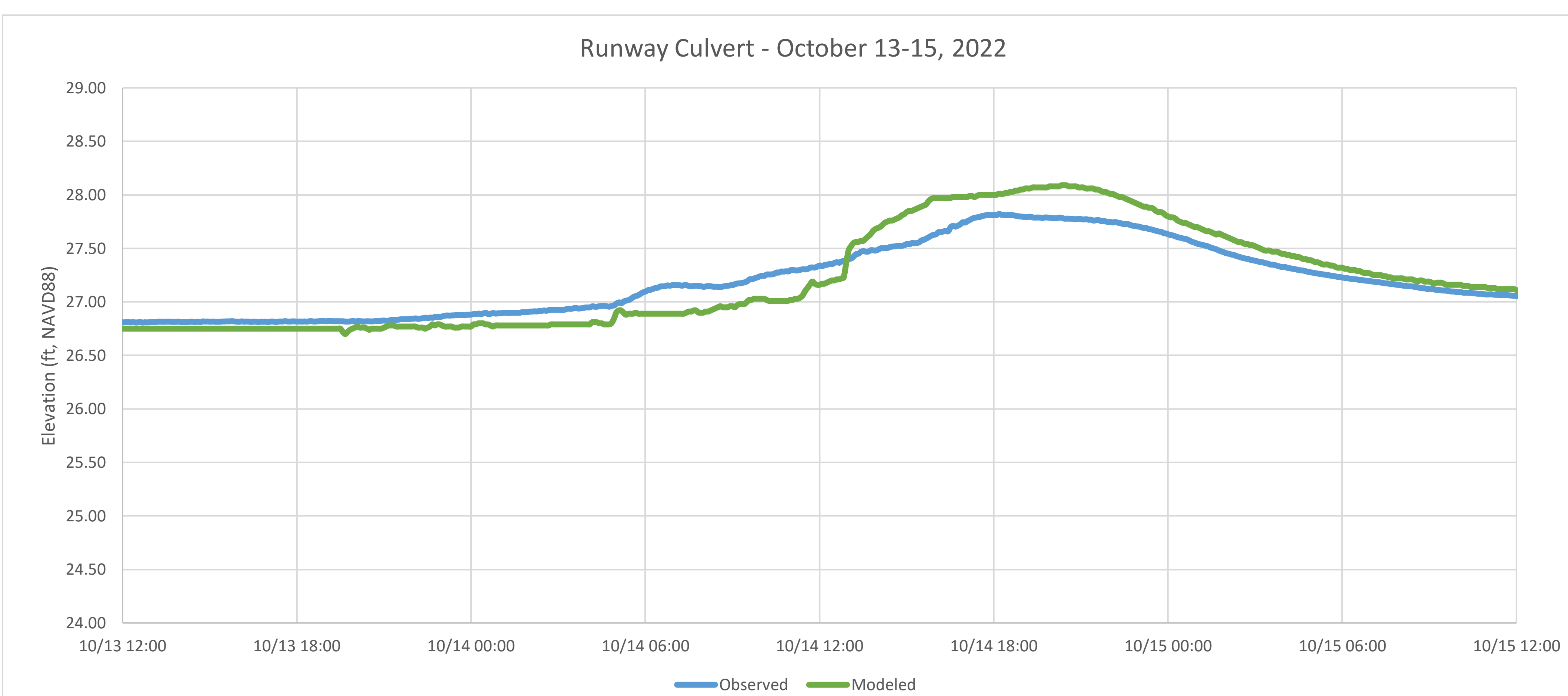
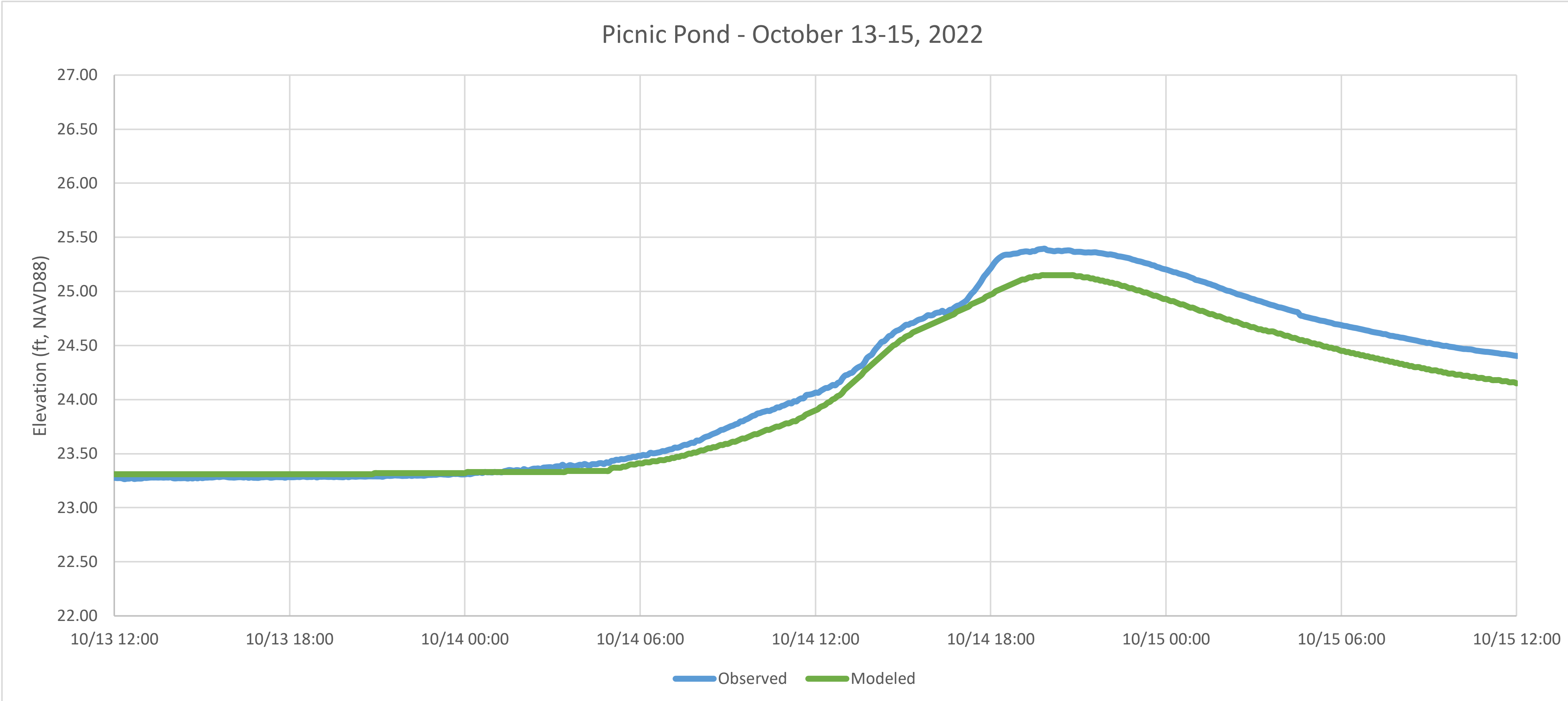
Appendix B

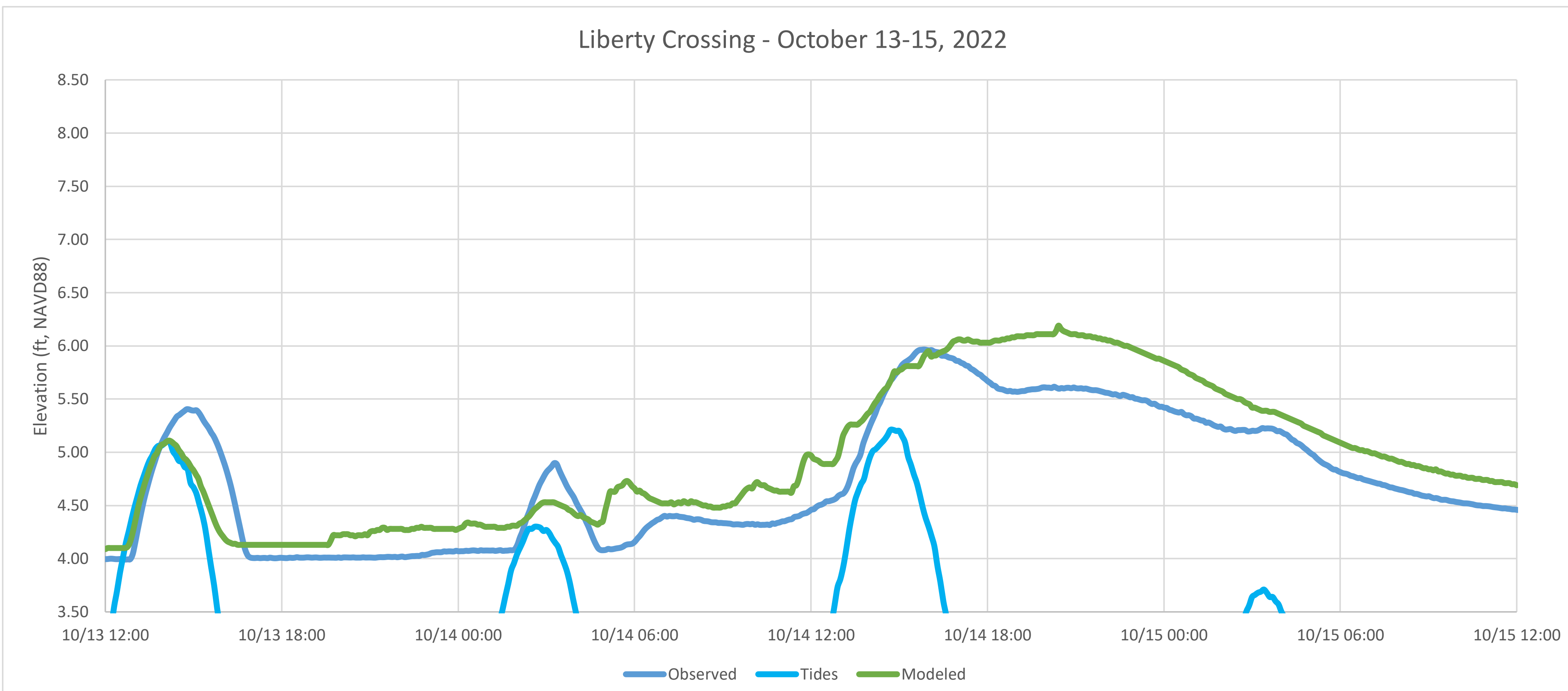
Model Calibration Graphs – October 14, 2022 Storm


Meadow Brook Crossing - October 13-15, 2022
Elevation (ft, NAVD88)
53.00
52.50
52.00
51.50
51.00
50.50
50.00
49.50
49.00
48.50
48.00
10/13 12:00
10/13 18:00
10/14 00:00
10/14 06:00
10/14 12:00
10/14 18:00
10/15 00:00
10/15 06:00
10/15 12:00
Observed
Modeled


Coffin Ice Pond - October 13-15, 2022
Elevation (ft, NAVD88)
51.00
50.50
50.00
49.50
49.00
48.50
48.00
47.50
47.00
46.50
46.00
10/13 12:00
10/13 18:00
10/14 00:00
10/14 06:00
10/14 12:00
10/14 18:00
10/15 00:00
10/15 06:00
10/15 12:00
Observed
Modeled


Runway Culvert - October 13-15, 2022
Elevation (ft, NAVD88)
29.00
28.50
28.00
27.50
27.00
26.50
26.00
25.50
25.00
24.50
24.00
10/13 12:00
10/13 18:00
10/14 00:00
10/14 06:00
10/14 12:00
10/14 18:00
10/15 00:00
10/15 06:00
10/15 12:00
Observed
Modeled


Picnic Pond - October 13-15, 2022
Elevation (ft, NAVD88)
27.00
26.50
26.00
25.50
25.00
24.50
24.00
23.50
23.00
22.50
22.00
10/13 12:00
10/13 18:00
10/14 00:00
10/14 06:00
10/14 12:00
10/14 18:00
10/15 00:00
10/15 06:00
10/15 12:00
Observed
Modeled


Liberty Crossing - October 13-15, 2022
Elevation (ft, NAVD88)
8.50
8.00
7.50
7.00
6.50
6.00
5.50
5.00
4.50
4.00
3.50
10/13 12:00
10/13 18:00
10/14 00:00
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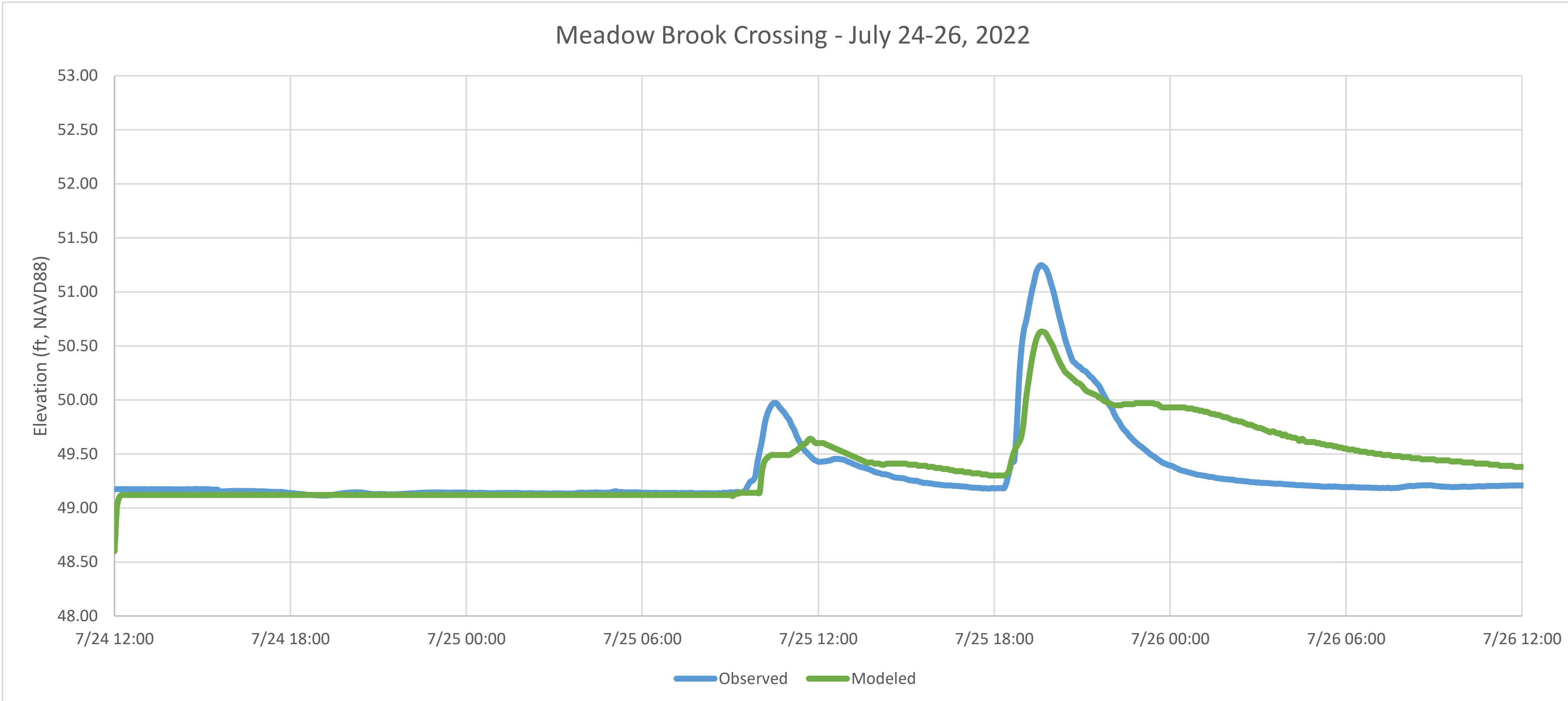
10/15 12:00
Observed
Tides
Modeled



Meadow Brook Crossing - July 24-26, 2022
Elevation (ft, NAVD88)
53.00
52.50
52.00
51.50
51.00
50.50
50.00
49.50
49.00
48.50
48.00
7/24 12:00
7/24 18:00
7/25 00:00
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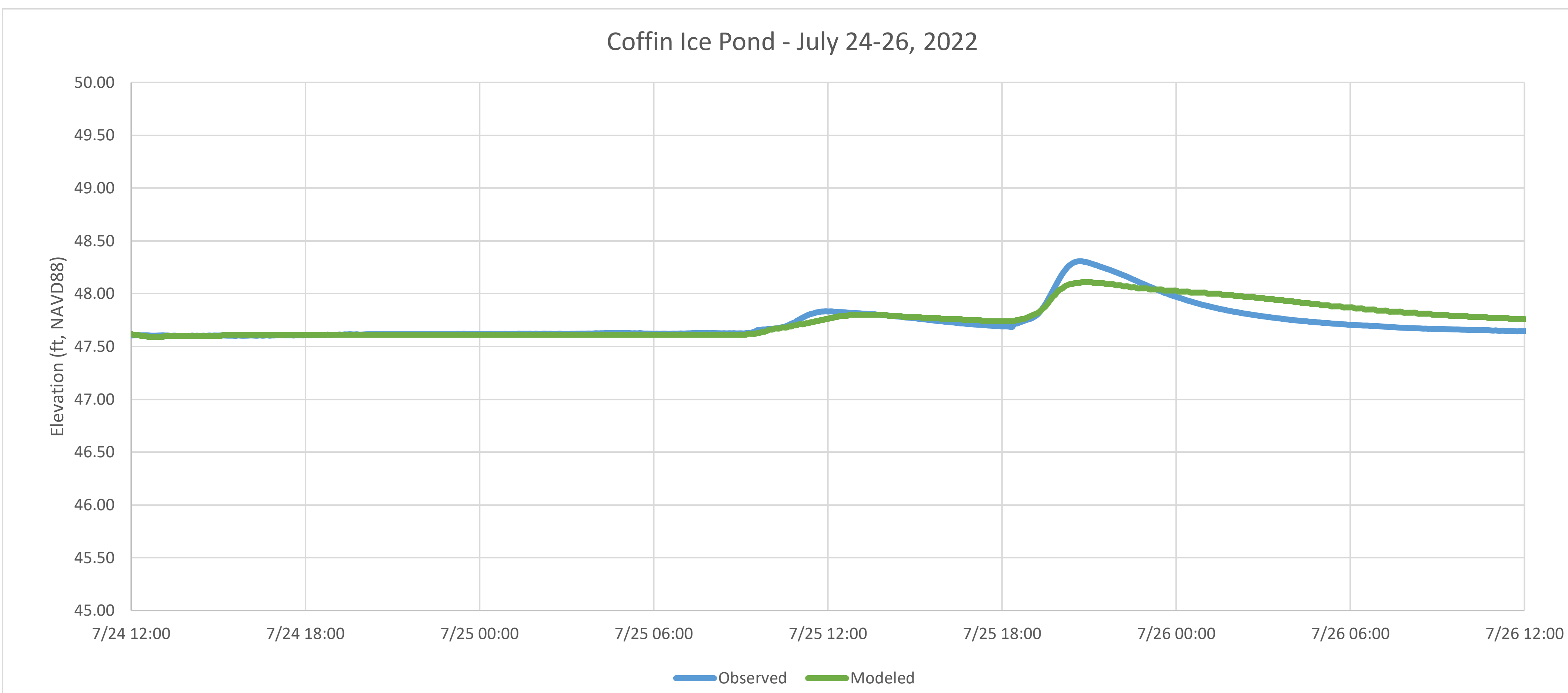
7/26 12:00
Observed
Modeled



Coffin Ice Pond - July 24-26, 2022
Elevation (ft, NAVD88)
50.00
49.50
49.00
48.50
48.00
47.50
47.00
46.50
46.00
45.50
45.00
7/24 12:00
7/24 18:00
7/25 00:00
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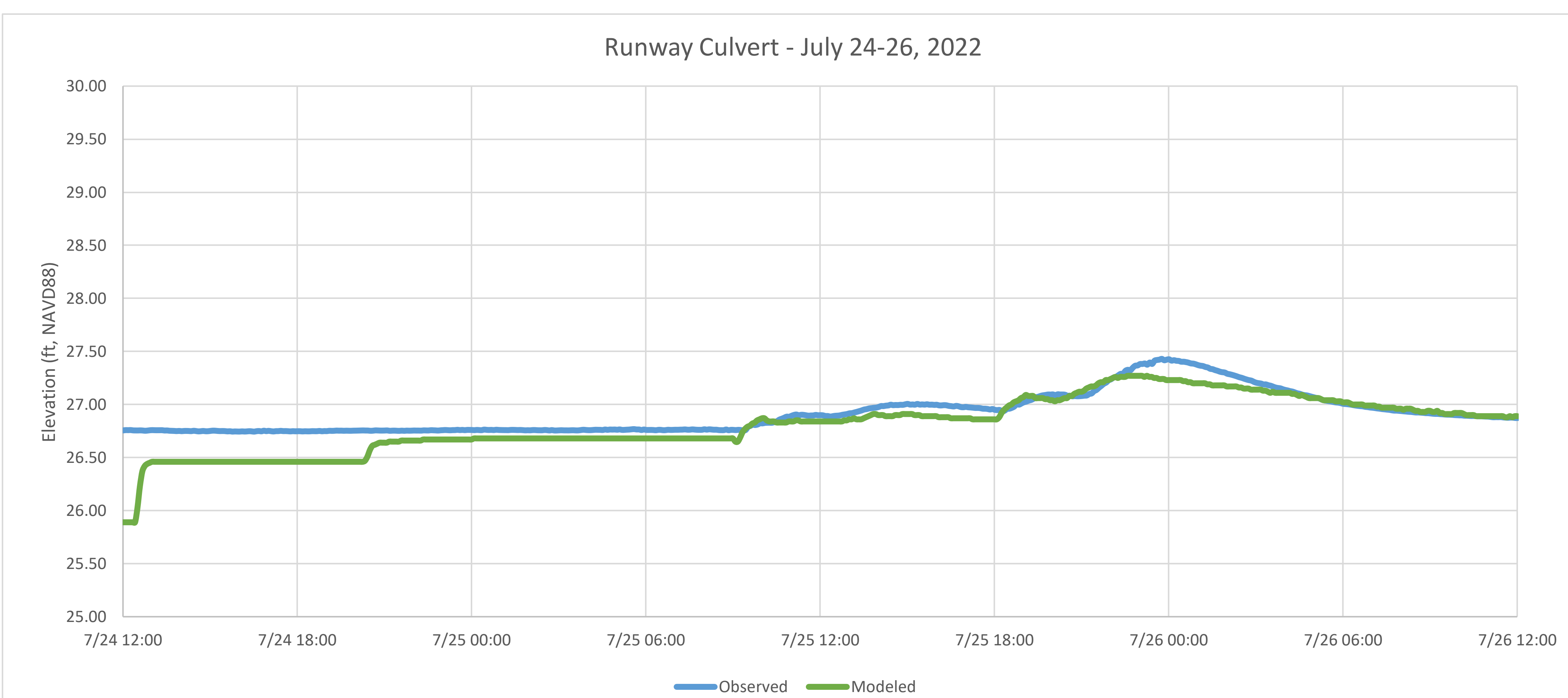
7/26 06:00
7/26 12:00
Observed
Modeled



Runway Culvert - July 24-26, 2022
Elevation (ft, NAVD88)
30.00
29.50
29.00
28.50
28.00
27.50
27.00
26.50
26.00
25.50
25.00
7/24 12:00
7/24 18:00
7/25 00:00
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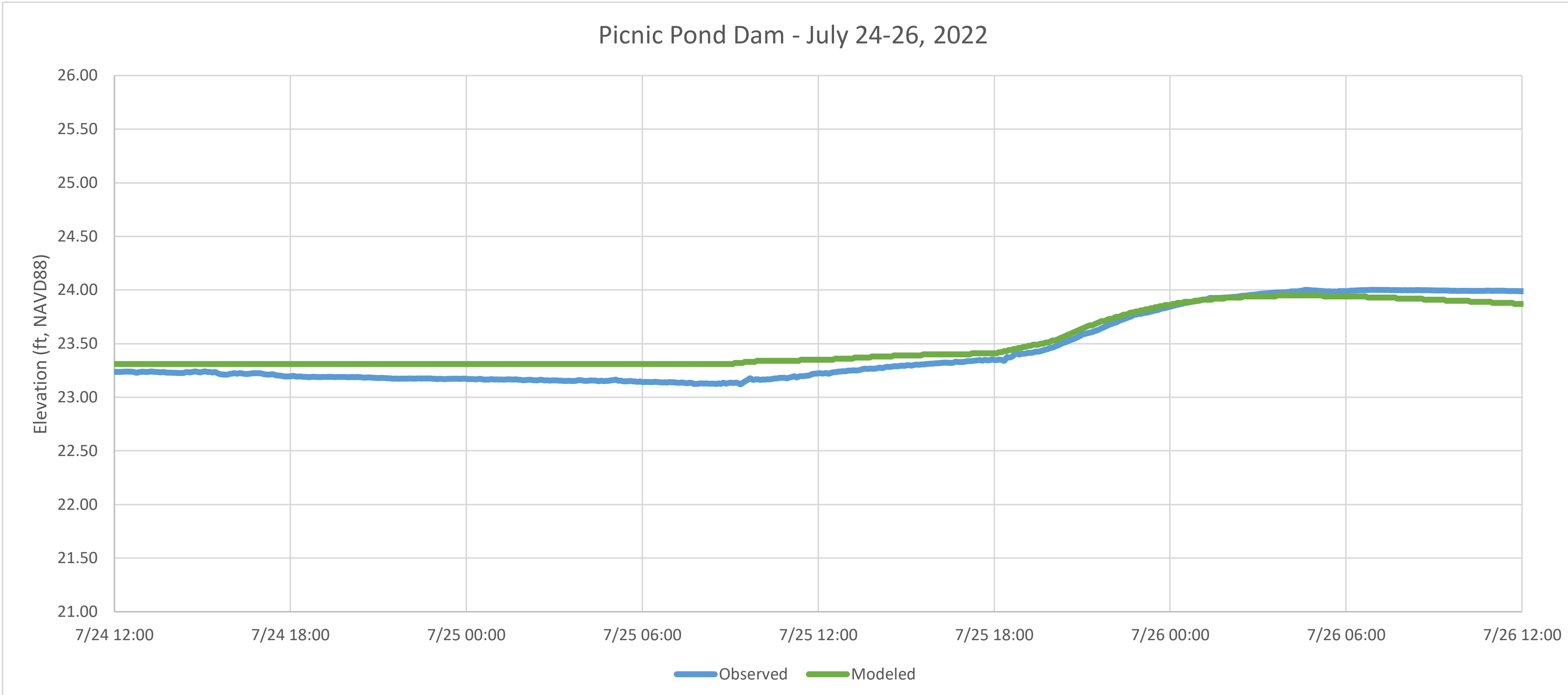
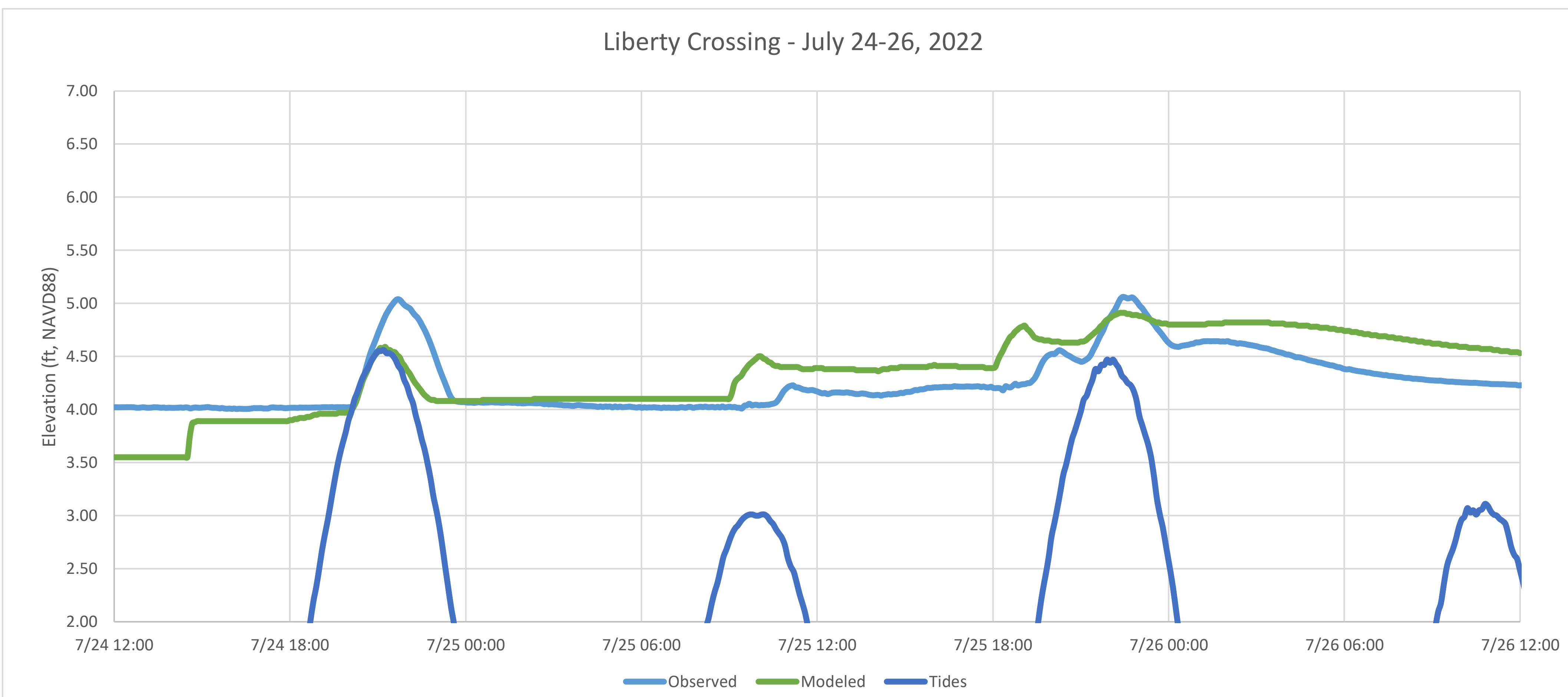
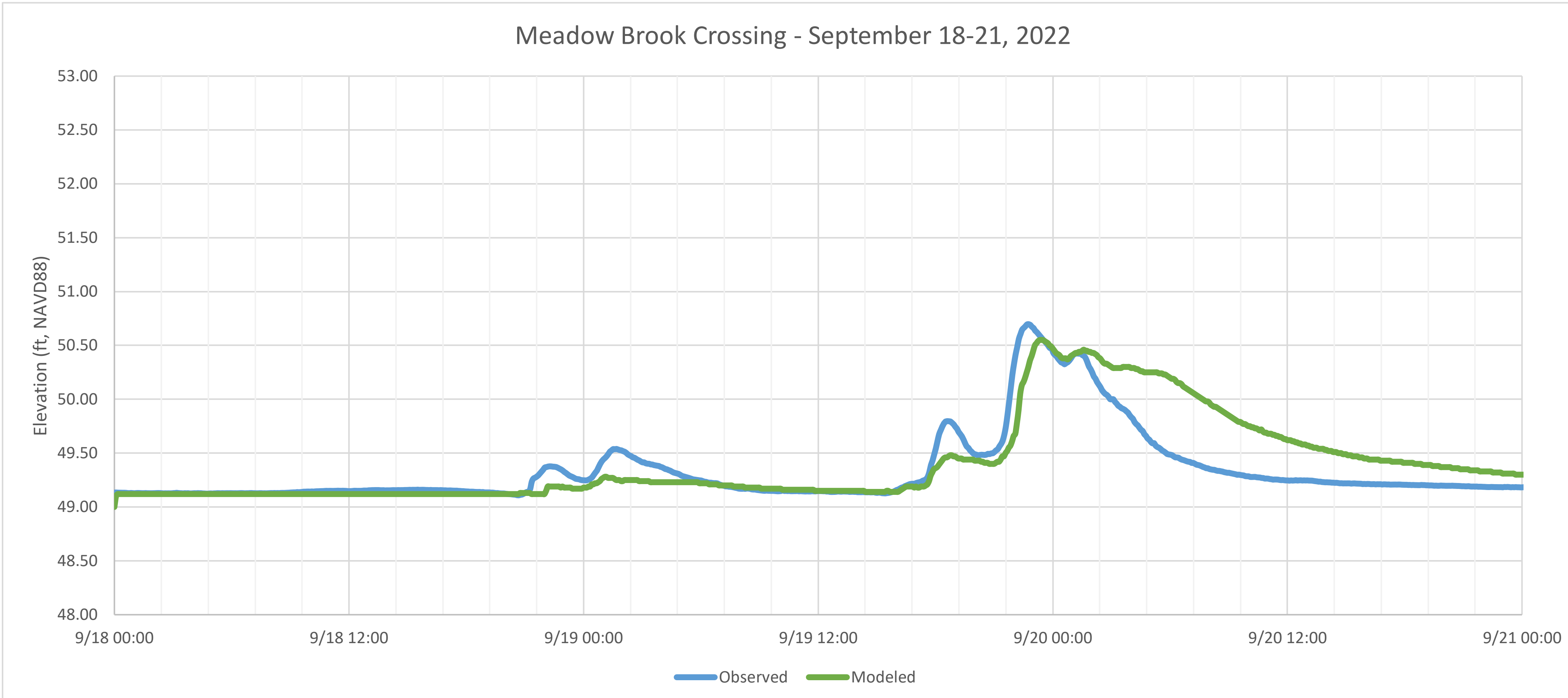
7/26 00:00
7/26 06:00
7/26 12:00
Observed
Modeled

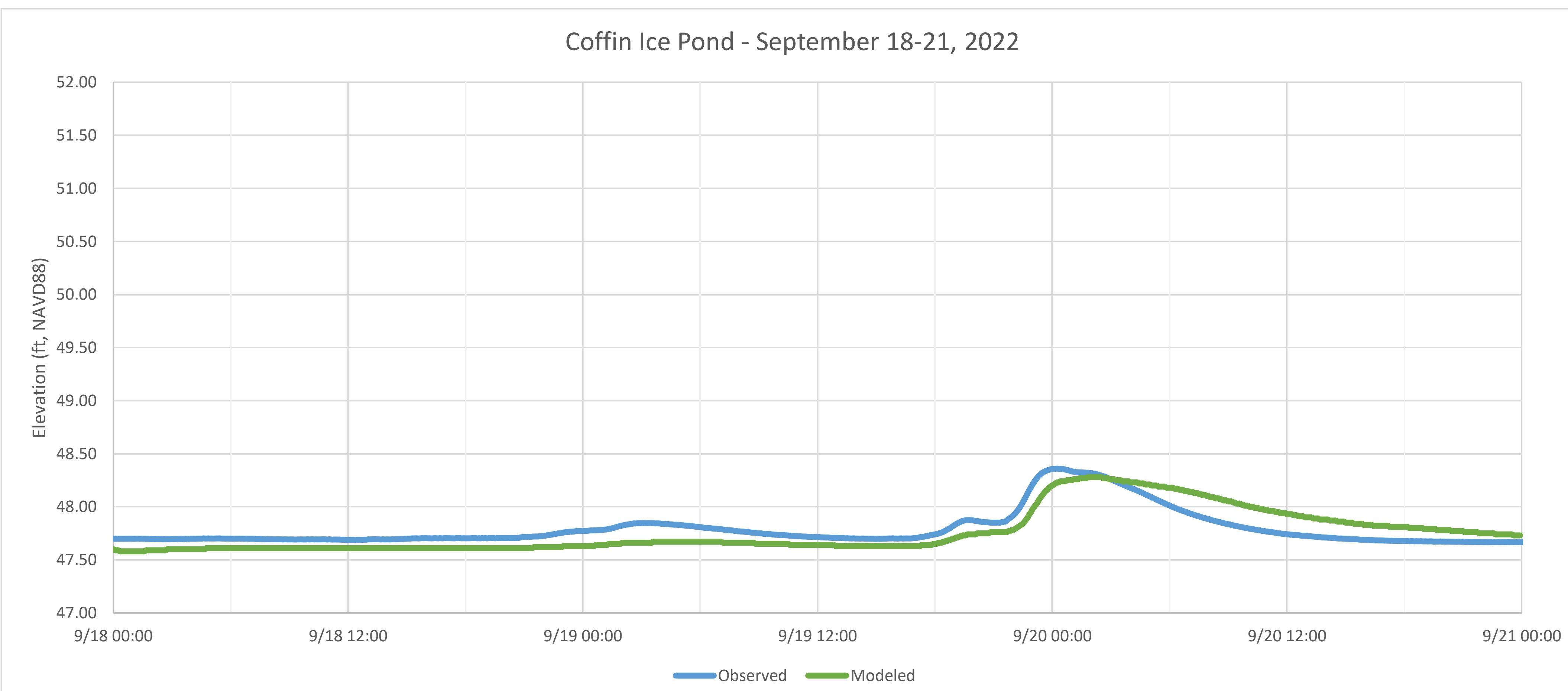

Picnic Pond Dam - July 24-26, 2022
Elevation (ft, NAVD88)
26.00
25.50
25.00
24.50
24.00
23.50
23.00
22.50
22.00
21.50
21.00
7/24 12:00
7/24 18:00
7/25 00:00
7/25 06:00
7/25 12:00
7/25 18:00
7/26 00:00
7/26 06:00
7/26 12:00
Observed
Modeled

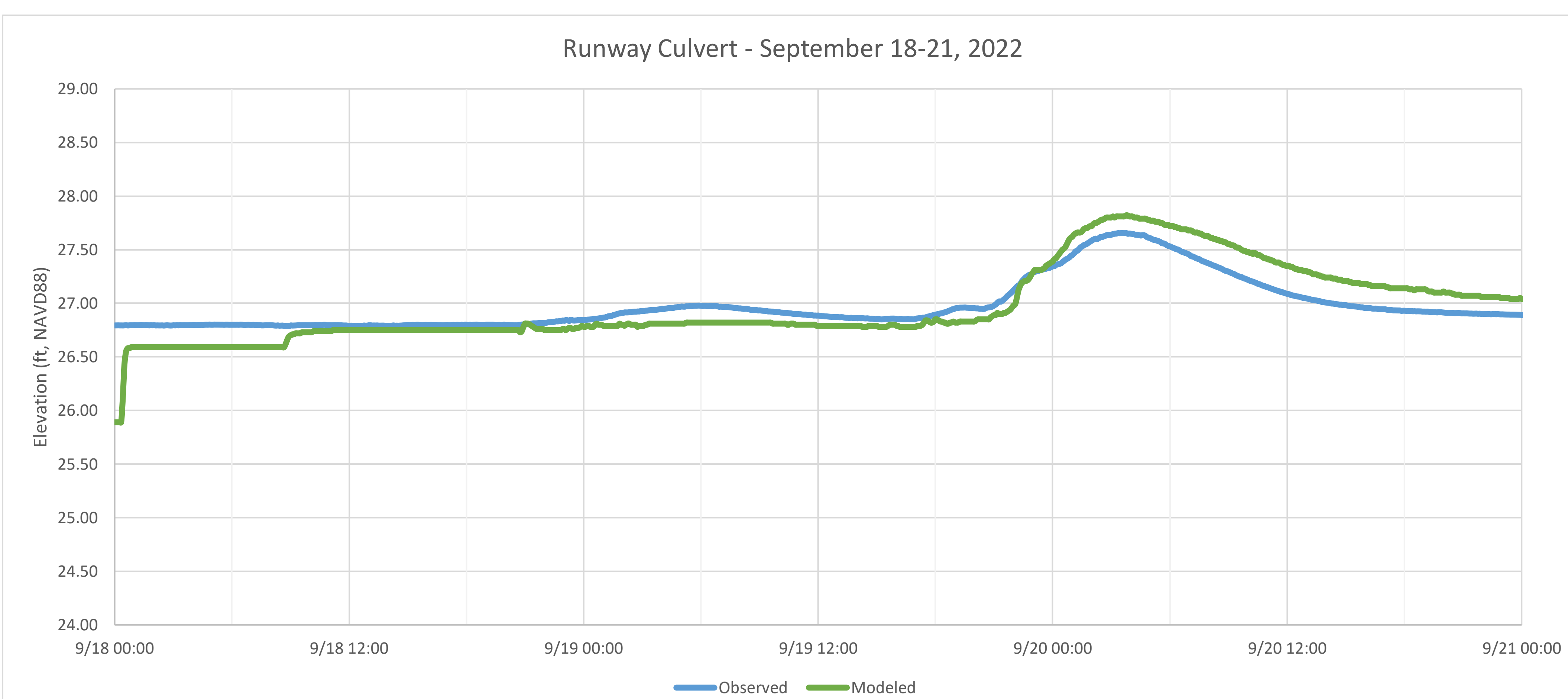

Liberty Crossing - July 24-26, 2022
Elevation (ft, NAVD88)
7.00
6.50
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
7/24 12:00
7/24 18:00
7/25 00:00
7/25 06:00
7/25 12:00
7/25 18:00
7/26 00:00
7/26 06:00
7/26 12:00
Observed
Modeled
Tides

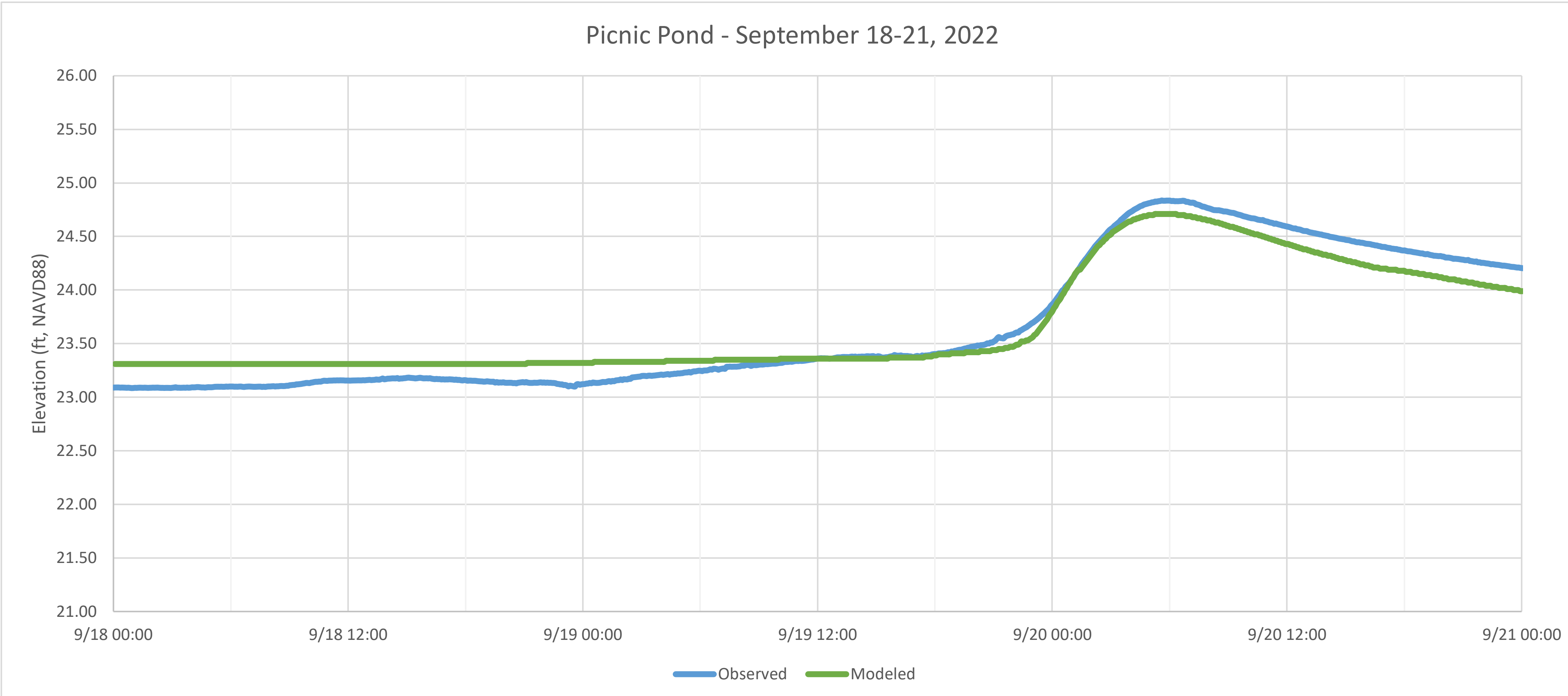
Appendix C

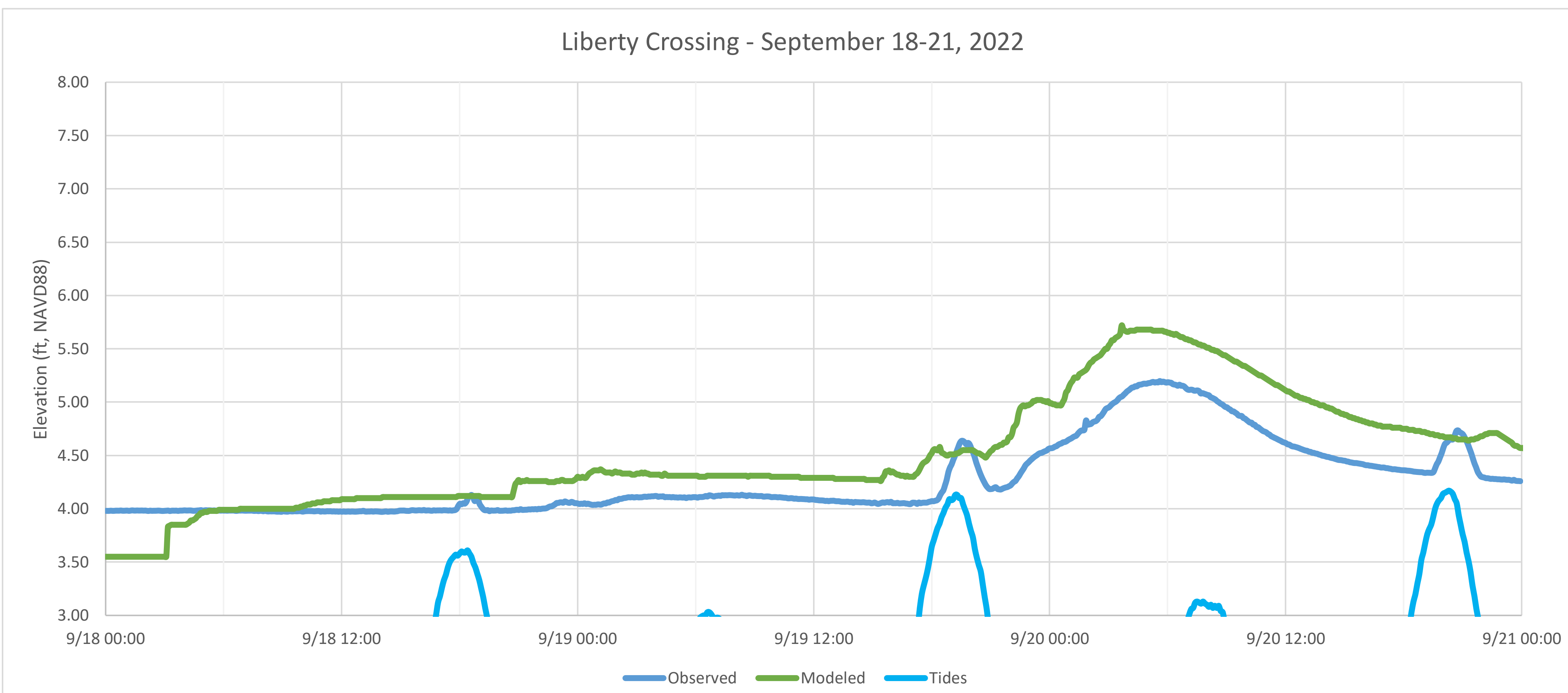
Model Validation Graphs – September 25, 2022 Storm


Meadow Brook Crossing - September 18-21, 2022
Elevation (ft, NAVD88)
53.00
52.50
52.00
51.50
51.00
50.50
50.00
49.50
49.00
48.50
48.00
9/18 00:00
9/18 12:00
9/19 00:00
9/19 12:00
9/20 00:00
9/20 12:00
9/21 00:00
Observed
Modeled


Coffin Ice Pond - September 18-21, 2022
Elevation (ft, NAVD88)
52.00
51.50
51.00
50.50
50.00
49.50
49.00
48.50
48.00
47.50
47.00
9/18 00:00
9/18 12:00
9/19 00:00
9/19 12:00
9/20 00:00
9/20 12:00
9/21 00:00
Observed
Modeled


Runway Culvert - September 18-21, 2022
Elevation (ft, NAVD88)
29.00
28.50
28.00
27.50
27.00
26.50
26.00
25.50
25.00
24.50
24.00
9/18 00:00
9/18 12:00
9/19 00:00
9/19 12:00
9/20 00:00
9/20 12:00
9/21 00:00
Observed
Modeled


Picnic Pond - September 18-21, 2022
Elevation (ft, NAVD88)
26.00
25.50
25.00
24.50
24.00
23.50
23.00
22.50
22.00
21.50
21.00
9/18 00:00
9/18 12:00
9/19 00:00
9/19 12:00
9/20 00:00
9/20 12:00
9/21 00:00
Observed
Modeled


Liberty Crossing - September 18-21, 2022
Elevation (ft, NAVD88)
8.00
7.50
7.00
6.50
6.00
5.50
5.00
4.50
4.00
3.50
3.00
9/18 00:00
9/18 12:00
9/19 00:00
9/19 12:00
9/20 00:00
9/20 12:00
9/21 00:00
Observed
Modeled
Tides

Appendix D

H&H Results

2-Year Storm								
ID#	Location	Culvert Size (in)	Invert Elev. (ft)	Peak U/S Elev. (ft, NAVD88)	Top of Road/Dam (ft, NAVD88)	Overtopping (+), Freeboard (-) (ft)	Peak Flow (cfs)	Headwater / Depth*
Cul04	Baribeau Drive Crossing Flood Control	30''	73.8	74.8	77.9	-3.1	15	0.4
Cul05	Baribeau Drive Crossing Main Pipe	Twin 30''	73.7					0.4
Cul10	Barrows Street Crossing	24''	64.2	66.6	70.8	-4.2	35	1.2
		48''	64.2					0.6
Cul14	Macmillan Drive Crossing	24''	60.4	62.4	69.2	-6.8	41	1.0
		48''	59.5					0.7
Cul16	Maine Street Crossing	84''W x 42''H (Ellipse)	57.7	60.3	64.8	-4.5	53	0.7
Cul17	Meadowbrook Road Crossing	48''	48.7	52.6	61.1	-8.5	63	1.0
Cul18	Sparwell Lane Tributary Crossing	30''	50.4	53.8	61.5	-7.7	29	1.4
Cul23	Harpswell Road Crossing	60''	38.8	44.5	57.3	-12.8	85	1.1
	Dams							
	Coffin Ice Pond Dam	NA	NA	49.0	49.1	-0.1	85	NA
	Picnic Pond Dam	NA	NA	25.5	25.5	0	23	NA

*Headwater / Depth ratio is equal to the peak water surface elevation minus culvert invert elevation divided by culvert height (ft)

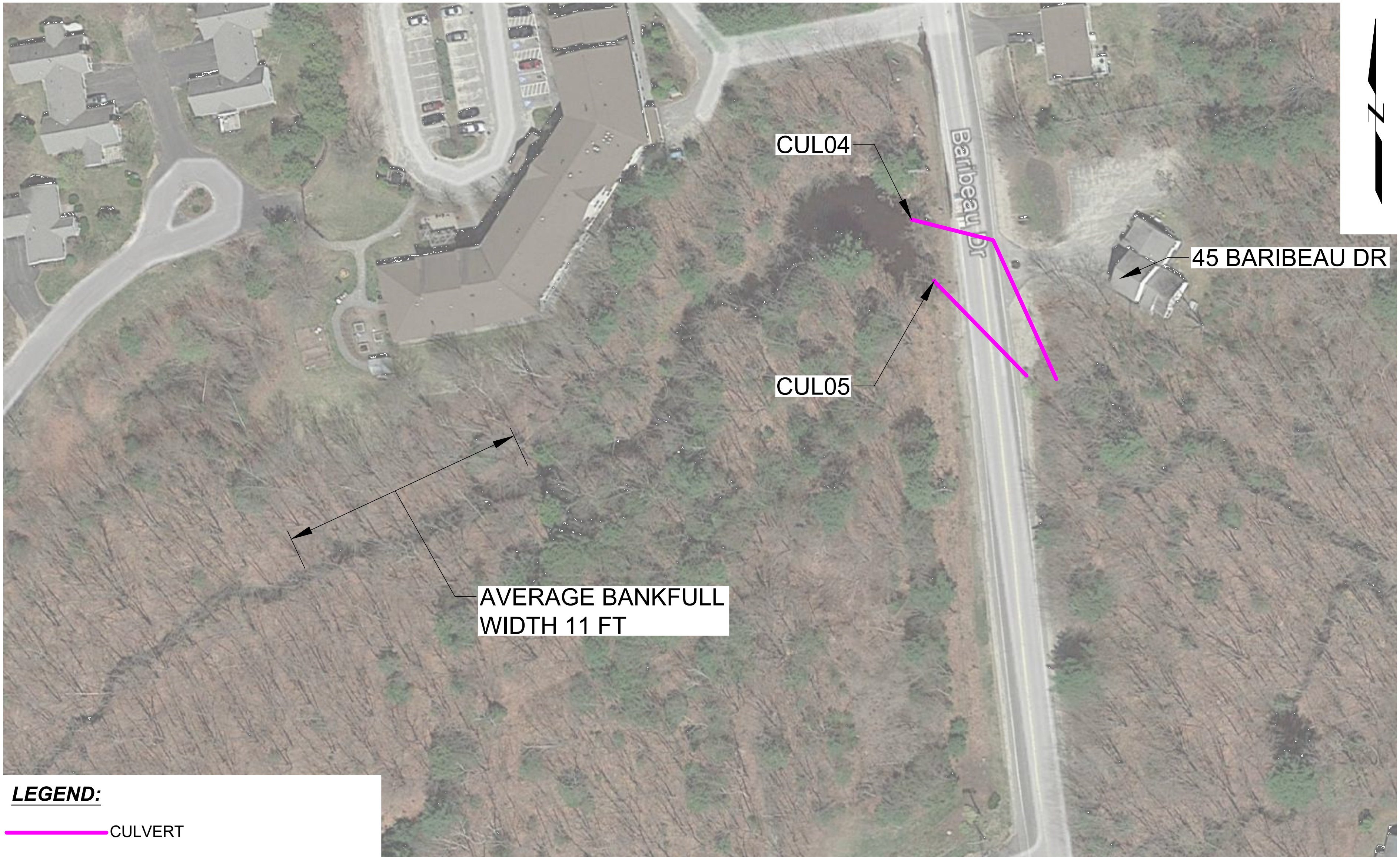
10-Year Storm								
ID#	Location	Culvert Size (in)	Invert Elev. (ft)	Peak U/S Elev. (ft, NAVD88)	Top of Road/Dam (ft, NAVD88)	Overtopping (+), Freeboard (-) (ft)	Peak Flow (cfs)	Headwater / Depth*
Cul04	Baribeau Drive Crossing Flood Control	30''	73.8	75.5	77.9	-2.4	35	0.7
Cul05	Baribeau Drive Crossing Main Pipe	Twin 30''	73.7					0.7
Cul10	Barrows Street Crossing	24''	64.2	67.8	70.8	-3	68	1.8
		48''	64.2					0.9
Cul14	Macmillan Drive Crossing	24''	60.4	64.1	69.2	-5.1	79	1.9
		48''	59.5					1.2
Cul16	Maine Street Crossing	84''W x 42''H (Ellipse)	57.7	62.1	64.8	-2.7	111	1.3
Cul17	Meadowbrook Road Crossing	48''	48.7	56.4	61.1	-4.7	126	1.9
Cul18	Sparwell Lane Tributary Crossing	30''	50.4	56.8	61.5	-4.7	44	2.6
Cul23	Harpswell Road Crossing	60''	38.8	48.6	57.3	-8.7	153	2.0
	Dams							
	Coffin Ice Pond Dam	NA	NA	49.6	49.1	0.5	168	NA
	Picnic Pond Dam	NA	NA	26.5	25.5	1	94	NA

*Headwater / Depth ratio is equal to the peak water surface elevation minus culvert invert elevation divided by culvert height (ft)

25-Year Storm								
ID#	**Location**	**Culvert Size (in)**	**Invert Elev. (ft)**	**Peak U/S Elev. (ft, NAVD88)**	**Top of Road/Dam (ft, NAVD88)**	**Overtopping (+), Freeboard (-) (ft)**	**Peak Flow (cfs)**	**Headwater / Depth***
Cul04	Baribeau Drive Crossing Flood Control	30''	73.8	76.0	77.9	-1.9	53	0.9
Cul05	Baribeau Drive Crossing Main Pipe	Twin 30''	73.7					0.9
Cul10	Barrows Street Crossing	24''	64.2	69.7	70.8	-1.1	110	2.8
		48''	64.2					1.4
Cul14	Macmillan Drive Crossing	24''	60.4	67.1	69.2	-2.1	115	3.4
		48''	59.5					1.9
Cul16	Maine Street Crossing	84''W x 42''H (Ellipse)	57.7	63.9	64.8	-0.9	153	1.8
Cul17	Meadowbrook Road Crossing	48''	48.7	60.0	61.1	-1.2	152	2.8
Cul18	Sparwell Lane Tributary Crossing	30''	50.4	59.2	61.5	-2.3	54	3.5
Cul23	Harpswell Road Crossing	60''	38.8	50.4	57.3	-6.9	177	2.3
	Dams							
	Coffin Ice Pond Dam	NA	NA	50.5	49.1	1.4	201	NA
	Picnic Pond Dam	NA	NA	27.0	25.5	1.5	173	NA

*Headwater / Depth ratio is equal to the peak water surface elevation minus culvert invert elevation divided by culvert height (ft)

Appendix B Bankfull Width Figures



LEGEND:

CULVERT

APPROXIMATE BANK MEASUREMENT LOCATIONS

NOTES:

1. BANK MEASUREMENT PERFORMED BY GEI ON MARCH 22, 2024

2. AERIAL IMAGERY SOURCE: GOOGLE (5/2018)

MARE BROOK BRUNSWICK, MAINE	GEI Consultants	BANKFULL WIDTH MEASUREMENT LOCATIONS BARIBEAU DRIVE
TOWN OF BRUNSWICK BRUNSWICK, MAINE	Project 2202137	AUGUST 2024 Fig. 1

CHMURA, MARC \\geiconsultants.com\data\Data_Storage\Working\BRUNSWICK ME, TOWN OF\2202137 Mare Brook H_H\00_CAD\Design\Sheets\Bankfull Width Estimation Figures.dwg - 8/26/2024

LEGEND:

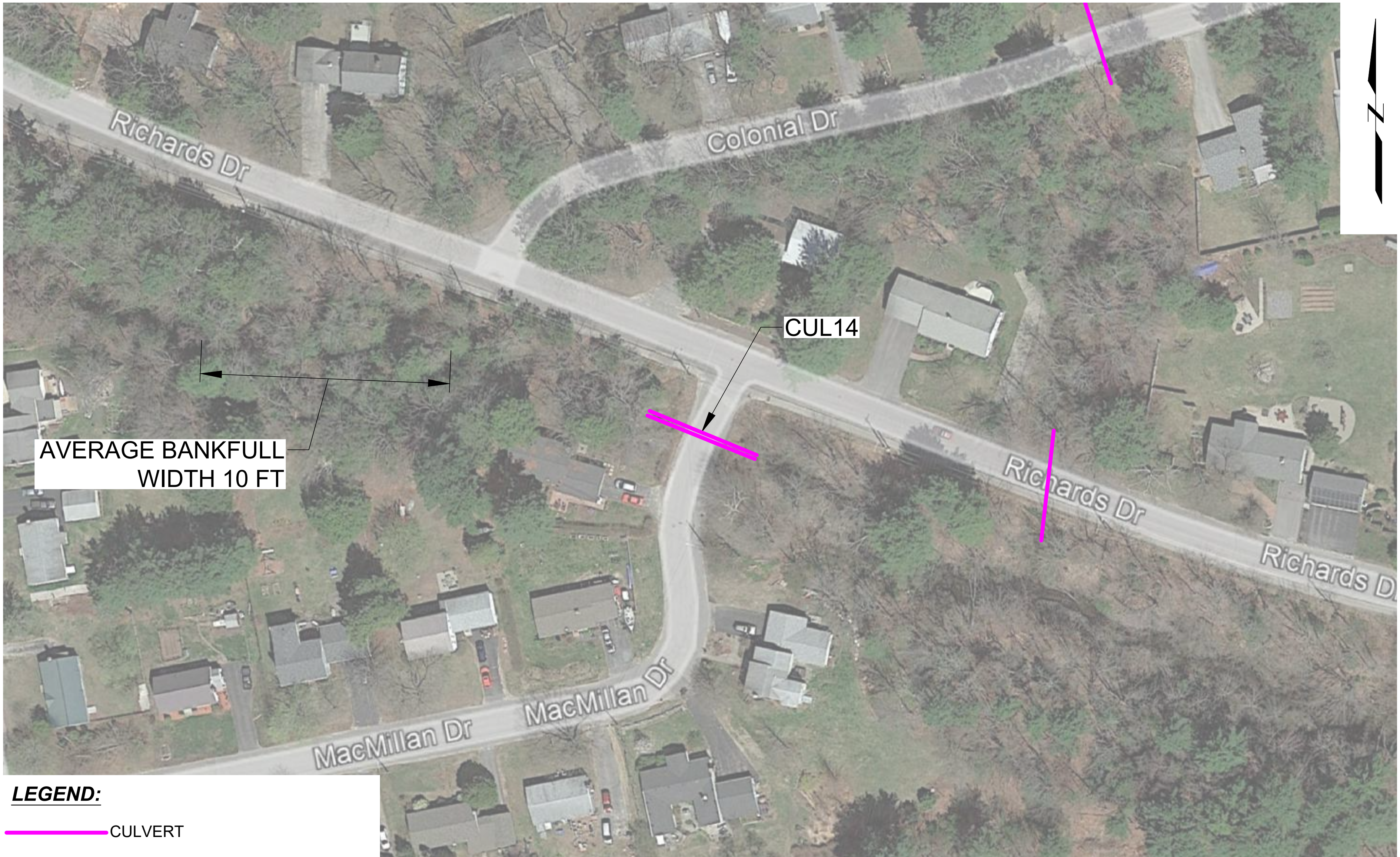
CULVERT

APPROXIMATE BANK MEASUREMENT LOCATIONS

NOTES:

1. **BANK MEASUREMENT PERFORMED BY GEI ON MARCH 22, 2024**
2. **AERIAL IMAGERY SOURCE: GOOGLE (5/2018)**

MARE BROOK BRUNSWICK, MAINE	GEI Consultants	BANKFULL WIDTH MEASUREMENT LOCATIONS BARROWS STREET	
TOWN OF BRUNSWICK BRUNSWICK, MAINE	Project 2202137	AUGUST 2024	Fig. 2



LEGEND:

CULVERT

APPROXIMATE BANK MEASUREMENT LOCATIONS

NOTES:

1. BANK MEASUREMENT PERFORMED BY GEI ON MARCH 22, 2024

2. AERIAL IMAGERY SOURCE: GOOGLE (5/2018)

MARE BROOK BRUNSWICK, MAINE	GEI Consultants	BANKFULL WIDTH MEASUREMENT LOCATIONS MACMILLAN DRIVE
TOWN OF BRUNSWICK BRUNSWICK, MAINE	Project 2202137	AUGUST 2024 Fig. 3

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LEGEND:

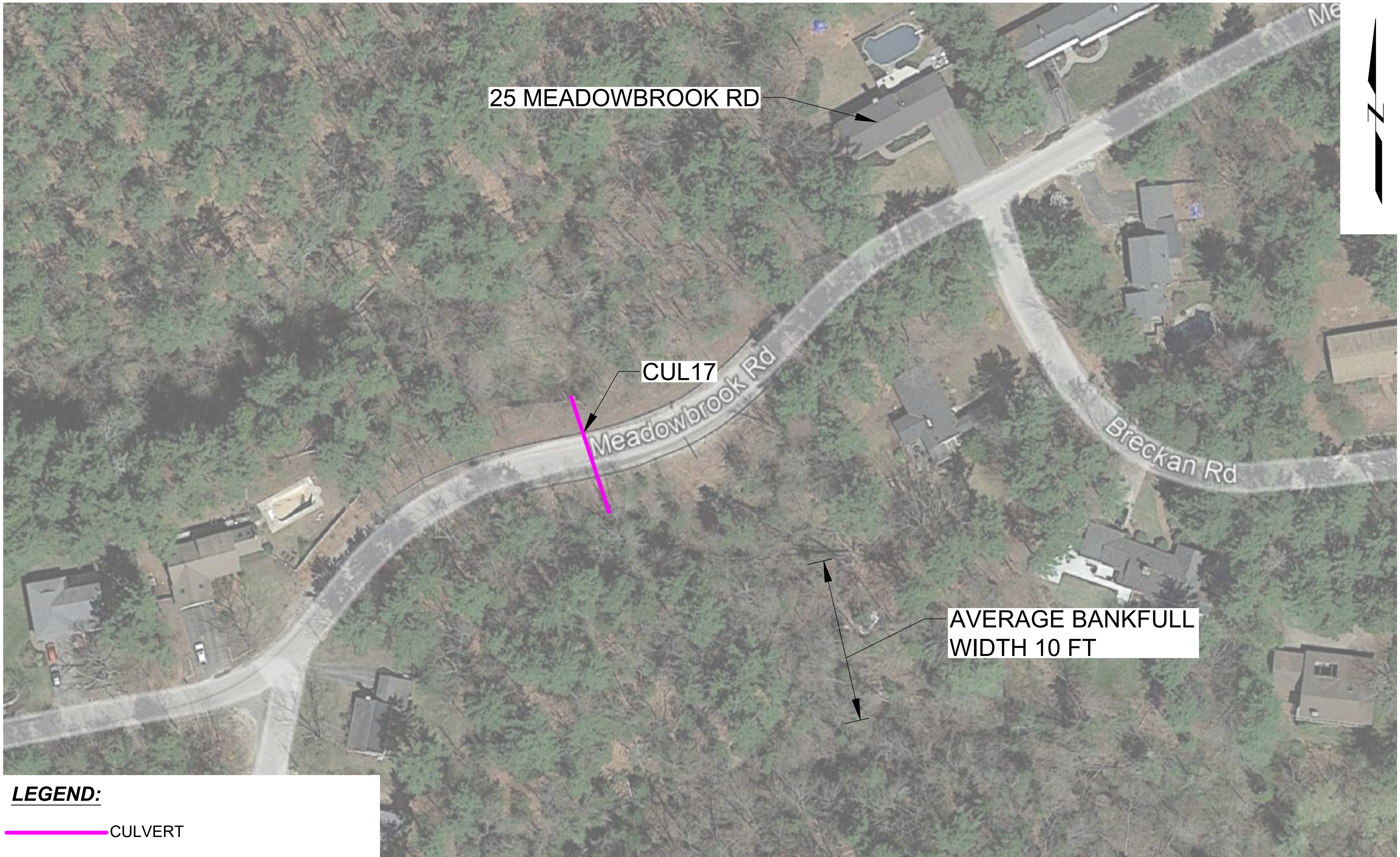
CULVERT

APPROXIMATE BANK MEASUREMENT LOCATIONS

NOTES:

1. **BANK MEASUREMENT PERFORMED BY GEI ON MARCH 22, 2024**
2. **AERIAL IMAGERY SOURCE: GOOGLE (5/2018)**

MARE BROOK BRUNSWICK, MAINE	GEI Consultants	BANKFULL WIDTH MEASUREMENT LOCATIONS MAINE STREET	
TOWN OF BRUNSWICK BRUNSWICK, MAINE	Project 2202137	AUGUST 2024	Fig. 4



LEGEND:

CULVERT

APPROXIMATE BANK MEASUREMENT LOCATIONS

NOTES:

1. **BANK MEASUREMENT PERFORMED BY GEI ON MARCH 22, 2024**
2. **AERIAL IMAGERY SOURCE: GOOGLE (5/2018)**

MARE BROOK BRUNSWICK, MAINE	GEI Consultants	BANKFULL WIDTH MEASUREMENT LOCATIONS MEADOWBROOK ROAD
TOWN OF BRUNSWICK BRUNSWICK, MAINE	Project 2202137	AUGUST 2024 Fig. 5

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LEGEND:

CULVERT

APPROXIMATE BANK MEASUREMENT LOCATIONS

NOTES:

1. BANK MEASUREMENT PERFORMED BY GEI ON MARCH 22, 2024

2. AERIAL IMAGERY SOURCE: GOOGLE (5/2018)

MARE BROOK BRUNSWICK, MAINE	GEI Consultants	BANKFULL WIDTH MEASUREMENT LOCATIONS HARPSWELL ROAD
TOWN OF BRUNSWICK BRUNSWICK, MAINE	Project 2202137	AUGUST 2024 Fig. 6

LEGEND:

CULVERT

APPROXIMATE BANK MEASUREMENT LOCATIONS

NOTES:

1. BANK MEASUREMENT PERFORMED BY GEI ON MARCH 22, 2024

2. AERIAL IMAGERY SOURCE: GOOGLE (5/2018)

MARE BROOK BRUNSWICK, MAINE	GEI Consultants	BANKFULL WIDTH MEASUREMENT LOCATIONS SECURITY ROAD
TOWN OF BRUNSWICK BRUNSWICK, MAINE	Project 2202137	AUGUST 2024 Fig. 7

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LEGEND:

CULVERT

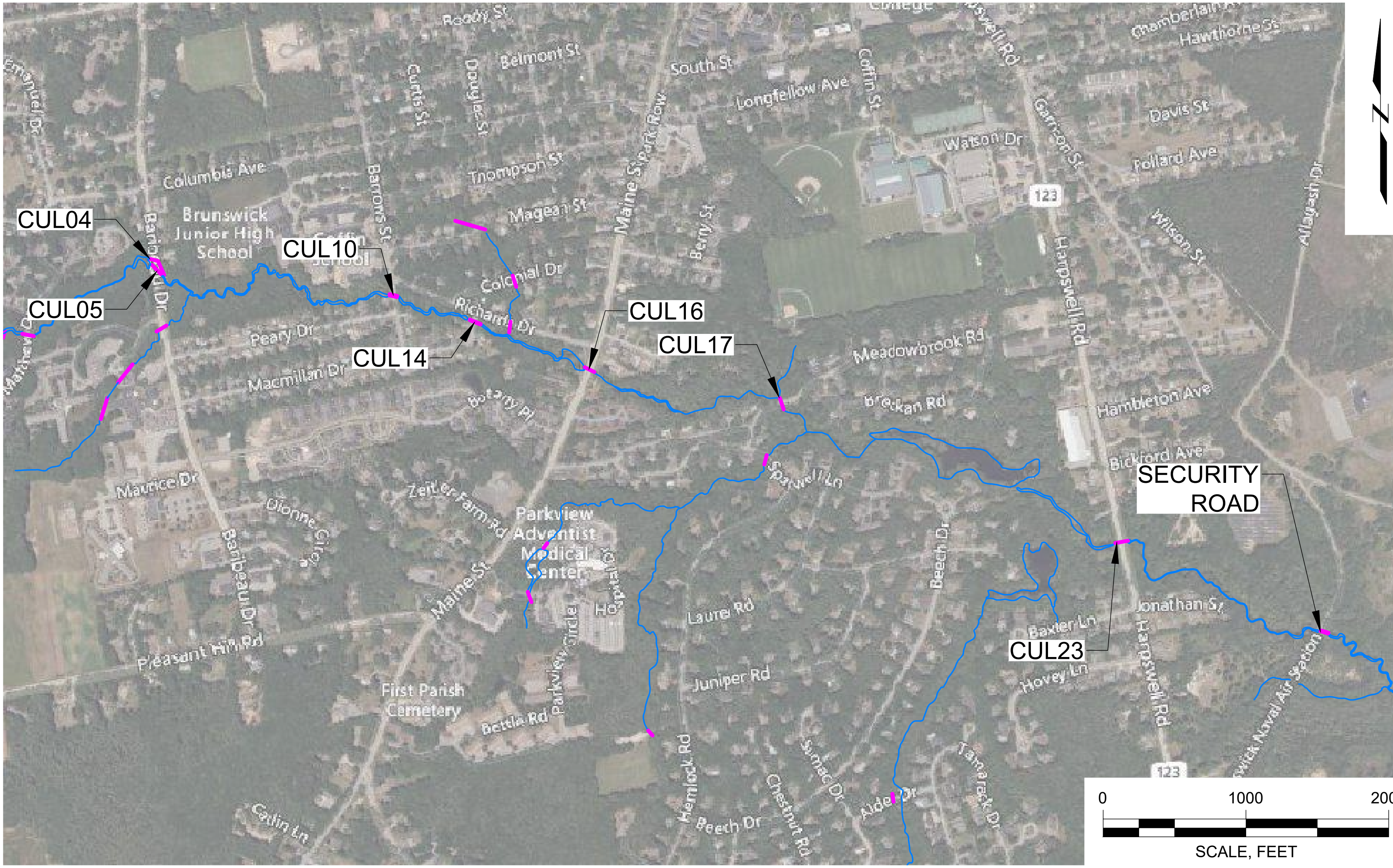
APPROXIMATE BANK
MEASUREMENT LOCATIONS

NOTES:

1. BANK MEASUREMENT PERFORMED BY GEI ON MARCH 22, 2024

2. AERIAL IMAGERY SOURCE: GOOGLE (5/2018)

MARE BROOK BRUNSWICK, MAINE	GEI Consultants	BANKFULL WIDTH MEASUREMENT LOCATIONS EAGLE DRIVE	
TOWN OF BRUNSWICK BRUNSWICK, MAINE	Project 2202137	AUGUST 2024	Fig. 8



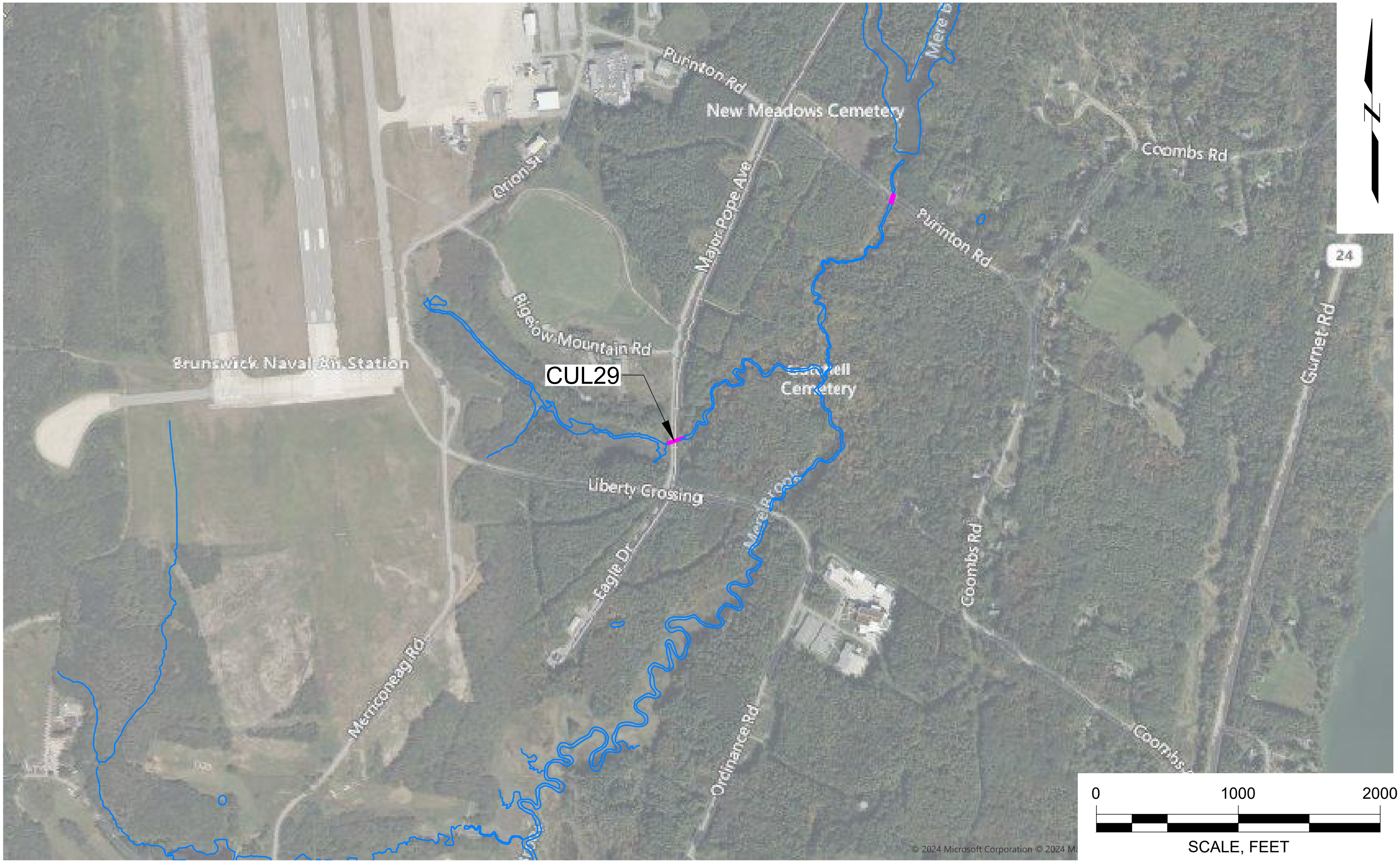
LEGEND:

CULVERT

BROOK

MARE BROOK BRUNSWICK, MAINE	GEI Consultants	CULVERT LOCATIONS	
TOWN OF BRUNSWICK BRUNSWICK, MAINE	Project 2202137	AUGUST 2024	Fig. 9

CHMURA, MARC \\geiconsultants.com\data\Data_Storage\Working\BRUNSWICK ME, TOWN OF\2202137 Mare Brook H_H\00_CAD\Design\Sheets\Bankfull Width Estimation Figures.dwg - 8/26/2024



LEGEND:

CULVERT

BROOK

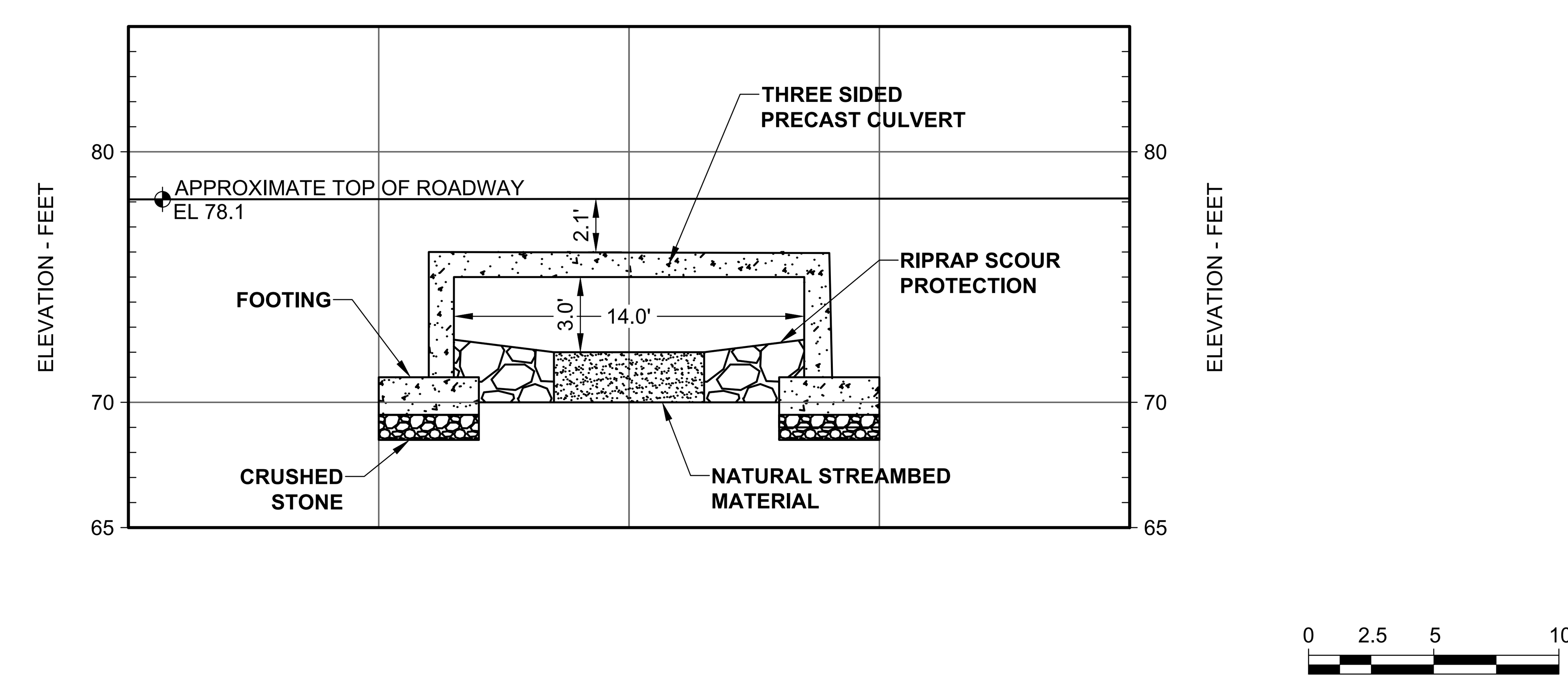
MARE BROOK BRUNSWICK, MAINE	GEI Consultants	CULVERT LOCATIONS
TOWN OF BRUNSWICK BRUNSWICK, MAINE	Project 2202137	AUGUST 2024 Fig. 10

CHMURA, MARC \\geiconsultants.com\data\Data_Storage\Working\BRUNSWICK ME, TOWN OF\2202137 Mare Brook H_H\00_CAD\Design\Sheets\Bankfull Width Estimation Figures.dwg - 8/26/2024

Appendix C Conceptual Culvert Replacement Design Drawings

BARIBEAU DRIVE CULVERT SITE PLAN

SCALE: 1" = 20'



1 TYPICAL CULVERT CROSS SECTION

SCALE: 1"=5'

ABBREVIATIONS

AC	=	ASBESTOS CEMENT
CL	=	CENTERLINE
DIA	=	DIAMETER
EL, ELEV	=	ELEVATION
FT	=	FEET OR FOOT
HDPE	=	HIGH DENSITY POLYETHYLENE
INV	=	INVERT
PVC	=	POLYVINYL CHLORIDE

SURVEY LEGEND

- CONTOURS - MAJOR
- CONTOURS - MINOR
- SPOT ELEVATION
- O/E — OVERHEAD ELECTRIC
- U/E — UNDERGROUND ELECTRIC
- WM — WATER MAIN
- WS — WATER SERVICE
- COMM — COMMUNICATIONS MAIN
- NGAS — NATURAL GAS
- SAN — SANITARY SEWER
- X — CHAIN LINK FENCE
- HYDRANT

NOTES:

1. CONCEPT DRAWINGS ARE FOR INFORMATIONAL AND PLANNING PURPOSES ONLY. FINISHED DIMENSIONS, ELEVATIONS, AND CONSTRUCTION METHODS TO BE DETERMINED DURING FINAL DESIGN.
2. AERIAL IMAGE OBTAINED FROM MAINE.GOV/GEOLIB/IMGDISCOVERY/SITE/, DATED 2018.
3. HORIZONTAL DATUM: NORTH AMERICAN DATUM OF 1983 (NAD83) MAINE STATE PLANE WEST – US SURVEY FOOT.
4. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88) – US SURVEY FOOT.
5. COORDINATES AND ELEVATIONS WERE NOT COLLECTED BY A LICENSED SURVEYOR AND ARE NOT INTENDED TO REPLACE A LAND SURVEY BY A LICENSED SURVEYOR.
6. CONTOURS DISPLAYED AT 1-FOOT INTERVALS (MINOR) WERE GENERATED USING LIDAR DATA FROM 2020 USGS LiDAR: SOUTH COASTAL MAINE (Q22).
7. BANK MEASUREMENTS ARE APPROXIMATE AND WERE RECORDED BY GEI ON SEPTEMBER 15, 2023.
8. LOCATION OF UTILITIES ARE APPROXIMATE ONLY, AND ARE NOT WARRANTED TO BE CORRECT.

ESTIMATED BANKFULL WIDTH: 11 FEET

NOT FOR CONSTRUCTION

Attention: 0 1" If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	MEC
Drawn:	MEC
Checked:	
Approved:	
P.E. No:	
GEI Project	2202137

GEI Consultants
GEI CONSULTANTS, INC.
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PORTLAND, ME 04101
(207)797-8901

TOWN OF BRUNSWICK, MAINE

85 UNION STREET
BRUNSWICK, ME 04011

MARE BROOK CULVERT AND COFFIN'S ICE POND DAM CONCEPTUAL DESIGN

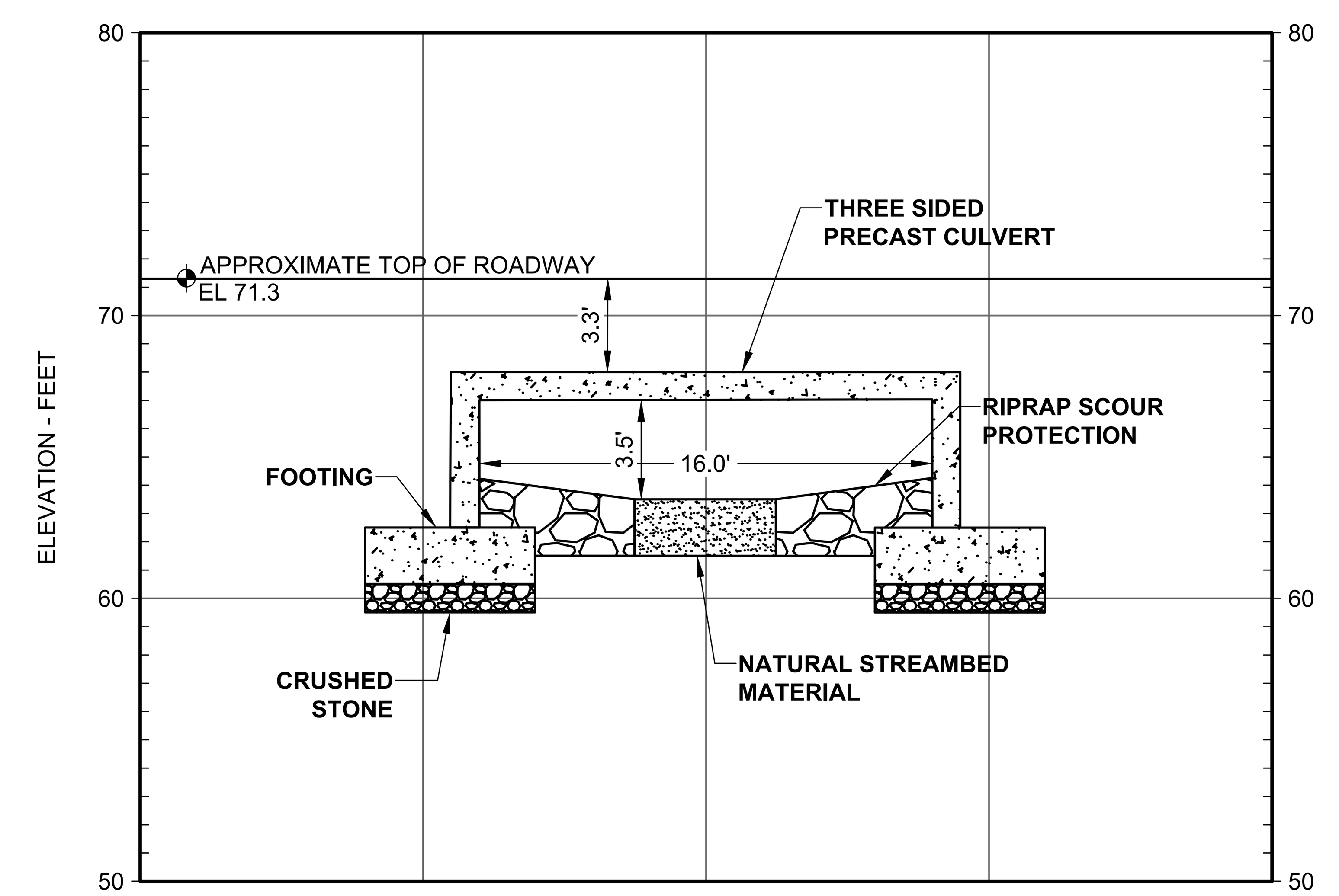
BRUNSWICK, MAINE

NO	DATE	ISSUE/REVISION	APP
0			

SHEET NAME	SHEET NO.
BARIBEAU DRIVE CONCEPT DESIGN	1

0 20 40
SCALE, FEET

BARROWS STREET CULVERT SITE PLAN
SCALE: 1" = 20'



0 2.5 5 10
SCALE, FEET

2 TYPICAL CULVERT CROSS SECTION
SCALE: 1"=5'

ABBREVIATIONS

AC	=	ASBESTOS CEMENT
CL	=	CENTERLINE
DIA	=	DIAMETER
EL, ELEV	=	ELEVATION
FT	=	FEET OR FOOT
HDPE	=	HIGH DENSITY POLYETHYLENE
INV	=	INVERT
PVC	=	POLYVINYL CHLORIDE

SURVEY LEGEND

- CONTOURS - MAJOR
- CONTOURS - MINOR
- X 50.00 SPOT ELEVATION
- O/E OVERHEAD ELECTRIC
- U/E UNDERGROUND ELECTRIC
- WM WATER MAIN
- WS WATER SERVICE
- COMM COMMUNICATIONS MAIN
- NGAS NATURAL GAS
- SAN SANITARY SEWER
- X FENCE
- HYDRANT

NOTES:

1. CONCEPT DRAWINGS ARE FOR INFORMATIONAL AND PLANNING PURPOSES ONLY. FINISHED DIMENSIONS, ELEVATIONS, AND CONSTRUCTION METHODS TO BE DETERMINED DURING FINAL DESIGN.
2. AERIAL IMAGE OBTAINED FROM MAINE.GOV/GEOLIB/IMGDISCOVERY/SITE/, DATED 2018.
3. HORIZONTAL DATUM: NORTH AMERICAN DATUM OF 1983 (NAD83) MAINE STATE PLANE WEST – US SURVEY FOOT.
4. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88) – US SURVEY FOOT.
5. COORDINATES AND ELEVATIONS WERE NOT COLLECTED BY A LICENSED SURVEYOR AND ARE NOT INTENDED TO REPLACE A LAND SURVEY BY A LICENSED SURVEYOR.
6. CONTOURS DISPLAYED AT 1-FOOT INTERVALS (MINOR) WERE GENERATED USING LIDAR DATA FROM 2020 USGS LiDAR: SOUTH COASTAL MAINE (Q22).
7. BANK MEASUREMENTS ARE APPROXIMATE AND WERE RECORDED BY GEI ON SEPTEMBER 15, 2023.
8. LOCATION OF UTILITIES ARE APPROXIMATE ONLY, AND ARE NOT WARRANTED TO BE CORRECT.

ESTIMATED BANKFULL WIDTH: 11 FEET

NOT FOR CONSTRUCTION

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	MEC
Drawn:	MEC
Checked:	
Approved:	
P.E. No:	
GEI Project	2202137

GEI Consultants
GEI CONSULTANTS, INC.
5 MILK STREET
PORTLAND, ME 04101
(207)797-8901

TOWN OF BRUNSWICK, MAINE

85 UNION STREET
BRUNSWICK, ME 04011

MARE BROOK CULVERT AND COFFIN ICE POND DAM CONCEPTUAL DESIGN

BRUNSWICK, MAINE

NO	DATE	ISSUE/REVISION	APP
0			

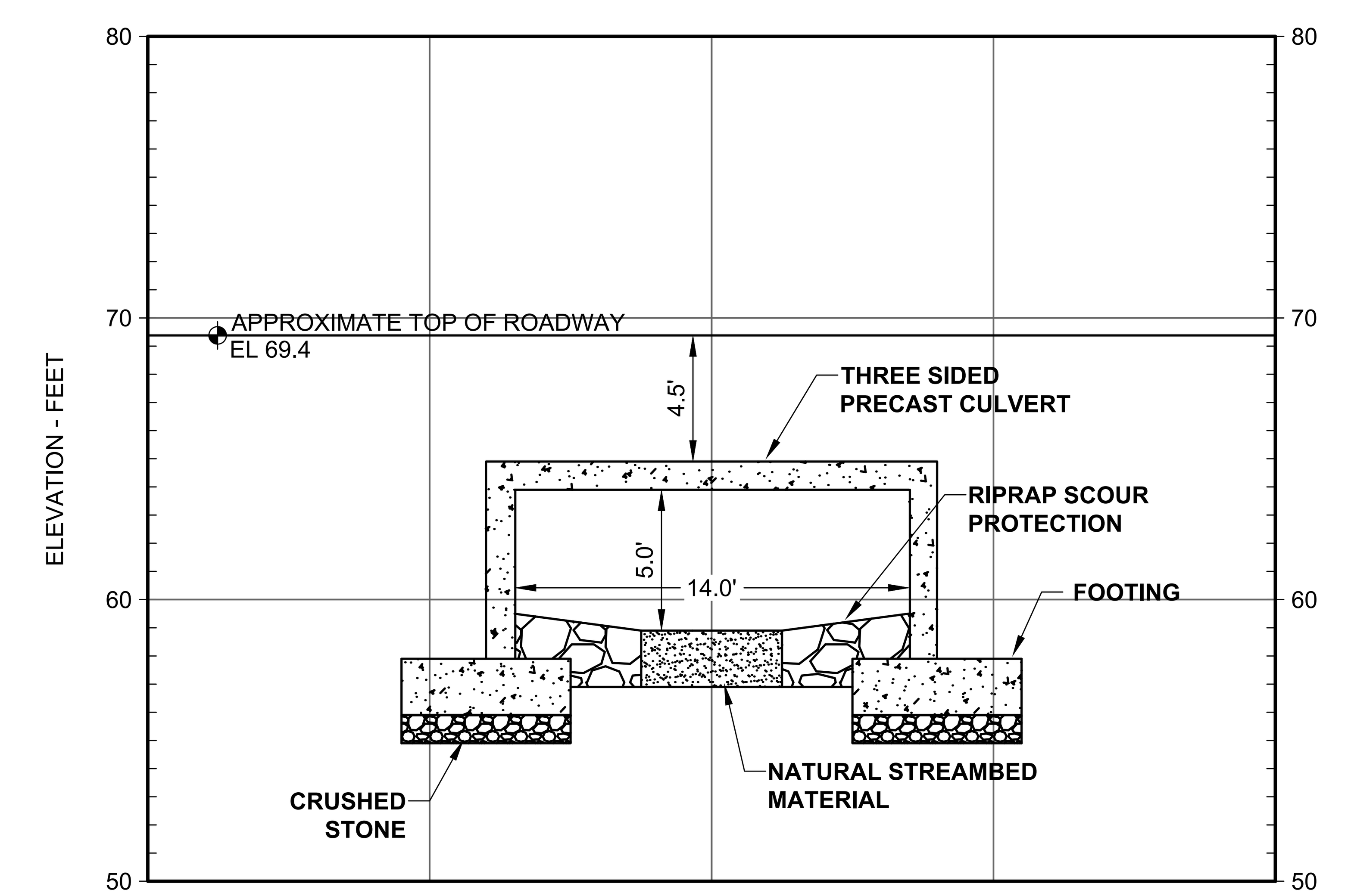
SHEET NAME: **BARROWS STREET CONCEPT DESIGN**

SHEET NO.: 2

CHMURA, MARC B:\Working\BRUNSWICK ME, TOWN OF\2202137 Mare Brook H_H\00_CAD\Design\Sheets\Marebrook_2202137_ConceptPlans.dwg - 8/27/2024

0 20 40
SCALE, FEET

MACMILLAN DRIVE CULVERT SITE PLAN
SCALE: 1" = 20'



0 2.5 5 10
SCALE, FEET

3 TYPICAL CULVERT CROSS SECTION
SCALE: 1"=5'

ABBREVIATIONS

AC	=	ASBESTOS CEMENT
CL	=	CENTERLINE
DIA	=	DIAMETER
EL, ELEV	=	ELEVATION
FT	=	FEET OR FOOT
HDPE	=	HIGH DENSITY POLYETHYLENE
INV	=	INVERT
PVC	=	POLYVINYL CHLORIDE

SURVEY LEGEND

- CONTOURS - MAJOR
- CONTOURS - MINOR
- X 50.00 SPOT ELEVATION
- O/E OVERHEAD ELECTRIC
- U/E UNDERGROUND ELECTRIC
- WM WATER MAIN
- WS WATER SERVICE
- COMM COMMUNICATIONS MAIN
- NGAS NATURAL GAS
- SAN SANITARY SEWER
- X FENCE
- HYDRANT

NOTES:

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2. AERIAL IMAGE OBTAINED FROM MAINE.GOV/GEOLIB/IMGDISCOVERY/SITE/, DATED 2018.
3. HORIZONTAL DATUM: NORTH AMERICAN DATUM OF 1983 (NAD83) MAINE STATE PLANE WEST – US SURVEY FOOT.
4. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88) – US SURVEY FOOT.
5. COORDINATES AND ELEVATIONS WERE NOT COLLECTED BY A LICENSED SURVEYOR AND ARE NOT INTENDED TO REPLACE A LAND SURVEY BY A LICENSED SURVEYOR.
6. CONTOURS DISPLAYED AT 1-FOOT INTERVALS (MINOR) WERE GENERATED USING LIDAR DATA FROM 2020 USGS LiDAR: SOUTH COASTAL MAINE (Q22).
7. BANK MEASUREMENTS ARE APPROXIMATE AND WERE RECORDED BY GEI ON SEPTEMBER 15, 2023.
8. LOCATION OF UTILITIES ARE APPROXIMATE ONLY, AND ARE NOT WARRANTED TO BE CORRECT.

ESTIMATED BANKFULL WIDTH: 10 FEET

NOT FOR CONSTRUCTION

Attention: 0 1" If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	MEC
Drawn:	MEC
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TOWN OF BRUNSWICK, MAINE

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BRUNSWICK, ME 04011

MARE BROOK CULVERT AND COFFIN ICE POND DAM CONCEPTUAL DESIGN

BRUNSWICK, MAINE

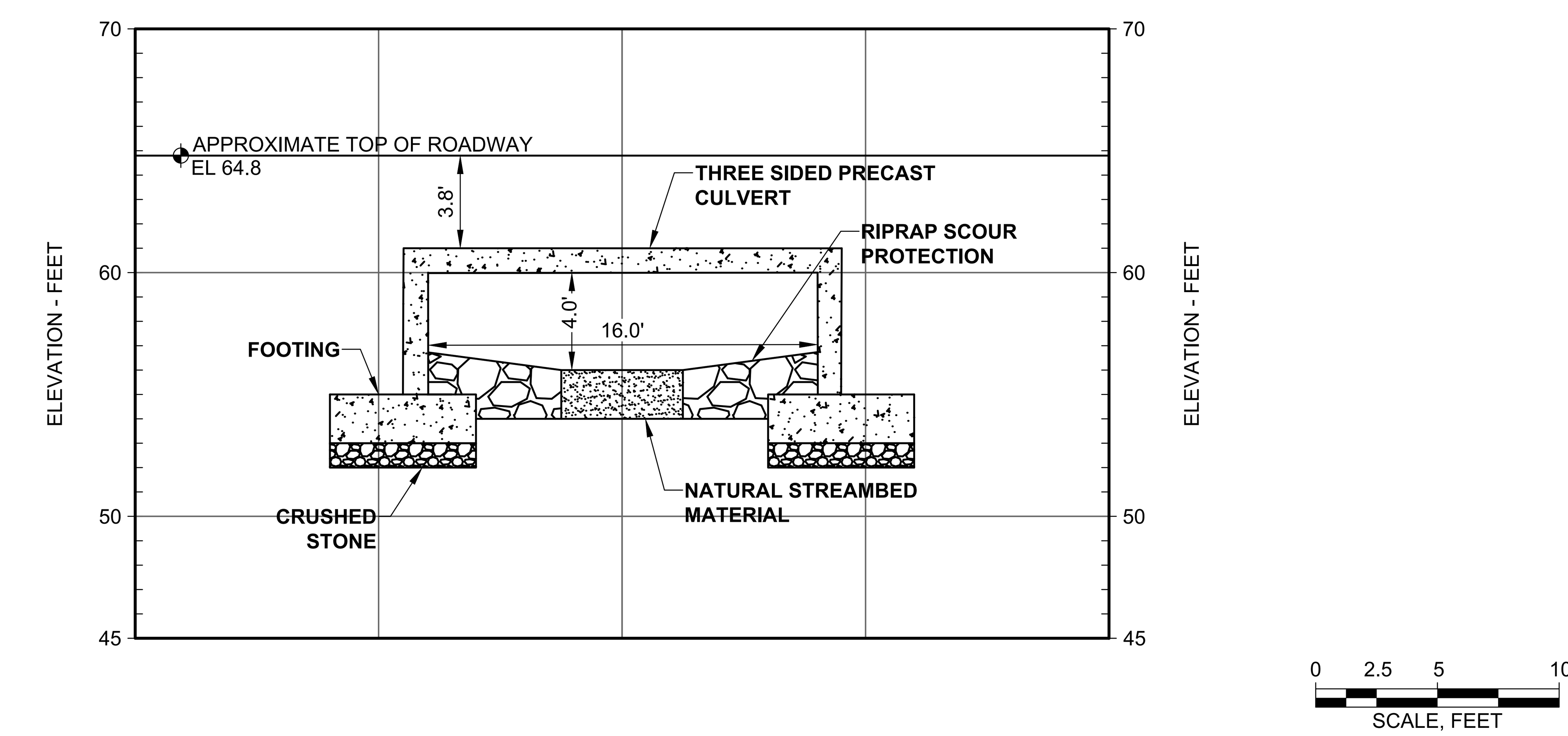
NO	DATE	ISSUE/REVISION	APP
0			

SHEET NAME: **MACMILLAN DRIVE CULVERT CONCEPT DESIGN**

SHEET NO. 3

MAINE STREET CULVERT SITE PLAN

SCALE: 1" = 20'



4 TYPICAL CULVERT CROSS SECTION

SCALE: 1"=5'

ABBREVIATIONS

AC	=	ASBESTOS CEMENT
CL	=	CENTERLINE
DIA	=	DIAMETER
EL, ELEV	=	ELEVATION
FT	=	FEET OR FOOT
HDPE	=	HIGH DENSITY POLYETHYLENE
INV	=	INVERT
PVC	=	POLYVINYL CHLORIDE

SURVEY LEGEND

——— ——— ———	CONTOURS - MAJOR
— — — — — —	CONTOURS - MINOR
X 50.00	SPOT ELEVATION
—— O/E ——	OVERHEAD ELECTRIC
—— U/E ——	UNDERGROUND ELECTRIC
—— WM ——	WATER MAIN
—— WS ——	WATER SERVICE
—— COMM ——	COMMUNICATIONS MAIN
—— NGAS ——	NATURAL GAS
—— SAN ——	SANITARY SEWER
—— X ——	FENCE
☋	HYDRANT

NOTES:

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7. BANK MEASUREMENTS ARE APPROXIMATE AND WERE RECORDED BY GEI ON SEPTEMBER 15, 2023.
8. LOCATION OF UTILITIES ARE APPROXIMATE ONLY, AND ARE NOT WARRANTED TO BE CORRECT.

ESTIMATED BANKFULL WIDTH: 10 FEET

NOT FOR CONSTRUCTION

Attention: 0 1" If this scale bar does not measure 1" then drawing is not original scale.

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Drawn:	MEC
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MARE BROOK CULVERT AND COFFIN ICE POND DAM CONCEPTUAL DESIGN

BRUNSWICK, MAINE

NO	DATE	ISSUE/REVISION	APP
0			

SHEET NAME: **MAINE STREET CULVERT CONCEPT DESIGN**

SHEET NO. 4

0 20 40
SCALE, FEET

MEADOWBROOK ROAD CULVERT SITE PLAN

SCALE: 1" = 20'

ABBREVIATIONS

AC	=	ASBESTOS CEMENT
CL	=	CENTERLINE
DIA	=	DIAMETER
EL, ELEV	=	ELEVATION
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SURVEY LEGEND

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- CONTOURS - MINOR
- X 50.00 SPOT ELEVATION
- O/E OVERHEAD ELECTRIC
- U/E UNDERGROUND ELECTRIC
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- WS WATER SERVICE
- COMM COMMUNICATIONS MAIN
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- SAN SANITARY SEWER
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- HYDRANT

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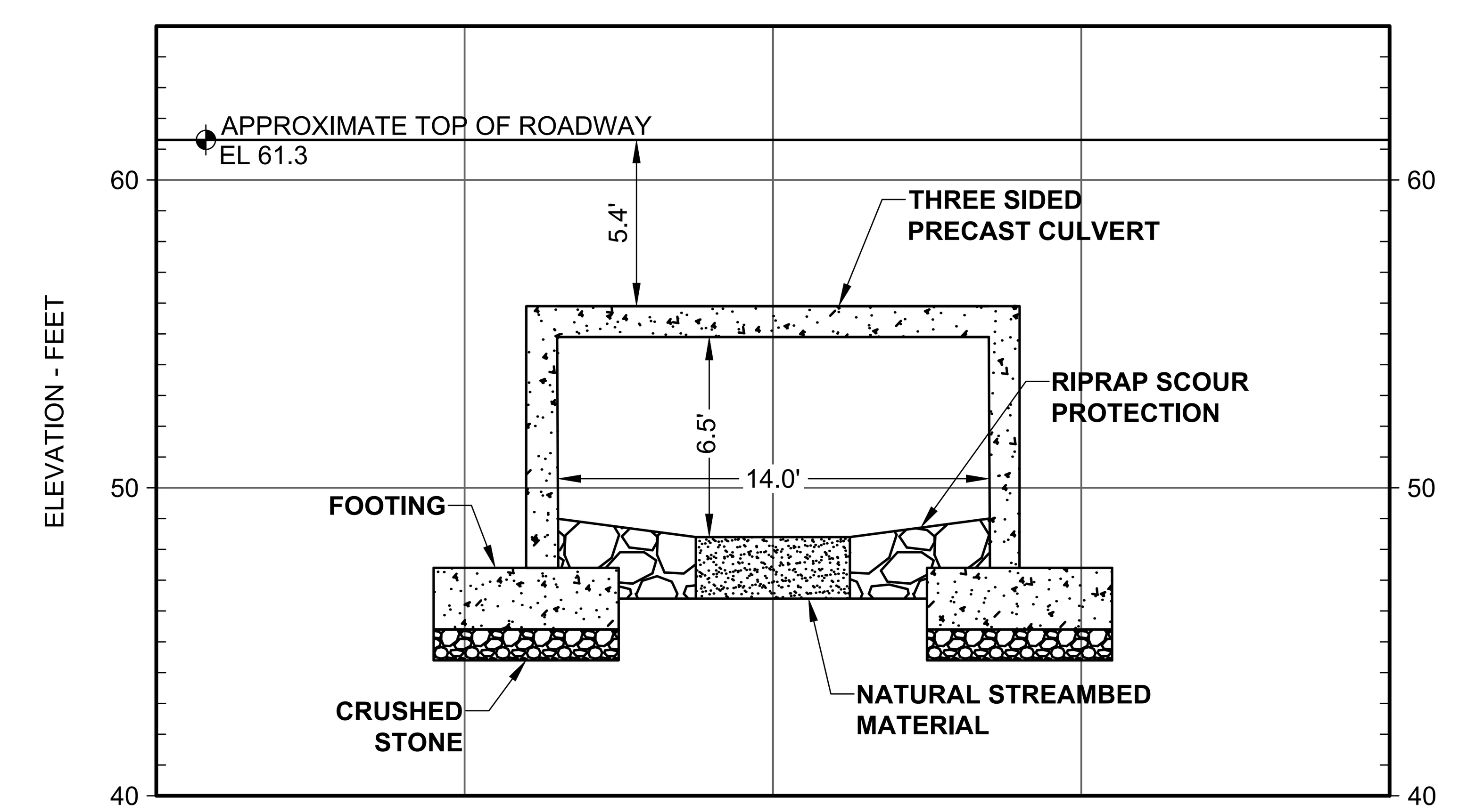
ESTIMATED BANKFULL WIDTH: 10 FEET



0 2.5 5 10
SCALE, FEET

5 TYPICAL CULVERT CROSS SECTION

SCALE: 1"=5'

NOT FOR CONSTRUCTION

Attention: If this scale bar does not measure 1" then drawing is not original scale.	DRAFT	Designed: MEC Drawn: MEC Checked: Approved: P.E. No: GEI Project 2202137

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MARE BROOK CULVERT AND COFFIN ICE POND DAM CONCEPTUAL DESIGN

BRUNSWICK, MAINE

NO	DATE	ISSUE/REVISION	APP
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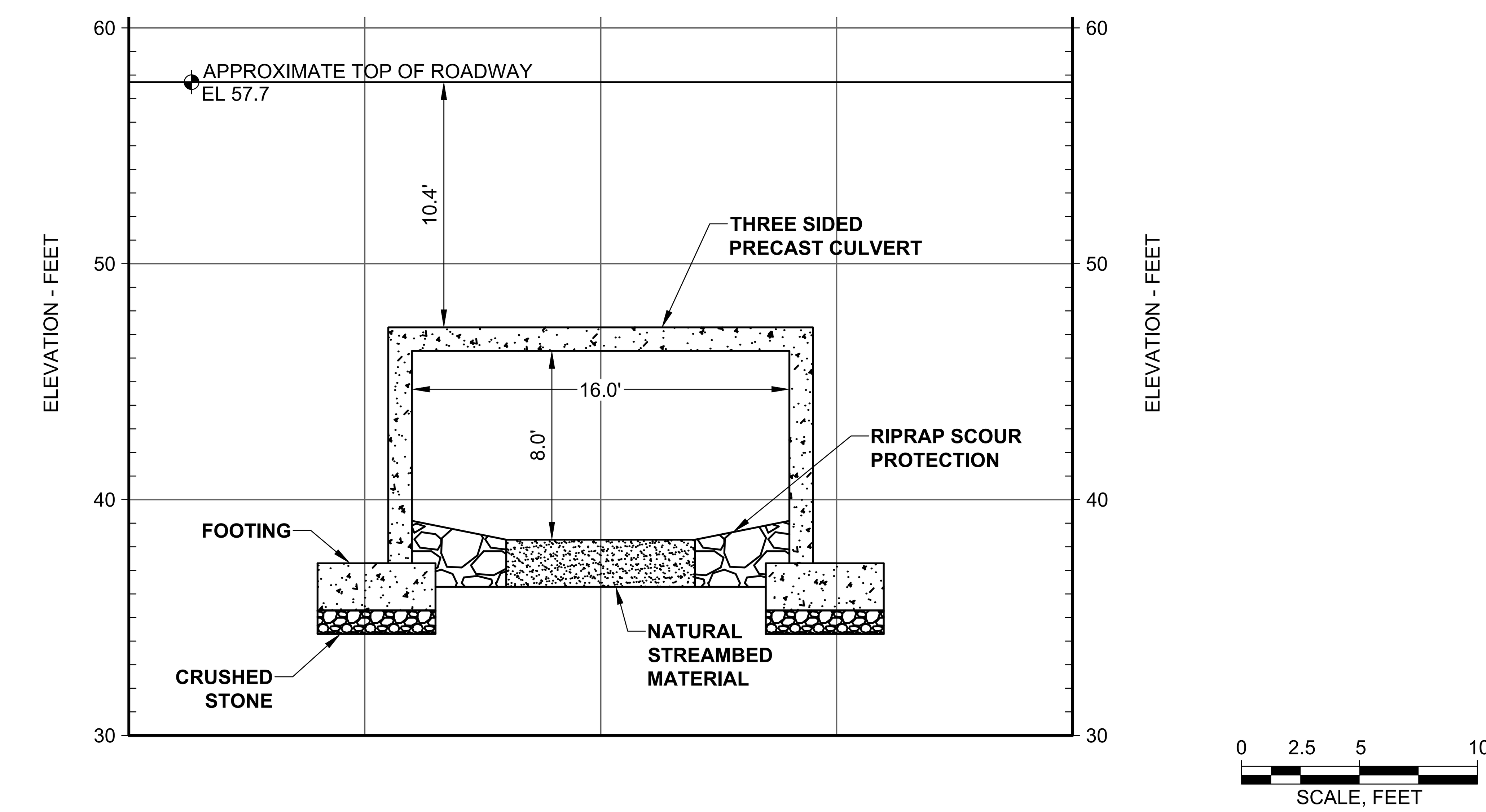
SHEET NAME: **MEADOWBROOK ROAD CULVERT CONCEPT DESIGN**

SHEET NO. 5

HARPSWELL ROAD CULVERT SITE PLAN
SCALE: 1" = 20'



6 TYPICAL CULVERT CROSS SECTION
SCALE: 1"=5'

NOT FOR CONSTRUCTION

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SURVEY LEGEND

- CONTOURS - MAJOR
- CONTOURS - MINOR
- X 50.00 SPOT ELEVATION
- O/E OVERHEAD ELECTRIC
- U/E UNDERGROUND ELECTRIC
- WM WATER MAIN
- WS WATER SERVICE
- COMM COMMUNICATIONS MAIN
- NGAS NATURAL GAS
- SAN SANITARY SEWER
- X FENCE
- HYDRANT

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ESTIMATED BANKFULL WIDTH: 13 FEET

Attention:
0 1"
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MARE BROOK CULVERT AND COFFIN ICE POND DAM CONCEPTUAL DESIGN

BRUNSWICK, MAINE

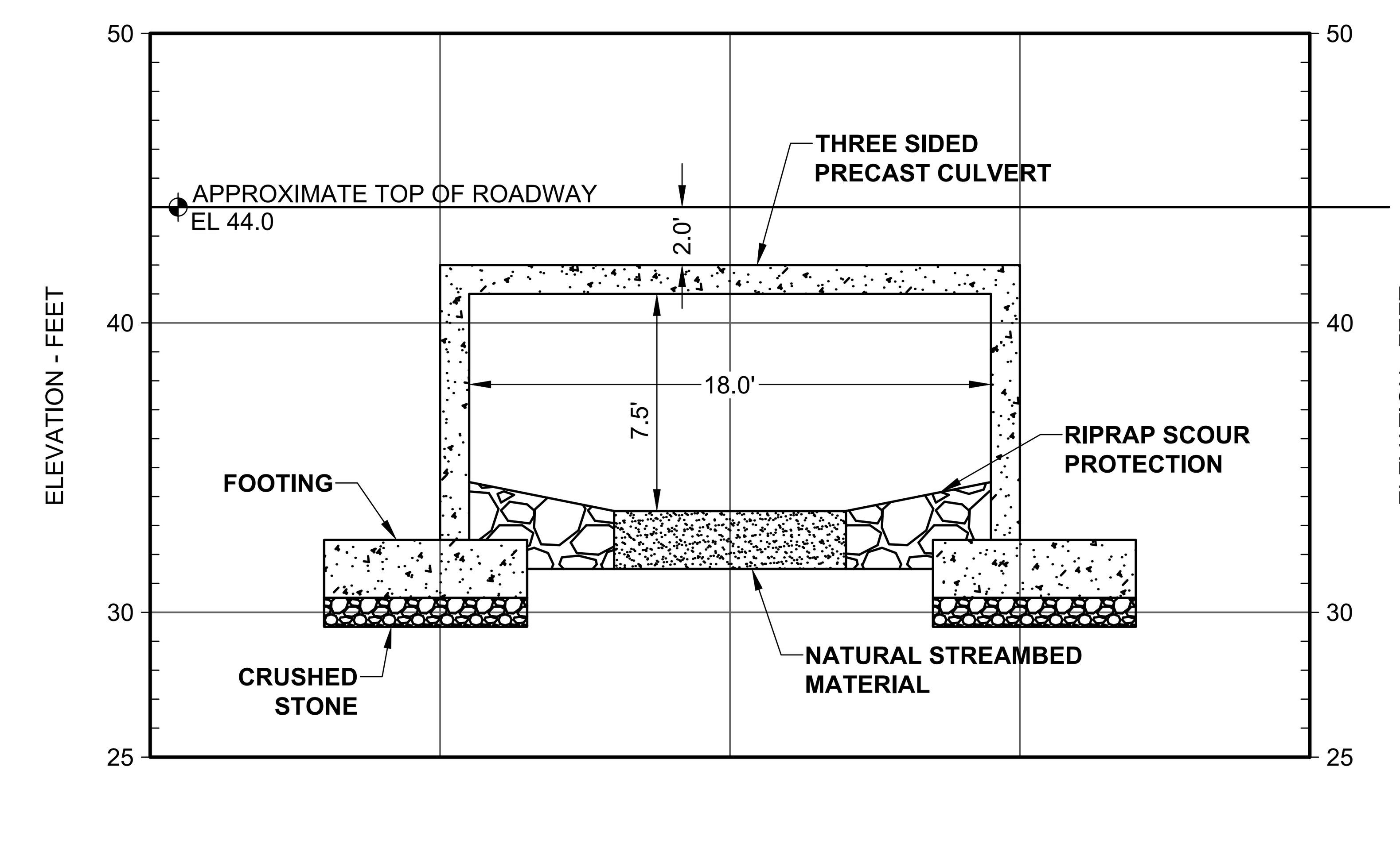
NO	DATE	ISSUE/REVISION	APP
0			

SHEET NAME: **HARPSWELL ROAD CULVERT CONCEPT DESIGN**

SHEET NO. 6

SECURITY ROAD CULVERT SITE PLAN

SCALE: 1" = 20'



7 TYPICAL CULVERT CROSS SECTION

SCALE: 1"=5'

ABBREVIATIONS

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DIA	=	DIAMETER
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ESTIMATED BANKFULL WIDTH: 15 FEET

NOT FOR CONSTRUCTION

Attention: 0 1" If this scale bar does not measure 1" then drawing is not original scale.

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MARE BROOK CULVERT AND COFFIN ICE POND DAM CONCEPTUAL DESIGN

BRUNSWICK, MAINE

NO	DATE	ISSUE/REVISION	APP
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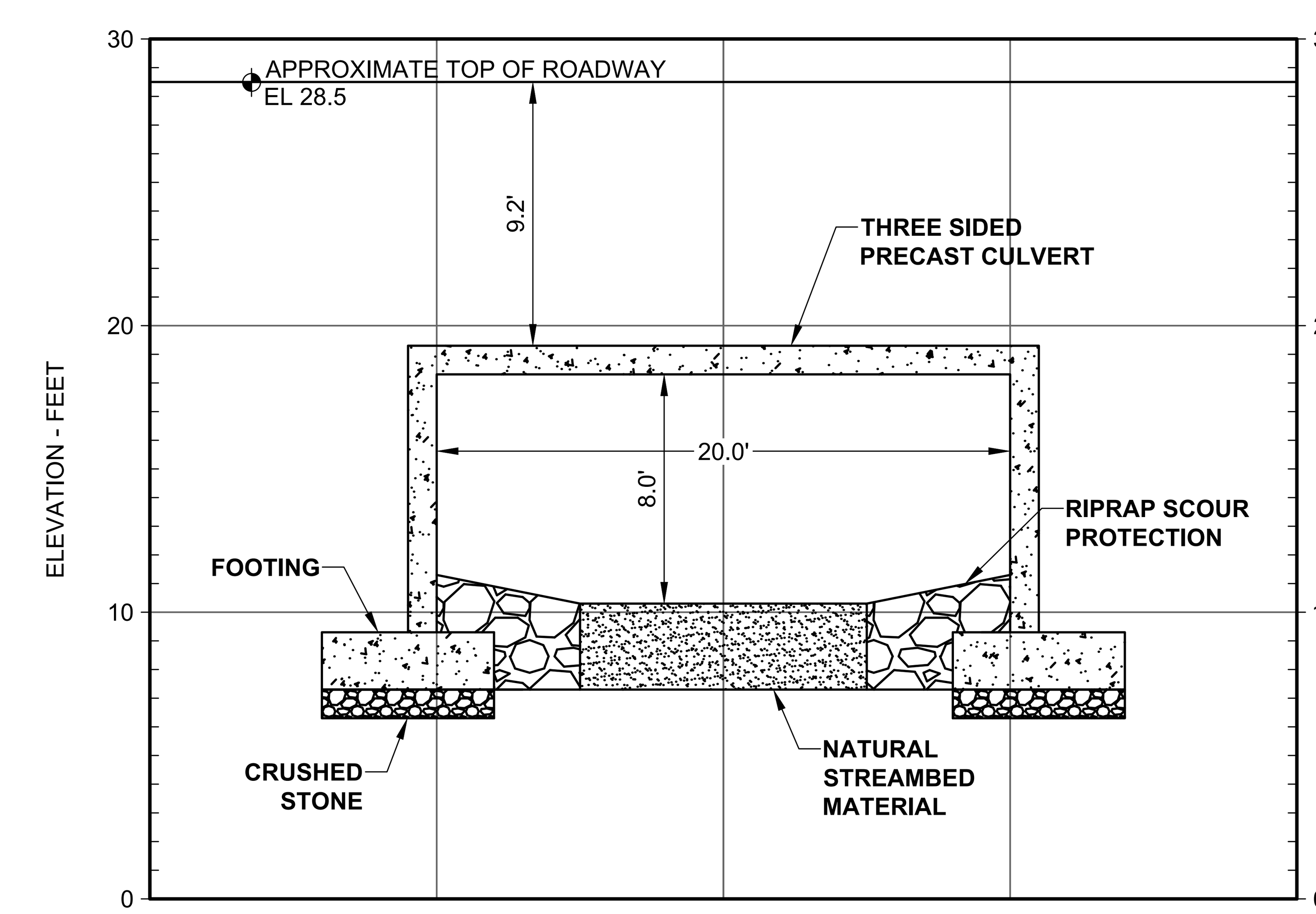
SHEET NAME	SHEET NO.
SECURITY ROAD CULVERT CONCEPT DESIGN	7

CHMURA, MARC B:\Working\BRUNSWICK.ME. TOWN OF\2202137 Mare Brook H_H\00_CAD\Design\Sheets\Marebrook_2202137_ConceptPlans.dwg - 8/27/2024

0 20 40
SCALE, FEET

EAGLE DRIVE CULVERT SITE PLAN

SCALE: 1" = 20'



0 2.5 5 10
SCALE, FEET

8 TYPICAL CULVERT CROSS SECTION

SCALE: 1"=5'

ABBREVIATIONS

AC	=	ASBESTOS CEMENT
CL	=	CENTERLINE
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ESTIMATED BANKFULL WIDTH: 16 FEET

NOT FOR CONSTRUCTION

Attention: 0 1" If this scale bar does not measure 1" then drawing is not original scale.

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MARE BROOK CULVERT AND COFFIN ICE POND DAM CONCEPTUAL DESIGN

BRUNSWICK, MAINE

NO	DATE	ISSUE/REVISION	APP
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SHEET NAME: **EAGLE DRIVE CULVERT CONCEPT DESIGN**

SHEET NO. 8

CHMURA, MARC B:\Working\BRUNSWICK ME, TOWN OF\2202137 Mare Brook H_H\00_CAD\Design\Sheets\Marebrook_2202137_ConceptPlans.dwg - 8/27/2024

Appendix D Detailed H&H Model Results

Baribeau Drive Cul4 & Cul5		
	Existing	Proposed
Geometry		
U/S Culvert Inv El. (ft)	73.8 / 73.59	72
D/S Culvert Inv El. (ft)	72.29 / 72.15	71.5
Length (ft)	106	108
Slope	1.4%	0.5%
Top of Road El. (ft)	78.1	78.1
Diameter (in)	30	-
Rise (ft)	-	3
Span (ft)	-	14
Crown El. (ft)	76.1	75
Bank Width (ft)	11	
100-Year Model Results		
Peak U/S WSEL (ft)	76.9	74.6
Freeboard (ft)	1.2	3.5
Flow Capacity	100%	88%
Peak D/S WSEL (ft)	74.2	74.3

Barrows Street Cul10		
	Existing	Proposed
Geometry		
U/S Culvert Inv El. (ft)	64.2 / 64.2	63.5
D/S Culvert Inv El. (ft)	63.3 / 63.0	63.1
Length (ft)	61	60
Slope	1.0%	0.7%
Top of Road El. (ft)	71.3	71.3
Diameter (in)	24 / 48	-
Rise (ft)	-	3.5
Span (ft)	-	16
Crown El. (ft)	66.2 / 68.2	67.0
Bank Width (ft)	11	
100-Year Model Results		
Peak U/S WSEL (ft)	71.6	66.8
Freeboard (ft)	-0.3	4.5
Flow Capacity	100%	93%
Peak D/S WSEL (ft	70.5	65.9

MacMillian Street Cul14		
	Existing	Proposed
Geometry		
U/S Culvert Inv El. (ft)	59.5 / 60.4	58.9
D/S Culvert Inv El. (ft)	59.2 / 58.9	58.5
Length (ft)	78	72
Slope	0.4%	0.6%
Top of Road El. (ft)	69.4	69.4
Diameter (in)	42 / 24	-
Rise (ft)	-	5
Span (ft)	-	14
Crown El. (ft)	63 / 62.4	63.9
Bank Width (ft)	10	
100-Year Model Results		
Peak U/S WSEL (ft)	70.5	63.8
Freeboard (ft)	-1.1	5.6
Flow Capacity	100%	98%
Peak D/S WSEL (ft	66.2	63.4

Maine Street Cul16		
	Existing	Proposed
Geometry		
U/S Culvert Inv El. (ft)	57.7	56
D/S Culvert Inv El. (ft)	57.2	55.7
Length (ft)	75	72
Slope	0.7%	0.4%
Top of Road El. (ft)	64.8	64.8
Diameter (in)	42 H x 84 W	55.7
Rise (ft)	-	4
Span (ft)	-	16
Crown El. (ft)	1.8	3.8
Bank Width (ft)	10	
100-Year Model Results		
Peak U/S WSEL (ft)	66.2	62.7
Freeboard (ft)	-1.4	2.1
Flow Capacity	100%	100%
Peak D/S WSEL (ft	62.7	61.7

Meadowbrook Road Cul17		
	Existing	Proposed
Geometry		
U/S Culvert Inv El. (ft)	48.73	48.4
D/S Culvert Inv El. (ft)	48	48
Length (ft)	87	72
Slope	0.8%	0.6%
Top of Road El. (ft)	61.3	61.3
Diameter (in)	48	-
Rise (ft)	-	6.5
Span (ft)	-	14
Crown El. (ft)	52.7	54.9
Bank Width (ft)	10	
100-Year Model Results		
Peak U/S WSEL (ft)	61.9	54.2
Freeboard (ft)	-0.6	7.1
Flow Capacity	100%	89%
Peak D/S WSEL (ft)	53.3	52.4

Harpswell Road Cul23		
	Existing	Proposed
Geometry		
U/S Culvert Inv El. (ft)	38.8	38.3
D/S Culvert Inv El. (ft)	39.14	38
Length (ft)	92	78
Slope	-0.4%	0.4%
Top of Road El. (ft)	57.7	57.7
Diameter (in)	60	-
Rise (ft)	-	8
Span (ft)	-	16
Crown El. (ft)	43.8	46.3
Bank Width (ft)	13	
100-Year Model Results		
Peak U/S WSEL (ft)	53.3	45.3
Freeboard (ft)	4.4	12.4
Flow Capacity	100%	88%
Peak D/S WSEL (ft)	42.4	42.6

Security Road (NoID#)*		
	Existing	Proposed
Geometry		
U/S Culvert Inv El. (ft)	35.8	33.5
D/S Culvert Inv El. (ft)	33.4	33.4
Length (ft)	60	42
Slope	4.0%	0.2%
Top of Road El. (ft)	44	44
Diameter (in)	48	-
Rise (ft)	-	7.5
Span (ft)	-	18
Crown El. (ft)	39.8	41
Bank Width (ft)	15	
100-Year Model Results		
Peak U/S WSEL (ft)	42.3	41.4
Freeboard (ft)	1.7	2.6
Flow Capacity	100%	100%
Peak D/S WSEL (ft)	36.2	40.9

Eagle Drive Cul29*		
	Existing	Proposed
Geometry		
U/S Culvert Inv El. (ft)	15.2	10.3
D/S Culvert Inv El. (ft)	13.5	10
Length (ft)	80	96
Slope	2.1%	0.31%
Top of Road El. (ft)	28.5	28.5
Diameter (in)	120	-
Rise (ft)	-	8
Span (ft)	-	20
Crown El. (ft)	25.2	18.3
Bank Width (ft)	16	
100-Year Model Results		
Peak U/S WSEL (ft)	23.6	17.2
Freeboard (ft)	5.0	11.4
Flow Capacity	84%	86%
Peak D/S WSEL (ft)	14.8	16.0

*Culvert has not been surveyed and elevations are estimated based on available LiDAR data

Appendix E Conceptual Coffin Ice Pond Dam Rehab Drawings

ICE POND DAM SITE PLAN

SCALE: 1" = 5'

ABBREVIATIONS

AC	=	ASBESTOS CEMENT
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SURVEY LEGEND

——— CONTOURS - MAJOR
— — — CONTOURS - MINOR
X 50.00 SPOT ELEVATION

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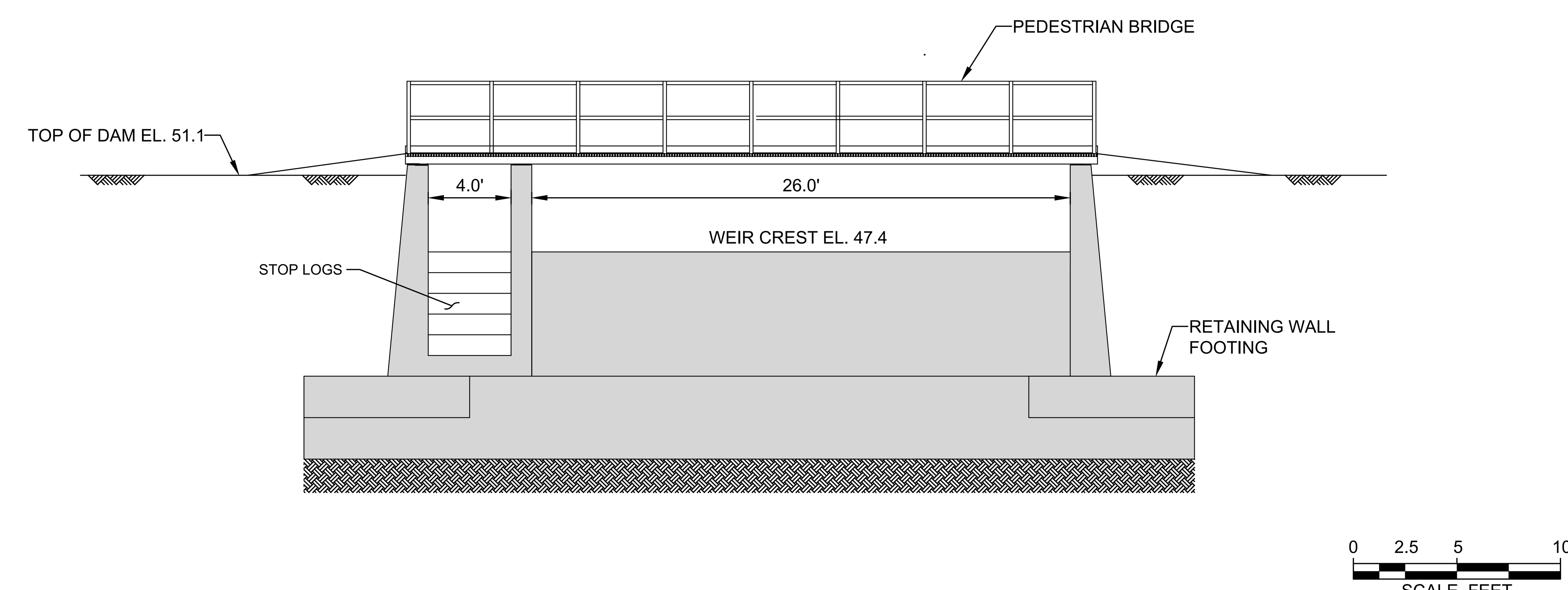

1 SPILLWAY SECTION

SCALE: 1"=5'

NOT FOR CONSTRUCTION

Attention: If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

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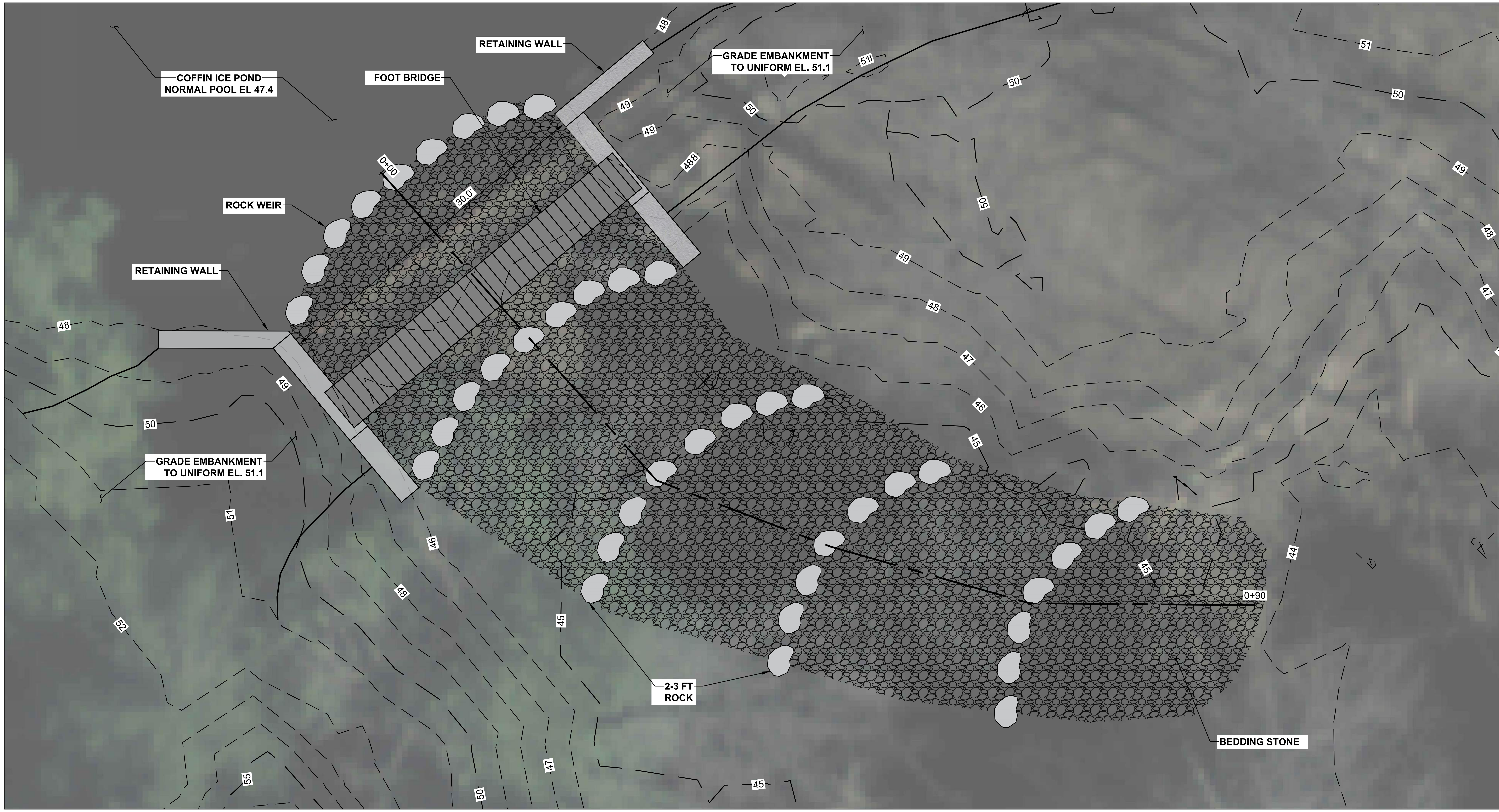
MARE BROOK CULVERT AND COFFIN'S ICE POND DAM CONCEPTUAL DESIGN

BRUNSWICK, MAINE

NO	DATE	ISSUE/REVISION	APP
0			

SHEET NAME	SHEET NO.
COFFIN'S ICE POND DAM REHABILITATION CONCEPT	1



COFFIN'S ICE POND DAM SITE PLAN

SCALE: 1" = 5'

0 2.5 5 10
SCALE, FEET

N

ABBREVIATIONS

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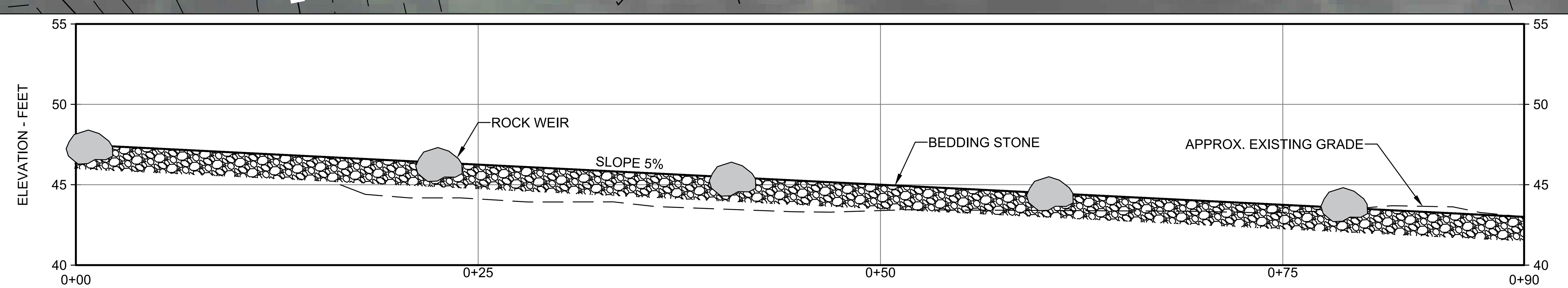
EL, ELEV	=	ELEVATION
FT	=	FEET OR FOOT
HDPE	=	HIGH DENSITY POLYETHYLENE
INV	=	INVERT
PVC	=	POLYVINYL CHLORIDE

SURVEY LEGEND

CONTOURS - MAJOR
CONTOURS - MINOR
X 50.00 SPOT ELEVATION



2 FISHWAY SECTION

SCALE: 1"=5'

NOTES:

1. CONCEPT DRAWINGS ARE FOR INFORMATIONAL AND PLANNING PURPOSES ONLY. FINISHED DIMENSIONS, ELEVATIONS, AND CONSTRUCTION METHODS TO BE DETERMINED DURING FINAL DESIGN.
2. AERIAL IMAGE OBTAINED FROM MAINE.GOV/GEOLIB/IMGDISCOVERY/SITE/, DATED 2018.
3. HORIZONTAL DATUM: NORTH AMERICAN DATUM OF 1983 (NAD83) MAINE STATE PLANE WEST – US SURVEY FOOT.
4. VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88) – US SURVEY FOOT.
5. COORDINATES AND ELEVATIONS WERE NOT COLLECTED BY A LICENSED SURVEYOR AND ARE NOT INTENDED TO REPLACE A LAND SURVEY BY A LICENSED SURVEYOR.
6. CONTOURS DISPLAYED AT 1-FOOT INTERVALS (MINOR) WERE GENERATED USING LIDAR DATA FROM 2020 USGS LiDAR: SOUTH COASTAL MAINE (Q22).

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	MEC
Drawn:	MEC
Checked:	
Approved:	
P.E. No:	
GEI Project	2202137

GEI Consultants
GEI CONSULTANTS, INC.
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TOWN OF BRUNSWICK, MAINE

85 UNION STREET
BRUNSWICK, ME 04011

MARE BROOK CULVERT AND COFFIN'S ICE POND DAM CONCEPTUAL DESIGN

BRUNSWICK, MAINE

NO	DATE	ISSUE/REVISION	APP
0			

SHEET NAME: **COFFIN'S ICE POND DAM FISHWAY CONCEPT**

SHEET NO. 2

CHMURA, MARC \\geiconsultants.com\data\Data_Storage\Working\BRUNSWICK ME, TOWN OF\2202137 Mare Brook H_H\00_CAD\Design\Sheets\Marebrook_2202137_Fishway.dwg - 8/27/2024

Appendix F Past Culvert Replacement Bid Estimates

	Town	Street	Bid Date	Span (ft)	Rise (ft)	Length (ft)	Area (sq/ft)	Type	Lowest bid	Average Bid	Cost/sq ft of Culvert (Low Bid)	Cost/sq ft of Culvert (Avg Bid)	Lowest Bid By:
Span ≤16 ft	Brunswick	Richards Drive	3/22/2024	8.00	6.00	72	576	Precast Concrete Box Culvert	$233,600	$327,423	$406	$568	Ray Labbe & Sons, INC.
	Denmark	E Main St	6/28/2023	13.00	8.00	148	1924	Precast Concrete Box Culvert	$597,280	$1,044,409	$310	$543	Skid Steer Services
	Woodland	New Sweden Road	4/26/2023	15.00	10.00	102	1530	Precast Concrete Box Culvert	$577,919	$730,589	$378	$478	Ed Pelletier & Sons, CO.
	Haynesville	Military Road	3/15/2023	14.00	6.00	84	1176	Precast Concrete Box Culvert	$496,241	$621,846	$422	$529	J Mclaughlin Construction, LLC
								Average	$476,000	$681,000	$379	$529	
Span >16 ft	Warren	Ridge Road	2/15/2023	17.00	7.00	100	1700	Precast Concrete Box Culvert	$775,126	$967,298	$456	$569	Bangor Lawn & Landscape
	New Sharon	Mile Hill Road	1/25/2023	18.00	10.00	148	2664	Precast Concrete Box Culvert	$1,821,754	$1,941,754	$684	$729	Eurovia Atlantic Coast LLC dba Northeast Paving
	Byron	Swift River Road	5/19/2021	23.00	10.00	97	2231	Precast Concrete Box Culvert	$1,069,519	$1,210,836	$479	$543	T Buck Construction, INC.
	Stockton Springs	Acadia Highway	4/29/2020	21.00	10.00	200	4200	Precast Concrete Box Culvert	$1,195,724	$1,747,023	$285	$416	F C Work & Sons, INC.
								Average	$1,216,000	$1,467,000	$476	$564	