SAWYER ROAD CULVERT TIDAL CROSSING ASSESSMENT

CAPE ELIZABETH & SCARBOROUGH, MAINE

PRELIMINARY DESIGN REPORT

ACADIA CIVIL WORKS
ENGINEERING DESIGN & CONSULTATION

DECEMBER 31, 2019

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PRELIMINARY DESIGN REPORT

SAWYER ROAD CULVERT
TIDAL CROSSING ASSESSMENT

CAPE ELIZABETH & SCARBOROUGH, ME

December 31, 2019

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PRELIMINARY DESIGN REPORT

SAWYER ROAD CULVERT – TIDAL CROSSING ASSESSMENT
CAPE ELIZABETH & SCARBOROUGH, ME

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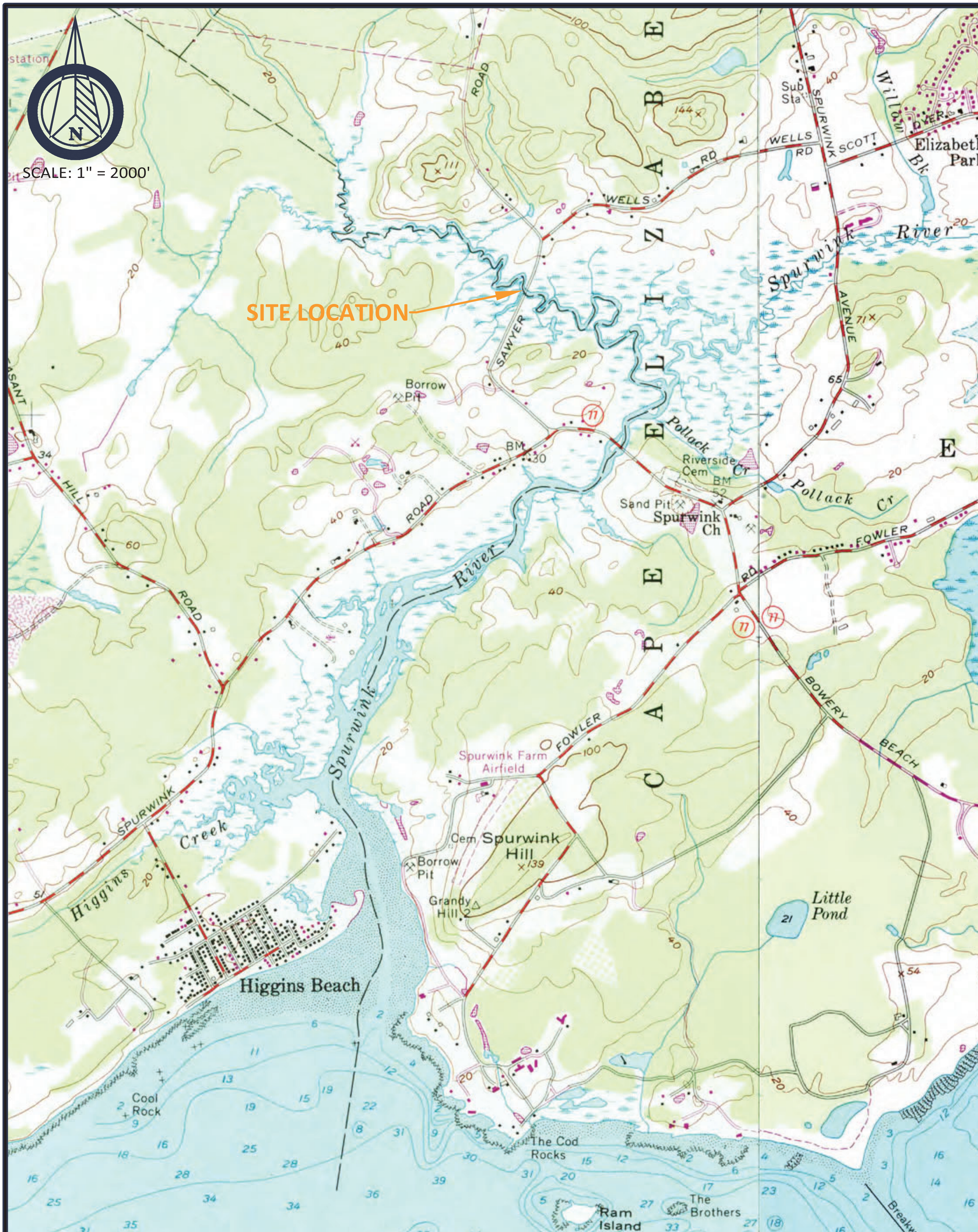
SECTION 1
INTRODUCTION

1.1 BACKGROUND

Sawyer Road crosses the Spurwink River in tidal areas of the Spurwink Marsh. A location map of the site is shown on the following page as Figure 1. The structure is an Aluminum culvert with an approximate span of 12 feet (measured along the direction of travel) and a height of approximately 11 feet. The structure was built in 1997 and passes an average of 1080 daily vehicular trips (2016).

Existing Aluminum Culvert Crossing at Sawyer Road
(Photo Credit: Wells National Estuarine Research Reserve)

Sawyer Road is overtopped and flooded during certain high tides, which can occur multiple times a year. During these flood periods, the roadway is closed, and vehicular traffic is rerouted. In addition to the flooding, the crossing infrastructure is inadequate to convey the ebb and flow of the tide. This has resulted in localized erosion in the vicinity of the crossing, as well as impacts to tide marsh habitats more broadly.



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SITE LOCATION MAP
SAWYER ROAD CROSSING

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FIGURE 1

Sawyer Road Crossing Overtopping During High Tide on 3/2/2018
(Photo Credit Town of Cape Elizabeth)

In 2017, the Maine DOT performed an inspection of the crossing structure. A copy of the inspection report is included as Appendix A. The primary conclusion of the report is that holes were found during underwater inspection of the structure. The report continues to state that these holes should be addressed as soon as practical to ensure continued safe use of the bridge.

The crossing connects the Maine Towns of Cape Elizabeth and Scarborough, located to the north and south of the Spurwink River (respectively). Both municipalities have a stake in this infrastructure as it serves each community and they share ownership.

Portions of the Spurwink Marsh, including the Sawyer Road Crossing, are located within the U.S. Fish and Wildlife Service's Rachel Carson National Wildlife Refuge. The Rachel Carson NWR was established in 1966 in cooperation with the State of Maine to protect valuable salt marshes and estuaries. Therefore, the USFWS is also a stakeholder in the crossing, as it effects tidal influence and the associated salt marsh ecosystem within the Refuge.

The Maine Coastal Program, in partnership with the Wells National Estuarine Research Reserve (WNERR) and the Casco Bay Estuary Partnership (CBEP) have all identified this location as a priority for restoration. As such, these organizations have contributed funding and time to assist the municipalities in evaluating the Sawyer Road infrastructure. While this is only one tidal crossing, the concerns of tidal flooding and undersized crossing infrastructure identified at Sawyer Road are issues that many municipalities across the Gulf of Maine are facing as sea levels rise and infrastructure ages. The Coastal Program, WNERR, and CBEP are stakeholders in this project, as well as the assessment, design, and planning of future tidal crossings throughout the State.

Acadia Civil Works was retained by the Town of Cape Elizabeth to work in partnership with the aforementioned group of stakeholders. A primary goal of our work was to provide preliminary engineering recommendations to improve the crossing infrastructure at Sawyer Road, while also incorporating goals of this diverse group of stakeholders. Our scope of work included the requisite hydrologic, hydraulic, and engineering analysis, as well as a series of stakeholder meetings and discussions about the Sawyer Road Crossing.

Sawyer Road Crossing Overtopping During High Tide on 12/14/2019
(Photo Credit: Casco Bay Estuary Partnership)

1.2 PURPOSE OF REPORT

The purpose of this report is to provide preliminary design guidance on engineering solutions associated with improvements to the Sawyer Road crossing infrastructure. This includes a summary of pertinent hydrologic and hydraulic analyses of the Spurwink River at its crossing with Sawyer Road, as well as associated tidal effects and sea level rise projections at this location. The report concludes with multiple conceptual design recommendations that will provide for serviceable and dependable roadway infrastructure, as well as accommodate sea level rise and associated salt marsh migration.

1.3 PROJECT TEAM AND STAKEHOLDERS

Throughout the report there is reference to the Project Team and/or Stakeholders. The following people comprise the group:

- Maureen O'Meara, Town of Cape Elizabeth
- Robert Malley, Town of Cape Elizabeth
- Jami Fitch, Town of Scarborough
- Angela Blanchett, Town of Scarborough
- Michael Shaw, Town of Scarborough
- Slade Moore, Maine Coastal Program
- Matt Craig, Casco Bay Estuary Partnership
- Kate O'Brien, Rachel Carson National Wildlife Refuge
- Bri Benvenuti, Rachel Carson National Wildlife Refuge
- Susan Adamovicz, Rachel Carson National Wildlife Refuge
- Jeremy Bell, The Nature Conservancy
- Jacob Aman, Wells National Estuarine Research Reserve
- Joseph McLean, Acadia Civil Works

SECTION 2

SECTION 2
SURVEY AND EXISTING CONDITIONS DATA

2.1 INTRODUCTION

A variety of survey and data collection activities were undertaken to support this assessment. This includes new data collection, such as the use of an Unmanned Aerial Vehicle (UAV) to take detailed aerial surveys of the site conditions, as well as a review of readily available data from GIS sources and record documents. Each of the substantive data collection efforts and data sets utilized in this assessment are described further in the following sections.

While this assessment is specifically focused on the Sawyer Road Crossing of the Spurwink River, the scope of data collection efforts covered the extent of the Spurwink Marsh, as well as other significant road-marsh crossings that are hydraulically connected to the Sawyer Road infrastructure. Specifically, data collection efforts were also focused on the Bridge at Route 77, as well as the culvert crossing on Spurwink Road. A map depicting these crossing locations is provided as Figure 2 – Study Area Map on the following page.

2.2 AERIAL PHOTOGRAMETRIC SURVEY

Acadia Civil Works retained Wright-Pierce to perform existing conditions survey within the study area via the use of an Unmanned Aerial Vehicle (UAV) in November of 2018. Detailed aerial photography was collected at the three major crossings in Spurwink Marsh: State Route 77, Spurwink Road, and Sawyer Road. The mosaic of photos taken at each location is provided as Figures 3, 4, and 5, respectively, on the following pages.

In addition to the photography, the Wright-Pierce surveyors utilized photogrammetric techniques to develop a topographic surface and an existing conditions topographic plan of the Sawyer Road crossing. A perspective view of the topographic relief of the Sawyer road site, as well as a clip of the CAD survey plan are provided as Figures 6 and 7, respectively.

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STUDY AREA MAP
SAWYER ROAD CROSSING ASSESSMENT

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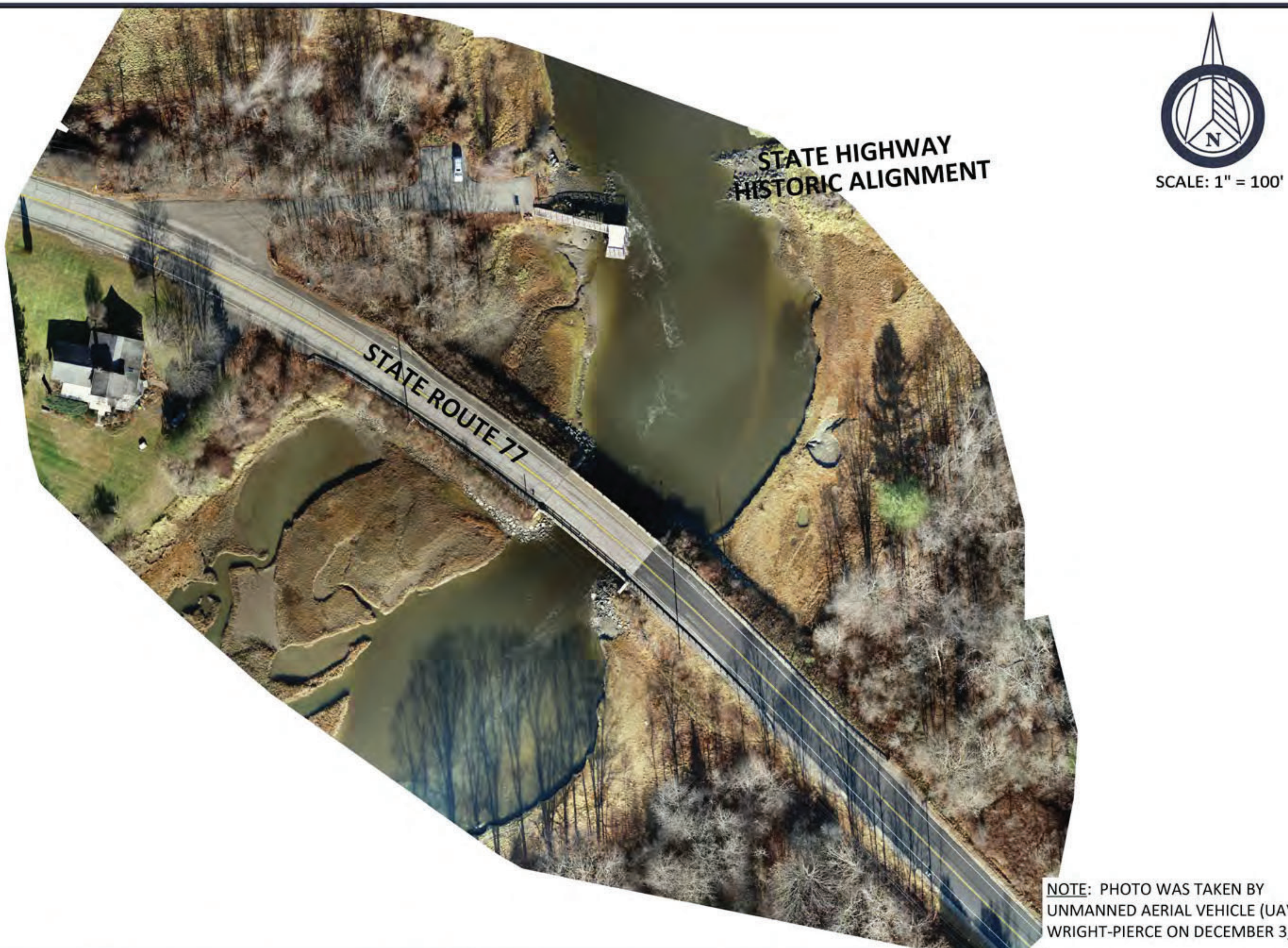
FIGURE 2



NOTE: PHOTO WAS TAKEN BY UNMANNED AERIAL VEHICLE (UAV) BY WRIGHT-PIERCE ON DECEMBER 3, 2018.

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STATE ROUTE 77 BRIDGE - AERIAL PHOTO
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FIGURE 3

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SPURWINK ROAD CROSSING - AERIAL PHOTO
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FIGURE 4

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SAWYER ROAD CROSSING - AERIAL PHOTO
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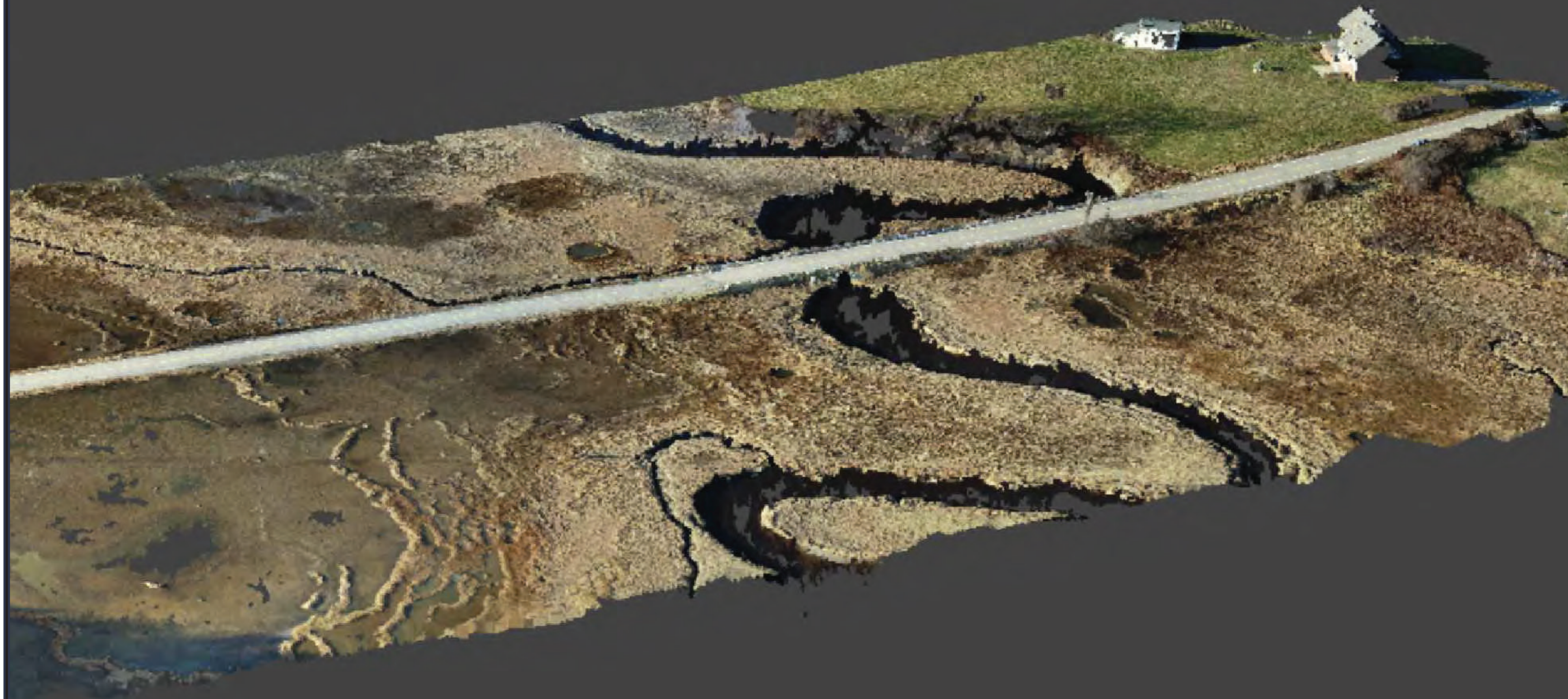
FIGURE 5



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SAWYER ROAD - TOPOGRAPHIC PERSPECTIVE
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FIGURE 6

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SAWYER ROAD - EXISTING CONDITIONS PLAN
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FIGURE 7

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2.3 LiDAR DATA

Light detection and ranging (LiDAR) is a survey technique that uses focused light or lasers to rapidly scan and measure distances to a variety of fixed points. The resulting measurements create a "cloud" of points that describe the scanned object. There are a variety of LiDAR data collection methods, however aerial vehicles (airplanes) are a popular means of providing LiDAR devices with a good vantage of the landscape and effective collection of ground surface elevation data. Several governmental agencies have funded large scale LiDAR data collection efforts that span much of the state of Maine. In particular, the National Oceanic and Atmospheric Administration (NOAA) has collected multiple sets of LiDAR elevation data along the Gulf of Maine Coast.

For this study, two separate LiDAR data sets were considered and utilized. One is a dataset commissioned by NOAA in 2004, which was focused on the coastline. As indicated by the metadata, this data was collected at a nominal two (2) meter post spacing between points. Unfortunately, this data set does not cover the entire footprint of Spurwink Marsh, however it did provide a useful second set of data at some key locations within the study area.

The second dataset utilized was collected from flights in 2006 and commissioned by the Federal Emergency Management Agency (FEMA). This 2006 data was focused on all of York and Cumberland Counties, as such it also covered the entire Spurwink Marsh footprint. As such, it was primarily utilized in the study for a complete and comprehensive description of the marsh areas.

2.4 FIELD CREW SURVEY

Localized data was also collected at each crossing location via traditional survey methods. Staff from the Wells National Estuarine Research Reserve (WNERR) crew utilized a total station unit and an RTK GPS unit to collect roadway centerline elevations, culvert inverts, key marsh cross sections, as well as channel information within the Spurwink River. This survey data was provided to Acadia Civil Works electronically and was utilized to calibrate the large LiDAR data sets, as well as for the detailed channel information that was not provided in other data sets.

2.5 PLAN FILE REVIEW

Acadia Civil Works staff reviewed plans available on file with the Maine Department of Transportation (MDOT). Several record plan sets were found for the Route 77 Bridge Structure. The most notable record plans included a set from 1933 that depicts the historic alignment of the bridge structure. However, the most relevant set of record plans is a set of "as-built" plans for the current bridge structure from 1988.

Additionally, the MDOT also had a set of plans associated with the Sawyer Road crossing structure (identified as the 'Town Line Bridge"). This plan set describes the replacement of an approximate 11' bridge span with a new culvert structure dated 1963. This culvert was the likely predecessor to the existing culvert structure constructed in 1997.

2.6 PRIOR INSPECTION REPORTS

As noted in Section 1.1, the MDOT performed an inspection of the Sawyer Road crossing in 2017. The report of that inspection is included as Appendix A. In addition, the Town of Cape Elizabeth retained Sebago Technics, Inc. to perform a Town wide assessment of various culverts and habitats. This study included a section related to the Sawyer Road crossing of the Spurwink River and was published on March 8, 2019.

SECTION 3

SECTION 3
HYDROLOGIC DATA

3.1 INTRODUCTION

Hydrology is the science that encompasses the study of water on the Earth, both above and below the grounds surface. It is critical to understand the hydrologic conditions at a particular site when evaluating infrastructure options, as well as associated affects and impacts.

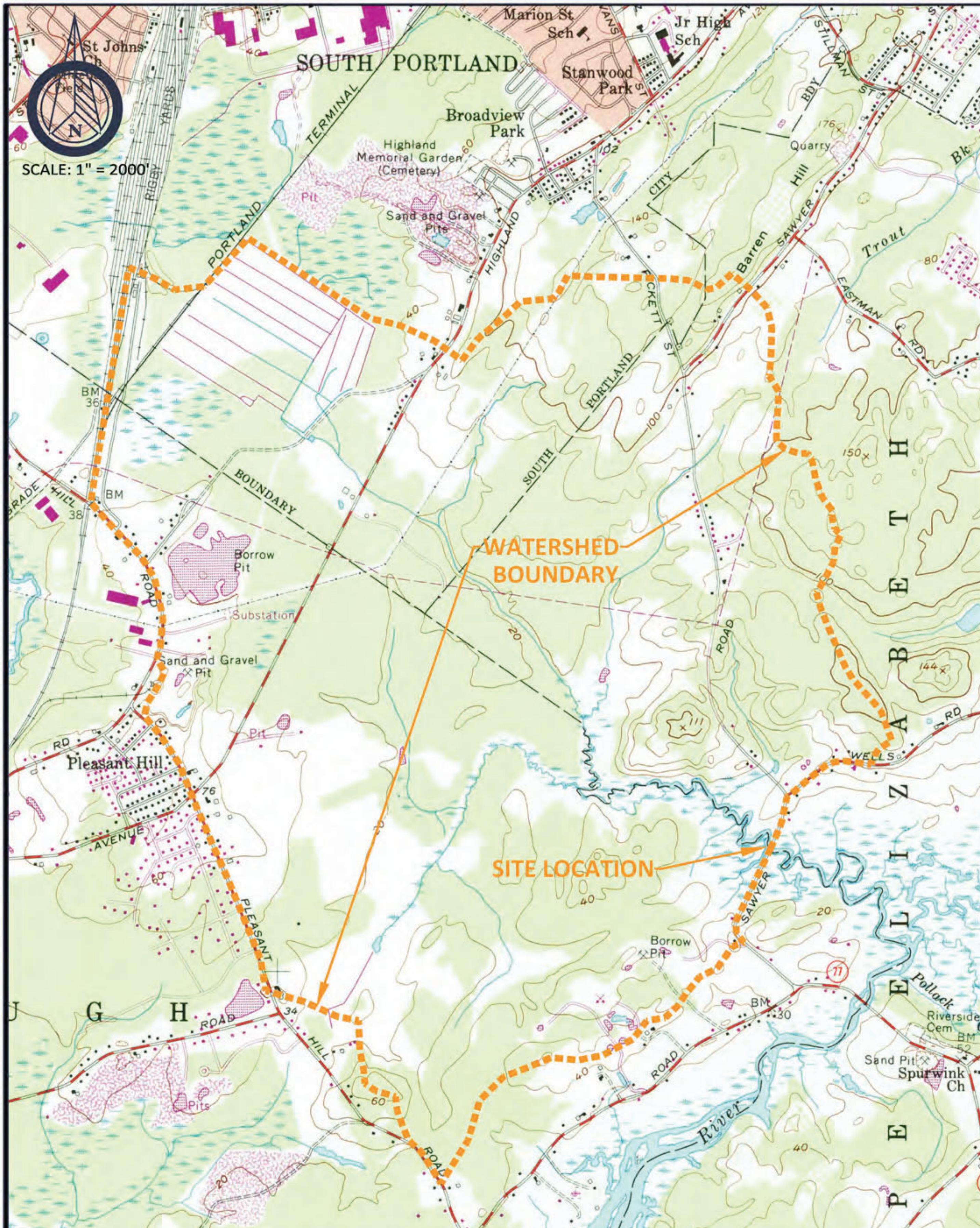
For the assessment at Sawyer Road we have focused on two primary hydrologic conditions. One condition is the surface water hydrology driven by rainfall, runoff, and groundwater conditions. This flow is generally watershed driven and represents the flows (both normal and extreme) that will be generated upstream of the crossing and will flow down through the structure. The second condition is the hydrology of the tidal driven waters.

In addition to evaluating conditions that exist today, the project team recognizes that ocean levels are rising. New infrastructure at Sawyer Road is likely to have design life of approximately 50 to 100 years. Over the course of that time, tidal hydrologic conditions are anticipated to change dramatically. This assessment also will look ahead to potential future tidal hydrologic conditions due to sea level rise.

3.2 WATERSHED HYDROLOGY

3.2.1 Watershed Characteristics

The Sawyer Road crossing has a tributary watershed of approximately 4.5 square miles. Of this area, approximately 0.35 square miles (7.8%) is mapped as a sand and gravel aquifer, and 1.0 square miles (23.0%) is wetland area as identified by the National Wetlands Inventory mapping. This 4.5 square mile water shed includes the areas of Spurwink Marsh upstream of Sawyer Road, as well as abutting development around the perimeter of the marsh and tributary stream channels. Figure 8, included on the following page, depicts the tributary watershed area to the project location overlain on the associated 7.5-minute USGS quadrangle.



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WATERSHED MAP
SAWYER ROAD CROSSING ASSESSMENT

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FIGURE 8

Discharges from this watershed form the western branch of the Spurwink River, which flows through the Spurwink Marsh and under Sawyer Road through the subject crossing infrastructure. There are no site-specific flow monitoring stations or data available within the watershed for this location.

3.2.2 Median Monthly Flows

If a person were to observe a stream on any given day, it is most probable that they would be witnessing the median flow condition (or something similar to the median condition). Certainly, periods of drought or periods of intense rainfall will influence those observations. However, statistically speaking, the median result is the one most likely to be experienced. These median flow rates are helpful to gauge the "typical" flow conditions at the site. The median condition for each month of a typical year is provided below in Table 3.1.

TABLE 3.1
ESTIMATED MEDIAN MONTHLY FLOW RATES

Month	Median Flow (cfs)
January	6.5
February	5.1
March	21.3
April	14.0
May	4.5
June	2.5
July	0.7
August	0.3
September	0.4
October	1.9
November	7.9
December	9.2

Acadia Civil Works utilized regression techniques via the USGS StreamStats webtool (the USGS StreamStats Report for this site is included as Appendix B) This methodology follows the equations and procedures established in USGS Scientific Investigations Report 2015-5151 to determine monthly flow rates at the crossing location. This methodology utilizes a number of stream flow gauging stations located around the state with a substantive history of recorded streamflow data to develop predictive equations based upon several explanatory variables. These variables include drainage basin area, areal fraction of the drainage basin underlain by sand and gravel aquifers, distance from the coast to the drainage basin centroid, mean drainage basin annual precipitation, and mean drainage basin winter precipitation.

It should be noted that some of the watershed characteristics are outside of the suggested range of parameters, and therefore these median monthly conditions have been extrapolated. Regardless, this technique provides a simple and relatively accurate means of understanding normal flow rates in the stream throughout the year.

3.2.3 Extreme Flow Events

During heavy rainfall and extreme events, flow within the Spurwink River will be much higher than the median conditions. An extreame event would be something that doesn't happen very often, such as a hurricane event or an very heavy rain storm coupled with melting snow or frozen ground. The likelihood of these rare events is often expressed as a "recurrence interval", such as the 100 year storm. Statistically, the 100-year storm will be equaled or exceeded at least once (and perhaps more than once) every 100-years. Another way of thinking about the reccurance interval is as its chance of annual occurance. For example a 100-year event has a 1% chance of occurring in any given year. Similarly, the 2-year event has a 50% chance occurring in any given year, and so on. The estimated extreame flow rates for the Sawyer Road crossing are shown below in Table 3.2.

TABLE 3.2
ESTIMATED EXTREME FLOW RATES

Recurrence Interval	Peak Flow (cfs)
1-year	30
2-year	97
5-year	148
10-year	181
25-year	237
50-year	268
100-year	314
250-year	344
500-year	411

To determine these extreme flow rates, Acadia Civil Works utilized regression techniques via the USGS StreamStats webtool (the USGS StreamStats Report for this site is included as Appendix B). This methodology follows the equations and procedures established in USGS Scientific Investigations Report 2015-5049. Similar to the methodology outlined in section 3.1.2, this methodology utilizes a number of stream flow gauging stations located around the state with a substantive history of recorded streamflow data to develop predictive equations based upon several explanatory variables. These variables include drainage basin area, as well as the areal fraction of NWI mapped wetland area.

It should be noted that some of the watershed characteristics are slightly outside of the suggested range of parameters, and therefore these extreme flow conditions have been extrapolated. Regardless, this technique provides a simple and relatively accurate means of understanding the magnitude of flows that can be generated during extreme events.

3.3 TIDAL HYDROLOGY

While the watershed hydrology is important to understand, tidal hydrology is more critical at Sawyer Road. The proximity of the Sawyer Road crossing to the open ocean, as well as its elevation below mean high tide levels, results in a substantial tidal influence at the crossing. As such, accuracy and understanding of tidal hydrology is a priority in this assessment.

3.3.1 Local Tidal Monitoring

Staff at the Wells National Estuarine Research Reserve (WNERR) deployed data loggers within the Spurwink Marsh to measure water surface elevations throughout the tidal cycle. These loggers were strategically placed both upstream and downstream of the three primary crossing locations (identified in Figure 2) and collected data at 15-minute intervals. At least two (2) weeks of upstream and downstream data was collected at each crossing location at different times over the course of 2018. The measured data is depicted below in the following figures (9 thru 11).

Figure 9 – Recorded Water Surface Elevations at Spurwink Road

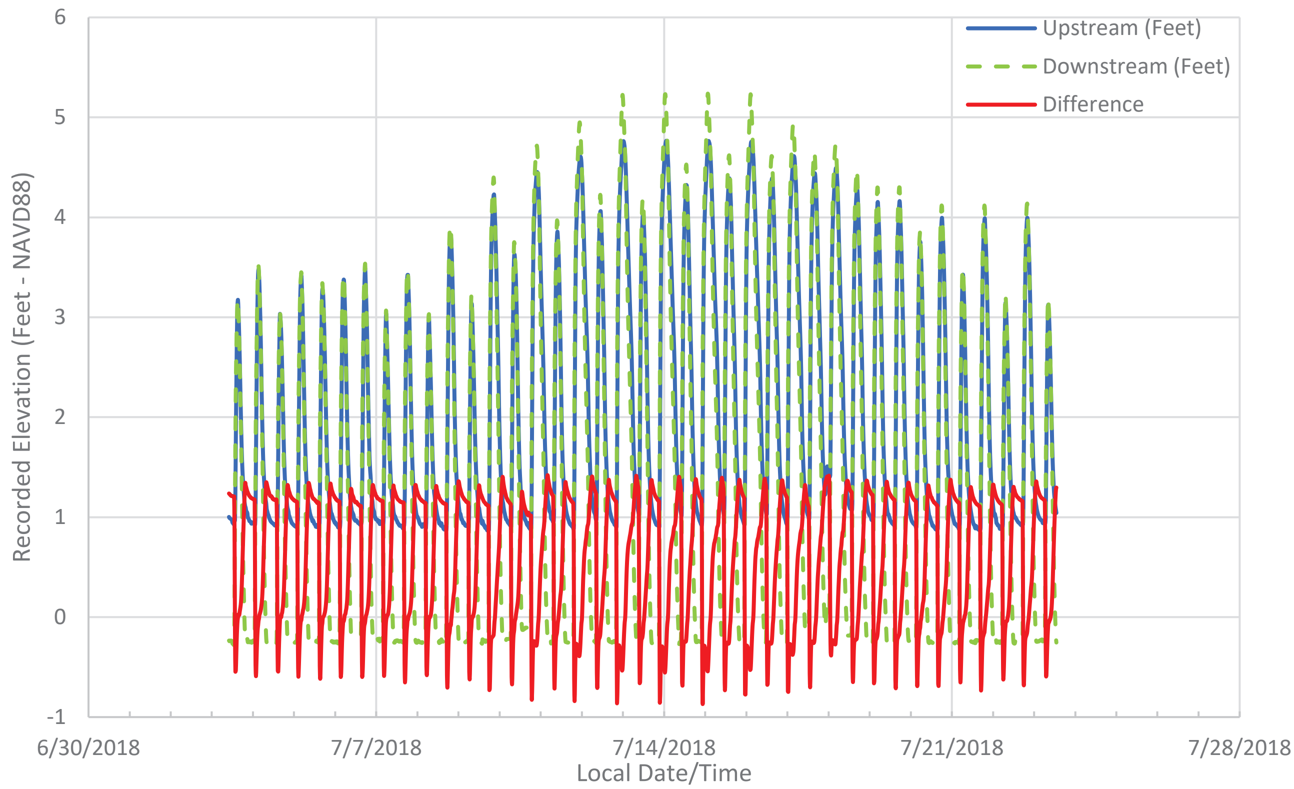


Figure 10 – Recorded Water Surface Elevations at Route 77 Bridge

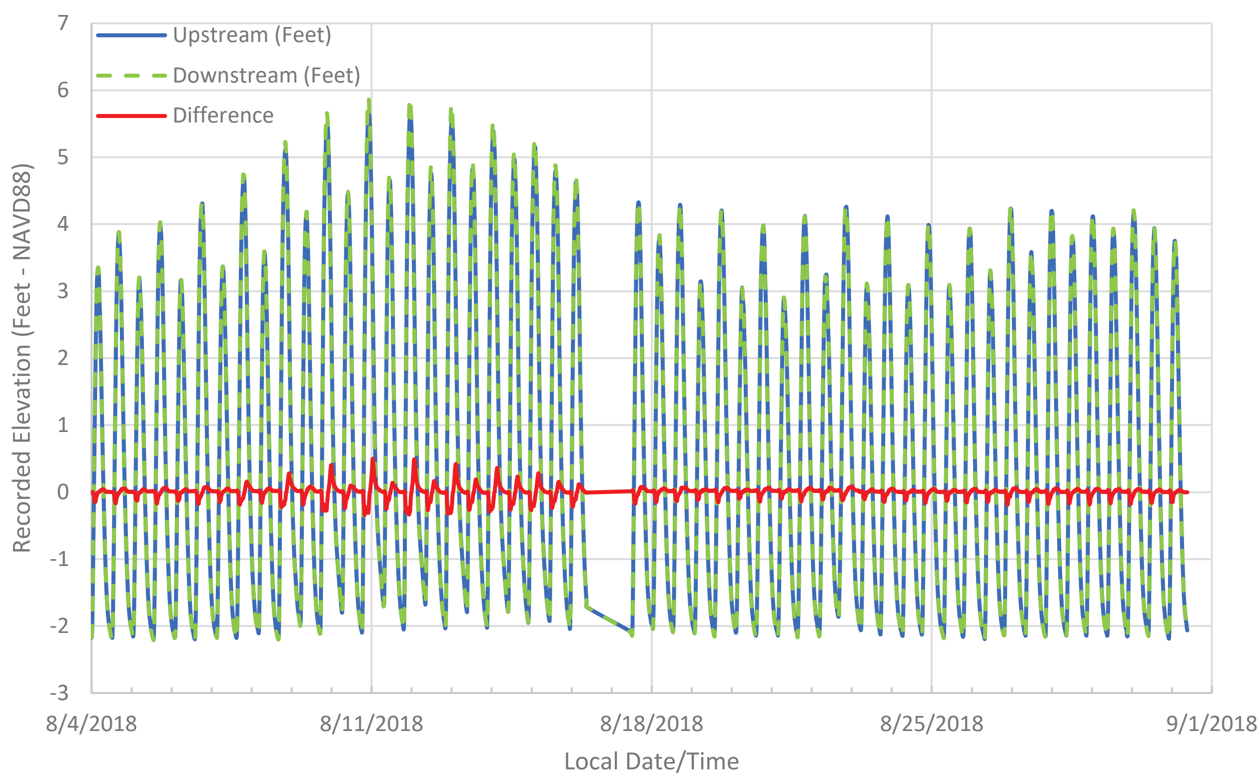
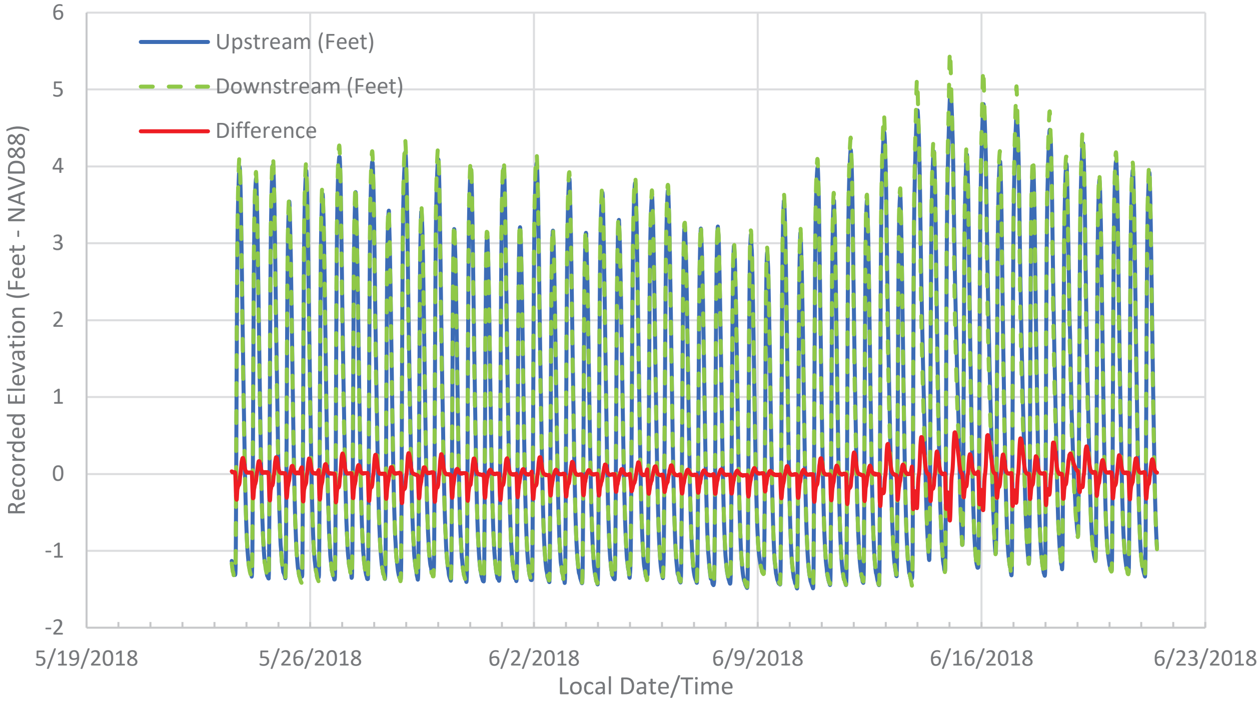


Figure 11 – Recorded Water Surface Elevations at Sawyer Road



As shown in Figures 9, 10, and 11, there is substantial tidal activity at each crossing location. Each figure contains data for both the upstream gauge and the downstream gauge. Additionally, a third dataset is plotted in red, which indicates the difference between the upstream and downstream values as the associated time of recording. A difference of zero (0) feet indicates that the upstream and downstream tidal observations are identical.

At Spurwink Road (Figure 9), there is substantial difference between upstream and downstream tidal elevations. This is most pronounced at the lower end of the tide cycle when upstream elevations are "hung" by the culvert crossing and the upstream area is impounded at higher elevations. However, the higher end of the tide cycle is also affected, as the downstream water surface reaches higher elevations than the upstream areas.

The Route 77 Bridge (Figure 10), does not vary much at all from downstream to upstream, which is reflected by the red "difference" line slightly oscillating around a value of zero (0). This indicates that the Route 77 bridge is somewhat effective at conveying the tide across the highway with minimal effect. However, it should be noted that the most significant difference to tidal elevations is during the higher tides (around 8/11/2018). As such, this may indicate that the Route 77 bridge will be a more substantial impact to the exchange of tides in the future as sea levels rise.

At the Sawyer Road crossing (Figure 11), three is not nearly as much difference between upstream and downstream as there is at Spurwink Road, however the difference is greater than that reflected at Route 77. However, similar to Route 77, it is notable that the most significant difference to tidal elevations is during the higher tides (around 6/16/2018). As such, this may indicate that the Sawyer Road Crossing will be a more substantial impact to the exchange of tides in the future as sea levels rise.

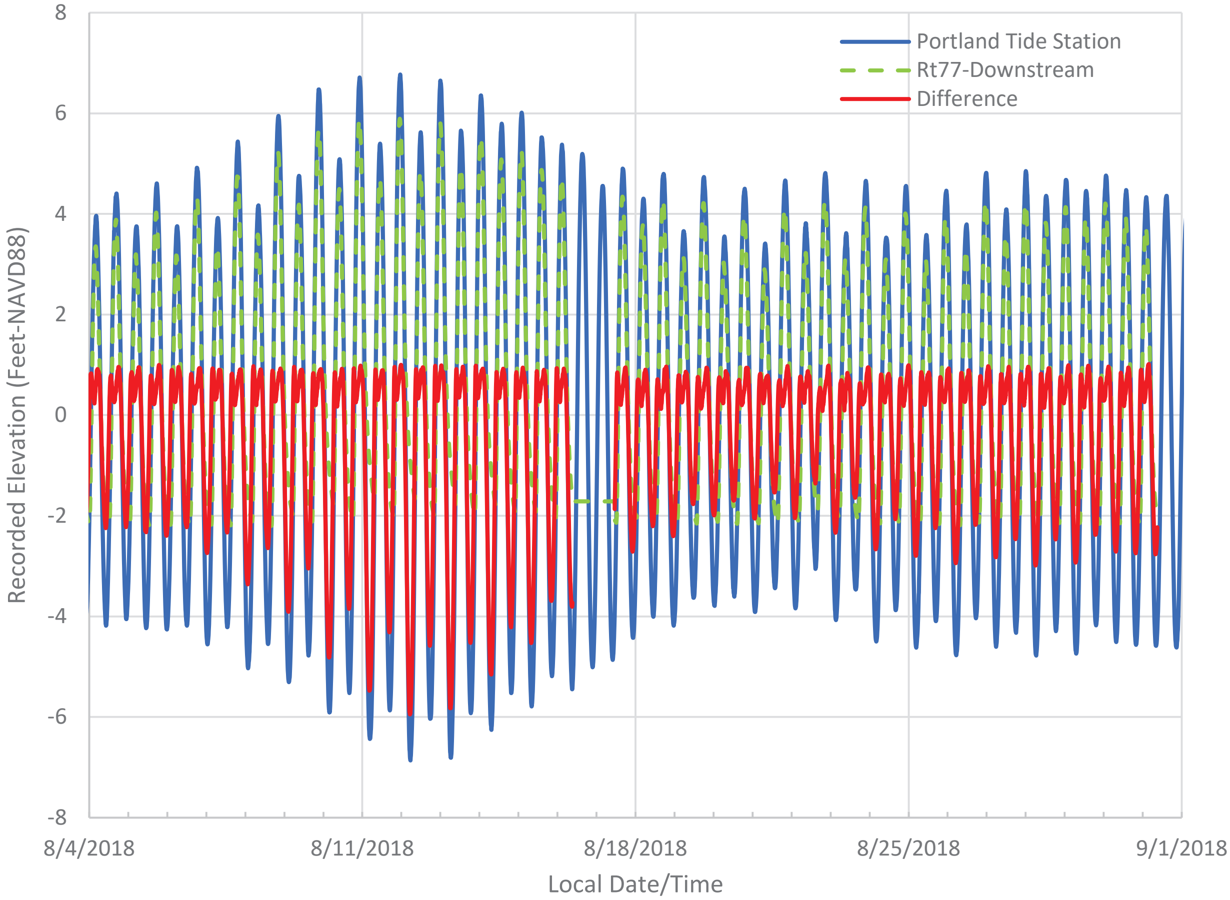
3.3.2 NOAA Tide Gauge Correlation

Collecting localized tidal hydrology data (as described in Section 3.2.1) is an important step in the understanding of tidal influence at the project site. However, these local data collection efforts are only a small snapshot in time, representing only a few weeks of a single year. Determining normal tidal conditions, as well as extreme tidal events require a much more extensive set of tidal data.
The most robust tidal information in close proximity to the project is at the NOAA Tide Station in Portland (Station ID: 8418150). The NOAA station in Portland was established in 1910 and the current installation of gauges have been in place since September of 1990. NOAA publishes a vast array of tidal statistics for the Portland Tide Gauge.

For the purposes of this assessment, a relationship between the local tide data collected by WNERR (described in Section 3.2.1) and the Portland Tide Gauge was developed. In particular, a correlation between the downstream data collected from the Route 77 Bridge (downstream extent of the study area) and the Portland Tide Gauge was evaluated. A comparison between the Portland Tide Gauge and the localized data is shown below in Figure 12.

It should be noted that the Portland Tide Gauge records data at 6 minute intervals. The data collected by WNERR was collected at 15 minute intervals. For the purposes of this exercise, the WNERR data was linearly interpolated to divide the data set into a corresponding 6 minute interval to best fit the data points with the Portland Tide Gauge.

Figure 12– Comparison of Portland Tide Gauge to the Recorded data Downstream of Route 77 (Overview)

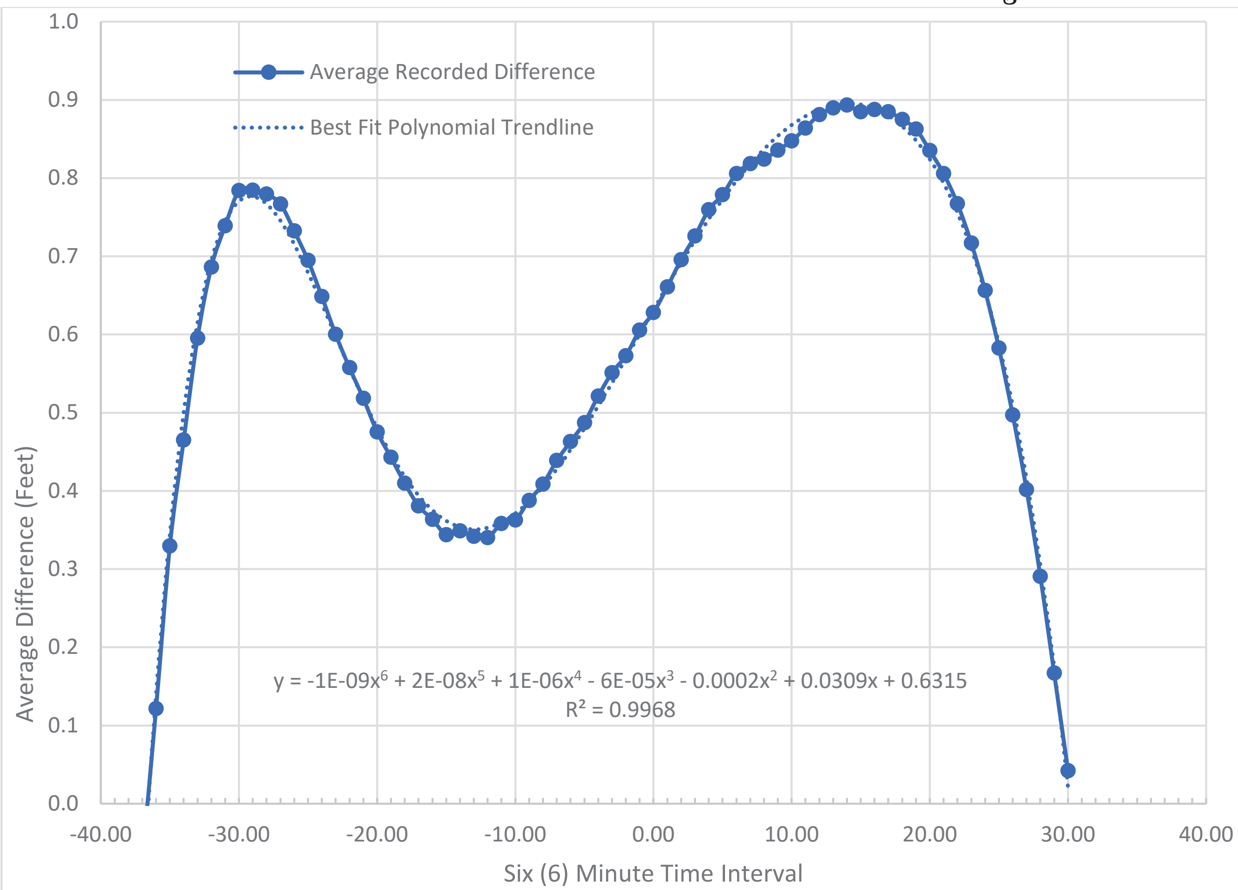


Note: The Portland Tide Gauge experiences peak high elevations approximately 24 minutes prior to the Route 77 Bridge. The Portland Tide Station Data shown on this figure has been translated in time to align the high tide elevations in each dataset.

As shown in Figure 12, there is rather substantial difference in the comparison, particularly at low tides. The difference at low tides is due to the fact that the Spurwink River thalweag channel elevations are located higher than the low tide. So, during low tides at the Portland Tide Gauge, the water surface elevation in the Spurwink River at Route 77 is not driven by the tide, but rather by typical subcritical flows driven by watershed related discharge. These are two different processes that will not have a good correlation.

However, the higher portions of the tide offer more interesting differences. As shown in Figure 12, the peak high tide elevation varies significantly over the data collection period. However, the difference between the high tide recorded at the Portland Tide Gauge and at Route 77 was remarkably similar. Note that the positive portion of the red colored "difference" line is very regular and exhibits the same basic shape during each high tide cycle, regardless of the tide height. The positive portion of each difference curve (each high tide cycle during the monitoring period) were combined to develop a mean value. This average difference curve is shown below in Figure 13.

Figure 13 – Average High Tide Difference Between Localized Route 77 Data and the Portland Tide Gauge



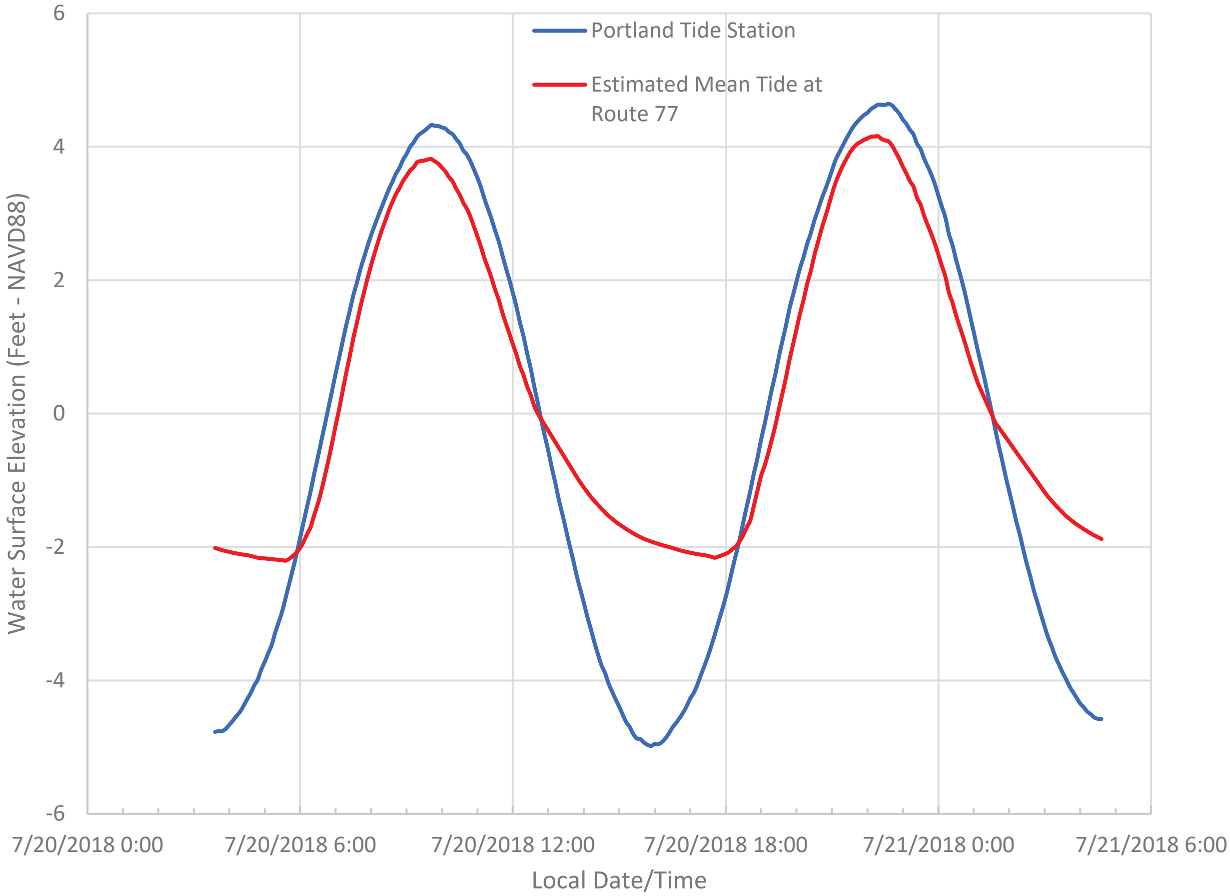
Note: The Portland Tide Gauge collects elevation data once every six minutes. Time interval zero (0) is the peak (high) tide elevation interval. Negative intervals are the six (6) minute intervals prior to high tide and positive interval values reflect the intervals after high tide occurs at the Portland Tide Gauge.

3.3.3 Regular Tide Events

NOAA reports that the Mean High and Mean High-High tide elevations (for the Present Epoch) are 4.21 and 4.65 feet (NAVD88), respectively. Based upon a review of the data recorded at the Portland Tide Gauge for 2018, there was an event that occurred on July 20, 2018 which was quite similar to these reported elevations and was not influenced by any significant weather event. Using the July 20th data as a proxy for mean tidal conditions, the curve shown in Figure 13 was applied to the Portland Tide Data to develop the approximated mean tide conditions downstream of the Route

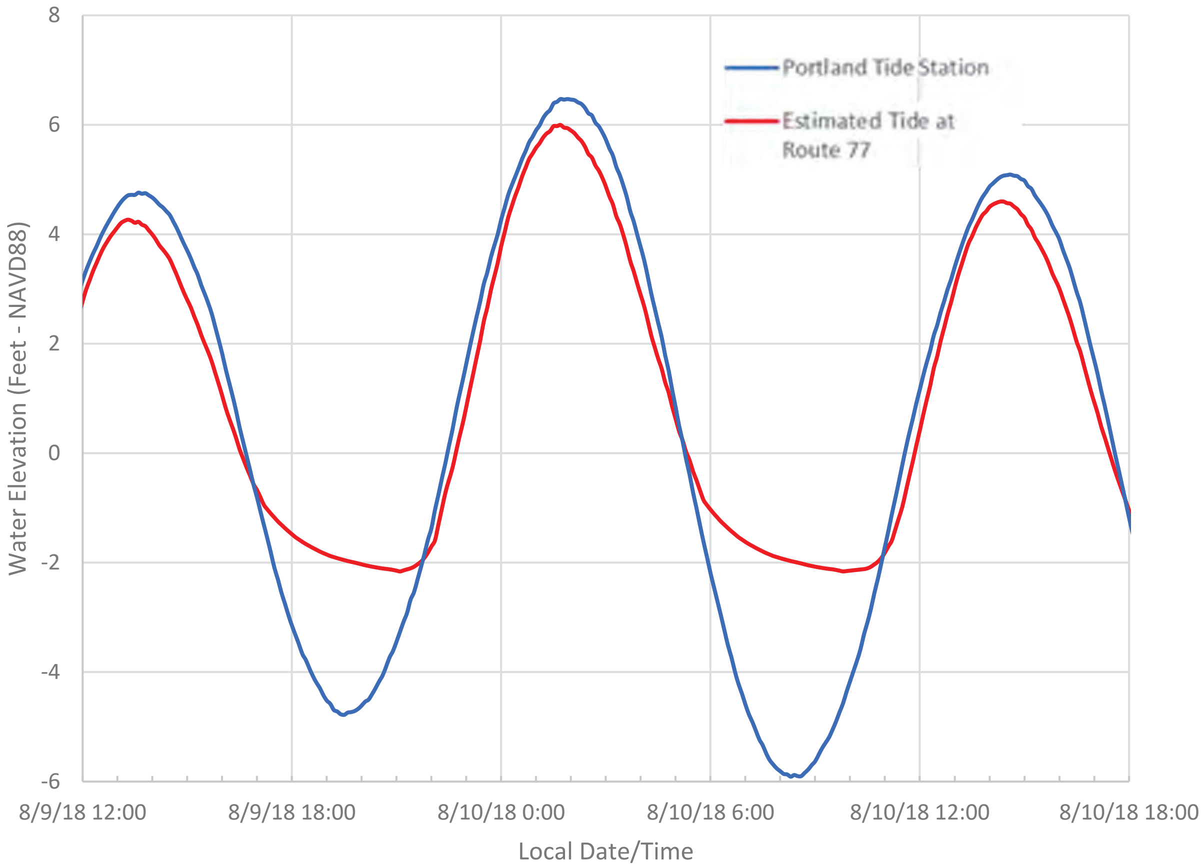
77 Bridge. Figure 14 depicts the estimated mean tidal conditions downstream of Route 77 and is overlain on the Portland Tide Station data for July 20, 2018.

Figure 14 – Estimated Mean Tide Conditions at Route 77 Bridge



The Maine Department of Environmental Protection (MeDEP) also publishes Highest Annual Tide (HAT) information across the coast of Maine. The HAT data published by the MeDEP in 2018 indicates that the HAT in Portland is 6.5 feet (NAVD88). After a review of the 2018 NOAA Portland Tide Gauge data, it was determined that the tide that occurred on August 10, 2018 was very similar to the HAT published by MeDEP. Using the August 10th data as a proxy for the HAT condition, the curve shown in Figure 13 was applied to the Portland Tide Data to develop the approximated HAT condition downstream of the Route 77 Bridge. Figure 15 depicts the estimated HAT condition downstream of Route 77 and is overlain on the Portland Tide Station data for August 10, 2018.

Figure 15 – Estimated HAT Condition at Route 77 Bridge



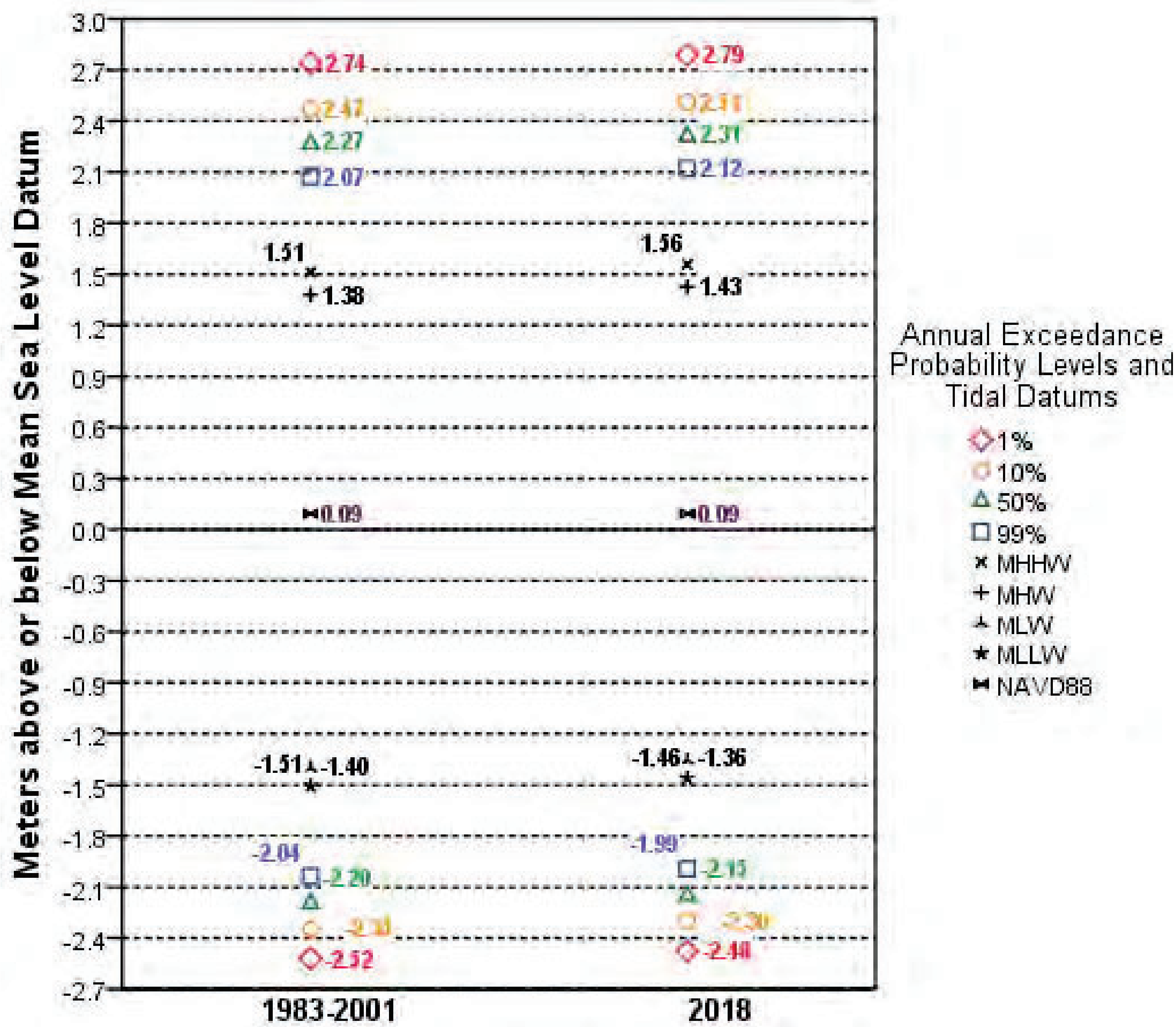
3.3.4 Extreme Tide Events

During large storms or other extreme conditions, tides will reach higher elevations that the HAT. NOAA has published the following data (See Figure 16) related to annual exceedance probability levels at the Portland Tide Gauge (ID# 8418150).

As shown in Figure 16, the 100-year tide elevation (1% annual exceedance) is estimated to be at an elevation of 2.79 meters above mean sea level (elevation 8.8 feet – NAVD88). The 10% exceedance (10-year) tide elevation is estimated to be at elevation 7.9 feet - NAVD 88 (2.51 meters above mean sea level). Similar to the estimated tides calculated in Section 3.2.3, a proxy was identified in 2018 for the 10% exceedance tidal event (March 2, 2018). Using the March 2nd data as a proxy for the 10% exceedance condition, the curve shown in Figure 13 was applied to the Portland Tide Data to develop the approximated 10% exceedance condition downstream of the Route 77 Bridge. Figure

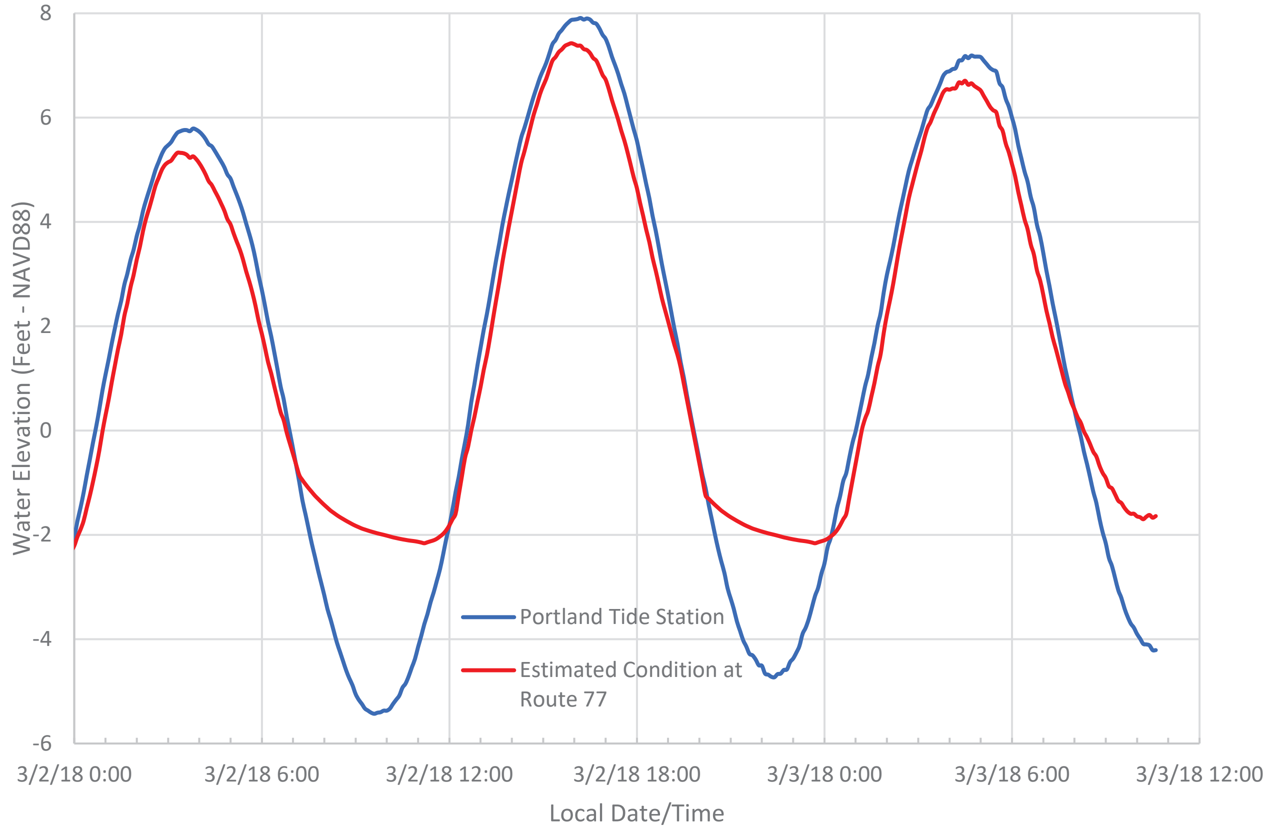
17 depicts the estimated 10% exceedance condition downstream of Route 77 and is overlain on the Portland Tide Station data for March 2, 2018.

Figure 16 – NOAA Portland Tide Station (8418150)



Note: This figure has been taken from the NOAA "Tides and Currents" website.

Figure 17 – Estimated 10% Exceedance (10-year) Event at Route 77 Bridge



3.4 SEA LEVEL RISE

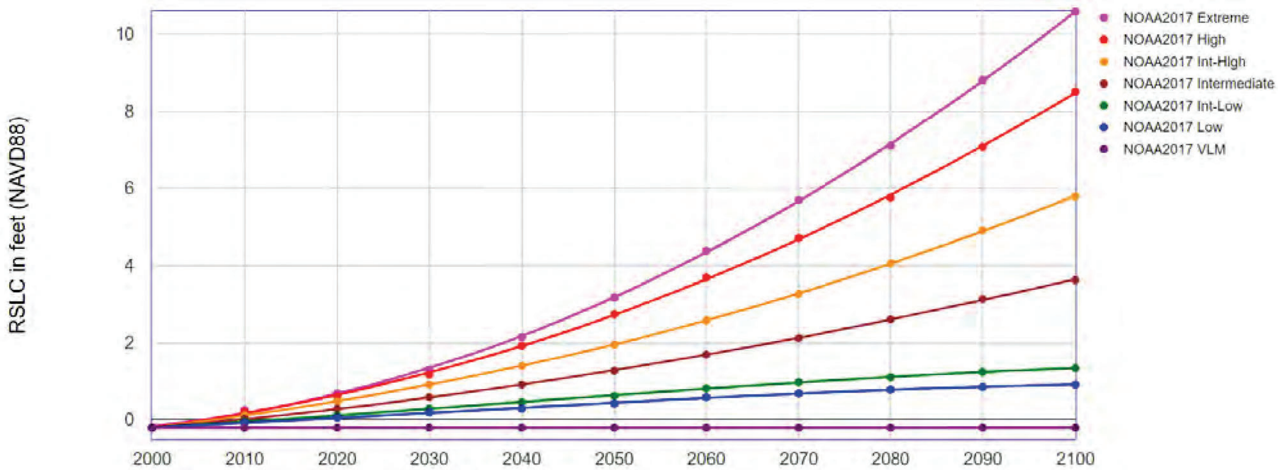
3.4.1 Corps Methodology

The US Army Corps of Engineers (Corps) has developed a web-based calculation tool for the prediction of future sea levels at a given site for a range of potential climate change scenarios. The tool is named the "Seal-Level Change Curve Calculator (Version 2019.21)" and is located on the Corps website. This web-tool utilizes localized land subsidence values, as well as local tidal information to determine potential future sea level rise values.

The Corps web tool relies heavily on work of other agencies to evaluate potential sea level rise scenarios. The most recent and comprehensive data related to potential sea level rise scenarios was published in 2017 as NOAA Technical Report NOS CO-OPS 083. This report was a collaboration of several institutional and governmental agencies, including the USGS, US EPA, and Rutgers University. The report provides regional guidelines for several potential sea level rise scenarios that range from "low" to "extreme." The variability in these scenarios are generally related to their assumptions associated with climate change and future carbon emissions. Refer to the full report for further details associated with these findings.

Using the Corps calculator and the recent NOAA (2017) climate change scenarios, Figure 18 was created, which depicts the potential relative sea level change at the Portland Tide Station.

Figure 18 – NOAA et al. 2017 Relative Sea Level Change Scenarios for Portland, ME



Year	NOAA2017 VLM	NOAA2017 Low	NOAA2017 Int-Low	NOAA2017 Intermediate	NOAA2017 Int-High	NOAA2017 High	NOAA2017 Extreme
2000	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21
2010	-0.21	-0.08	-0.04	0.02	0.12	0.22	0.25
2020	-0.21	0.06	0.12	0.29	0.48	0.61	0.68
2030	-0.21	0.19	0.29	0.58	0.91	1.17	1.30
2040	-0.21	0.29	0.45	0.91	1.40	1.93	2.16
2050	-0.21	0.42	0.61	1.27	1.96	2.75	3.17
2060	-0.21	0.58	0.81	1.70	2.58	3.70	4.39
2070	-0.21	0.68	0.97	2.12	3.27	4.71	5.70
2080	-0.21	0.78	1.11	2.61	4.06	5.76	7.11
2090	-0.21	0.84	1.24	3.14	4.91	7.08	8.82
2100	-0.21	0.91	1.34	3.63	5.80	8.52	10.59

As identified in Figure 18, there are a range of potential sea level rise scenarios. These range from more than 10 feet of relative sea level change to minimal change over the course of the current century.

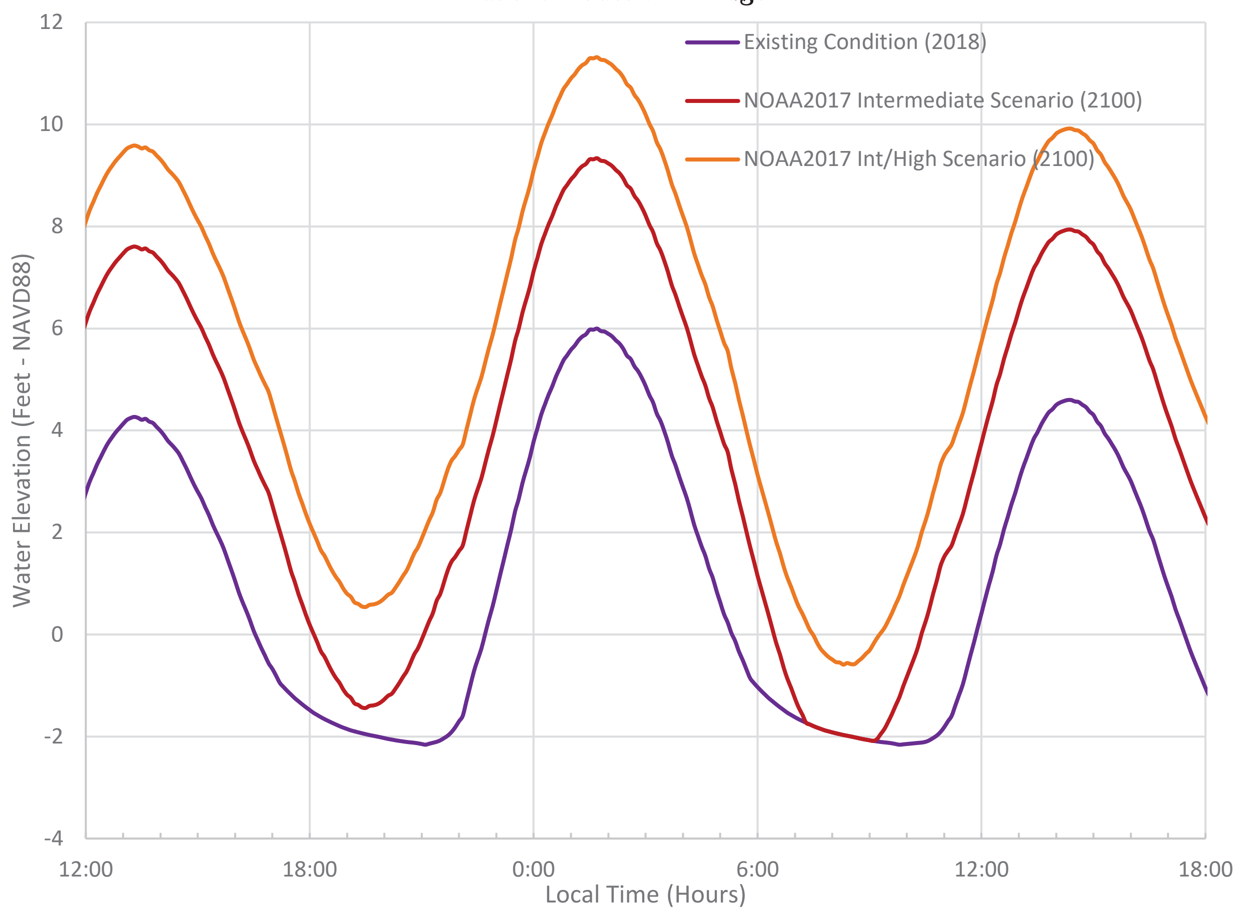
3.4.2 Anticipated Future Conditions

In the public sphere, there is significant debate and discourse regarding climate change. Acadia Civil Works consulted closely with the Project Team and Stakeholders to determine the most appropriate scenarios to consider. There was a consensus amongst the group that the NOAA2017

Intermediate curve would be the minimum design assumption. It was also concluded that the NOAA2017 Int-High curve should also be considerd. While there is no established regulatory standard for this criterion, it is worth noting that the Maine Department of Transportation (MeDOT) has recently an informal policy to use the NOAA2017 Intermediate curve as their baseline for infrastructure design.

As shown in Figure 18, there is approximately 3.34 feet of relative sea level change that will occur over the next 80 years (2020 to 2100) in the NOAA2017 Intermediate curve scenario. That change increases to 5.32 feet of change when considering the NOAA2017 Int-High scenario. This calculated change was applied to the estimated HAT condition at the Route 77 bridge. The existing and anticipated future HAT conditions downstream from the Route 77 Bridge are depicted on Figure 19.

Figure 19 – Estimated Current and Potential Future HAT Conditions at the Route 77 Bridge



SECTION 4

SECTION 4
HYDRAULIC ANALYSIS

4.1 INTRODUCTION

Hydraulics is an applied science concerned principally with the practical applications of fluids in motion. In this assessment, a computer model was constructed to evaluate the hydraulic performance of the existing and proposed infrastructure in a variety of geometric and hydrologic conditions. Additional details regarding the computer model and associated hydraulic modeling techniques, as well as associated hydraulic performance results are contained in the following sections.

The primary purpose of this hydraulic analysis is to provide recommendations on infrastructure improvements at the Sawyer Road Crossing. While the modeling footprint covers a great extent of the Spurwink Marsh, the ultimate focus of detail is specific to the Sawyer Road Crossing Infrastructure.

4.2 INITIAL HYDRAULIC ANALYSIS

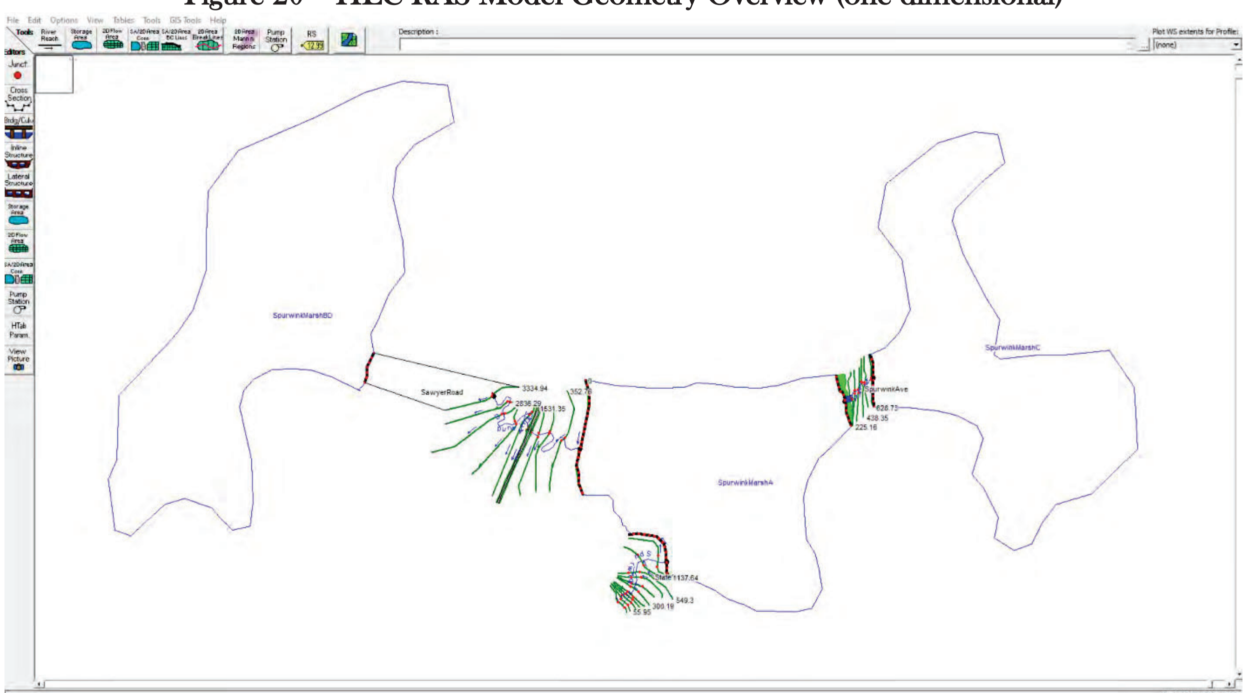
The U.S Army Corps of Engineers (Corps) Hydraulic Engineering Center's (HEC) River Analysis System (RAS) computer modeling software (version 5.0.7) was utilized in the hydraulic analysis of this project. This software was developed by the Corps to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. Over the years, additional versions have added more detailed and advanced hydraulic assessment tools, most significantly is the development of two-dimensional modeling capabilities with the release of software version 5.

This section of the report (4.2) focuses on the initial hydraulic analysis that have been performed to determine the appropriate size of the crossing improvement structures. These initial calculations are generally centered around a one-dimensional hydraulic model, which has been run with a variety of improvement structure sizes to develop a sizing curve. Additional detail regarding he model assumptions and results are in the following sections.

4.2.1 Model Assumptions

The initial HEC-RAS modeling was developed utilizing a variety of data sources. The most significant of which, is the 2006 LiDAR dataset (Section 2.3). This LiDAR data formed the foundation of the model geometry construction, which was supplemented by field crew survey efforts (Section 2.4) and record drawings (2.5). The model was constructed as a network of reaches and storage volumes. Each of the three major crossings (Route 77 Bridge, Spurwink Road, and Sawyer Road) were modeled as a reach with cross sections extend several hundred feet up and downstream from the crossing structure. Connecting each of these reaches is a large storage volume, representing the central section of the Spurwink Marsh. Additional storage nodes were developed upstream of Sawyer Road and Spurwink Road to model these upper marsh extents. A depiction of the model geometry is shown below in Figure 20.

Figure 20 – HEC-RAS Model Geometry Overview (one-dimensional)



As noted, the 2006 LiDAR dataset was used as the foundation of the model geometry. As described in Section2, LiDAR information is collected utilizing concentrated light (lasers) and measures surface data from an elevated location (in this case an airplane). LiDAR is incredibly accurate and measuring distances, however it has been criticized for its use in locations with dense vegetation as describing a ground surface that it too high. This is likely due to the lasers returning measurements that are from the dense vegetation, as opposed to the actual mineral ground surface. For this study, 45 points were utilized as a basis for comparison between the 2006 LiDAR data and the field survey performed by WNERR. Each of the 45 points were on the open marsh surface (as opposed to within the channel or some other more detailed feature). Ultimately, the compared elevations varied as much as 1.17 feet (LiDAR was higher than WNERR field survey), however the average value across all compared points was 0.48 feet (5.76 inches). As such, the entire 2006 LiDAR surface was adjusted down by the 0.48 feet.

The existing conditions model was calibrated using the localized tide data collected by WNERR and described in Section 3. Values such as Mannings roughness (n) and hydraulic loss parameters were adjusted to provide results similar to the existing observed performance. Ultimately, the calibrated model produced results that were within one inch of the tidal data collected by WNERR.

As stated previously, the primary purpose of the hydraulic modeling assessment is to provide analysis and recommendations related to infrastructure improvements at Sawyer Road. As such, two significant assumptions were made in the analysis of proposed infrastructure at Sawyer Road, as follows:

- Eliminate Other Crossings: The Spurwink Road culvert and road fill, as well as the Route 77 Bridge and associated road fill (including road fill from the historic alignment of Route 77) were removed from the model geometry. The purpose of this removal was to allow tidal exchange and movement within the marsh, unimpeded by the existing infrastructure. It is very possible (if not likely) that the Route 77 Bridge and the Spurwink Road crossing will be reconstructed or replaced in a substantive way over the life of any proposed Sawyer Road Infrastructure. Utilizing this approach will ensure that the Sawyer Road infrastructure has been sized adequately and will not be undersized in the future as a result to changes in other marsh infrastructure (such as an expansion to the Route 77 Bridge.
- Eliminate Roadway Overtopping: In the existing condition, Sawyer Road will overtop during certain high tide events. The proposed model conditions all eliminate this overtopping of the roadway and require all tidal exchange to occur within the proposed crossing infrastructure.

4.2.2 Results and Sizing Curves

The proposed model was used to evaluate a range of proposed crossing infrastructure sizes at Sawyer Road. The peak differential of the tide surfaces (downstream subtracted from upstream) was recorded and plotted on a graph to generate a curve of the tide differential versus structure open area. This curve is intended to be used as a tool for decisions related sizing of the proposed crossing infrastructure. A separate curve was developed for each evaluated hydrologic condition.

Through discussion with the Projects Team the Highest Annual Tide (HAT) published by the MeDEP was utilized as the design hydrologic condition. While this tide is higher than average, it is essentially the 1-year tide, which has a statistical 100% chance of occurring in each calendar year. Sizing curves for the existing HAT, as well as the HAT due to future sea level rise was evaluated. The sizing curve for each of these hydrologic conditions is shown below as Figures 21, 22, and 23.

Figure 21 – Existing (2018) HAT Sizing Curve at Sawyer Road

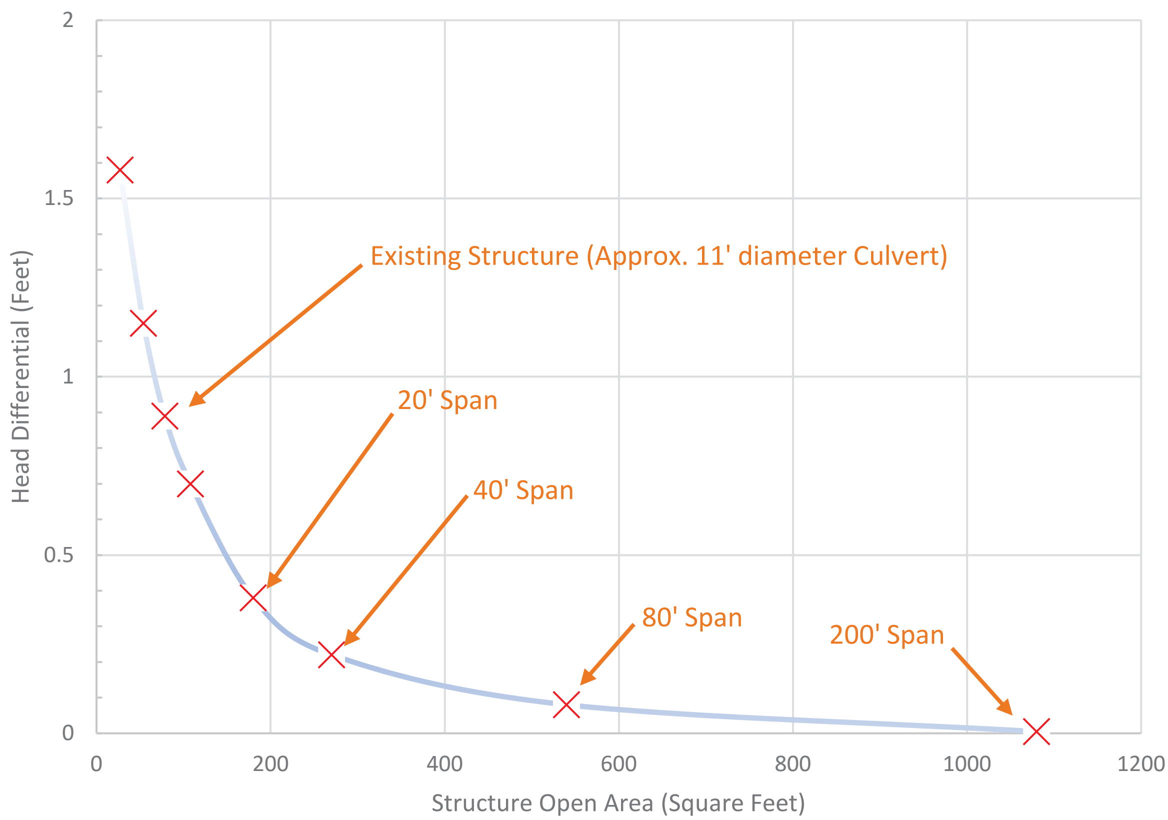


Figure 22 – Future (2100 – NOAA17 Intermediate) HAT Sizing Curve at Sawyer Road

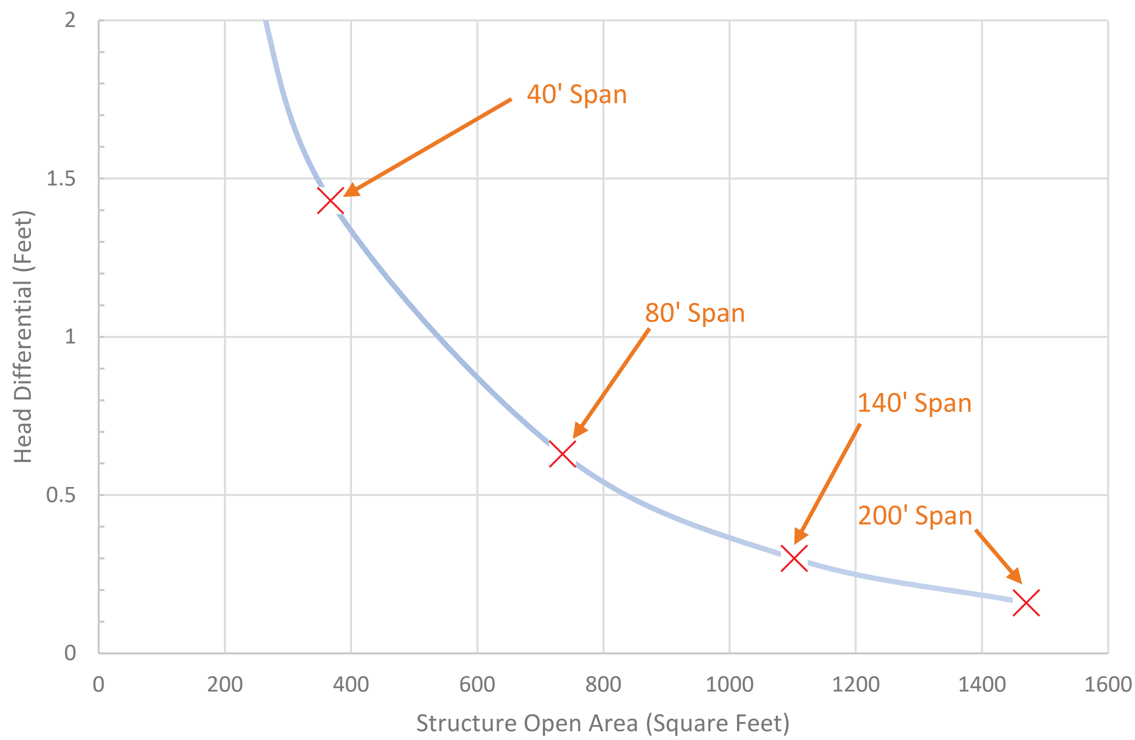
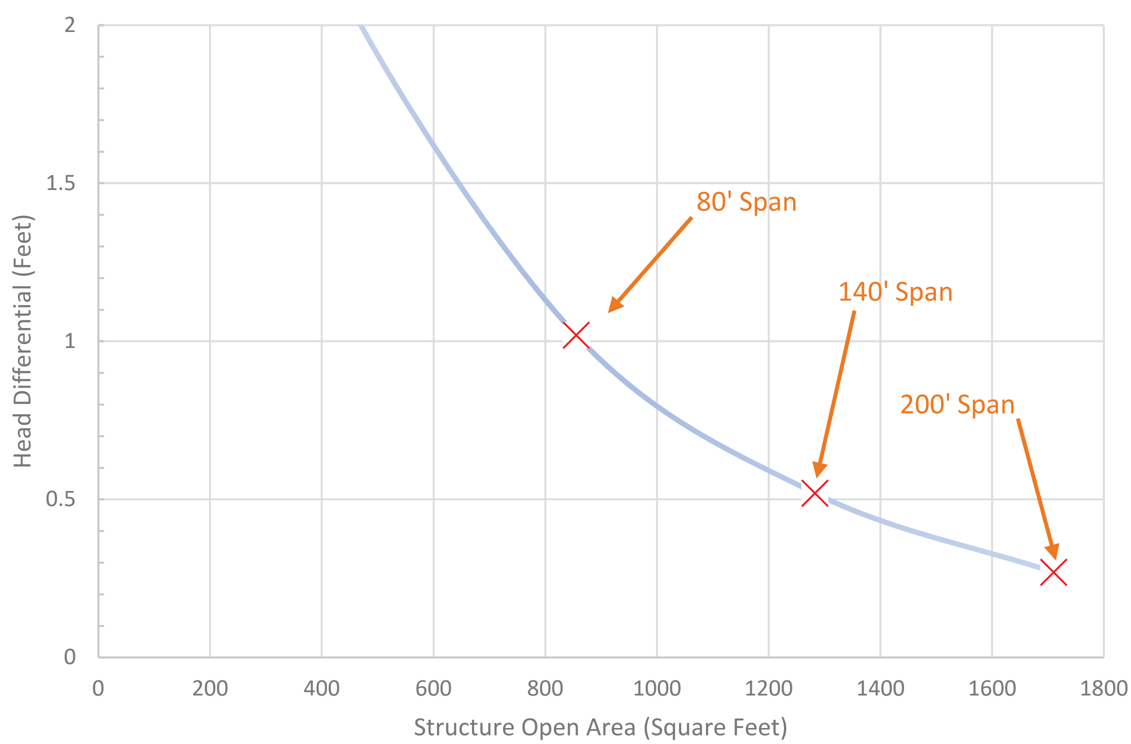


Figure 23 – Future (2100 – NOAA17 Int-High) HAT Sizing Curve at Sawyer Road



The sizing curves shown in Figures 21, 22, and 23 also include an approximate "span size" label at key data points. This "span size" should be considered approximate as there are a number of details associated with the final structural design, which will affect the actual span size (such as abutment configuration, location in the channel versus overbank, etc.). However, the span size should provide context and reference to the approximate magnitude of structures under consideration. As an additional point of reference, Table 4.1 is provided below, which shows the peak head differential in relation to the approximate span size for each of the tide conditions shown in Figures 21 thru 23.

TABLE 4.1
PEAK HEAD DIFFERENTIAL DURING HAT TIDE

Approximate Span (Feet)	Peak Differential (Feet)		
	2018	2100 (Int)	2100 (Int-High)
Existing Culvert	0.89	--	--
20' Span	0.38	2.15	3.74
40' Span	0.22	1.43	2.14
80' Span	0.08	0.61	1.02
140' Span	--	0.30	0.52
200' Span	0.005	0.16	0.27

4.3 TWO-DIMENSIONAL ANALYSIS

4.3.1 Model Assumptions

In addition to the initial one-dimensional hydraulic modeling described in section 4.2, additional two-dimensional analysis was also performed on the existing condition, as well as two improvement options. The existing condition is discussed further in the following section (4.3.2) and the improvement options are discussed further in Section 5.

The HEC-RAS (version 5.0.7) computer software was utilized to construct and analyze the two-dimensional models. The extent of the two-dimensional modeling was focused on the Sawyer Road crossing structure and immediate marsh areas. The terrain model was constructed from the photogrammetric survey data prepared by Wright-Pierce (refer to Section 2.2). Hydrologic and hydraulic boundary conditions of the model were referenced from cross-sections associated with the initial one-dimensional models (refer to Section 4.2).

4.3.2 Existing Conditions

The existing condition of the roadway and crossing infrastructure was modeled under the existing (2018) 10% exceedance (10-year) tidal event. A depiction of the model terrain is shown below in Figure 24. As shown in the figure, the extent of the model is limited to the immediate marsh areas upstream and downstream of Sawyer Road.

Figure 25 depict a “Heat Map” of the modeled results at Sawyer Road (existing conditions) during the 10-year event (2018). The coloration of the figure is based upon the peak velocity of water experienced at that point during the event. Blue colors reflect lower (calmer) velocity and the red colors reflect higher (intense) velocity. As shown on the color legend, the deepest red color reflects a velocity of 3.5 feet per second. It is likely that the marsh surface will erode when it experiences velocities greater than 3 feet per second.

The most intense velocities are shown within the channel and culvert. While the corrugates metal culvert surfaces will not erode, the channel will likely erode during this event. This may result in sloughing of the banks and or general channel widening.

Red coloration, as well as gradients of yellow can also be seen where the roadway is overtopping. It should be noted that the roadway embankment and surface are more durable than the marsh vegetation and soils, as it is stabilized with stone and bituminous pavement. As such, it is unlikely that the roadway structure will be compromised during this event, however the water depths would trigger a closure to traffic until the event runs its course.

Figure 24 – Existing Conditions 2-Dimensional Terrain Model

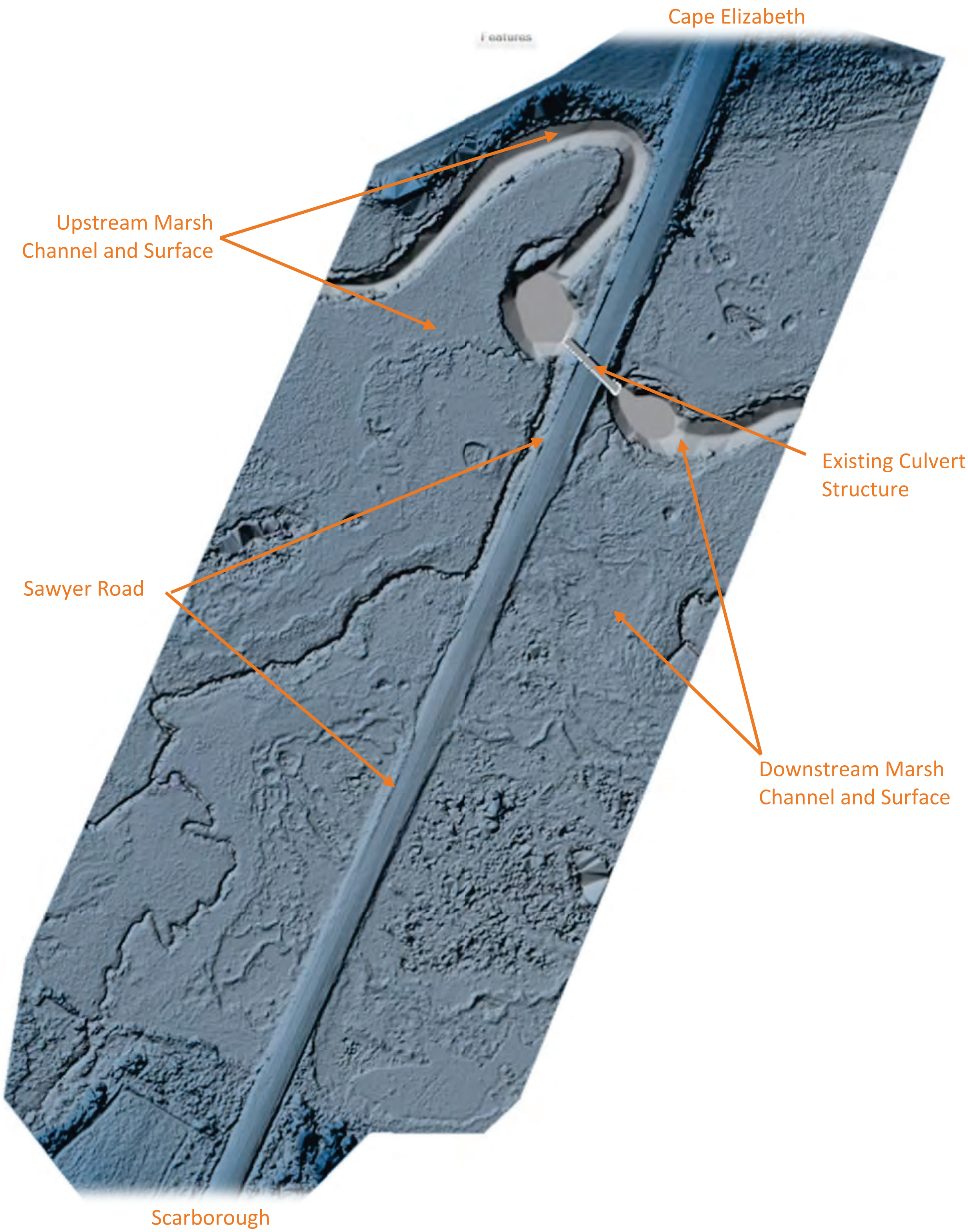
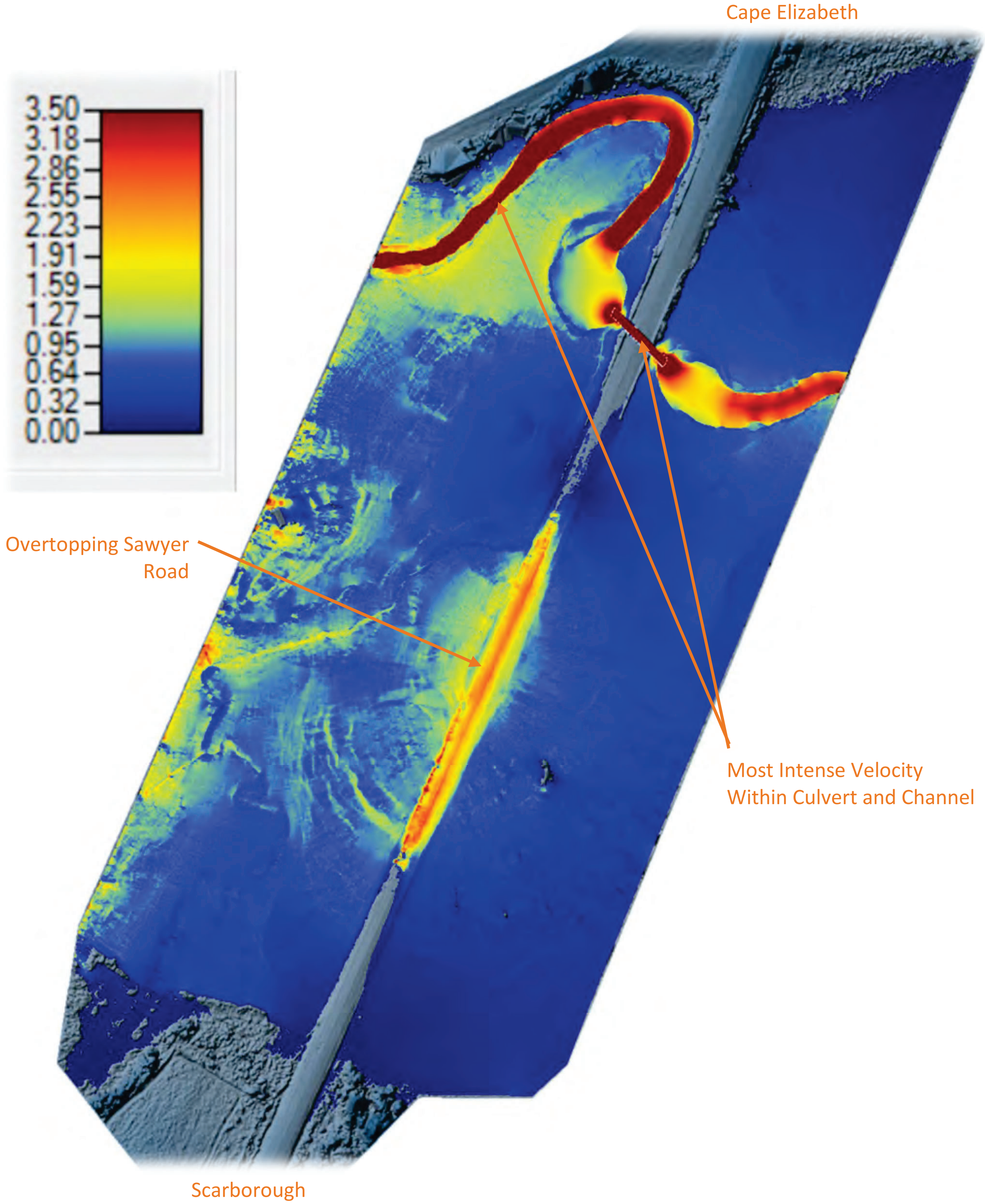


Figure 25 – Existing Conditions Peak Velocity Heat Map



SECTION 5

SECTION 5
IMPROVEMENT SCENARIOS

5.1 INTRODUCTION

During the course of this assessment, there were several Project Team meetings to discuss hydrologic conditions and the results of the hydraulic assessment. A variety of scenarios for improvement were also discussed. Opinions of the Stakeholders varied, however there were some common themes.

One point of substantive discussion was regarding the magnitude of the spans required to minimize the differential of the tide (refer to Figures 21, 22, and 23). Particularly, when looking to the future of potential sea level rise in 2100, spans of 80 or 140 feet may be warranted. An expansion of the existing 10-foot culvert to such larger sizes is perhaps politically and financially untenable at this time (For a frame of reference, the Route 77 Bridge is an 80-foot span structure). That said, it is possible to achieve these spans via a phased approach by installing a smaller span sized appropriately for current tidal conditions, with plans to install additional auxiliary structures over time as sea levels rise and additional spans are needed.

The following sections of this report provide two concepts for improvement. Each of the concepts represent a phased approach.

5.2 CONCEPT A – 80 FOOT SPAN

5.2.1 Basis of Design

Concept A represents an improvement scenario that will ultimately result in approximately 80 feet in total installed span. This concept involves the construction of a 40' span initially, with provisions for the installation of two (2) – 20-foot auxiliary structures in the future. The configuration of these structures is shown below in Figure 26.

When evaluating the existing HAT sizing curve (Figure 21), the 40-foot span is located just past the inflection point of the curve. It also corresponds to a peak differential of 0.22 feet (2.6") across Sawyer Road during the current HAT tide. While there is no precise threshold for the minimum required size, the 40' span seems to be an appropriate minimum span size for the existing conditions.

Looking forward to 2100, the additional two (2) twenty-foot span structures would provide for a reasonable hydraulic performance in the NOAA2017-Intermediate Condition (Figure 22). In this scenario the total of 80 span would result in a 0.63 foot (7.5") peak differential. However, when considering the NOAA2017-Int-High Condition (Figure 23), this option performs substantively worse as the differential jumps to more than a foot.

It should be expected that this improvement would perform well upon initial installation of the 40-foot span. However, it would require supplementation with at least one of the 20-foot auxiliary culverts within a couple decades to maintain its hydraulic performance as sea levels rise. Additionally, the total of span width of 80 feet will maintain a reasonable performance throughout the design life of the structure (anticipated through 2100), provided that sea level rise follows the NOAA2017 Intermediate Scenario (or a lesser amount of sea level rise). However, if sea level rise proves to follow the NOAA2017-Int-High Scenario (or greater amount of sea level rise), the effective design life of this option may be shortened as it will be inadequately sized prior to 2100. Note that the NOAA2017-Int-High scenario will reach the design capacity of this option by 2075, as opposed to 2100.

5.2.2 Two-Dimensional Analysis

Similar to the existing conditions analysis described in Section 4.3.2, Concept A was also modeled in two-dimensions to depict the hydraulics of this option. Figure 26, shown above, depicts the Concept A model geometry and configuration of the proposed improvement scenario. Figure 27 follows below and depicts the peak velocity heat map during the NOAA2017-Intermediate HAT tide event.

Figure 26 – Concept A - Two-Dimensional Terrain Model

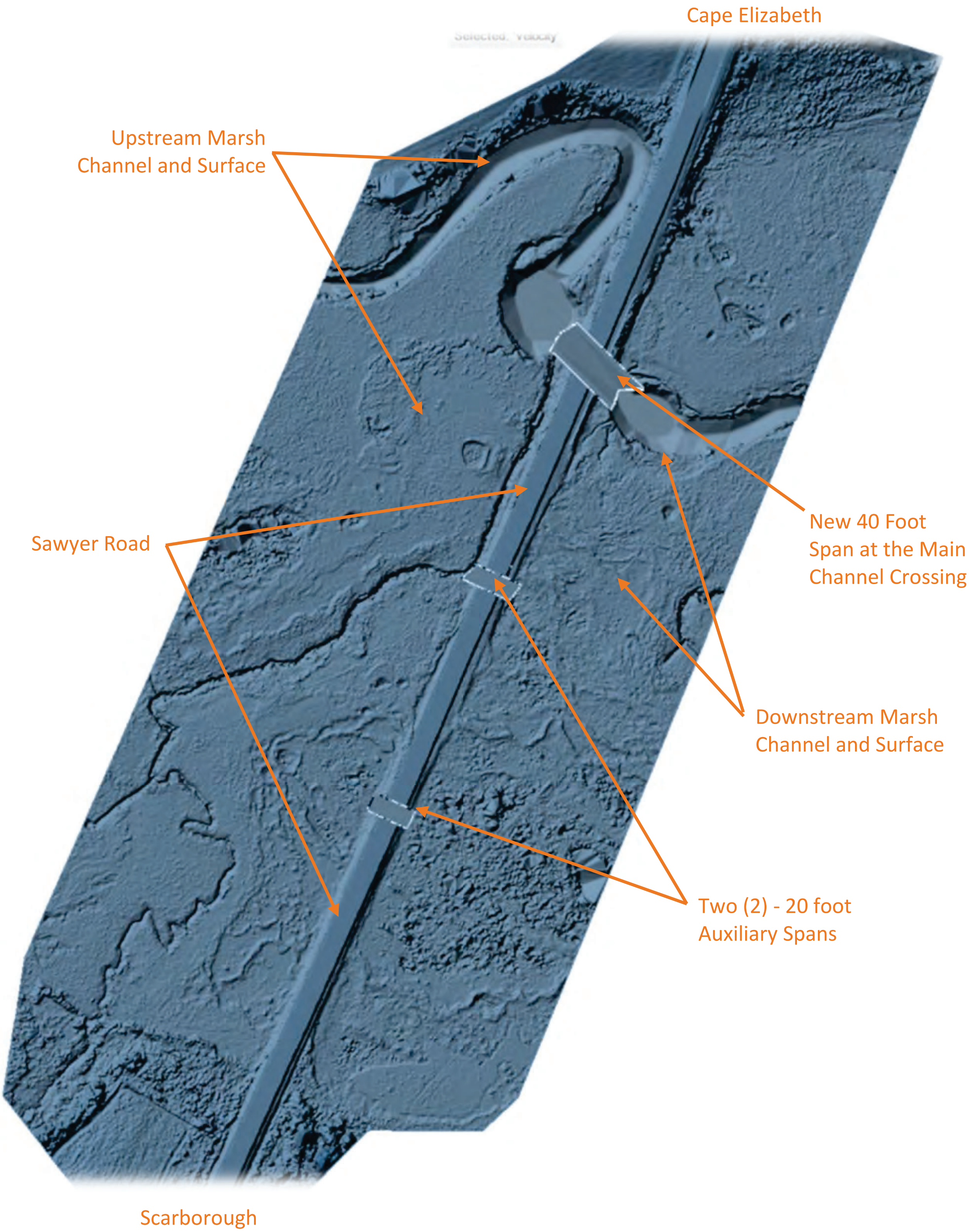
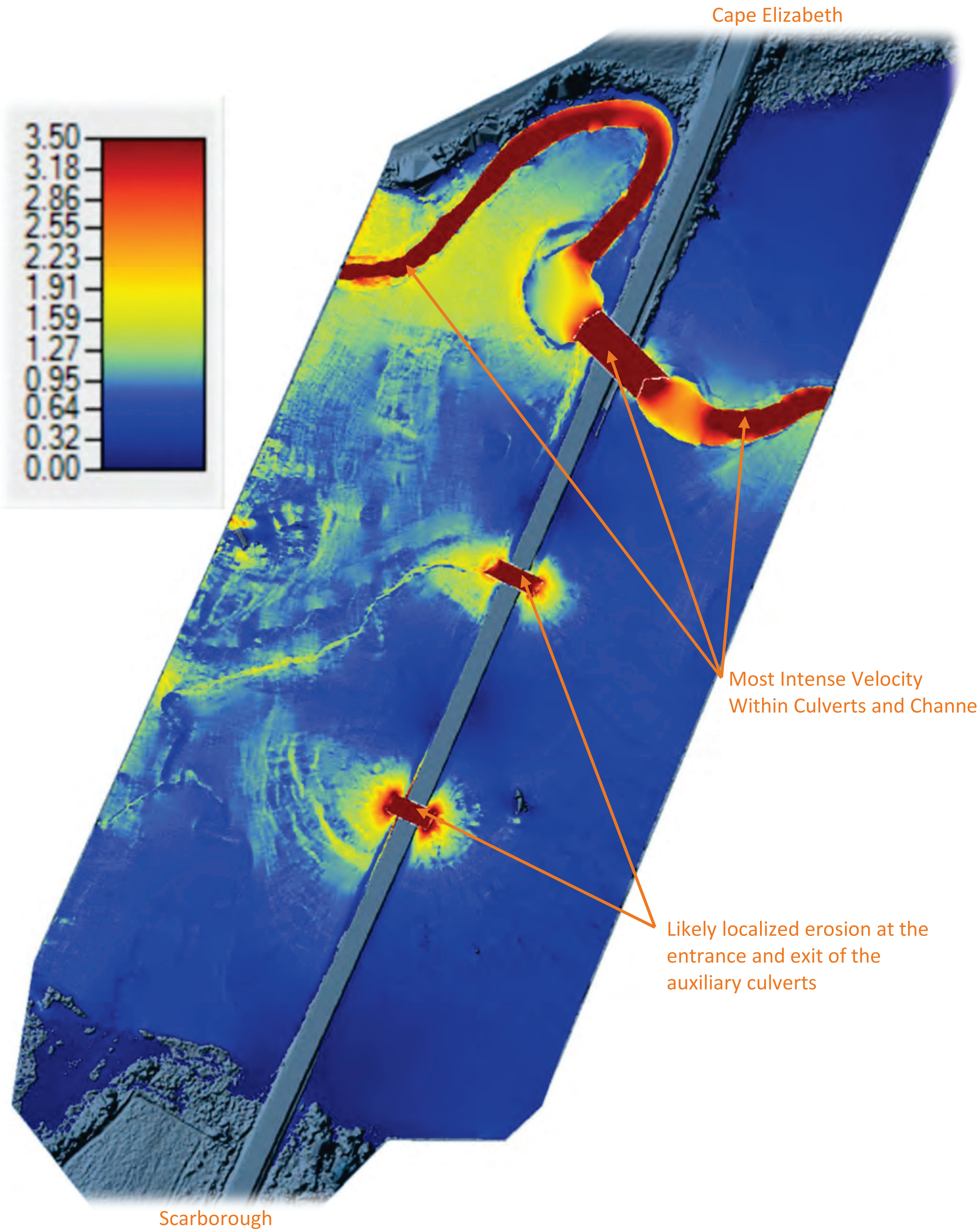


Figure 27 – Concept A – Peak Velocity Heat Map



5.3 CONCEPT B – 140 FOOT SPAN

5.3.1 Basis of Design

Concept B follows a similar logic as Concept A, however it will ultimately result in approximately 140 feet in total installed span. This concept involves the construction of a 60' span initially, with provisions for the installation of two (2) – 40-foot auxiliary structures in the future. The configuration of these structures is shown below in Figure 28.

When evaluating the existing HAT sizing curve (Figure 21), the 60-foot span is located well past the inflection point of the curve. It also corresponds to a peak differential of approximately 0.13 feet (1.5") across Sawyer Road during the current HAT tide.

Looking forward to 2100, the additional two (2) forty-foot span structures would provide for a solid hydraulic performance in the NOAA2017-Intermediate Condition (Figure 22). In this scenario the total of 140 span would result in a 0.30 foot (3.6") peak differential. Additionally, when considering the NOAA2017-Int-High Condition (Figure 23), this option continues to perform respectably at a peak differential of 0.52 feet (6.24").

It should be expected that this improvement would perform well upon initial installation of the 60-foot span. Compared to Concept A, it would not require supplementation with an auxiliary structure as soon. Also, the additional span (140' versus 80') would maintain an acceptable performance for a longer design life. However, if sea level rise proves to follow the NOAA2017-High Scenario (or greater amount of sea level rise), the effective design life of this option may be shortened as it will be inadequately sized prior to 2100. Note that the NOAA2017-High scenario will reach the design capacity of this option by 2080, as opposed to 2100.

5.3.2 Two-Dimensional Analysis

Similar to the existing conditions analysis described in Section 4.3.2, Concept B was also modeled in two-dimensions to depict the hydraulics of this option. Figure 28, shown above, depicts the Concept B model geometry and configuration of the proposed improvement scenario. Figure 29 follows below and depicts the peak velocity heat map during the NOAA2017-Intermediate HAT tide event.

Figure 28 – Concept B – Two-Dimensional Terrain Model

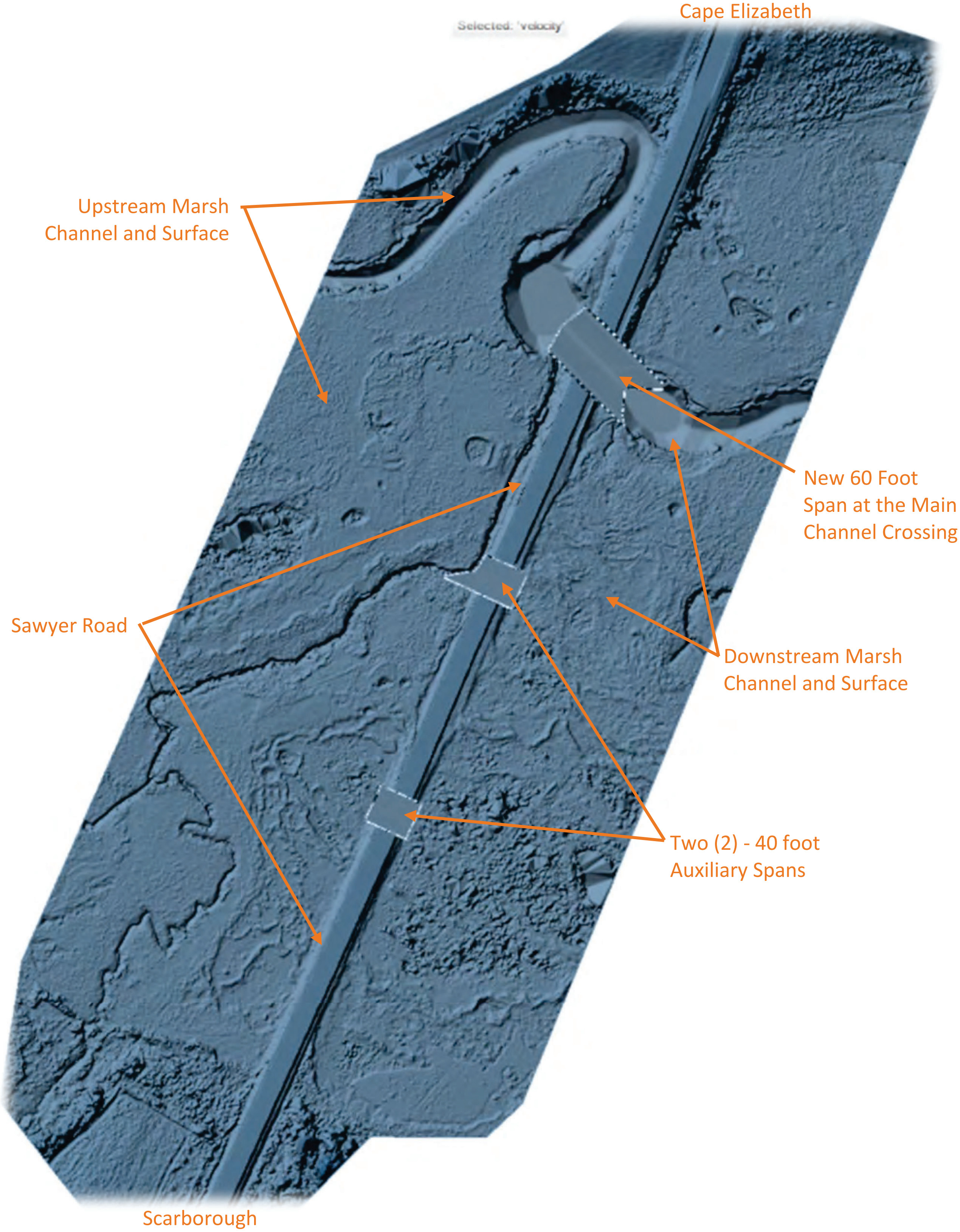
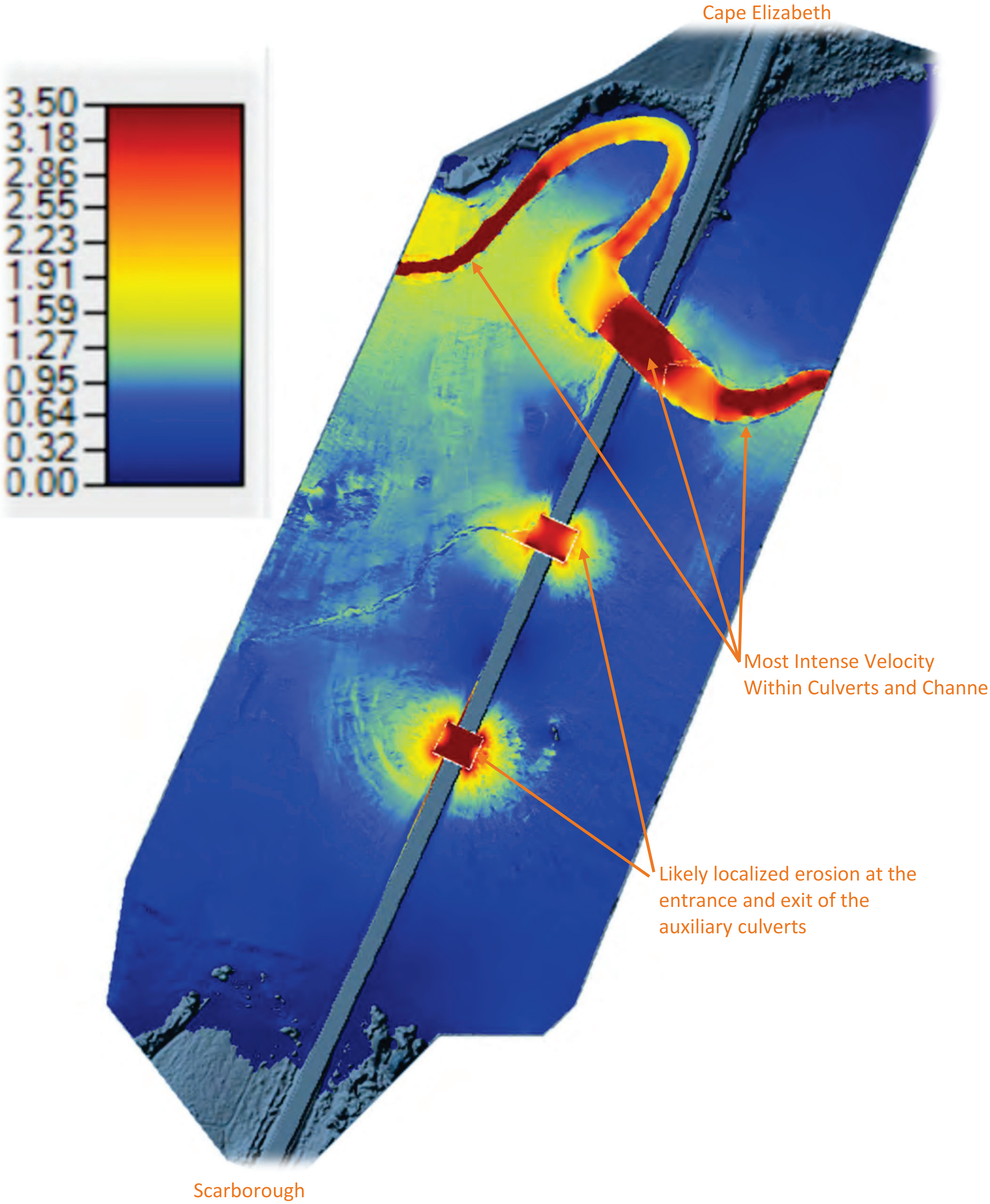


Figure 29 – Concept B – Peak Velocity Heat Map



5.4 ADDITIONAL DESIGN CONSIDERATIONS

It is important to recognize that the two-dimensional hydraulic modeling performed represent results with a fixed terrain at a snapshot in time. The velocity heat maps provide insight into where erosive velocities may form, as well as identifies potential problem areas. However, geomorphic changes to the Spurwink Marsh and River are not reflected.

For example, the heat maps show erosive velocities within the Spurwink Marsh channel. It is likely that the channel will erode and widen during extreme events. It is also likely that this will occur in the future as sea levels rise and additional tidal volumes and flow are exchanged across the extent of the Marsh. This type of channel enlargement, as well as the potential for channel meandering, is likely to occur regardless of the infrastructure solution implemented.

That said, the introduction of auxiliary spans should be carefully evaluated to ensure that the erosion at the inlet and outlet of these structures remains localized. If the auxiliary spans are placed along the marsh surface incorrectly (such as too low in elevation), there is the potential that new channels will correspondingly head-cut themselves across the marsh surface and/or erosion at the inlet/outlet of these structures could be substantial. Some localized erosion should be expected at the auxiliary structures, but care should be taken to ensure that it minimized and localized.

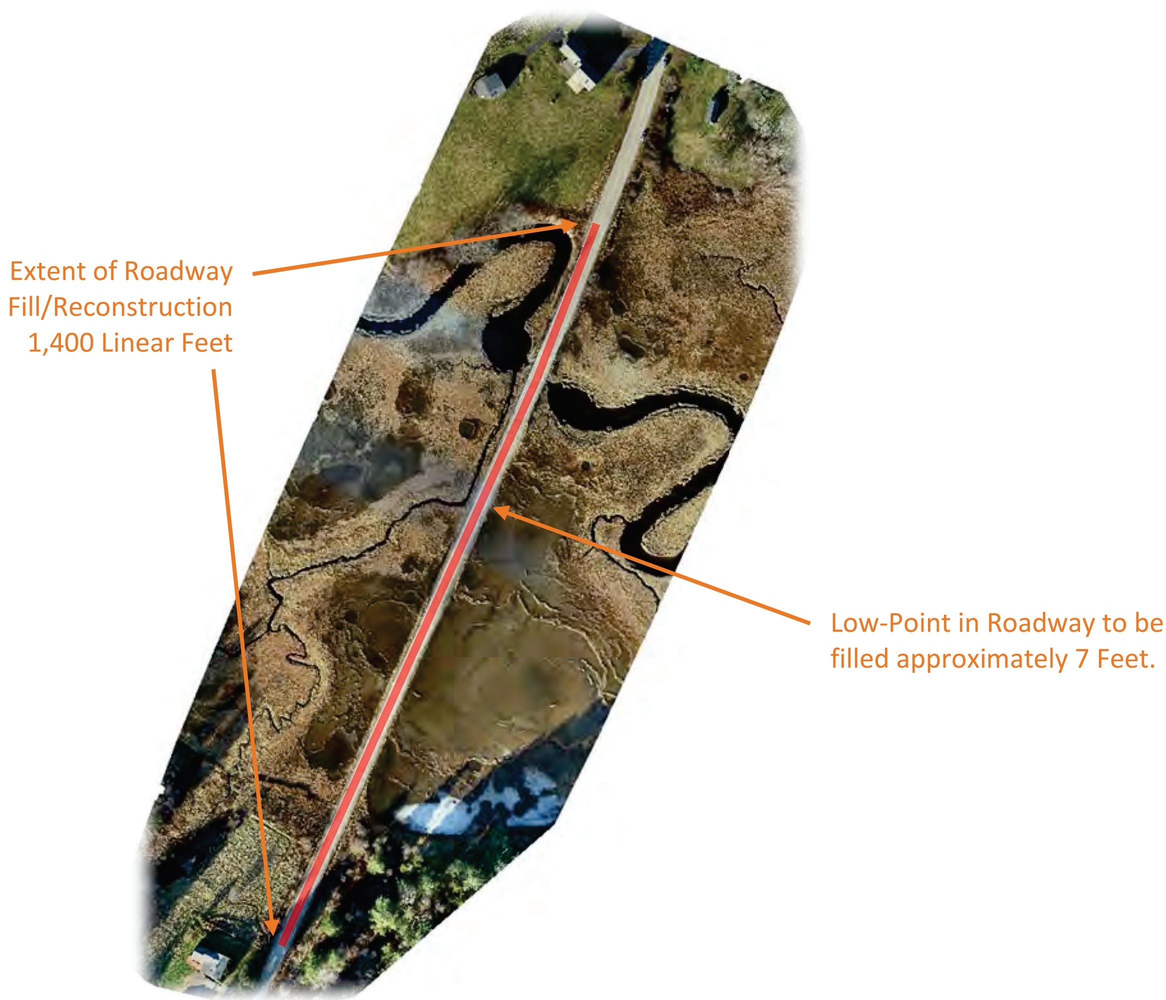
5.5 ROAD SURFACE ELEVATION

Much of this assessment has been focused on the appropriate sizing of potential crossing infrastructure. However, it should be noted that there is also a corresponding adjustment that will be required to raise the road surface. Ultimately, the crossing infrastructure will allow for the tides to ebb and flow under the roadway, but the roadway must be elevated above the tides to remain serviceable and prevent damage (both to the roadway and marsh surface).

As described in Section 3.3.4 – Extreme Tide Events, the current (2018) 100-year peak tide elevation is 8.8 feet (NAVD88). The 50-year and 10-year peak tides are 8.5 and 7.9 feet, respectively. As described in Section 3.4 – Sea Level Rise, the NOAA2017-Intermediate will increase these elevations by approximately 3.34 feet by 2100.

The existing low-point of the Sawyer Road centerline is currently at elevation 5.85 feet (NAVD88). We recommend raising the roadway surface to a level of one-foot higher than the 50-year tide, including the NOAA2017 Intermediate Sea Level rise scenario. This would require the road to be raised to a minimum elevation of 12.8 feet. This represents a fill of approximately 7 feet at the low point of the roadway, it would also require approximately 1,400 linear feet of roadway reconstruction and corresponding embankment fill. This extent of roadway fill and reconstruction is shown below in Figure 30.

Figure 30 – Extent of Roadway Reconstruction to Prevent Overtopping by the 50-year Tide (including the NOAA17 Intermediate Sea Level Rise)



The paved width of the roadway is approximately 22 feet. A gravel shoulder of approximately 3 to 4 feet is also located on each side of the pavement. To maintain this width, while also raising the roadway (as described above), there will be a rather steep embankment (approximately 2 horizontal to 1 vertical) located on either side of the roadway. At its peak, this embankment may be as much as 9 feet tall. The total width of the roadway embankment measured to the toe of embankment on each side of the roadway may be as much as 65 feet. Based upon the MDOT record plans for Sawyer Road dated 1963, the road Right-of-way width is approximately 50 feet. This indicates that the embankment fill may extend beyond the limits of the Right-of-way.

From a regulatory perspective, the salt marsh located around Sawyer Road is a high value resource area. The footprint and volume of fill associated with the roadway embankment will require permitting from the U.S. Army Corps of Engineers and the Maine Department of Environmental Protection. Each of these agencies will require the project to undergo an avoidance and minimization exercises to ensure that the proposed fills and associated impacts to the adjacent resource is minimized.

In addition to the regulatory issues associated with the embankment, any fill that occurs outside of the ROW would occur on land associated with the Rachel Carson National Wildlife Refuge under management by the USFWS. It is unlikely that these fills will be acceptable. As such, a retaining structure will likely be required for a significant extent of the roadway to contain the roadway embankment within the existing road right of way. This retaining structure may have a substantive additional impact to the overall engineering and construction effort associated with the roadway fill.

5.6 PROJECT COST ESTIMATES

The approximate magnitude of cost for each of these scenarios was estimated. The design options outlined in this report shall be considered conceptual. Substantive additional engineering and design work will be required to advance any of these concepts through design and construction. Significant unknown variables remain in the design process, including geotechnical conditions.

5.6.1 Road Fill and Reconstruction

As noted in Section 5.5, approximately 1,400 linear feet of road will require reconstruction, with significant fills and embankment construction. Unit quantities of materials for this work were estimated by Acadia Civil Works and past similar project unit prices were applied to this work to generate the estimated value. Overall, we expect the road fill and reconstruction portion of the project (not including any structures) to be in the range of $600,000 to $900,000. This includes engineering, design, and permitting costs.

5.6.2 Crossing Structure Improvements

The crossing structure improvements were estimated based upon a review of past similar projects. This includes the bridge crossing and box culvert projects bid and awarded by the Maine DOT in 2019. Significant design work will be required to further refine these estimates, however based upon other similar structures and spans we estimate the following range of magnitudes:

Concept A (80-foot Span) - $2,000,000 to $3,000,000

Concept B (140-foot Span) - $3,500,000 to $5,500,000

5.6.3 Project Cost Summary

The estimates above represent the cost to construct the bridge span structures, as well as the roadway improvements. To determine the total project cost, the scope of roadway fill and reconstruction should be added to the selected concept. A summary of each conceptual anticipated project cost is shown below in Table 5.1.

TABLE 5.1
PROJECT COST ESTIMATE SUMMARY
(Cost is in Millions of Dollars)

	Concept A 80 Foot Span	Concept B 140 Foot Span
Roadway Improvements	$0.6 to $0.9	$0.6 to $0.9
Structure Improvements	$2.0 to $3.0	$3.5 to $5.5
Total Project Cost	**$2.6 to $3.9**	**$4.1 to $6.4**

SECTION 6

SECTION 6
CONCLUSION

Acadia Civil Works was retained by a diverse group of project stakeholders to evaluate the Sawyer Road crossing of the Spurwink River, as well as the associated Spurwink Marsh. Sawyer Road connects the Towns of Scarborough and Cape Elizabeth, who have apparent joint ownership of the crossing infrastructure. The crossing is also located within the Rachel Carson National Wildlife Refuge and is regarded as a valuable tide marsh ecosystem.

A primary goal of this assessment was to provide recommendations for tidal crossing infrastructure at Sawyer Road that will provide appropriate tidal exchange within the Spurwink Marsh while considering future sea level rise. In addition, it is important to the Towns of Cape Elizabeth and Scarborough that Sawyer Road does not flood and remains serviceable throughout the year.

Acadia Civil Works worked closely with the project partners, particularly the Wells National Estuarine Research Reserve (WNERR) to collect existing conditions information at the crossing location, including localized tide elevations and topographic survey. Additional existing conditions information was collected with aerial photogrammetric survey via an unmanned aerial vehicle (UAV), as well as LiDAR data publicly available from NOAA and other GIS based data sources.

After a review and assessment of the hydrologic conditions at the site, the Highest Annual Tide (HAT) published by the Maine DEP was utilized as the primary design condition. This event has a near statistical probability of 100% occurrence each year and is considered the 1-year tide event. The NOAA2017-Intermediate sea level rise scenario predicts an increase in ocean levels by 3.3 feet between 2020 and 2100, which is the anticipated design life of the improved infrastructure. The NOAA2017 Intermediate-High sea level rise scenario predicts a cooresponding increase of 5.3 feet.

Considering the HAT tide and sea level rise, two scenarios were developed. Option A consists of a series of crossing structures, including a 40’ bridge span and two auxiliary 20’ spans, totaling 80 total feet of span length. At full buildout, this option would be appropriate for the Intermediate sea level rise scenario and the 40’ bridge span would be appropriate for the current tidal conditions. This would allow for a phased approach of installing the 40' bridge span now and the additional auxiliary structures later as sea levels rise.

Option B similarly consists of a series of crossing structures, including a 60' bridge span and two auxiliary 40' crossing structures, totaling 140' of span length. This option involves more substantial infrastructure, however the initial phase of 60' bridge span construction will be appropriatly sized for several years longer than Option A before auxiliary structure installation is required. Additionally, the full buildout of this option would provide for adequate sizing during the Intermediate-High sea level rise scenario.

Both improvement options would also be performed in conjunction with raising the road above tidal elevations to ensure it is serviceable and avoids annual flooding. This includes raising the road by as much as seven (7) feet at its current low point to bring the road surface at least one-foot above the 50-year tide condition (including the NOAA2017-Intermediate sea level rise scenario). The total length of road reconstruction is approximately 1,400 linear feet.

Project costs to design, permit, and construct Option A (80-foot span) could range in the magnitude of $2,000,000 to $3,000,000 dollars. The Option B (140-foot span) project costs could range in the magnitude of $3,500,000 to $5,500,000. Additionally, the cost to reconstruct and raise the existing roadway likely is in the range of $600,000 to $900,000 for both options.

APPENDIX A

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

Paul R. LePage
GOVERNOR

David Bernhardt
COMMISSIONER

April 24, 2018

Municipality of Cape Elizabeth
320 Ocean House Road, PO Box 6260
Cape Elizabeth, Maine 04107

RE: Town Line Bridge #6014

Dear Municipal Officials,

Enclosed is a copy of the 2017 Bridge Inspection Report for the bridge above that has identified deficiencies or preventative maintenance issues that should be addressed by the Town. Listed below is an itemized list of the deficiencies.

Town Line Bridge #6014

- Holes found during underwater inspection

The bridge and guardrail deficiencies should be addressed as soon as practical to ensure continued safe use of the bridge. Neglect of these deficiencies may result in a diminished function of the bridge through load posting or even closure.

Due to bridge legislation, there is no funding mechanism for the bridge, which is considered Minor Spans on a Town Way. The Department will inspect the bridges again in 2018. If you have any questions, do not hesitate to contact me at 624-3423.

Sincerely,

Benjamin W. Foster

Benjamin W. Foster, P.E.
Assistant Bridge Maintenance Engineer

Enclosures

cc: Bridge Management
Road Commissioner
file

Highway Bridge Inspection Report

TOWN LINE
SAWYER ST.
over
SPURWINH RIVER

Asset Code: 6014

Inspection Date: 11/09/2017

Inspected By: Tim Merrithew

Inspection Type(s): Routine

National Bridge Inventory

Status: 1 - SD   Bridge Name: TOWN LINE   Sufficiency Rating: 69.8

Inspections

(90) INSPECTION DATE & (91) DESIGNATED INSPECTION FREQUENCY		24	11/09/2017
(92) CRITICAL FEATURE INSPECTION & (93) CFI DATE			
(92A) FRACTURE CRITICAL DETAIL	N		
(92B) UNDERWATER INSPECTION	Y	24	05/31/2017
(92C) OTHER SPECIAL INSPECTION	N		

Identification

(1) STATE CODE	231 - Maine
(8) STRUCTURE NUMBER	6014
(5) INVENTORY ROUTE	
(5A) RECORD TYPE	1: Route carried "on" the structure
(5B) ROUTE SIGNING PREFIX	5 - CITY STREET
(5C) DESIGNATED LEVEL OF SERVICE	0 - None
(5) INVENTORY ROUTE	0
(5) INVENTORY ROUTE	0 - NOT APPLICABLE
(2) HIGHWAY AGENCY DISTRICT	01 - Southern
(3) COUNTY CODE	005 Cumberland
(4) PLACE CODE	10180
(6) FEATURES INTERSECTED	SPURWINH RIVER
(7) FACILITY CARRIED	SAWYER ST.
(9) LOCATION	.5 MI N RTE 77
(11) MILEPOINT	0.010
(12) BASE HIGHWAY NETWORK	Inventory Route is not on the Base Network
(13) LRS INVENTORY ROUTE, SUBROUTE	
(13A) LRS INVENTORY ROUTE	0000500530
(13B) SUBROUTE NUMBER	00
(16) LATITUDE	43.58851
(17) LONGITUDE	-70.26293
(98A) BORDER BRIDGE CODE	
(98B) PERCENT RESPONSIBILITY	0
(99) BORDER BRIDGE STRUCT NO.	n/a

Structure Type and Material

(43) STRUCTURE TYPE, MAIN	
(43A) KIND OF MATERIAL/DESIGN	9 - Aluminum, Wrought Iron or Cast Iron
(43B) TYPE OF DESIGN/CONSTR	19 - Culvert (includes frame culverts)
(44) STRUCTURE TYPE, APPROACH SPANS	
(44A) KIND OF MATERIAL/DESIGN	0 - Other
(44B) TYPE OF DESIGN/CONSTRUCTION	00 - Other
(45) NUMBER OF SPANS IN MAIN UNIT	1
(46) NUMBER OF APPROACH SPANS	0
(107) DECK STRUCTURE TYPE	N - Not Applicable
(108) WEARING SURFACE/PROTECTIVE SYSTEMS	
(108A) WEARING SURFACE	N - NA
(108B) DECK MEMBRANE	N - NA
(108C) DECK PROTECTION	N - NA

Age of Service

(27) YEAR BUILT	1997
(106) YEAR RECONSTRUCTED	0
(42) TYPE OF SERVICE	
(42A) TYPE OF SERVICE ON BRIDGE	1 - Highway
(42B) TYPE OF SERVICE UNDER BRIDGE	5 - Waterway
(28) LANES	
(28A) LANES ON THE STRUCTURE	02
(28B) LANES UNDER THE STRUCTURE	00
(29) AVERAGE DAILY TRAFFIC	1080
(30) YEAR OF AVERAGE DAILY TRAFFIC	2016
(109) AVERAGE DAILY TRUCK TRAFFIC	5
(19) BYPASS DETOUR LENGTH	2

Geometric Data

(48) LENGTH OF MAXIMUM SPAN (ft.)	12.0
(49) STRUCTURE LENGTH (ft.)	11.0
(50) CURB/SIDEWALK WIDTHS	
(50A) LEFT CURB SIDEWALK (ft.)	0
(50B) RIGHT CURB SIDEWALK (ft.)	0
(51) BRDG RDWY WIDTH CURB-TO-CURB (ft.)	0
(52) DECK WIDTH, OUT-TO-OUT (ft.)	0
(32) APPROACH ROADWAY WIDTH (ft.)	26.0
(33) BRIDGE MEDIAN	0 - No median
(34) SKEW (deg.)	15
(35) STRUCTURE FLARED	0 - No flare
(10) INV RTE, MIN VERT CLEARANCE (ft.)	328.05
(47) TOTAL HORIZONTAL CLEARANCE (ft.)	31.0
(53) VERTICAL CLEARANCE OVER BRIDGE ROADWAY (ft.)	327.76
(54) MIN VERTICAL UNDERCLEARANCE	
(54A) REFERENCE FEATURE	N - Feature not a highway or railroad
(54B) MIN VERTICAL UNDERCLEARENCE (ft.)	0
(55) MIN LATERAL UNDER CLEARANCE RIGHT	
(55A) REFERENCE FEATURE	N - Feature not a highway or railroad
(55B) MIN LATERAL UNDER CLEARANCE RIGHT (ft.)	327.76
(56) MIN LATERAL UNDER CLEARANCE (ft.)	0

Classification

(112) NBIS BRIDGE LENGTH	No
(104) HIGHWAY SYSTEM OF THE INVENTORY ROUTE	0 - Structure/Route is NOT on NHS
(26) FUNCTIONAL CLASSIFICATION OF INVENTORY ROUTE	19 - Urban - Local
(100) STRAHNET HIGHWAY DESIGNATION	Not a STRAHNET route
(101) PARALLEL STRUCTURE DESIGNATION	N - No parallel structure
(102) DIRECTION OF TRAFFIC	2-way traffic
(103) TEMP STRUCTURE	
(105) FEDERAL LANDS HIGHWAYS	Not Applicable
(110) DESIGNATED NATIONAL NETWORK	Inventory route not on network
(20) TOLL	3 - On Free Road
(21) MAINTENANCE RESPONSIBILITY	03 - Town or Township Highway Agency
(22) OWNER	03 - Town or Township Highway Agency
(37) HISTORICAL SIGNIFICANCE	5 - Not eligible

Condition

(58) DECK	N - Not Applicable
(59) SUPERSTRUCTURE	N - Not Applicable
(60) SUBSTRUCTURE	N - Not Applicable
(61) CHANNEL & CHANNEL PROTECTION	7 - Bank protection needs minor repairs
(62) CULVERT	4 - Large spalls, heavy scaling, wide cracks

Load Rating and Posting

(31) DESIGN LOAD	9 - HS 25 or greater
(63) METHOD USED TO DETERMINE OPERATING RATING	1 - Load Factor (LF)
(64) OPERATING RATING	60.8
(65) METHOD USED TO DETERMINE INVENTORY RATING	1 - Load Factor (LF)
(66) INVENTORY RATING	40.8
(70) BRIDGE POSTING	5 - Equal to or above legal
(41) STRUCTURE OPEN/POSTED/CLOSED	A - Open

Appraisal

(67) STRUCTURAL EVALUATION	4
(68) DECK GEOMETRY	N
(69) UNDERCLEARANCES, VERTICAL & HORIZONTAL	N
(71) WATERWAY ADEQUACY	8 - Bridge Above Approaches
(72) APPROACH ROADWAY ALIGNMENT	8 - Equal to present desirable criteria
(36) TRAFFIC SAFETY FEATURE	
36A) BRIDGE RAILINGS:	0 - Does not meet acceptable standards/safety feature is required
36B) TRANSITIONS:	0 - Does not meet acceptable standards/safety feature is required
36C) APPROACH GUARDRAIL	0 - Does not meet acceptable standards/safety feature is required
36D) APPROACH GUARDRAIL ENDS	0 - Does not meet acceptable standards/safety feature is required
(113) SCOUR CRITICAL BRIDGES	8 - Stable for scour conditions

Proposed Improvements

(75) TYPE OF WORK

(75A) TYPE OF WORK PROPOSED	
(75B) WORK DONE BY	
(76) LENGTH OF STRUCTURE IMPROVEMENT (ft.)	
(94) BRIDGE IMPROVEMENT COST (SK)	
(95) ROADWAY IMPROVEMENT COST (SK)	
(96) TOTAL PROJECT COST	
(97) YEAR OF IMPROVEMENT COST ESTIMATE	
(114) FUTURE ADT	1620
(115) YEAR OF FUTURE ADT	2036

Navigation Data

(38) NAVIGATION CONTROL	0 - No navigation control on waterway (bridge
(111) PIER OR ABUTMENT PROTECTION	
(39) NAV VERT CLEARANCE	0
(116) MIN NAVIGATION VERT CLEARANCE, VERT LIFT BRIDGE	0
(40) NAV HORIZONTAL CLEARANCE	0

Inspection Notes

Structure Number: 6014

Town: Cape Elizabeth

Structure Name: TOWN LINE

Structure Notes

11 foot aluminum bolted pipe culvert.

Wearing Surface

Deck **NBI Item 58:** N

Superstructure **NBI Item 59:** N

Substructure **NBI Item 60:** N

Culvert **NBI Item 62:** 4

Pipe itself in generally fair condition w/minor deflection of southerly side. corrosion along bolt line. Dive inspection found holes along top plate. Embankments have both eroded, beginning to effect shoulder pavement (photo). Pavement is cracked and opened up over center line of pipe. Fill has washed away from sides of pipe making it a high point allowing the pavement to break over the top. Additional rip rap is necessary to prevent further erosion. Pavement is worn and may need replacement over pipe. Too deep to wade see latest dive report.

Channel **NBI Item 61:** 7

Other

Special Inspection

Monitoring

Pontis Notes

Pictures

PHOTO 1

Description View of roadway facing North

PHOTO 2

Description Down stream view

Pictures

PHOTO 3

Description General view of barrel showing some corrosion along bolt line

PHOTO 4

Description View showing crack in pavement above pipe

Pictures

PHOTO 5

Description Up stream view

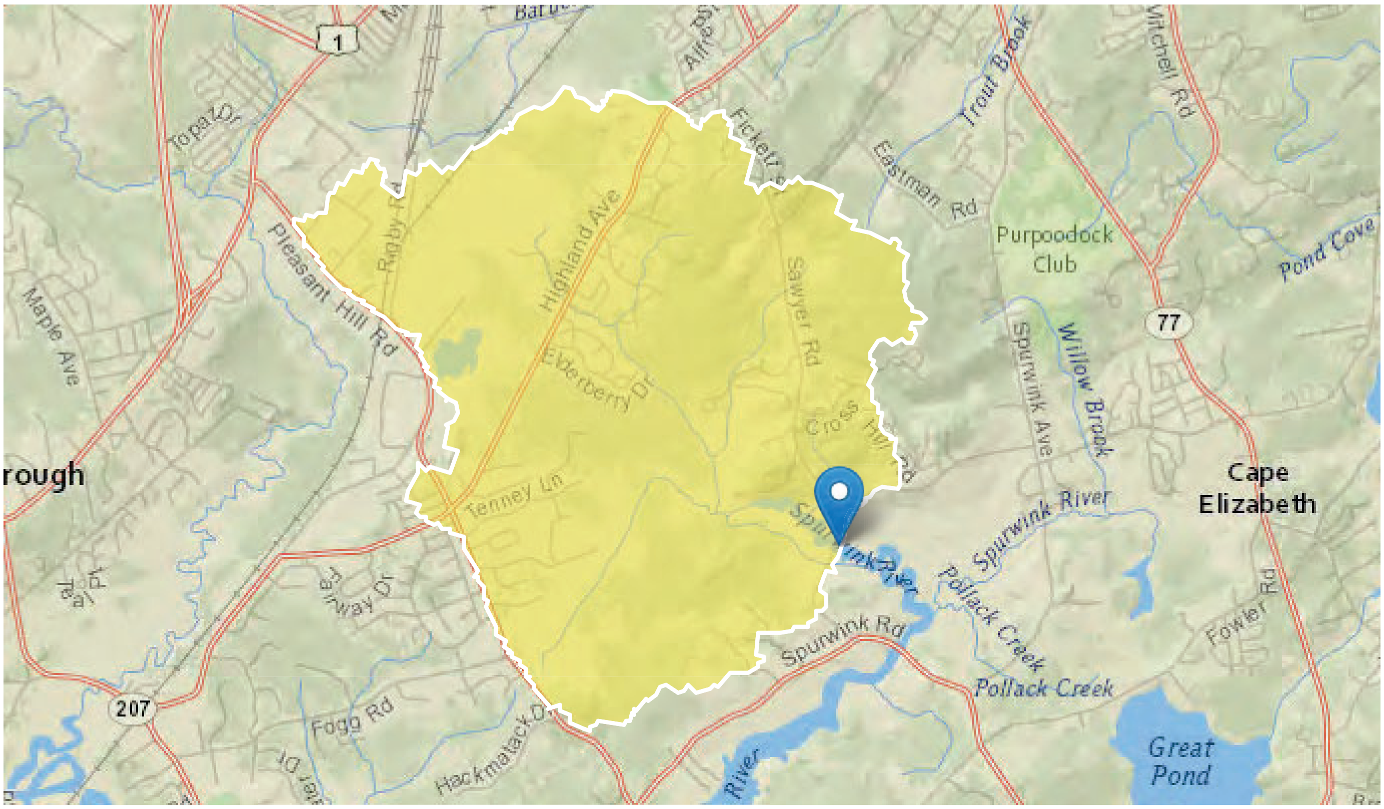
PHOTO 6

Description View showing low approach rail

APPENDIX B

StreamStats Report

Region ID: ME
Workspace ID: ME20200106193407983000
Clicked Point (Latitude, Longitude): 43.58850, -70.26268
Time: 2020-01-06 14:34:25 -0500



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	4.5	square miles
STORNWI	Percentage of storage (combined water bodies and wetlands) from the National Wetlands Inventory	23.01	percent
SANDGRAVAF	Fraction of land surface underlain by sand and gravel aquifers	0.078	dimensionless
BSLDEM10M	Mean basin slope computed from 10 m DEM	4.11	percent
CENTROIDX	Basin centroid horizontal (x) location in state plane coordinates	396660	meters

Parameter Code	Parameter Description	Value	Unit
CENTROIDY	Basin centroid vertical (y) location in state plane units	4828074.58	meters
COASTDIST	Shortest distance from the coastline to the basin centroid	31	miles
ELEV	Mean Basin Elevation	44.4	feet
ELEVMAX	Maximum basin elevation	161.5	feet
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	34.3	percent
LC06WATER	Percent of open water, class 11, from NLCD 2006	0.99	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	10.3	percent
PRECIP	Mean Annual Precipitation	45.2	inches
SANDGRAVAP	Percentage of land surface underlain by sand and gravel aquifers	7.83	percent
STATSGOA	Percentage of area of Hydrologic Soil Type A from STATSGO	32	percent

General Disclaimers

The delineation point is in an exclusion area. Warning! Coastal/Tidal areas are outside the hydrologic region defined by the study. Accuracy of regression equations is not defined.

Peak-Flow Statistics Parameters[Statewide Peak Flow DA LT 12sqmi 2015 5049]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	4.5	square miles	0.31	12
STORNWI	Percentage of Storage from NWI	23.01	percent	0	22.2

Peak-Flow Statistics Disclaimers[Statewide Peak Flow DA LT 12sqmi 2015 5049]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Peak-Flow Statistics Flow Report[Statewide Peak Flow DA LT 12sqmi 2015 5049]

Statistic	Value	Unit
1.01 Year Peak Flood	30.2	ft^3/s
2 Year Peak Flood	96.9	ft^3/s
5 Year Peak Flood	148	ft^3/s
10 Year Peak Flood	181	ft^3/s
25 Year Peak Flood	237	ft^3/s
50 Year Peak Flood	268	ft^3/s
100 Year Peak Flood	314	ft^3/s
250 Year Peak Flood	344	ft^3/s
500 Year Peak Flood	411	ft^3/s

Peak-Flow Statistics Citations

Lombard, P.J., and Hodgkins, G.A.,2015, Peak flow regression equations for small, ungaged streams in Maine— Comparing map-based to field-based variables: U.S. Geological Survey Scientific Investigations Report 2015–5049, 12 p. (http://dx.doi.org/10.3133/sir20155049)

Low-Flow Statistics Parameters[Statewide LowFlow SIR 2004 5026]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	4.5	square miles	9.79	1418
SANDGRAVAF	Fraction of Sand and Gravel Aquifers	0.078	dimensionless	0	0.455

Low-Flow Statistics Disclaimers[Statewide LowFlow SIR 2004 5026]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Low-Flow Statistics Flow Report[Statewide LowFlow SIR 2004 5026]

Statistic	Value	Unit

Statistic	Value	Unit
7 Day 10 Year Low Flow	0.212	ft^3/s

Low-Flow Statistics Citations

Dudley, R.W.,2004, Estimating Monthly, Annual, and Low 7-Day, 10-Year Streamflows for Ungaged Rivers in Maine: U.S. Geological Survey Scientific Investigations Report 2004-5026, 22 p. (http://water.usgs.gov/pubs/sir/2004/5026/pdf/sir2004-5026.pdf)

Application Version: 4.3.11

ACADIA CIVIL WORKS
ENGINEERING DESIGN & CONSULTATION