Woodtick Peninsula
Section 204 Beneficial Use of Dredged Material for Ecosystem Restoration
Monroe County, Michigan

Appendix F - Qualitative Climate Preparedness and Resiliency Assessment

U. S. Army Corps of Engineers
Detroit District
Great Lakes and Ohio River Division
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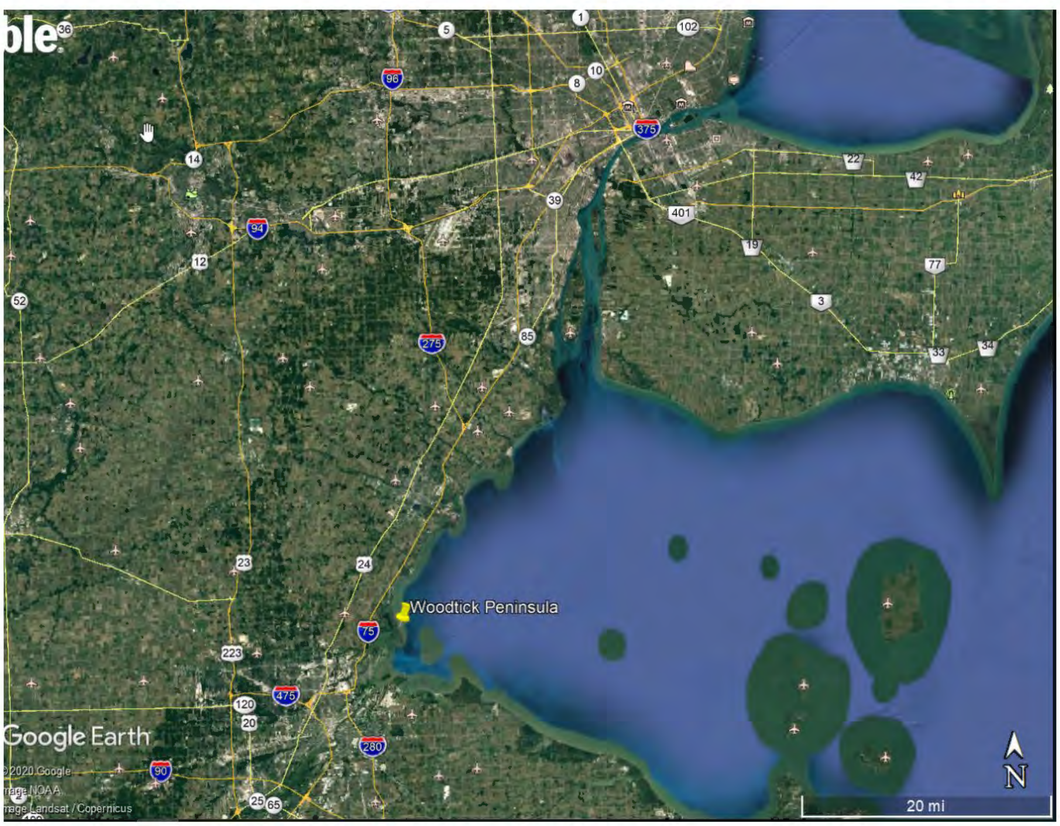
Introduction

USACE projects, programs, missions, and operations have generally proven to be robust enough to accommodate the range of natural climate variability over their operating life spans. However, recent scientific evidence shows that in some places and for some impacts relevant to USACE operations, climate change is shifting the climatological baseline about which that natural climate variability occurs and may be changing the range of that variability as well. This is relevant to USACE because the assumptions of stationary climatic baselines and a fixed range of natural variability as captured in the historic hydrologic record may no longer be appropriate for extended-period projections of the climatologic parameters, which are important in hydrologic assessments for projects on the inland Great Lakes, such as the Woodtick Peninsula Section 204 project in western Lake Erie.

Woodtick Peninsula is located in Monroe County, Michigan. The peninsula is in southeastern Michigan along the western shoreline of Lake Erie, in an area referred to as North Maumee Bay. The peninsula is located approximately 45 miles southwest of Detroit, Michigan and, at its most southern point, lies 5 miles north of Toledo, Ohio (see figure below). The pre-European settlement Woodtick Peninsula extended south from the shoreline as an unbroken barrier beach, 19,000 feet in length, and up to 2,600 feet in width (at its maximum). In recent decades, shoreward migration of the peninsula and reduction in its size has been accelerated by wave attack from strong storms and resultant erosion, breaching and (likely) starvation of sand sources from the north. The near record-high Lake Erie water levels have resulted in erosion higher on the shoreline profile, contributing to the wash-out of sections of the peninsula.

Today, due to long-term erosion and human modifications to the littoral environment, the peninsula is a series of islands separated by shallow channels. The peninsula protects the 2,149-acre Erie Marsh, which is 11% of the remaining marshland in southeastern Michigan and is the largest marsh on Lake Erie.



General Location of Woodtick Peninsula in Michigan

To address the erosion and loss of habitat, the Detroit District is utilizing the CAP Section 204 authority to study the renourishment of Woodtick Peninsula and restoration of the degraded habitat on the landward side of the peninsula. The future sustainability of the peninsula and Erie Marsh relies on the resiliency of the peninsula against the wave climate of Lake Erie and how it is impacted by a changing climate in the southern Great Lakes. As such, per *Engineering and Construction Bulletin 2018-14: Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects*, all civil works decision documents require a minimum of a qualitative Climate Preparedness and Resiliency (C-P-R) analysis be performed. Because of this directive, a qualitative climate change assessment has been conducted for the Woodtick Peninsula Section 204 feasibility study.

Although long-term climate projections are not developed for such a small region as the Woodtick Peninsula, the Great Lakes Environmental Research Laboratory (GLERL - Ann Arbor, MI) of the National Oceanic and Atmospheric Administration, has downscaled several Global Circulation Models (GCMs), and nested them with the Large Basin Runoff Model (LBRM) for the sub-basins of the Great Lakes region. The LBRM calculates Net Basin Supplies (NBS) to each of the Great Lakes (NBS is the calculated totality of water inflow, minus outflow, to/from each of the Great Lakes) used in shorter-term water level forecasting. Further, GLERL's Great Lakes Seasonal Hydrological Forecasting System (GLSHFS) can be used to produce long-term trends in temperatures, precipitation, ice-cover, Net-Basin Supplies, cloud cover and a host of other variables.

These models, along with climate models developed by other organizations, indicate that the Great Lakes region as a whole will likely see increases in mean air temperatures (and corresponding Great Lake water temperatures), longer growing seasons, less lake ice cover and more variable precipitation patterns. The models indicate that more precipitation may be concentrated in the fall, winter, and spring seasons, while increased periods of summer drought may become the norm. Precipitation events, when they occur, are indicated to be more intense, with more frequency of damaging winds and greater temperature differences between air masses.

Qualitative Analysis of Potential Climate Vulnerability

As mentioned above, this is a qualitative evaluation of potential climate vulnerabilities facing the Western Lake Erie Basin. This assessment has been performed to highlight existing and future challenges facing the project due to past and future climatic changes, in accordance with the guidance in Engineering Construction Bulletin (ECB) 2018-14, revised 10 Sep 2020. Background information on the project can be found in the main report, and pertinent information on climate-affected risks to projects and assessments thereof can be found in the ECB.

Literature Review

The USACE publication *Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions - GREAT LAKES REGION 04* (April 2015) is a climate change and hydrology literature synthesis for USACE missions in the U.S. Other works have also been referenced in the preparation of this analysis. The text below is a summary of observed and future climate projection findings for the Great Lakes region, including western Lake Erie:

- **Observed Temperature Changes:** In the Great Lakes region, the U.S. states bordering the Great Lakes have seen an overall increase in annually averaged temperature of 1.4°F for the period 1986-2016 relative to 1901-1960, with the largest changes in the northern Great Lakes (i.e., the Upper Peninsula of Michigan and northern Minnesota). For the extent of the Great Lakes Basin, the temperature change is 1.6°F over this time period. These trends are higher than the overall change of 1.2°F over the contiguous United States (and found globally) for the trends over these time periods

(USGCRP, 2018). For the Lake Erie basin, the upward trend in temperatures is more modest at 0.5 to 1.0°F, with the higher end of this range toward the eastern portions of the lake.

- **Projected Temperature Changes:** There is strong consensus in the literature that air temperatures will increase in the study region over the next century, but the amount of the increase varies based upon the model projection used. The increase in mean annual air temperature from ensemble climate model outputs ranges from 0 to 12.6 °F by the latter half of the 21st century across the Great Lakes. Reasonable consensus is also seen in the literature with respect to projected increases in extreme temperature events, including more frequent, longer, and more intense summer heat waves.

- **Observed & Projected Precipitation Changes:** Annual precipitation averaged across the United States shows that there is a generally positive trend for U.S. states bordering the Great Lakes in annual precipitation for present-day (1986–2016) relative to 1901–1960, but with strong local variations in the trend across the states. There is a noted 9.6% increase in annual precipitation averaged over these states, while the Great Lakes Basin shows a comparable 10.0% increase. The largest increasing trends are for fall season (~15.8% for the bordering states), with summer (9.9%) precipitation also being larger events relative to winter precipitation (7.7%) and spring precipitation (7.0%). Spatially, the largest increases in precipitation have been across the upper Great Lakes, while the driest (relative) conditions have been across the Lake Erie basin.

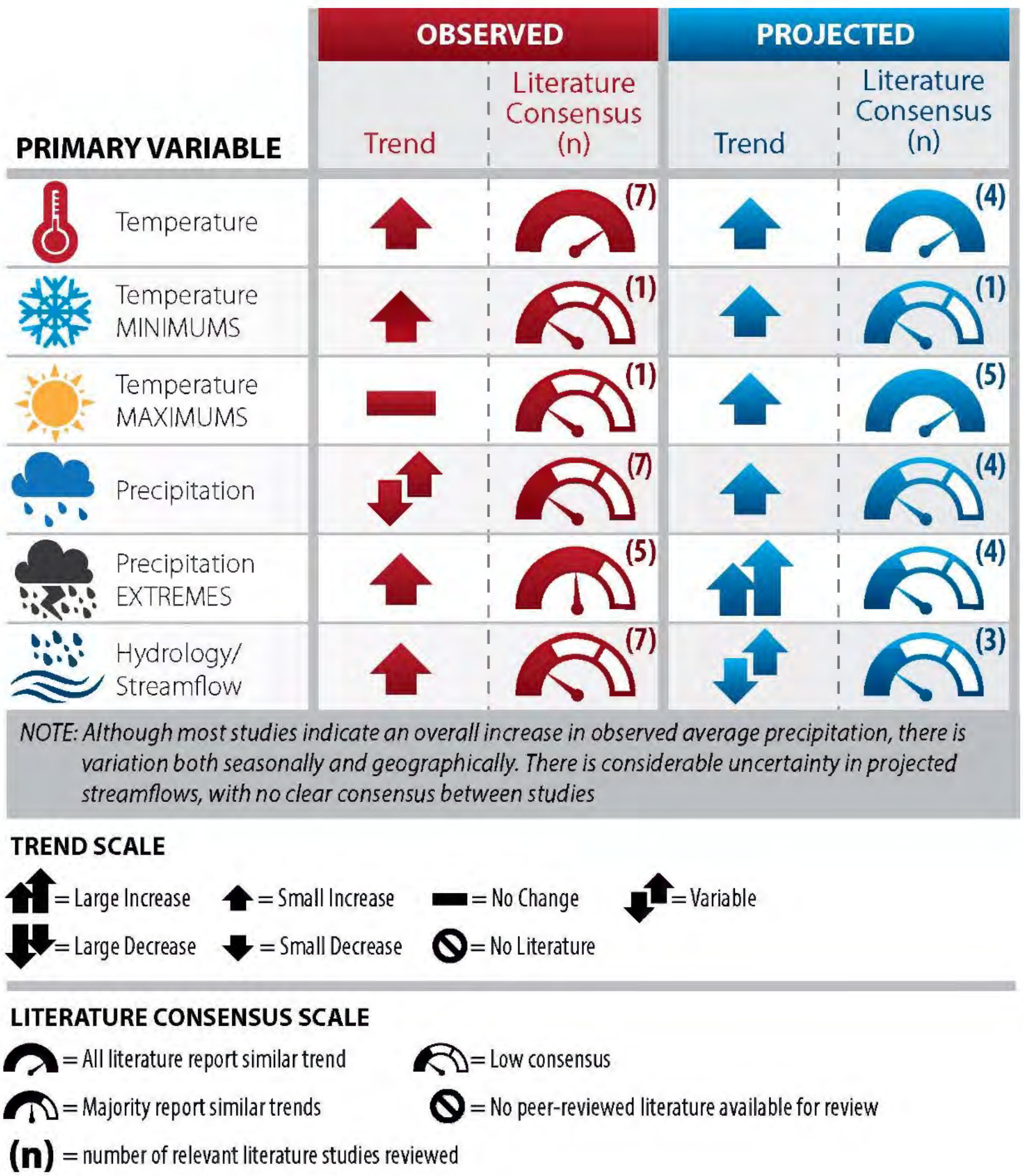
  Projections of precipitation in the study area are less certain than those associated with air temperature. In general terms, annual precipitation is expected to increase with a general shift to wetter winter and spring conditions and more variable summers that are likely to become hotter and drier by the end of the century. Less Great Lakes ice cover and expected warmer air temperatures will continue to increase evaporation. Runoff to the Lakes will increase in the winter and spring, and it will likely decrease in the summer. The effect of these changes on NBS is critical to determining future lake levels (Gronewold et al., 2013).

  Significant uncertainty exists in hydrologic projections for this region. Projections generated by coupling GCMs with macro–scale hydrologic models indicate - in some cases - a reduction in future streamflows (i.e., a component of lake NBS), but in other cases, indicate a potential increase in streamflow in (mostly northern) portions of the Great Lakes region. The trends and literary consensus of observed and projected primary variables noted above are summarized for reference and comparison in the figure on the next page.

  The 4th National Climate Assessment (NCA) also provides a more recent summary of valuable background and context related to precipitation and temperature changes in the region. Reviewing the NCA-4 for potential climate change impacts within the Great Lakes Region, most of the trend information for temperatures and precipitation through the end of this century mirrors much of what is written above, however, the magnitude of the projections varies somewhat. This may be a result of additional or updated model simulations based on different parameters.

  More importantly to the Woodtick Peninsula project is the expected trends in Lake Erie water levels (also see page 5 of this summary), and the future character of storms since these have the most impact on the erosion and potential loss of the peninsula. Recent projections with updated methods of lake levels for the next several decades under 64 global model-based climate change simulations (from the Coupled Model Intercomparison Project Phase 5, or CMIP5 database, using the RCP4.5, RCP6.0, and RCP8.5 scenarios) on average, show small drops in water levels over the 21st century (approximately 6 inches for Lakes Michigan and Huron and less for the other lakes), with a wide range of uncertainty toward the end of the century.

Summary matrix of observed and projected climate trends and literary consensus.
The trends and literary consensus of observed and projected primary variables for the Great Lakes Region, as contained in the *Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions – 04 Great Lakes,* are summarized below for reference and comparison.



Climate Change Reviews Specific to Great Lakes Hydrology and Water Levels

As part of the research for this analysis, and to focus more on the influence that Lake Erie water levels have on the condition of Woodtick Peninsula, we conducted an additional literature search on 'Climate Change and the Great Lakes'. After reading several studies and articles, a piece in '*The Conversation*' (by Drew Gronewold (former GLREL Researcher) and Richard B. Rood), a June 2019 feature in *Scientific American*, summarizes what many studies about this topic indicate, but don't explicitly say:

> *"Rapid changes in weather and water supply conditions across the Great Lakes and upper Midwest are already challenging water management policy, engineering infrastructure and human behavior. We are undoubtedly observing the effects of a warming climate in the Great Lakes, but many questions remain to be answered."* And -
>
> *"As researchers specializing in hydrology and climate science, we believe rapid transitions between extreme high and low water levels in the Great Lakes represent the "new normal." Our view is based on interactions between global climate variability and the components of the regional hydrological cycle. Increasing precipitation, the threat of recurring periods of high evaporation, and a combination of both routine and unusual climate events—such as extreme cold air outbursts—are putting the region in uncharted territory."*

Other researchers using singular, or a blend of Regional Climate Models (of various constructs) to anticipate future NBS, and corresponding trends in lake levels, largely conclude that:

> *On average, we find that the mean monthly NBS for Lake Superior will increase by less than 1 %, while that for Michigan-Huron will decrease by 2 %. On the other hand, the reduction in NBS for Lake Erie is more substantial at more than 9 %. (to 6 cm (~2.4") for Lake Erie, in the future climate (2021-50) scenario.). Again, median results suggest very small changes in level(s) for all the upper Great Lakes in the future climate. The corresponding results for these GCM projections based on the approach of Angel and Kunkel (2010) indicate the traditional approach projects larger declines for each lake, but only by a few cm (~1").* [On the Simulation of Laurentian Great Lakes Water Levels Under Projections of Global Climate Change. MacKay, M. & Seglenieks, F., August 2012]

Business Line Vulnerabilities

The Great Lakes Region touches many US states, including portions of Pennsylvania, New York, Ohio, Michigan, Indiana, Illinois, Minnesota and Wisconsin. Climate impacts to this area may be affected by climatic conditions beyond this given region, especially from impacts to the Great Lakes in Canada. The USACE recognizes the potential impacts of future climate considering the exposure and dependency of many of its projects on the natural environment. To assess the potential vulnerabilities that climate change may pose on USACE's missions, a set of primary USACE business lines were identified, with that of the Woodtick Peninsula project highlighted below:

Navigation
Flood Risk Management
Water Supply
Ecosystem Restoration
Hydropower
Recreation
Emergency Management
Regulatory
Military Programs

USACE implements ecosystem restoration projects in the region to restore degraded or destroyed habitats. The USACE also conducts maintenance dredging throughout the Great Lakes to support its navigation mission, including in the Maumee River (Toledo Harbor). Overall indicators point to an increase in annual precipitation through the remainder of the 21st century for the region, and an increase in the frequency of extreme storm events. This would logically lead to an increase of sediment runoff and deposition in navigation channels, while more frequently intense low-pressure (storm) systems result in periods of large wind-driven waves that cause significant lake shoreline erosion and damage coastal ecosystems.

USACE Climate Assessment Tool Outputs

In addition to the hydrology literature synthesis provided above, the Detroit District, USACE conducted a Climate Vulnerability Assessment for the Western Lake Erie basin (HUC 0401), which includes Woodtick Peninsula. The execution of these tools normally includes the USACE Climate Hydrology Assessment Tool (CHAT), the USACE Nonstationarity Detection Tool and the USACE Watershed Vulnerability Assessment Tool. In the execution of all the assessment tools, the default parameters were used in all the USACE C-P-R tool applications.

Nonstationarity Detection Tool (NDT)

Due to the fact that the project location is in Western Lake Erie, the use of the typical CPR application of NDT for inland hydrology (rivers) was deemed to be an inappropriate application of this tool. Instead, discussion began about investigating the use of the NDT that is contained in the Time Series Toolbox (TST) and applying lake level data as input to detect nonstationarities. After discussing various options, and the uncertainty of lake level data reliability with a Hydraulic Engineer (who also attended LRD C-P-R training classes), it is thought that the NDT would not provide meaningful benefit in this application either. The reasoning is that the NDT detects events that are assumed to be independent of each other, where the water levels on the Great Lakes are highly dependent on previous levels and water supplies. Lake seiche events, which are very common on Lake Erie, will also cause unwanted irregularities in the analysis. As such, looking at the data statistically in this manner may not be sufficient when it is recognized that lake levels year-to-year are not independent events.

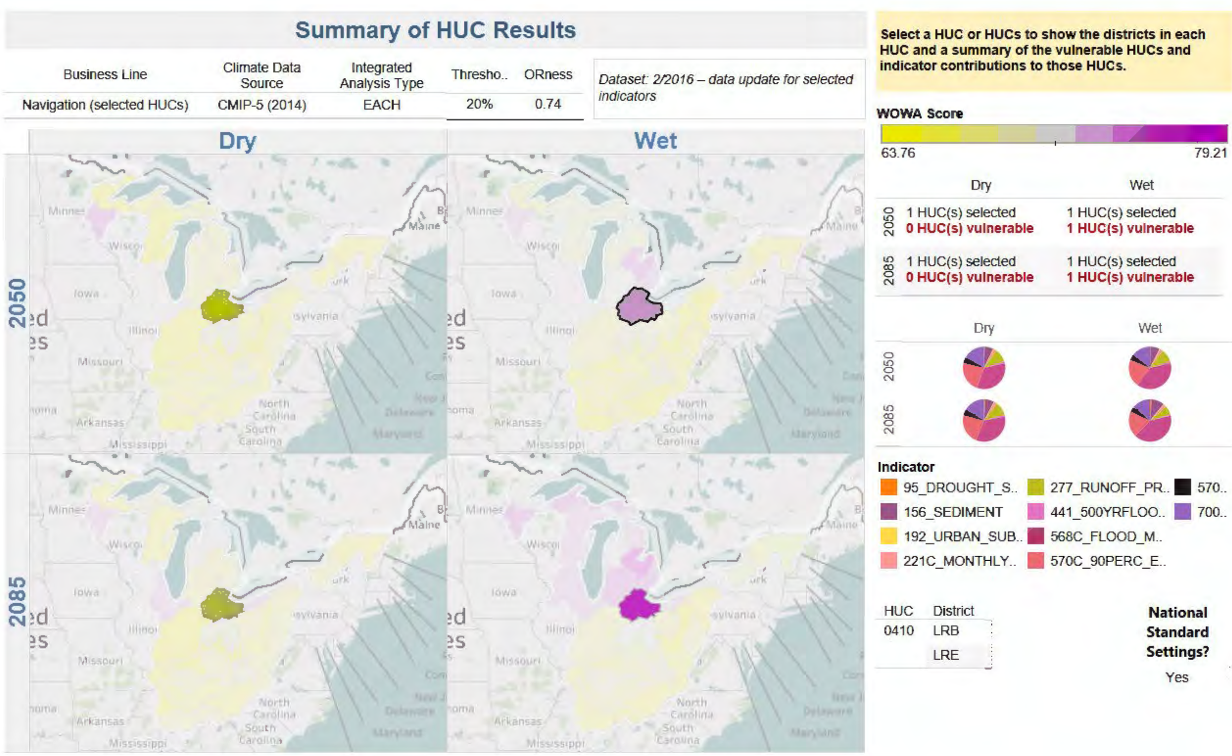
Vulnerability Assessment

The USACE Watershed Climate Vulnerability Assessment (VA) Tool facilitates a screening level, comparative assessment of the vulnerability of a given business line and HUC-4 watershed to the impacts of climate change, relative to the other HUC-4 watersheds within the continental United States (CONUS). It uses the CMIP5 GCM-BCSD-VIC dataset (2014) to define projected hydrometeorological inputs, combined with other data types to define a series of indicator variables to define a vulnerability score.

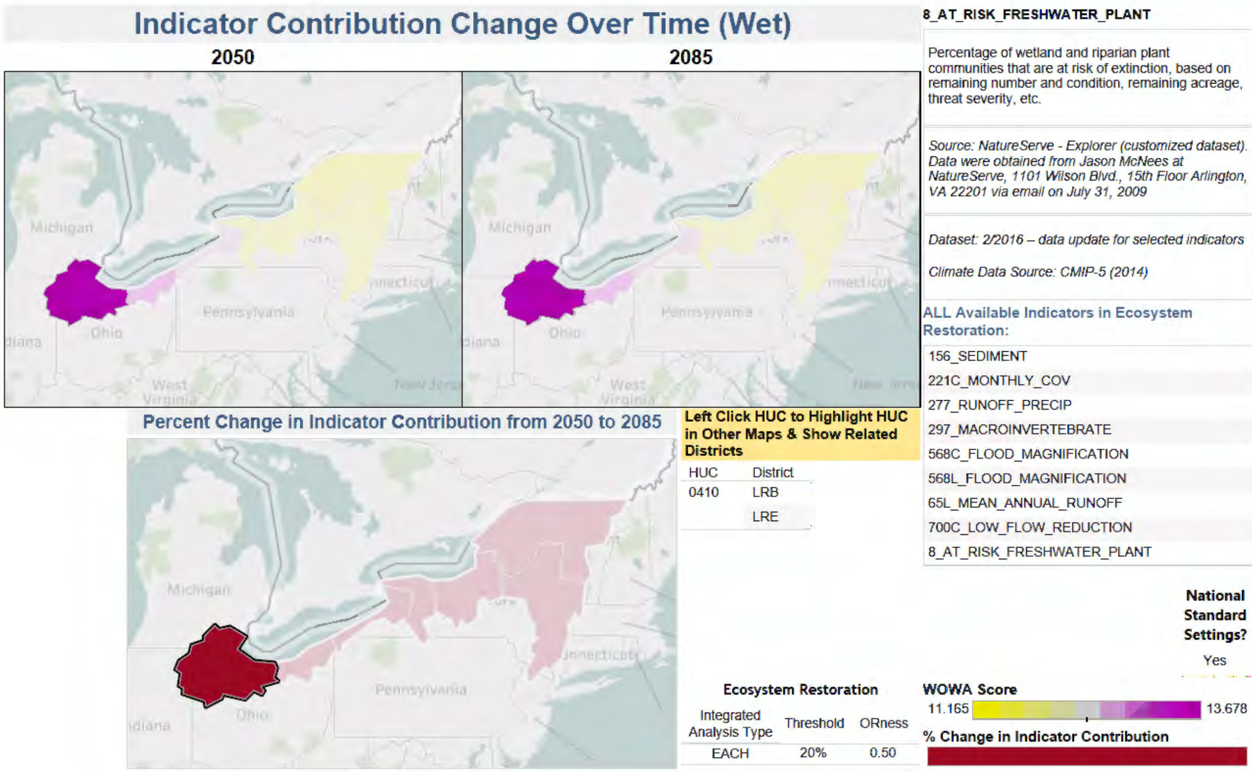
Vulnerabilities are represented by a weighted-order, weighted-average (WOWA) score generated for two subsets of simulations (wet- top 50% of cumulative runoff projections and dry- bottom 50% cumulative runoff projections). Data are available for three epochs. The epochs include the current time period (“Base”) and two 30-year, future epochs (centered on 2050 and 2085). The Base epoch is not based on projections and so it is not split into different scenarios. For this application the tool was applied using its default, National Standards Settings. In the context of the VA Tool, there is some uncertainty in all of the inputs to the vulnerability assessments. Some of this uncertainty is already accounted for in that the tool presents separate results for each of the scenario-epoch combinations rather than presenting a single aggregate result.

The VA Tool was used to examine the vulnerability of the Western Lake Erie basin (HUC 0410), including the Maumee River and Ottawa River subbasins. to fulfill its primary project objectives given a changing climate with the primary mission business lines of Ecosystem Restoration and Navigation in consideration for the Woodtick Peninsula Section 204 study. It should be kept in mind that the assessment is only a screening level tool and should not be construed as an accurate forecast of site-specific conditions or impacts, or inclusive of all impacts that climate change may present. There are also uncertainties associated with the hydrologic outlooks that the Vulnerability Assessment tool uses, which may impact the conclusions.

The results of the VA tool indicate that the 0410 watershed, which includes the basin that directly discharges to western Lake Erie adjacent to Woodtick Peninsula, shows vulnerability for the Navigation business line under indicator "568C – Flood Magnification" in both the 2050 and 2085 timelines, and interestingly, under both the "wet" and "dry" scenarios (projections with total runoff values above the median value for the set are grouped as "wet" and ones with total runoff values below the median as "dry"). However, under the "wet" scenario, the Flood Magnification threshold of 20% is exceeded, as well as the "570C – 90 Percent Exceedance" indicator. The indicator for this vulnerability also increases by approximately 9% between 2050 and 2085. This indicator also shows a rise in both the 'dry' and 'wet' scenarios. The figures below show some of the results of this analyses:



An assessment was also conducted for the Ecosystem Restoration Business line. The resuts of that assessment showed no indicators as being vulnerable, the greatest vulnerability threats (i.e. the "dominant indicator" – the indicator that contributes to the climate risk score in the E.R. Business Line) showed to be for "297 – Macroinvertabrates" and "8 – At-Risk Freshwater Plants". Interestingly, the assessment showed no changes in vulnurability to either of these indicators uder 'wet' or 'dry' scenarios, and between epochs (see figure below).



In essence, the results of VA tool indicate that, with the Navigation business line, the 'Flood Magnification' indicator shows an increase through 2080, especially under the "wet" scenario. This may translate to increases in river flows and sediment being carried by the rivers emptying into western Lake Erie, resulting in more sediment deposition (and possible scour) in the project area. This may also indicate increased sediment load in the Maumee River, which would increase the amount of material that would need to be dredged from the Maumee River federal channel in the future.

Regarding the Ecosystem Restoration business line, the VA tool shows no vulnerabilities above the established thresholds through 2080 but does point to some potential vulnerabilities to 'macroinvertebrates' and 'at-risk freshwater plants'. These impacts could stem from increased suspended sediments in the water column, potential burial of habitat by increased sedimentation, and/or increasing Lake Erie water temperatures into the future. It has been well documented that average water temperatures in the Great Lakes have been rising and have led to a notable change in aquatic species populations, locations, and compositions. This is likely to continue into the future if current temperature trends endure as expected.

Conclusions

The Great Lakes basin has already seen evidence of climate change as more intense storms result in more frequent and damaging floods, interspersed with lengthy periods of dry weather, as well as increasing lake water temperatures and reduced ice cover in winter. The recent (2019-early 2021) near-record high water levels on the Great Lakes has contributed to significant erosion throughout the Great Lakes, including Lake Erie. This has undoubtedly contributed to a period of greater-than-average erosion of Woodtick Peninsula. Taken at face value, the projected Regional Climate Models that provide input to Net Basin Supplies for the Great Lakes Basin largely indicate a general (minor) decline in water levels throughout the basin (except for some outcomes) through mid-century. As noted above, Lake Erie may see a larger average lowering of mean water levels of roughly 2-4" during that timeframe. However, as stated by

Gronewold and Rood, drastic swings in water levels throughout the basin, as witnessed in the last decade, could be the 'new normal' for the Great Lakes.

As outlined in the literature review for the Great Lakes Region, "projections of precipitation in the study area are less certain than those associated with air temperature. Most studies project increases, but other studies project decreases, and some project variability within the region or by season. Similarly, while the projections tend toward more intense and frequent storm events than the recent past, some show a reduction in parts of the Great Lakes Region."

While it is impossible to predict when and where within the Great Lakes basin that more frequent and/or higher-intensity storms may occur, there appears to be an increasing trend of more intense storm systems (in both terms of precipitation and wind) across the Great Lakes and upper Midwest, especially during the transitional seasons of spring and fall. Combining this trend with the USACE Vulnerability Assessment tool indications of greater runoff and potential flood magnification into the future, there is an indication that storm intensity will continue to increase across the Great Lakes through the 21st century.

Residual Risk Due to Climate Change Woodtick Peninsula

Feature or Measure	Trigger	Hazard	Harm	Qualitative Likelihood
Rebuilding Woodtick Peninsula	More intense storms, with high Lake Erie water levels	Increased erosion and possibly wave over-wash	Loss of placed sediment, and loss of restored habitat on and behind peninsula	Moderate, although indications are for lower future levels, more intense storms would increase erosion
Channel Restoration	Increased sedimentation	In the Navigation Business Line, Flood Magnification is shown to increase, which would increase sediment loading	Buried or altered habitat; erosion/ scour in places due to increased flows from the Ottawa River	Low, as the primary flow to western Lake Erie comes from the Maumee River, and those flows are directed southeast of Woodtick
Channel Restoration/Erie Marsh	Higher air and lake water temperatures	Alteration of habitat from native to invasive; vulnerability to freshwater plants.	Habitat value could decrease and not support desired aquatic species.	Moderate, as the mean temperature of the Great Lakes is already shown to be increasing.

Potential adaptation strategies to address these vulnerabilities include placing additional dredged material on the peninsula to increase its resiliency, monitoring the condition of the peninsula, and providing occasional nourishment from future dredging operations in the Maumee River. Additionally, to mitigate against higher air and water temperatures for the channel restoration measure, a variable-depth channel adjacent to the vegetated shoreline may afford some level of protection for fishes and other aquatic wildlife. This may also help to mitigate for a large range of future Lake Erie water levels.

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U.S. Army Corps of Engineers Climate Hydrology Assessment tool (https://maps.crrel.usace.army.mil/apex/f?p=313:2:0::NO:::)

U.S. Army Corps of Engineers Time Series Toolbox (https://climate-test.sec.usace.army.mil/tst_app/)

U.S. Army Corps of Engineers Watershed Vulnerability Assessment tool
(https://maps.crrel.usace.army.mil/apex/f?p=201:1:)