Brunswick Harbor Navigation Project Modifications and Harbor Dredging Operations and Maintenance Glynn County, Georgia

Final Integrated Feasibility Report and Environmental Assessment

Appendix E: Climate Change

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APPENDIX E
CLIMATE CHANGE FOR
BRUNSWICK HARBOR MODIFICATION STUDY

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E CLIMATE CHANGE ASSESSMENT ON BRUNSWICK HARBOR MODIFICATION STUDY

This appendix discusses the climate change assessment performed for the Brunswick Harbor Modification Study (BHMS). Climate change assessments are required for all phases of the project life cycle including feasibility and pre-construction engineering and design (PED), for both existing and proposed projects. Because climate science is continuing to evolve, additional climate assessments may be performed during future project phases, which may include quantitative climate assessments on sea-level change (SLC) and/or updated hydrology. SLC and hydrologic changes in air temperature, precipitation, and stream flow patterns associated with climate change could have a dramatic impact on hydrologic conditions and water resources infrastructure in the state of Georgia.

In this appendix, all elevations use North American Vertical Datum of 1988 (NAVD88) unless otherwise indicated.

E.1. INTRODUCTION

The USACE Civil Works Program and its water resources infrastructure represent a tremendous federal investment that supports public health and safety, regional and national economic development, and national ecosystem restoration goals.

Climate change is one of many global changes the USACE faces in carrying out its missions to help manage the nation's water resources infrastructure. The hydrologic and coastal processes underlying water resources infrastructure have the potential to be sensitive to changes in climate. Therefore, the USACE has the need to understand and adapt to climate change and variability, while continuing to provide the authorized level of performance under changing conditions. The objective of the USACE Climate Preparedness and Resilience (CPR) Community of Practice (CoP) is to mainstream climate change adaptation in all activities to enhance the resilience of the USACE water resources infrastructure and to reduce their potential vulnerabilities to the effects of climate change (USACE, 2019).

Recognizing that, over time, uncertainty may decrease as we increase our knowledge of climate change, its impacts, and the effects of adaptation and mitigation options (including unintended consequences), water resource engineers must establish decision processes that incorporate new information. The use of rigorous management in an adaptive fashion, where decisions are made sequentially over time, allows adjustments to be made as more information is known. The use of longer planning horizons, combined with updated economic analyses, will support sustainable solutions in the face of changing climate that meet the needs of the present without compromising the ability of future generations to meet their own needs (USACE, 2018d).

As part of its water resources management missions and operations, the USACE has been working together with other federal agencies, academic experts, nongovernmental organizations, and the private sector to translate climate science into actionable science for decision-making. The USACE Civil Works Program has developed tools to analyze the potential effects and uncertainties associated with climate change and SLC relative to the USACE portfolio.

Engineering Construction Bulletin (ECB) no. 2018-14 (USACE ECB 2018) provides guidance for incorporating climate change information in hydrologic analysis in accordance with the USACE overarching climate change adaptation policy. It calls for a qualitative analysis. The goal of a qualitative analysis of potential climate threats and impacts to USACE hydrology-related projects and operations is to describe the observed present and possible future climate threats, vulnerabilities, and impacts of climate change specific to the study. This includes consideration of both past (observed) changes as well as potential future (projected) changes to relevant meteorological and hydrologic variables.

E.1.1. Climate Change Assessment Limitations and Areas of Future Study

At this feasibility stage in the BHMS, many factors were analyzed with regard to Climate Change. There are additional factors that can affect Brunswick Harbor. The following changes are assumed to affect the Harbor with or without project. Shoaling rates, shoreline changes, velocities and salinity were not evaluated in this Climate Change Assessment. Shoaling rates, velocities and salinity would take additional ADH modeling, including the addition of sedimentation transport modeling.

E.2. KEY FINDINGS

1) The main climate change assessment is the potential of impacts from future Sea Level Change (SLC).
2) The SLC in the Brunswick Harbor is only forecasted to be Sea Level Rise (SLR).
3) Impacts from SLR are unchanged from the No Action Alternative versus all Action Alternatives.
4) Inland hydrology is not expected to affect Brunswick Harbor, because it is the outlet of the drainage area.
5) Shoaling rates, shoreline changes, velocities and salinity were not evaluated with regard to Climate Change at this feasibility stage of the project.
6) There is a strong agreement in the literature that temperature for the Southeast region, and the entire country, will increase over the next century.
7) Projections for precipitation events and hydrology are less certain than temperature projections for the Southeast Region.

E.3. PROJECT OVERVIEW

To better understand how climate change impacts the BHMS, it is important to understand how the project fits in with the surrounding region. For most studies in waterways, projects are part of a larger watershed and interconnected ecosystem (Figure E. 1). The interaction between the Brunswick Harbor modifications and the larger watershed and interconnected ecosystem is complex. In order to assess future adaptations in the project needed for climate change, these will need to be comprehensively assessed for the Satilla Watershed, which is where the Brunswick Harbor is located.

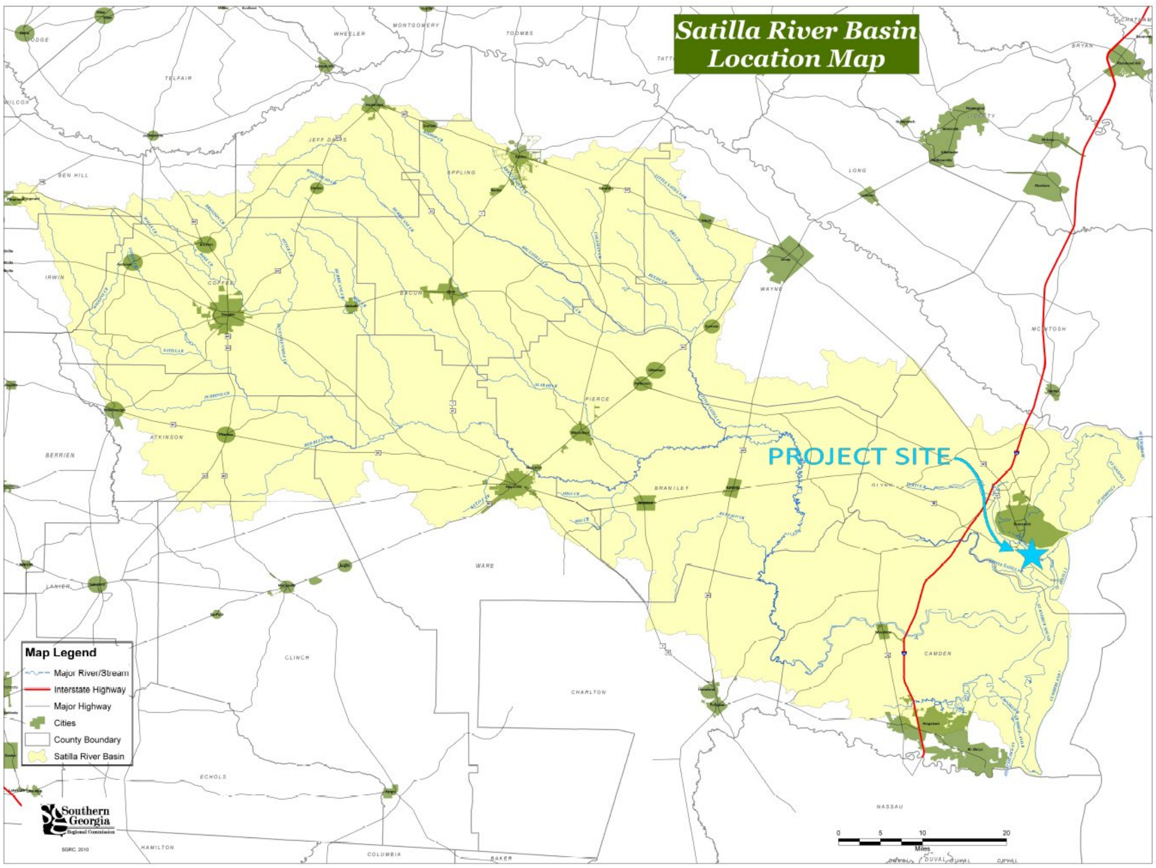


Figure E. 1 Brunswick Harbor Satilla Watershed (Satilla Riverkeeper, 2019).

E.3.1 BHMS Project Description

The feasibility study will analyze alternatives for navigation improvements to Brunswick Harbor, including a bend widener, two meeting areas and a turning basin. The study will identify and evaluate a full range of reasonable alternatives including the No-Action alternative. The non-federal sponsor of the project is Georgia Ports Authority (GPA). The feasibility study is authorized through WRDA 2016.

Figure E. 2 Map of Brunswick Harbor and existing channel.

E.3.2 Proposed Brunswick Harbor Channel Modifications

The Brunswick Harbor Modification study (BHMS) is to modify the existing federal navigation project in Brunswick Harbor, Glynn County, Georgia. The study includes nine alternatives, with combinations of four different proposed modifications. The proposed modifications are:

A. Bend Widener (Widener 13): Widen the existing bend at Cedar Hammock Range between stations 20+300 and 23+300. The Bend Widener widens the channel approximately 400 feet.
B. Turning Basin: Expanding the Colonel's Island Turning Basin between stations 0+900 to 5+300, located at the confluence of Turtle River and South Brunswick River. The Turning Basin widens the channel along the northwest side.
C. Sidney Lanier Bridge Meeting Area: Widen the channel northwest of the Sidney Lanier Bridge between stations 34+200 to 43+200. The meeting area widens the

channel from 400 feet to 800 feet, expanding the channel equally on both sides of the centerline of the channel.

D. St. Simons Sound Meeting Area: Widen the channel north in St. Simons Sound between stations -6+800 to 4+300. The meeting area expands the channel an additional 400 feet to the north of the existing channel.

The targeted benefits of the Brunswick Harbor Channel Modifications (BHCM) are:

- Transportation cost savings: the modifications result in reduced transportation cost by creating fewer delays and less congestion when traversing the port. Furthermore, the creation of a meeting area reduces wait times in the harbor.
- Safety: The proposed BHCM would result in improved safety for the vessels and better environmental protection.

USACE conducted the following model runs, using a 2D Adaptive Hydraulics (ADH) model, to develop alternatives for further analysis. Each of the 4 proposed modification proponents (Bend Widener, Turning Basin, Sidney Lanier Bridge Meeting Area and St. Simons Sound Meeting Area) were models using ADH. The alternatives included in the BHMS are, as follows:

Alternative 1:
- No Action

Alternative 2:
- Bend Widener

Alternative 3:
- Turning Basin

Alternative 4:
- Sidney Lanier Bridge Meeting Area

Alternative 5:
- St. Simons Sound Meeting Area

Alternative 6:
- Bend Widener
- Turning Basin

Alternative 7:
- Bend Widener
- Turning Basin
- Sidney Lanier Bridge Meeting Area

Alternative 8:
- Bend Widener
- Turning Basin
- St. Simons Sound Meeting Area

Alternative 9:
- Bend Widener
- Turning Basin
- Sidney Lanier Bridge Meeting Area
- St. Simons Sound Meeting Area

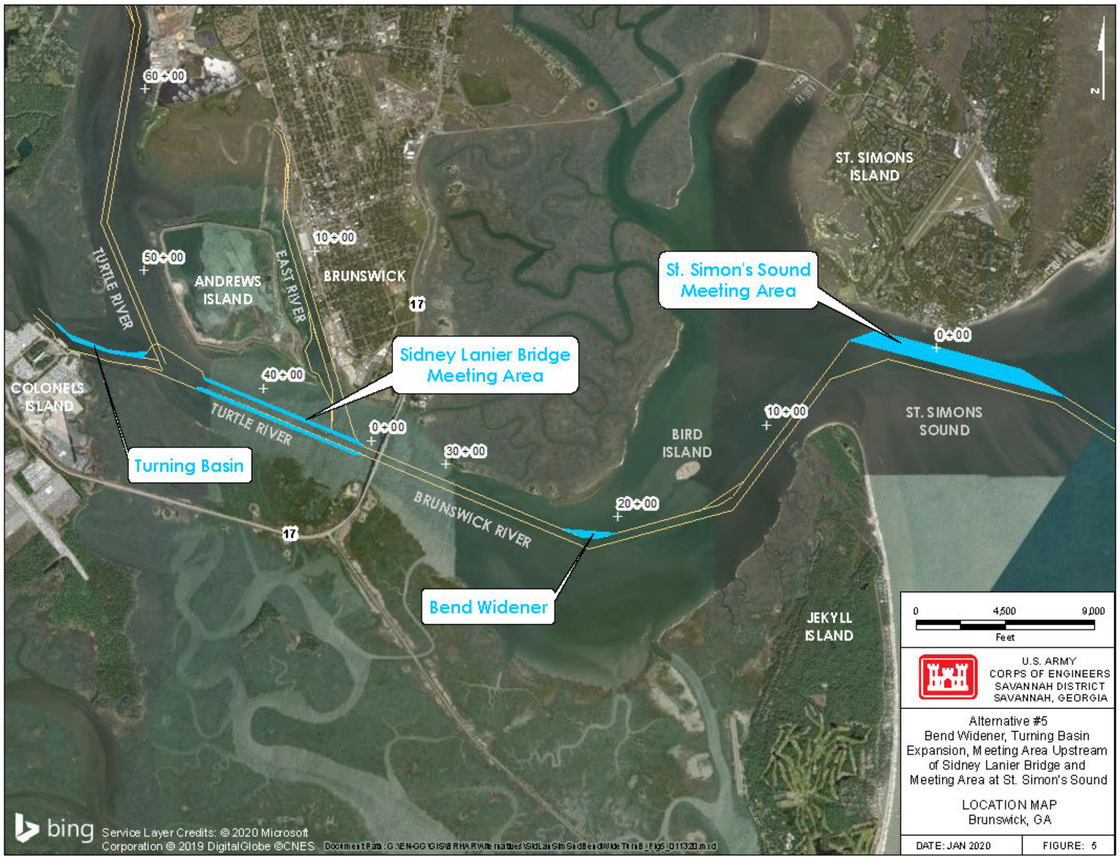


Figure E. 3 Map of proposed BHCM feature locations.

E.4. LITERATURE REVIEW

As required by ECB 2018-14, a hydrologic literature review was conducted to summarize peer reviewed literature on current climate and observed climate trends and projected climate trends in the project area. The literature review includes sources specific to Georgia, and the surrounding Southeast United States:

1) *Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions: South Atlantic-Gulf Region 03* (USACE, 2015)
2) *Climate Change Indicators in the United States (U.S. Environmental Protection Agency, 2019)*
3) *Climate Science Special Report: Fourth National Climate Assessment, Volume I (Carter, et al., 2014)*
4) *NOAA State Climate Summaries (Frankson & Kunkel, 2017)*

The literature focuses on the following climate variables, which are consistent with those identified for the project: precipitation, temperature and streamflow.

A summary of the USACE peer-reviewed climate literature is available for the South Atlantic-Gulf Region and is referenced as one of the primary sources of information in this literature review. This USACE report summarizes observed and projected climate and hydrological patterns cited in reputable peer-reviewed literature and authoritative national and regional reports, and characterizes climate threats to the USACE business line (USACE, 2015). The project watershed falls within the South Atlantic-Gulf Region, which is also referred to as Water Resources Region 03 (2-digit hydrologic unit code, or HUC03).

E.5. TEMPERATURE TRENDS

According to the Third National Climate Assessment, climate change is expected to intensify current, observed trends in temperature and precipitation in the U.S., including the Southeast region (Carter, et al., 2014). The BHMS is located at the Brunswick Harbor, approximately 30 miles north of the Florida-Georgia border on the Atlantic Ocean, just south of Brunswick, Georgia. The project location relative to the Southeast region is highlighted in Figure E. 4.

E.5.1. Historic and Existing Temperature Trends

Georgia's latitude and close proximity to the warm waters of the Gulf of Mexico and the Atlantic Ocean characterize the climate as long, hot, humid summers and short, mild winters. Over the last 100 years, the Southeast's observed, average annual temperatures have cycled between warm and cool periods, but since 1970, temperatures have increased an average of 2°F. In that time, the number of days above 95°F and nights above 75°F have been increasing, while extremely cold days have been decreasing (Frankson & Kunkel, 2017).

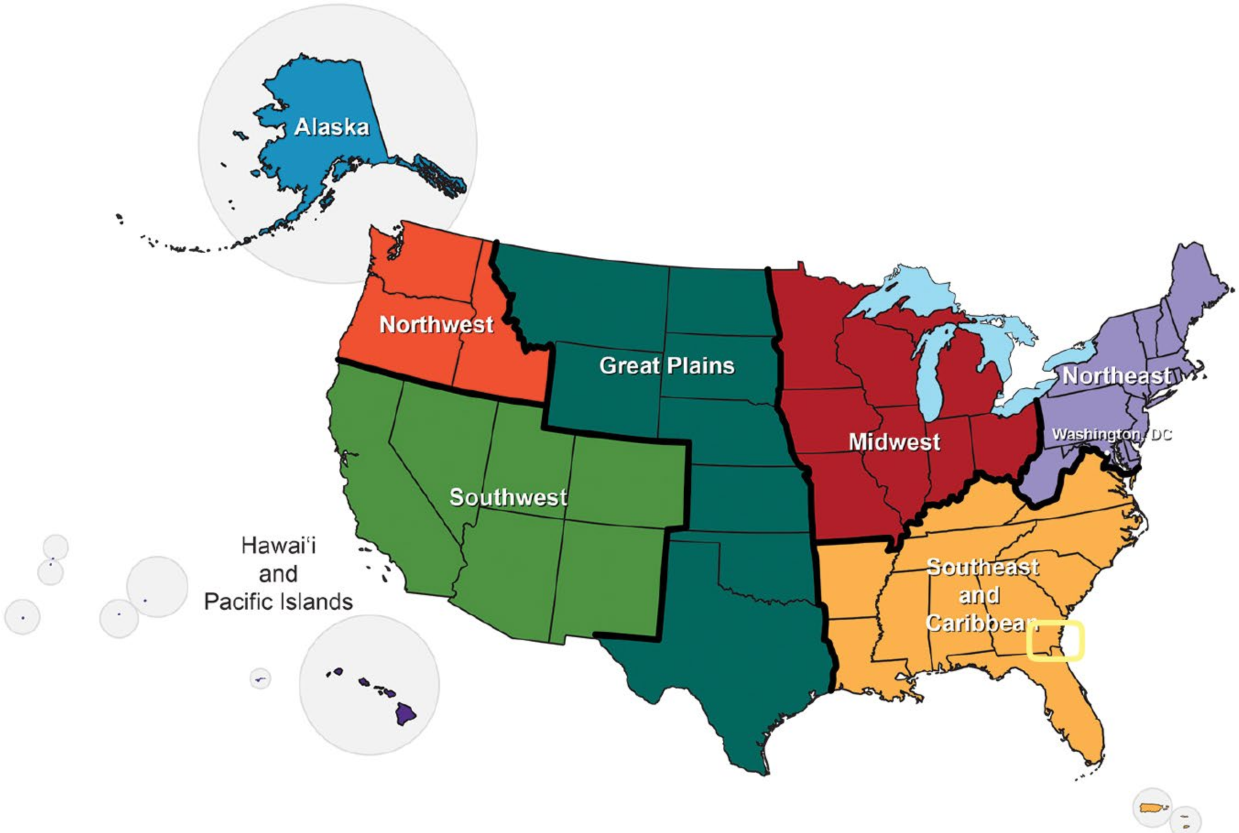


Figure E. 4 Regions identified as part of the Third National Climate Assessment - Approximate project area circled in yellow - Southeast region is in light orange (Carter, et al., 2014).

E.5.2. Projected Temperature Trends

Temperatures across the Southeast are projected to increase during this century as depicted in Figure E. 5. Major consequences of warming include significant increase in the number of hot days, 95°F and above (Carter, et al., 2014). This increases evaporation and decreases freezing events. Increased evaporation correlates to overall less flow in the river, possibly exposing more shoaling areas and diminishes the amount of spawning areas available for fish (Carter, et al., 2014). The river flows are not anticipated to affect the study area because of the proximity to the Atlantic Ocean.

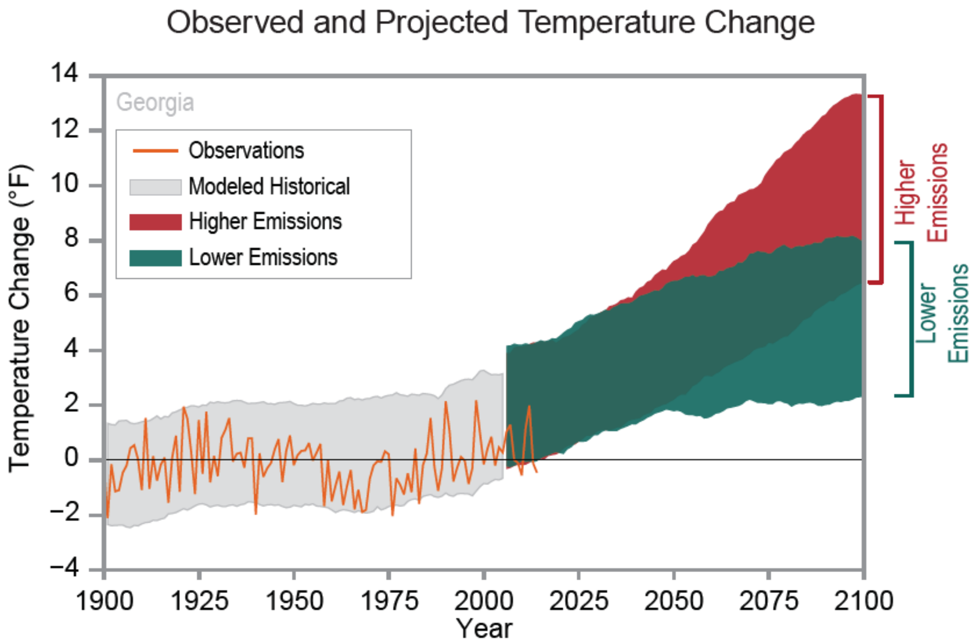


Figure E. 5 Georgia observed temperature change (orange line) and projected temperature change (Carter, et al., 2014).

E.6. PRECIPITATION TRENDS

E.6.1. Historic and Existing Precipitation Trends

Georgia receives frequent precipitation throughout the year, ranging from upwards of 80 inches in the mountainous northeastern corner of the state to around 45 inches in the eastern and central portions. Precipitation projections for Georgia are uncertain Figure E. 6. Even if average annual precipitation remains constant, higher temperatures will increase evaporation rates and decrease soil moisture during dry spells, leading to greater drought intensity. This could increase competition for limited water resources.

The Eastern portion of the Southeast has observed drier conditions whereas the rest of the region has experienced wetter conditions. Daily and five-day observed rainfall intensities have increased (Ingram, Dow, Carter, & Anderson, 2013), but summers have been either increasingly dry or extremely wet, which is indicative of the variability of the climate in the Southeast (Frankson & Kunkel, 2017). Linear trends in observed annual precipitation indicate a +5 - +10% increase in precipitation in the Satilla Watershed (McRoberts & Nielsen-Gammon, 2011). The Southeast has seen a 27% increase in heavy precipitation events (defined as the heaviest 1% of all daily events) since 1900 (Karl, Melillo, & Peterson, 2009) and is projected to see a varied increase in storm severity and in the frequency of severe storms in the future.

E.6.2. Projected Precipitation Trends

The frequency and intensity of precipitation is projected to increase more across the northern portion of the region and show less of an increase in the southern part of the Southeast region. As can be seen in Figure E. 6, precipitation is projected to increase throughout Georgia, however, these changes are small relative to the natural variability in this region. Soil moisture, critical for vegetation and agriculture, is determined in part by precipitation and temperature, which drives evapotranspiration (ET). Soil moisture fluctuates seasonally and has been observed to be decreasing over time in the Southeast (Hay, Markstrom, & Ward-Garrison, 2011).

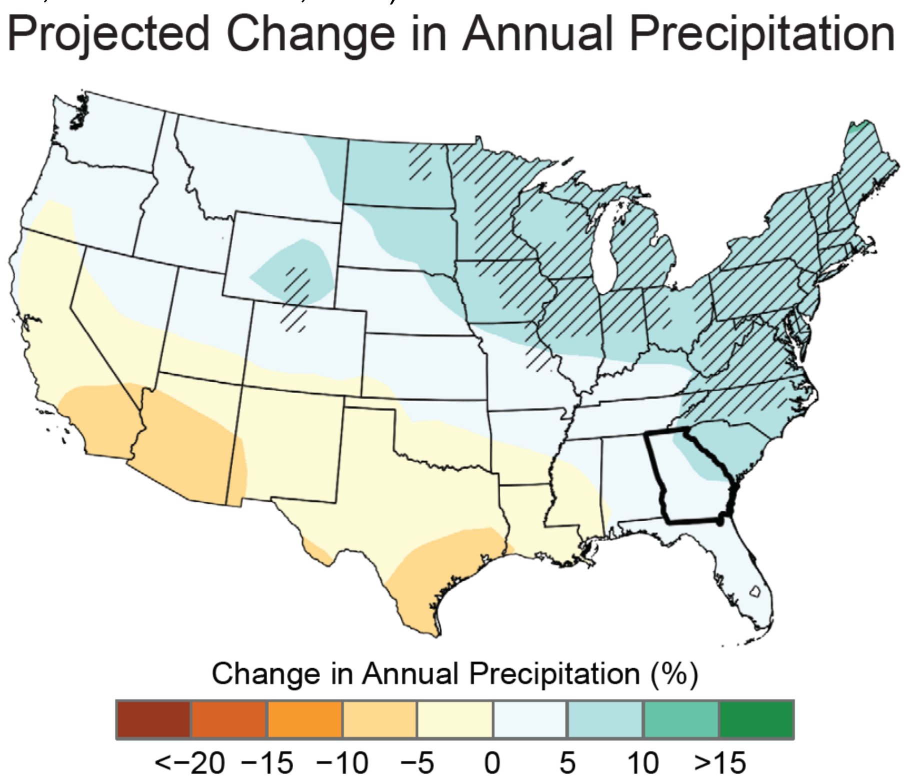


Figure E. 6 Climate model projections of changes (%) in annual precipitation for the middle of the 21st century compared to the late 20th century under a higher emissions pathway. Precipitation is projected to increase throughout Georgia, however these changes are small relative to the natural variability in this region. Source: CICS-NC, NOAA NCEI, and NEMAC (Frankson & Kunkel, 2017).

E.7. STREAMFLOW TRENDS

E.7.1. Historic and Existing Streamflow Trends

Studies of trends and non-stationarities in streamflow datasets collected over the past century have been performed throughout the continental U.S., some of which include the South Atlantic-Gulf Region. With the exception of two stations in Florida, the vast majority of stations distributed throughout the region showed no significant trend in streamflow in either direction (USACE, 2015).

E.7.2. Projected Streamflow Trends

A number of global and national scale studies have attempted to project future changes in hydrology, relying primarily on a combination of Global Climate Models (GCMs) and macro-scale hydrologic models. These studies include projections of potential hydrologic changes in the South Atlantic-Gulf Region. Thomson et al. (2005) applied two GCMs, across a range of varying input assumptions, in combination with the macro-scale Hydrologic Unit Model to quantify potential changes in water yield across the United

States. For the South Atlantic-Gulf Region, contradictory results are generated by the two GCMs. For the same set of input assumptions, one model predicts significant decreases in water yield, the other projects significant increases in water yield (USACE, 2015). No clear consensus has been found in projected streamflow changes in the South Atlantic-Gulf Region. Some studies point towards mild increases in flow, while other studies point toward mild decreases in projected streamflow.

E.8. WATERSHED VULNERABILITY ASSESSMENT

The USACE Watershed Vulnerability Assessment (VA) Tool provides a nationwide, screening-level assessment of climate change vulnerability relating to the USACE mission, operations, programs and projects. Indicators are used to develop vulnerability scores specific to each of the 200 watersheds within the contiguous United States and to each of the USACE business lines. The Weighted Order Weighted Average (WOWA) method is used to aggregate individual vulnerability indicators and their associated datasets into the watershed scale vulnerability scores. The WOWA score combines indicators using a weighting technique to control how much an indicator with a small value can average out an indicator with a large value, thereby affecting perceived vulnerability. An increasing WOWA score is increasing in vulnerability. The VA Tool is based on downscaled climate information and hydrology aggregated at the watershed level for selected indicator variables. The tool supports a qualitative identification of potential vulnerabilities for more detailed study (USACE, 2020).

The VA Tool examines the vulnerability of projects within all the USACE business lines using data for two scenarios and three epochs. The epochs include the current time period as the base period and two future 30-year periods centered on the years 2050 (2035-2065) and 2085 (2070-2099). Within each future epoch, GCMs are sorted by cumulative runoff projections and divided into two equal-sized groups that represent a Dry scenario and a Wet scenario. All results are thus given for each combination of scenario and future epoch: Dry-2050, Dry-2085, Wet-2050 and Wet-2085. The VA Tool allows the user to explore dominant indicators and summarize vulnerability in several different ways for each scenario/epoch combination. The current study will use the VA Tool to perform such an analysis on Coastal Georgia (HUC 0307), which includes the BHMS area, with emphasis on the indicators of vulnerability for the primary business line, Navigation.

Table E. 1 provides the name of selected indicators for the Navigation business line and the importance weight within the VA Tool within a National Standard View, along with a brief description of each.

Table E. 1 Number, name and description of selected indicators for the Navigation Business Line within the VA Tool.

Importance Weight	Name	Description
2.0	FLOOD MAGNIFICATION	Change in flood runoff: ratio of indicator 571C (monthly runoff exceeded 10% of the time, including upstream freshwater inputs) to 571C in base period.
2.0	DROUGHT SEVERITY	Greatest precipitation deficit: The most negative value calculated by subtracting potential evapotranspiration from precipitation over any 1-, 3-, 6-, or 12-month period.
1.75	90% EXCEEDANCE	Low runoff: monthly runoff that is exceeded 90% of the time, including upstream freshwater inputs (cumulative).
1.50	SEDIMENT	The ratio of the change in the sediment load in the future to the present load.
1.50	RUNOFF PRECIPITATION	Median of: deviation of runoff from monthly mean times average monthly runoff divided by deviation of precipitation from monthly mean times average monthly precipitation.
1.50	LOW FLOW REDUCTION	Change in low runoff: ratio of indicator 570C (monthly runoff exceeded 90% of the time, including upstream freshwater inputs) to 570C in base period.
1.25	90% EXCEEDANCE	Low runoff: monthly runoff that is exceeded 90% of the time, excluding upstream freshwater inputs (local).
1.0	URBAN SUBURBAN	Land area that is urban or suburban as a percentage of the total U.S. land area.
1.0	MONTHLY COV	Measure of short-term variability in the region's hydrology: 75th percentile of annual ratios of the standard deviation of monthly runoff to the mean of monthly runoff. Includes upstream freshwater inputs (cumulative).
1.0	0.2 AEP FLOODPLAIN AREA	Area in the 0.2% Annual Exceedance Probability floodplain

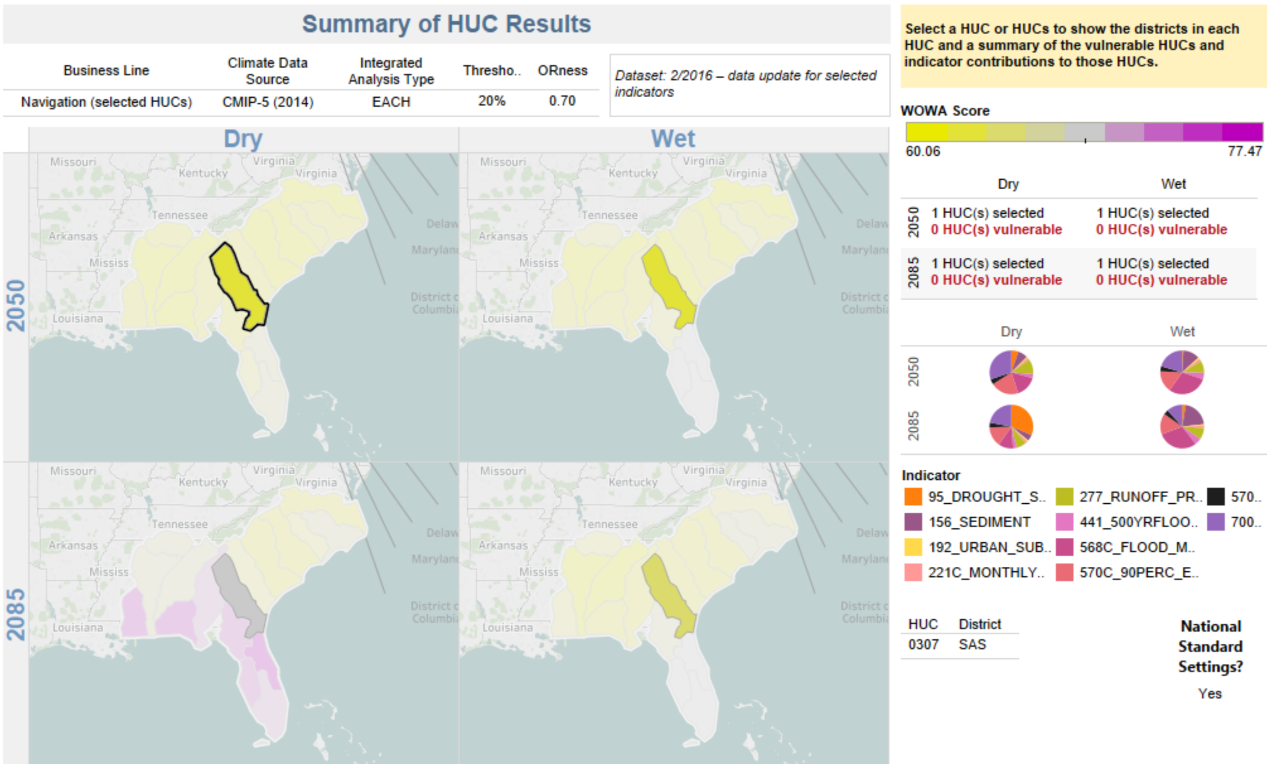
To set the context of this watershed nationally, within the USACE South Atlantic Division (SAD), and within the Savannah District (SAS), Table E. 2 lists the vulnerability scores for the Navigation business line for HUC 0307 as well as the range of scores nationally and for SAD and SAS for all scenario-epoch combinations. Vulnerability of the Navigation business line within HUC 0307 for the 2085 epoch for both wet and dry scenarios appears to be ranked near the top in the Savannah District. For all scenarios and epochs HUC 0307 appears to rank slightly above average nationally and in the South Atlantic Division. For HUC 0307, no scenarios or epochs classify as vulnerable for the Navigation business line when compared to the rest of the nation (top 20%). These results suggest that climate impacts may be considered low in the planning and design of navigation within HUC 0307, including the BHMS.

Table E. 2 Vulnerability Scores for HUC 0307 (WOWA Score) for the Navigation business line for each scenario-epoch combination nationally, SAD and SAS.

Business Line	Epoch	WOWA Score	Range Nationally	Range in SAD	Range in SAS
Navigation	Dry - 2050	63.46748	54.86 - 77.47	60.06 - 77.47	62.32 - 69.33
	Dry - 2085	69.32591			
	Wet - 2050	63.83378	56.39 - 84.43	60.43 - 69.33	60.96 - 64.06
	Wet - 2085	64.05832			
	Base	60.23054			

In Figure E. 7 it shows the HUC 307 highlighted from yellow to pink based on the WOWA score. To the right of the figure shows a pie chart for each scenario, showing the weighted contributing indicators to vulnerability. For example, for the scenario epoch 2050 Dry condition low flow reduction and 90% exceedance are the major indicators contributing to vulnerability. For the scenario in epoch 2085, wet condition flood magnification and drought severity are the largest contributing indicators to vulnerability.

Figure E. 7 Results of the USACE climate vulnerability analysis for the Navigation WOWA score of the Satilla Watershed compared to SAD.



E.9. SEA-LEVEL CHANGE OVERVIEW

The climate assessment for SLC follows the USACE guidance of Engineer Regulation (ER) 1100-2-8162, “Incorporating Sea Level Change in Civil Works Programs,” and Engineer Pamphlet (EP) 1100-2-1, “Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation.” ER 1100-2-8162 and EP 1100-2-1 provide guidance for incorporating the direct and indirect physical effects of projected future SLC across the project life cycle in managing, planning, engineering, designing, constructing, operating, and maintaining the USACE project. Planning studies and engineering designs over the project life cycle, for both existing and proposed projects, will consider alternatives that are formulated and evaluated for the entire range of possible future rates of SLC.

Per guidance from Engineering and Construction Bulletin (ECB) 2018-14, “Guidance for Incorporating Climate Change Impacts to inland Hydrology in Civil Works Studies, Designs, and Projects,” for project areas at elevations less than or equal to 50 feet, a determination should be made as to whether SLR will affect the river stage or performance/operation of the project by increasing (or decreasing) the water surface elevation downstream of the project area. If the project area is at an elevation less than or equal to 50 feet, then policy and procedures outlined in ER 1100-2-8162 will apply. For this project and all projects in southeast Georgia, projects are located at elevations less than 50 feet; therefore sea level guidance in ER 1100-2-8162 will apply. However, in this case, the ocean is downstream of the harbor and the project will not affect downstream or the local sea level.

SLC has been a persistent trend for decades in the United States and elsewhere in the world. Observed and reasonably foreseeable global SLR means that local sea levels will continue beyond the end of this century. In most locations, global SLR results in local relative SLR, which has already caused impacts such as flooding and coastal shoreline erosion to the nation's assets located at or near the ocean. These impacts will continue to change in severity. Along the U.S. Atlantic Coast alone, almost 60 percent of the land that is within a vertical meter of sea level is planned for further development. Wise decision-making requires adequate information on the potential rates and amount of SLC. Accordingly, the risks posed by SLC motivate decision-makers to ask: "What is the current rate of SLC, and how will that impact the future conditions that affect the performance and reliability of my infrastructure, or the current and future residential, commercial, and industrial development?" To better empower data-driven and risk-informed decision-making, the USACE has developed two web-based SLC tools: Sea Level Change Curve Calculator and the Sea Level Tracker. Both tools provide a consistent and repeatable method to visualize the dynamic nature and variability of coastal water levels at tide gauges, allow comparison to the USACE projected SLC scenarios, and support simple exploration of how SLC has or will intersect with local elevation thresholds related to infrastructure (e.g. roads, power generating facilities, dunes), and buildings. Taken together, decision-makers can align various SLR scenarios with existing and planned engineering efforts, estimating when and how the sea level may impact critical infrastructure and planned development activities (USACE, 2018b).

Both the Sea Level Change Curve Calculator and the Sea Level Tracker are designed to help with the application of the guidance found in ER 1100-2-8162 and EP 1100-2-1. The tools use equations in the regulation to produce tables and graphs for the following three SLC scenarios:

1) Baseline (or "low") estimate, which is based on historic SLR and represents the minimum expected SLC.
2) Intermediate estimate.
3) High estimate, representing the maximum expected SLC.

The calculator accepts user input—including project start date, selection of an appropriate NOAA long- term tide gauge, and project life span—to calculate projected SLCs for the respective project. The Sea Level Tracker has more functionality for quantifying and visualizing observed water levels and SLC trends and projections against existing threshold elevations for critical infrastructure and other local elevations of interest (USACE, 2018b). The start date used by the calculator is 1992, which corresponds to the midpoint of the current National Tidal Datum Epoch of 1983-2001.

E.9.1. Historic and Existing Conditions Sea Level Change

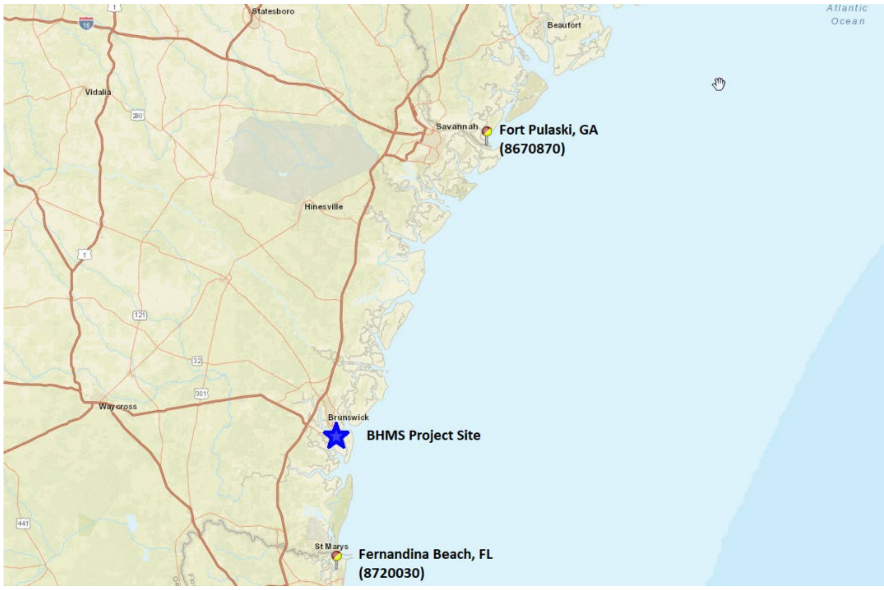


Figure E. 8 Location map of nearest tide gauges to the BHMS project site (NOAA, 2020).

The nearest NOAA tide gauge, located 30 miles south of Brunswick Harbor, is Fernandina Beach, FL 8720030. The relative sea level trend is 2.15 mm/year +/- 0.18 mm/year with a 95% confidence interval. This trend is based on monthly mean sea level data from 1897 to 2019 which is equivalent to a change of 0.71 feet in 100 years (NOAA, 2019). **Figure** E.8 shows a map that shows the two nearest NOAA tide gauges to Brunswick Harbor.

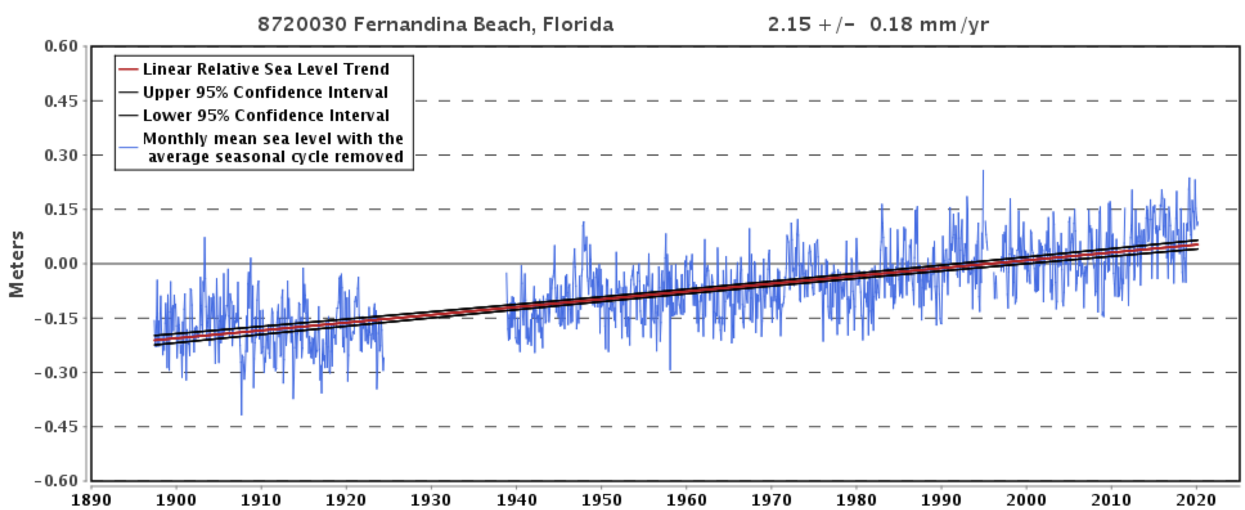


Figure E. 9 The relative sea level trend from Fernandina Beach, FL (NOAA, 2019).

The next nearest tide gauge and the only gauge located in Georgia is the Fort Pulaski, GA 8670870. The relative sea level trend is 3.33 mm/year +/- 0.27 mm/year with a 95% confidence interval. This trend is based on monthly mean sea level data from 1935 to 2019 which is equivalent to a change of 1.09 feet in 100 years (NOAA, 2019).

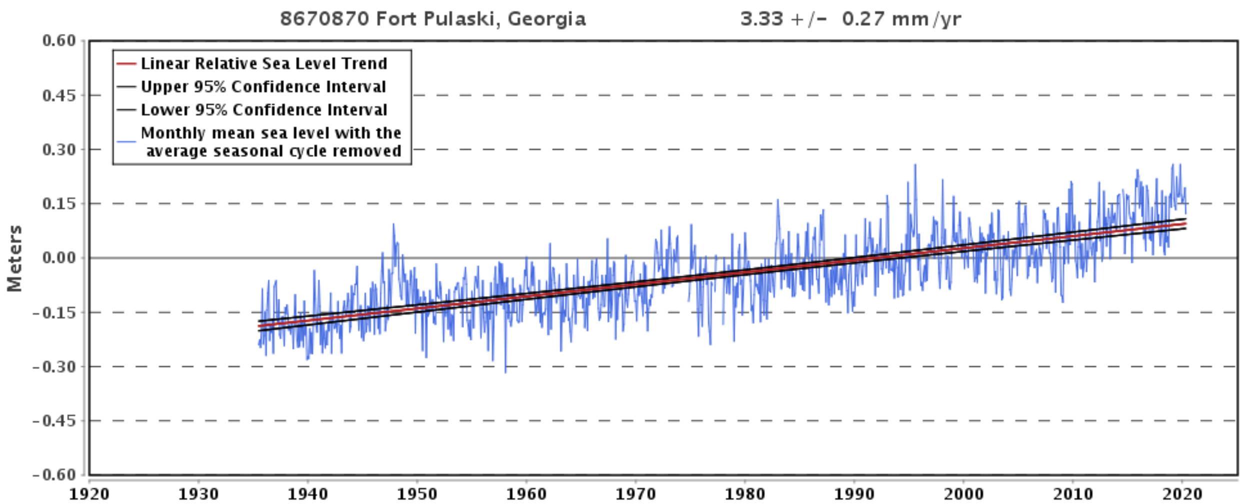


Figure E. 10 The relative sea level trend from Fort Pulaski, GA (NOAA, 2019).

E.9.2. Potential Impacts to the Project from Future Sea-level Change

The following analysis evaluates potential effects on operation of Brunswick Harbor. The project start of construction date is 2025, the following years are evaluated:

- 2025 (beginning of the BHMS planning horizon at the start of construction)
- 2075 (50 years beyond start of construction)
- 2125 (100 years beyond start of construction)

Climate for which the project is designed can change over the planning life cycle of that project and may affect its performance, or impact operation and maintenance activities. Given these factors, the USACE guidance from ECB 2018-14, suggests that the project life cycle should be up to 100 years. For most projects, the project life cycle starts when construction is complete which typically corresponds to the time when the project starts accruing benefits. For the BHMS, the project life cycle begins in 2025, when construction is planned to be complete. The navigation benefits could ultimately be affected in the 2075 and 2125 horizons. The economic analysis is conducted for a 50-year planning horizon. Hence, SLC considerations can show the magnitude of those impacts and will depend on how soon the sea rises to a level that impacts project performance.

Sea levels around Brunswick Harbor are expected to rise, depending on the projected rates of rise for low, intermediate, and high scenarios. Figure E. 11 shows the estimated relative SLC from 2025 to 2125, calculated with the USACE Sea Level Change Curve Calculator, Version 2019.21, at the Fernandino Beach, Florida and Fort Pulaski, Georgia NOAA gauges, which are located 30 miles south and 60 miles north of Brunswick Harbor, respectively. The defined rate of change was used from the NOAA sea level trend rates, shown in Figure E. 9 and Figure E. 10. The values shown for the Low, Intermediate and High USACE scenarios is the mean sea level expressed using NAVD88 elevation datum.

	BHMS 8720030, Fernandina Beach, FL User Defined Rate: 0.00705 feet/yr All values are expressed in feet relative to NAVD88				BHMS 8670870, Fort Pulaski, GA User Defined Rate: 0.01093 feet/yr All values are expressed in feet relative to NAVD88			
	Year	USACE Low	USACE Int	USACE High	Year	USACE Low	USACE Int	USACE High
PROJECT START	2025	-0.30	-0.20	0.11	2025	0.13	0.23	0.53
	2030	-0.26	-0.13	0.27	2030	0.19	0.31	0.72
	2035	-0.23	-0.06	0.46	2035	0.24	0.40	0.93
	2040	-0.19	0.01	0.66	2040	0.29	0.50	1.15
	2045	-0.16	0.09	0.89	2045	0.35	0.60	1.39
	2050	-0.12	0.18	1.13	2050	0.40	0.70	1.65
	2055	-0.09	0.27	1.39	2055	0.46	0.81	1.93
	2060	-0.05	0.36	1.66	2060	0.51	0.92	2.23
	2065	-0.02	0.46	1.96	2065	0.57	1.04	2.54
	2070	0.02	0.56	2.28	2070	0.62	1.16	2.88
50-YR ECONOMIC PLANNING ANALYSIS	2075	0.06	0.67	2.61	2075	0.68	1.29	3.23
	2080	0.09	0.78	2.96	2080	0.73	1.42	3.60
	2085	0.13	0.90	3.33	2085	0.79	1.56	3.99
	2090	0.16	1.01	3.72	2090	0.84	1.70	4.40
	2095	0.20	1.14	4.13	2095	0.90	1.84	4.83
	2100	0.23	1.27	4.56	2100	0.95	1.99	5.27
	2105	0.27	1.40	5.00	2105	1.00	2.14	5.74
	2110	0.30	1.54	5.46	2110	1.06	2.30	6.22
	2115	0.34	1.68	5.95	2115	1.11	2.46	6.72
	2120	0.37	1.83	6.45	2120	1.17	2.63	7.24
100-YR PLANNING HORIZON	2125	0.41	1.98	6.97	2125	1.22	2.80	7.78

Figure E. 11 Estimated USACE low, intermediate and high SLC projections at Fernandina Beach, Florida and Fort Pulaski, Georgia in feet relative to NAVD88, from years 2025 to 2125 (https://cwbi-app.sec.usace.army.mil/rccslc/slcc_calc.html).

E.9.3. Fernandina Beach, Florida NOAA Tidal Gauge

The closest tidal gauge to Brunswick Harbor is NOAA tidal gauge 8720030 in Fernandina Beach, Florida. Using the USACE Sea Level Change Curve Calculator, the three projected SLC elevation range between -0.30 to 0.11 feet by 2025, 0.06 to 2.61 feet by 2075 (50 years) and 0.41 to 6.97 feet by 2125 (100 years). These elevations are given in NAVD88. The existing mean sea level in NAVD88 is -0.53 feet, tidal epoch 1983-2001. The SLC rate is 0.00705 feet/year, from Figure E. 9 for the Fernandina Beach gauge. See Figure E. 12 for details on the three USACE-adopted projected trends.

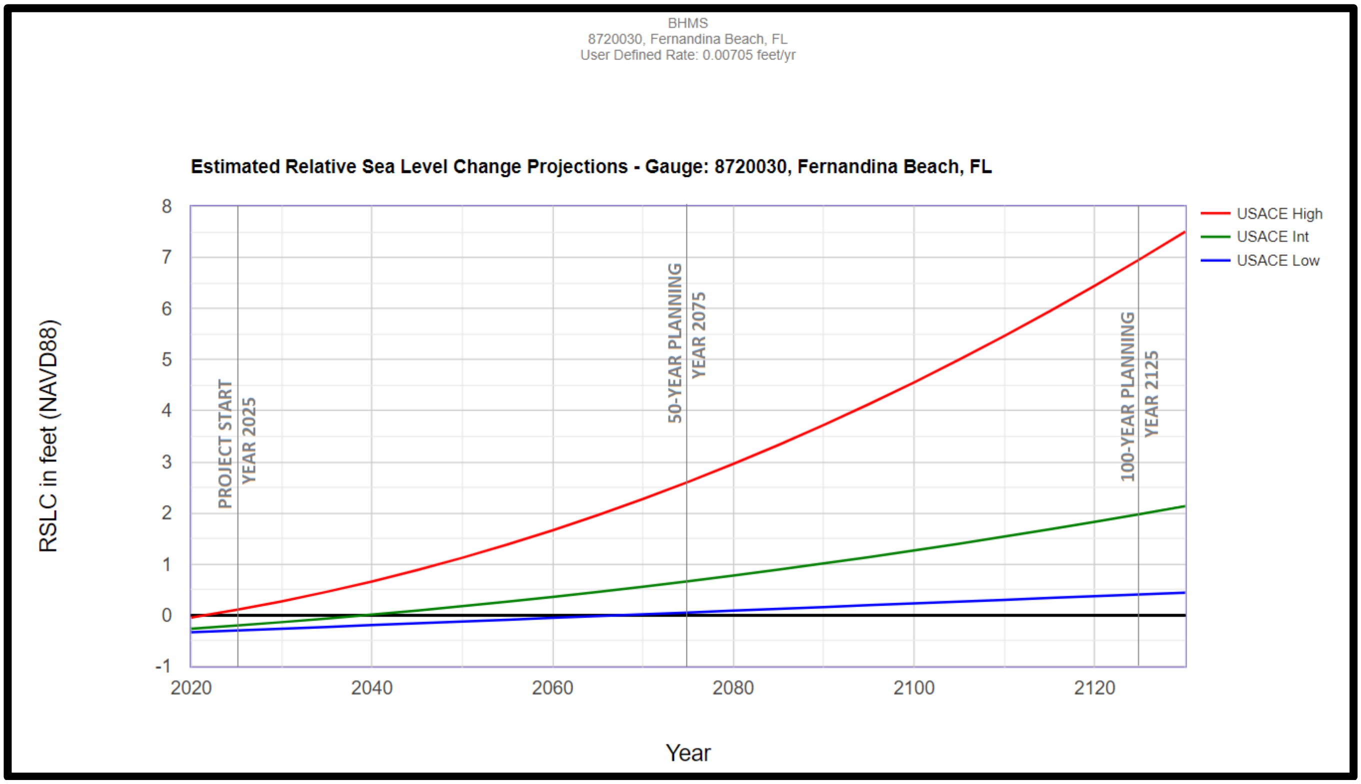


Figure E. 12 Relative SLC projections related to Fernandina Beach, Florida NOAA Gauge (https://cwbi-app.sec.usace.army.mil/rccslc/slcc_calc.html).

Following the SLC projections from Figure E. 11, the identified SLR for the 50-year economic planning horizon at approximately 0.4 feet for the low projected curve, 0.9 feet for the intermediate projected curve and 2.5 feet for the high projected curve. For the 100-year planning horizon the SLR is estimated at approximately 0.7 feet for the low projected curve, 2.2 feet for the intermediate projected curve and 6.9 feet for the high projected curve.

E.9.4. Fort Pulaski, Georgia NOAA Tidal Gauge

The closest tidal gauge to the north of Brunswick Harbor is NOAA tidal gauge 8670870 in Fort Pulaski, Georgia. Using the USACE Sea Level Change Curve Calculator, the three projected SLC elevations range between 0.13 to 0.53 feet by 2025, 0.68 to 3.23 feet by 2075 (50 years) and 1.22 feet to 7.78 feet by 2125 (100 years). These elevations are given in NAVD88. The existing mean sea level in NAVD88 at this tide gauge is -0.23 feet, tidal epoch 1983-2001.

The 2019 NOAA published SLC rate is 0.0109 feet/year for the Fort Pulaski, Georgia gauge (which is based on observational data from 1935-2019). See Figure E. 13 for details on the three USACE-adopted projected trends.

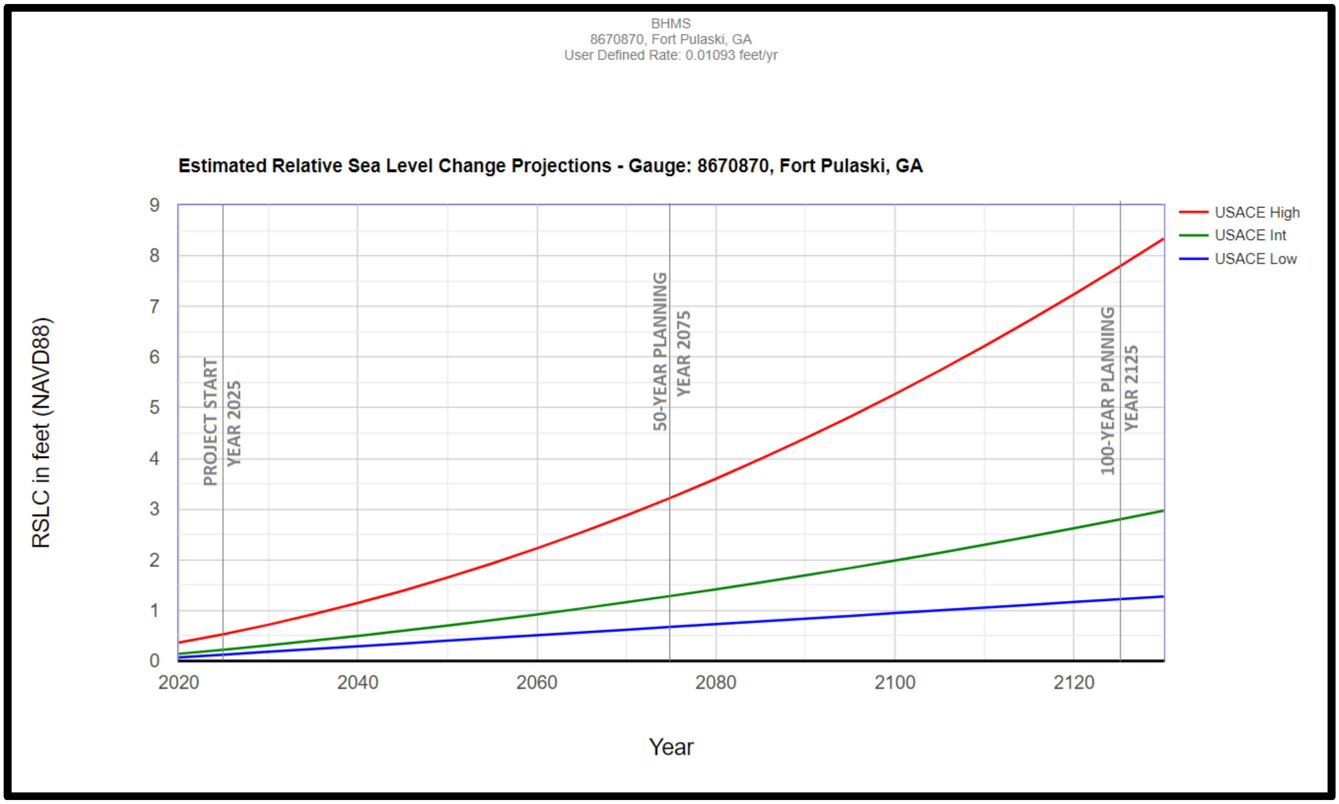


Figure E. 13 Estimated relative SLC projections related to Fort Pulaski, Georgia NOAA Gauge (https://cwbi-app.sec.usace.army.mil/rccslc/slcc_calc.html

Following the SLC projections from Figure E. 13, the identified SLR for the 50-year economic planning horizon at approximately 0.6 feet for the low project curve, 1.1 feet for the intermediate projected curve and 2.7 feet for the high projected curve. For the 100 year planning horizon for SLC is estimated at approximately 1.1 foot for the low projected curve, 2.6 feet for intermediate project curve and 7.3 feet for the high projected curve.

E.10. IMPACTS ON THE BHMS BENEFITS DUE TO SEA-LEVEL CHANGE

Although all the management measures proposed for the BHMS are located within 5 miles of Georgia's coast, there will not be direct effects to the hydrologic boundaries governing the performance and operation of BHMS project features. Estuary boundaries may change due to SLC, but the estuary changes are not anticipated to effect the BHMS project features.

The proposed channel modifications were measured in a 2D Adaptive Hydraulic modeling system (AdH). The alternatives were modeled in AdH and no increase in water levels throughout the channel were observed. Therefore, it is assumed that the channel modifications will not change water levels from the existing water level and therefore SLR, will have the same affect on Alternative 1, the No Action Alternative, compared to the other alternatives. Comparison of water levels between alternative depths to future without project conditions, using the low, intermediate and high sea level rates, show no difference due to the project.

Below in Figure E. 14, The NOAA Sea Level Rise Viewer was used to preliminarily understand what the effects of SLR would look like at the port and the disposal area. Figure E. 14 shows inundated areas in blue, with dark blue being the deepest and lighter blue being more shallow. Areas in green are low-lying areas. The NOAA SLR viewer is a preliminary analysis and can be used for preliminary study. The disposal area remains unflooded at the low, intermediate and high SLC projections. The Port appears to see inundation at a SLR around 3-feet, or the intermediate projected curve at the 100 year planning stage, or the high curve at the 50 year planning stage..

The existing dock heights at the existing GPA terminals are 14.5 feet MLW (Georgia Ports Authority, 2020), which is approximately 18.8 feet NAVD88. The tidal range of Brunswick Harbor is approximately 7.6 feet (Georgia Ports Authority, 2020). The estimated SLR for the 50-year period of economic analysis ranges between 0.06 feet NAVD88 and 3.23 feet NAVD88 between the years of 2025 and 2075 (up to an additional 0.53 feet of Sea Level Rise could occur between the 1992 epoch to the 2025 year of construction). It is unlikely that SLR will affect the dock operations within the 50-year economic period of analysis. Preliminary qualitative analysis, from Figure E. 14, there could be flooding on the north and south ends of Colonel's Island within the 50-year planning period, which may require modifications within Colonel's Island terminal. Further analysis, with higher resolution elevation data and sea level rise models would be needed to develop further conclusions on flooding due to sea level rise.

The air draft under the Sidney Lanier Bridge will need to be assessed with rising sea levels. Currently there is 185 feet of clearance at MHW. Currently the tallest vessels are around 150 feet. Therefore the addition of three feet of SLR, still leaves approximately 30 feet of clearance beneath the bridge, which leaves some conservative room for changes in harbor dynamics with SLR. Significant SLR, greater than the current SLR projections for the 50 and 100 year planning analysis would appear to require greater analysis of air draft clearance beneath the Sidney Lanier Bridge. However, the efforts to replace a bridge are significant and require lengthy planning, design and construction timelines. The air draft clearance beneath the bridge should consistently be evaluated within regular planning periods.

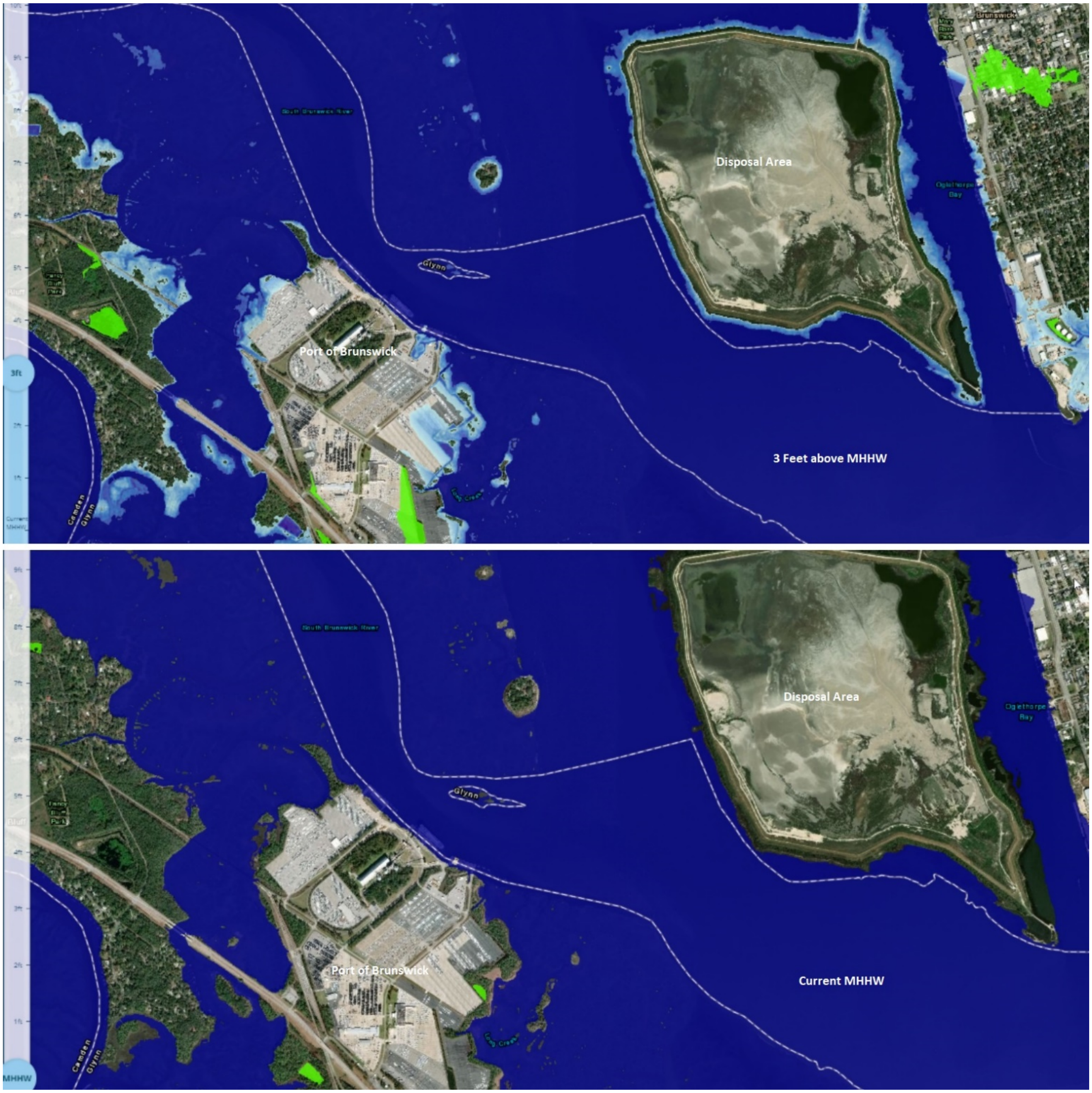


Figure E. 14 Sea Level Rise Viewer of Port of Brunswick and Disposal Area. The bottom figure shows the existing water level at Mean High Higher Water (epoch: 1983-2001). The top figure shows the Port and disposal Area at MHHW + 3 feet of Sea Level Rise (NOAA, 2020). Water depth is shown in blue, dark blue being deep water and lighter blue is shallower water. Green areas are low-lying areas.

USACE will assess the need for modification as part of normal operations and maintenance actions. As part of normal maintenance of disposal areas, erosion and toe protection would be evaluated as needed. Low-lying and marsh areas will be impacted and waterfront property owners will need to assess their own risk and adapt. The increase does not change any of the impacts over the without condition alternative. It is expected that more tidal alerts would occur with higher sea level changes.

The effect of SLC on estuarine habitat will vary depending upon the location and elevation of the affected lands. Based on the topography and the existing infrastructure, inland impacts from SLR on estuaries will be restricted primarily to increased water depths and saline conditions in the estuaries and canal systems, as the majority of the coastline is built out and protected by seawalls and other hardened structures. SLR has the potential to effect harbor hydrodynamics including tides, currents, wave growth and fetch, and possibly sedimentation and shoaling. Wave growth and fetch could potentially increase with deeper waters that are inundating more area horizontally. Deeper water could potentially reduce velocities deeper in the water column and allow more sediment to settle out or change existing shoaling patterns. It does not appear that SLR will change any of the impacts over the without condition alternative. In order to reach further conclusions of changes in harbor hydrodynamics, additional modeling would need to be completed.

SLR during the next century will increase the exchange and circulation of Atlantic Ocean water with waters in the Brunswick River, Turtle River and South Brunswick River. The effect of this would be a more saline condition overall and a shift in salinity ranges and their location within the estuary. Figure E.15 is the Marsh Migration Viewer from NOAA. The shift in saline conditions could affect the location and health of most of the flora and fauna in the estuary, including freshwater SAV, oysters, benthic communities, and shoreline vegetation. Salinities and canal stages are expected to increase in the Brunswick River, increasing the probability of urban flooding and saltwater intrusion. Figure E.15 shows that with an increase in SLC of +3 feet salt water marsh (shown in dark purple) will transition to unconsolidated shore (showni n light blue).

To reduce the risk associated with implementing the project, flexibility in the design and operation of features can be incorporated into the project during the planning phases. Features planned and operated for one purpose can be repurposed as SLR begins to affect water management needs in the future.

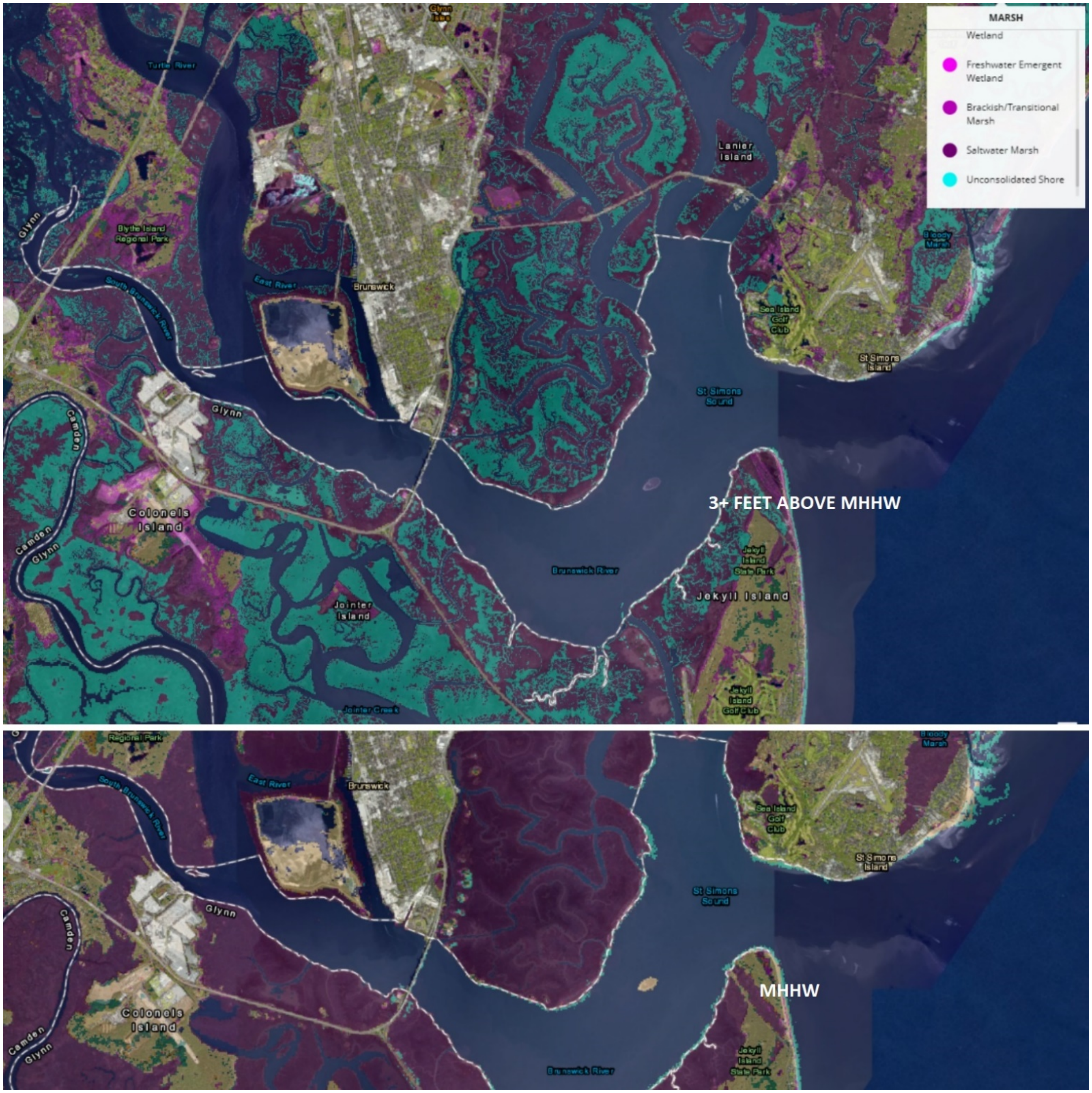


Figure E. 15 Marsh migration viewer. Bottom figure shows primarily saltwater marsh, with the existing MHHW level shown in blue. The top figure shows a water level 3+ feet above MHHW and the transition of marsh types (NOAA, 2020).

E.11. SUMMARY FINDINGS

These are the summary findings of the climate change assessment:

1) The effects of SLC have been analyzed per ER 1100-2-8162 and EP 1100-2-1.
2) The USACE requires that all existing and planned studies evaluate climate change for inland hydrology and sea level if the project's elevation is less than 50 feet NAVD88.
3) A qualitative climate change assessment of inland hydrology was conducted per ECB 2018-14 using the USACE statistical tools that evaluate observed and future climate trends.
4) A quantitative climate assessment of SLR was conducted per ER 1110-2-8162 using a USACE statistical tool that projects future SLR.
5) The SLC in the Brunswick Harbor is only forecasted to be Sea Level Rise (SLR).
6) Impacts from SLR are unchanged from the No Action Alternative versus all Action Alternatives.
7) Inland hydrology is not expected to affect Brunswick Harbor, because it is the outlet of the drainage area.
8) Shoaling rates, shoreline changes, velocities and salinity were not evaluated with regard to Climate Change at this preliminary stage of the project.

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