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FLOOD IMPACT ASSESSMENT: APPENDIX B

NENJ MODELING AND COASTAL FLOOD MAPPING UPDATES AND METHODOLOGY

May 2022

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1 About this document

This document describes a series of updates made to New Jersey Department of Environmental Protection (NJDEP) Resilient New Jersey Study HEC-HMS (Hydrologic Engineering Center Hydrologic Modeling System) hydrologic models, HEC-RAS hydraulic models, and coastal floodplain mapping for the Northeastern New Jersey (NENJ) study area.

NJDEP provided the applicable baseline HEC-RAS models to the NENJ consulting team (led by Arcadis). In coordination with the Steering Committee and other subject matter experts, Arcadis identified adjustment that could be made to the HEC-RAS models for the NENJ study area that would improve the quality of model output. NJDEP agreed to the proposed changes, which Arcadis and the NJDEP consultant that developed the original models subsequently implemented. Table 1 shows the identified improvements and the party responsible for making the changes.

The NENJ study area is spanned by three HEC-RAS models, each covering a USGS HUC 8 watershed. 02030103 covers the Hackensack River and Passaic River watersheds (HP), and the northwestern portion of the NENJ study area; 02030104 covers Sandy Hook and Staten Island (SHSI), and the southern half of the NENJ study area; and 02030101 covers the Lower Hudson River (LH), and the northeastern portion of the NENJ study area. Figure 1 shows the boundaries of the HEC-RAS models relative to the NENJ study area.

The following sections will describe in detail the improvements made to the model and the underlying methodologies used in their implementation. Besides the changes noted in this document, the modeling approach and methodology is identical to that described in the *Resilient New Jersey - Floodplain Mapping Methodology* (2020) report submitted to the NJDEP.

Note that while these model changes improve the model representation of the runoff and flooding in the region, this is still a planning-level study. The modeling is appropriate for use to inform planning decisions on the potential level of risk communities face both currently and in the future, but it should not be used for engineering design. The models could be further developed for that purpose.

Table 1 – Overview of identified improvements and implementation responsibilities for NENJ baseline models

APPLICABLE MODEL OR SCENARIO	BASELINE NJDEP MODEL SETUP	IDENTIFIED IMPROVEMENT(S)	IMPLEMENTATION RESPONSIBILITY
All HEC-RAS Modeling	CoNED data, including coastal areas with poor delineation of the shoreline resulted in sudden, unrealistic changes in bathymetry.	Updated with Post-Sandy Lidar for better representation.	NJDEP Consultant
All HEC-RAS Modeling	Limited bathymetry for Hackensack and Passaic rivers in baseline model terrain	Update DEM with bathymetric data for Hackensack and Passaic	Arcadis
All HEC-RAS Modeling	Filled, hydrologically enforced DEM used for hydraulic modeling. Local depressions filled in northern Newark, Hoboken.	Update DEM with 2014 Post-Sandy Lidar in Hackensack/Passaic and Lower Hudson model domains	Arcadis
Current and future 2% and 1% rainfall models	Large cell size and no breaklines cause “leaky cells” where discharge can traverse high points in terrain	Add breaklines to the model geometry along major elevated transportation corridors	Arcadis
Sandy Models	Sandy & Future Sandy modeling based on incorrect high-water mark (HWM), using constant water surface elevation (WSEL) instead of time-varying boundary condition	Revise HWM data for Sandy. Update Hackensack/Passaic HEC-RAS model to use time-varying boundary condition. Use HWM data to map floodplain in GIS for Sandy Hook / Staten Island model domain.	Arcadis
Future Tidal Models / Current and future 2% and 1% rainfall models	Constant tidal boundary condition used (i.e., 72 hours of high tide)	Adjust boundary condition to include typical tidal variation.	Arcadis
Current and future 2% and 1% rainfall models	Storm sewer drainage system capacity not considered in baseline model methodology	Adjust excess rainfall in HEC-HMS with approximation of storm sewer capacity, including sensitivity analysis to select design storm. Use updated rainfall in HEC-RAS model.	Arcadis

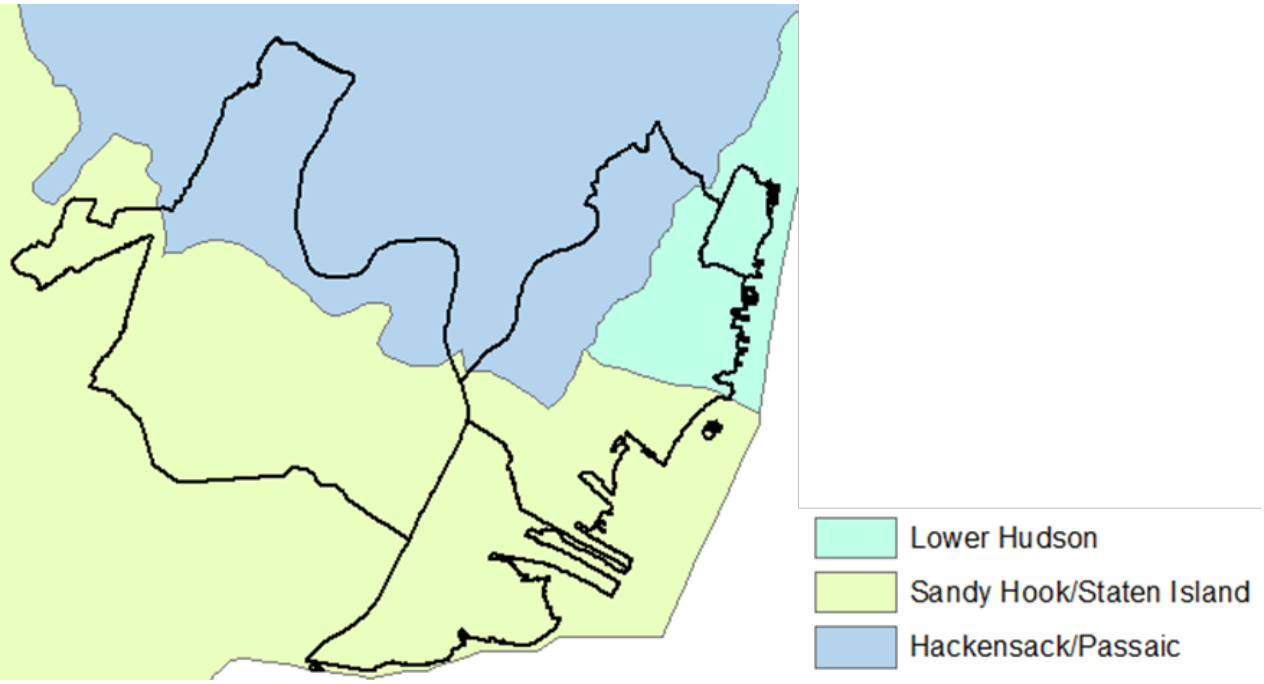

Figure 1 – Map showing the boundaries the three HEC-RAS models relative to the NENJ study area.

2 HEC-RAS Geometry Improvements

2.1 Bathymetry Updates

The baseline NENJ HEC-RAS models had limited bathymetric data in the Hackensack and Passaic rivers. Arcadis updated the bathymetry so that the conveyance capacity of both rivers would be better represented in the model. Arcadis also supplemented the existing bathymetry with improved data in the LH and SHSI models. Table 2 provides an overview of the bathymetric data used to update the model geometry.

Table 2 – Overview of sources of bathymetry data used to update the HEC-RAS model geometry

BATHYMETRY SOURCE	COVERAGE AREA	COMMENTS
NCEI Continuously Updated DEM (DEM)[1]	Offshore areas besides the Hackensack and Passaic rivers	Used to supplement existing bathymetry in the LH, SHSI and HP models. Additional sources used for the Hackensack and Passaic rivers in the HP model (see below)
NOAA Navigational Charts[2]	Upper Newark Bay, Hackensack River from Newark Bay north to Overpeck Creek confluence	Chart 12337
USACE Controlling Depth Surveys[3]	Upper Newark Bay, Hackensack River from Newark Bay north to turning basin near Penhorn Creek, Passaic River from Newark Bay north to Second River	USACE Surveys: • NJ_17_HAC_20211014_CS_5107_30 (2021) • PR_01_PAR_20151216_CS_4400_15 (2020) • PR_01_PAR_20171222_CS_4640_30 (2020)
Passaic River Public Digital Library (Our Passaic)[4]	Passaic River from Second River north to Dundee Lake	Passaic Bathymetry 1989-2004. 2004 Bathymetry points used

2.2 Model Geometry Updates

The baseline NENJ HEC-RAS models did not have any breaklines in the study area. Breaklines are used in HEC-RAS 2D to align the grid cell faces along elevation features in the topography to ensure that they are captured in the model geometry. Without breaklines, the coarse grid cell size (200-ft) of the NENJ model causes some grid cells to straddle high points in the terrain, which allows water in the model to traverse the elevated. This behavior is known as “leaky cells” and results in water not pooling behind impediments in the terrain, which can lead to areas not being identified as at risk to flooding. To reduce the impact of “leaky cells,” breaklines were added along transportation corridors (roadways, freeways, and railroads) and other high points in the terrain throughout the NENJ study area.

[1] https://chs.coast.noaa.gov/htdata/raster2/elevation/NCEI_ninth_Topobathy_2014_8483/
[2] https://www.charts.noaa.gov/OnLineViewer/12337.shtml
[3] https://navigation.usace.army.mil/Survey/Hydro
[4] https://sharepoint.ourpassaic.org/SitePages/Passaic%20River%20Datasets.aspx

3 Sandy & Tidal Updates

3.1 Sandy Updates

The baseline HEC-RAS models used a single flood elevation in the study area to map the inundation from Hurricane Sandy. This approach did not accurately capture the spatial variation in the storm surge elevation observed during the event, particularly in the NENJ study area. Two approaches were used to fix this. First, in the Hackensack and Passaic model (HUC8 – 02030103), Sandy was modeled using a time-series water surface elevation boundary at the mouth of the Raritan River. Running the model with a transient boundary condition better represents the upstream propagation of storm surge along the rivers than a steady-state value, which can overestimate the extent of flooding.

The time-series data were developed by scaling observed data form the Bergen Point NOAA gauge to match observed highwater mark data at the confluence of the Hackensack and Passaic rivers with Newark Bay. For the 2070 scenario, the storm hydrograph was adjusted to future sea level rise conditions by adding 2.4 ft to the hydrograph. Additional documentation of the hydrograph boundary condition development is included as Attachment A to this report.

The second approach was used for the SHSI (HUC8 – 02030104) and LH (HUC8 – 02030101) model domains. The models have extensive coastlines with a lot of variation in storm surge elevation. Because of this, it was not realistic to represent Sandy in HEC-RAS with a single boundary condition since the model would not capture the spatial variation in storm surge elevations resulting from the storm. It was decided that it would be better to map Sandy in these model domains using highwater mark data for the storm obtained from the USGS Flood Event Viewer. The mapping was performed by creating a TIN using the observed highwater marks and then comparing it to the ground elevation to map the resulting floodplain. The same process was repeated for the 2070 timeframe scenario after adding 2.4 ft of SLR to the highwater marks. Figure 2 shows the updated Sandy Mapping for the SHSI and LH model domains with present-day SLR conditions.

3.2 Tidal Updates

For the rainfall event modeling and the 2070 mean higher high water (MHHW) scenario, the model was updated to use a transient tidal boundary instead of a constant water elevation. This change was made to allow floodwater to drain from inland areas during the low point of the tidal cycle, which could result in lower inland flood elevations than the baseline models. Additional documentation of how the tidal boundary conditions were developed is included as Attachment A to this report.

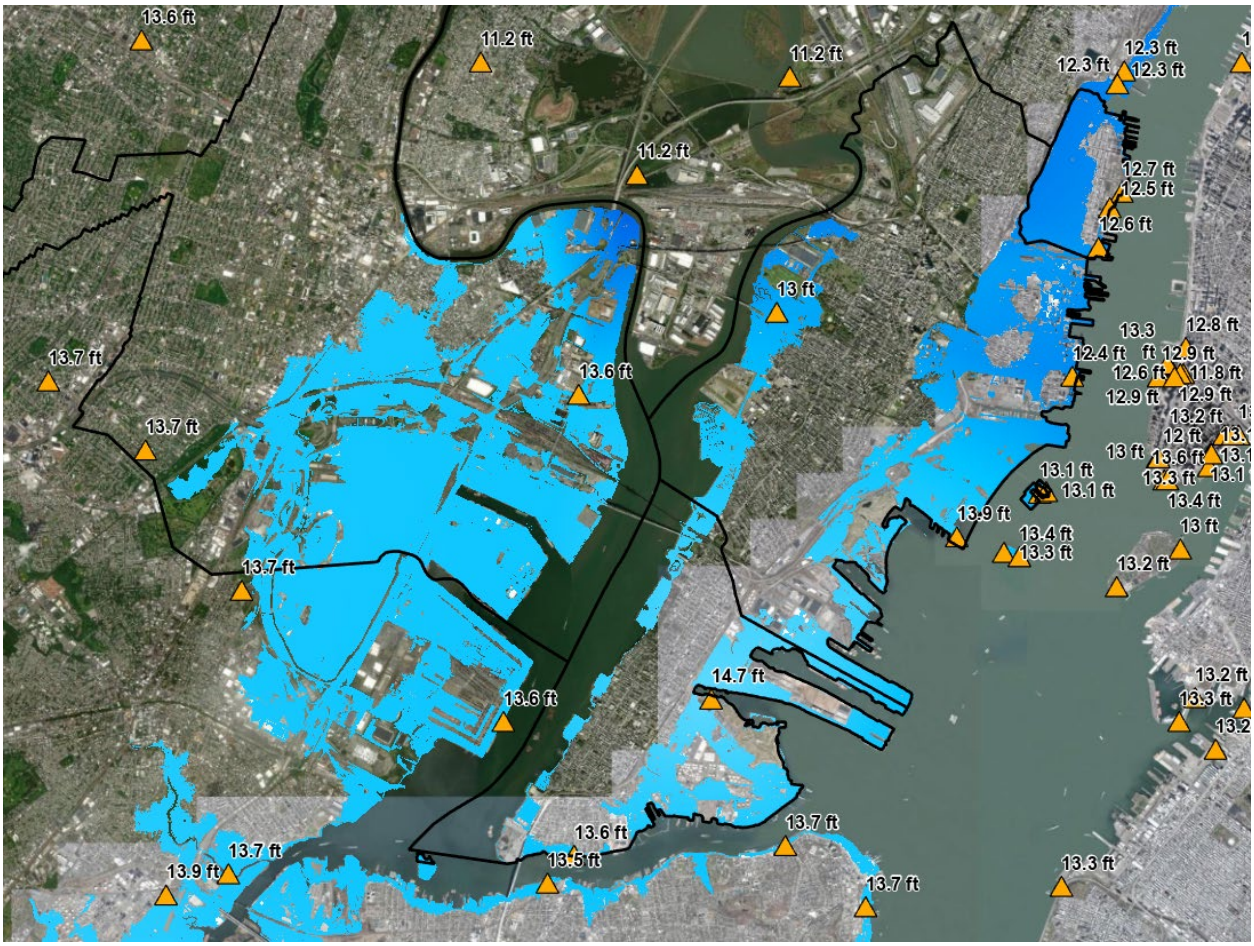

Figure 2 – Updated Sandy WSEL mapping for present-day SLR for the SHSI and LH model domains based on observed highwater marks from the storm event.

4 Storm Sewer Capacity Adjustments

The baseline HEC-RAS model uses the rain-on-grid capability of HEC-RAS 2D to transform rainfall into rainfall runoff. The baseline HEC-RAS models use HEC-HMS to perform the loss calculations and then use the precipitation excess as the input to the model. This accounts for the infiltration capacity of the soil as well as other losses, but it omits the capacity of the storm sewer. The NENJ study area is largely urbanized, so not accounting for the storm sewer capacity in the modeling process likely leads an overestimation of flooding from a given storm event.

To account for the conveyance capacity provided by the storm sewer system in the model, Arcadis developed an approach to adjust the rainfall excess by a constant rainfall intensity. To identify a representative intensity value to act as a proxy for the storm sewer capacity, Arcadis performed a sensitivity analysis using a PC-SWMM model of the Jersey City stormwater drainage system that was readily available. Several design storms and constant rainfall intensities were tested in the model and the system outfalls were observed to see when they would reach capacity – or when the discharge value would reach a constant value that was sustained even when a more intense rainfall was run in the model.

Figure 3 is a plot showing some of the results from the sensitivity analysis. As shown on the chart, the smaller outfalls in the Jersey City system began reaching capacity with about 1-in/hr of constant rainfall intensity, which is close to the peak 1-hr intensity for the 1-year design storm. Based on this observation, and after receiving feedback from local municipalities in the study area, the 1-in/hr intensity value was selected as a reasonable estimate, conservatively low, estimate of the storm sewer capacity.

The rainfall excess in the HEC-RAS models was updated to reflect the storm sewer capacity by subtracting 1.0 in/hr from the rainfall excess of the modeled rainfall scenarios in HEC-HMS. The storm sewer adjustment was only applied to the NENJ study area. Other parts of the model domains were modeled with the original, unadjusted rainfall excess. This was modeled using the new spatial rainfall feature in HEC-RAS version 6.1. Rain gauges with the storm sewer adjustment were added around in the study area and rain gauges without the storm sewer adjustment were added along the outside of the study area perimeter. Figure 4 shows the rain gauges used to create the spatially varying rainfall in HEC-RAS and the resulting rainfall distribution in the models.

Figure 5 shows the change in the 100-year, 24-hr floodplain in the study area with and without the storm sewer capacity adjustment. As shown in the figure, there is a noticeable, but minor, decrease in the extent of flooding when the storm sewer capacity is considered. However, as shown in Figure 6, flood depths decrease by as much as 2 feet in a large portion of the study area. This change in depth has the potential to have a large impact on the risk assessment, as even small changes in elevation can have a large impact on estimated damage; this is particularly the case when the water elevation is close to the finished floor of the structure.

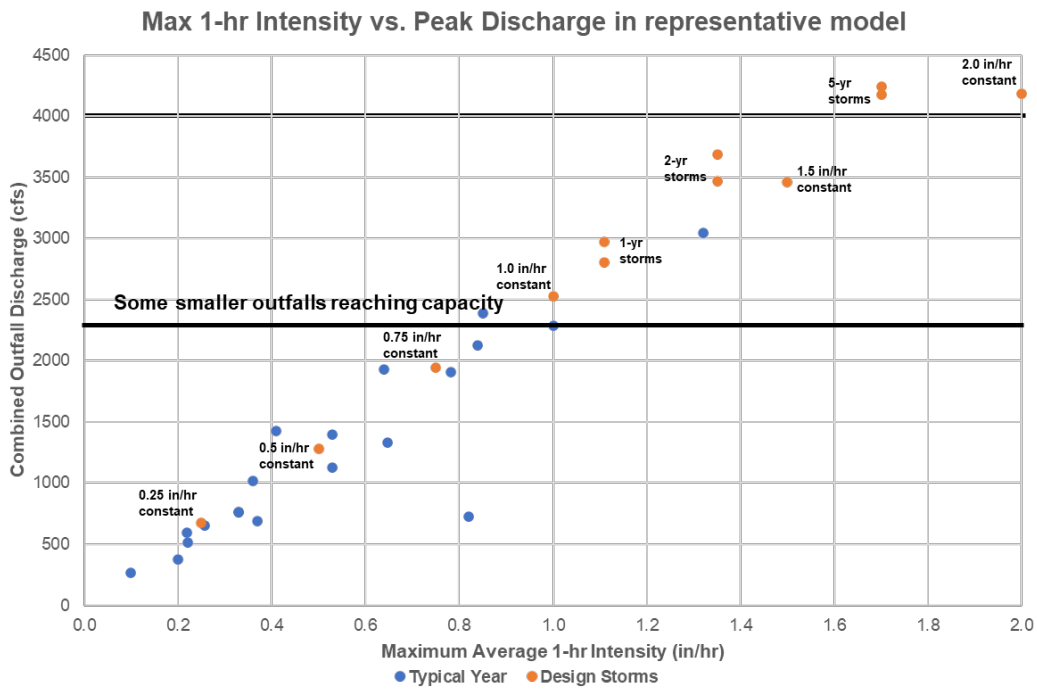

Figure 3 – Max 1-hr rainfall intensity vs. combined outfall discharge for the storm water system sensitivity analysis used estimate the drainage system capacity.

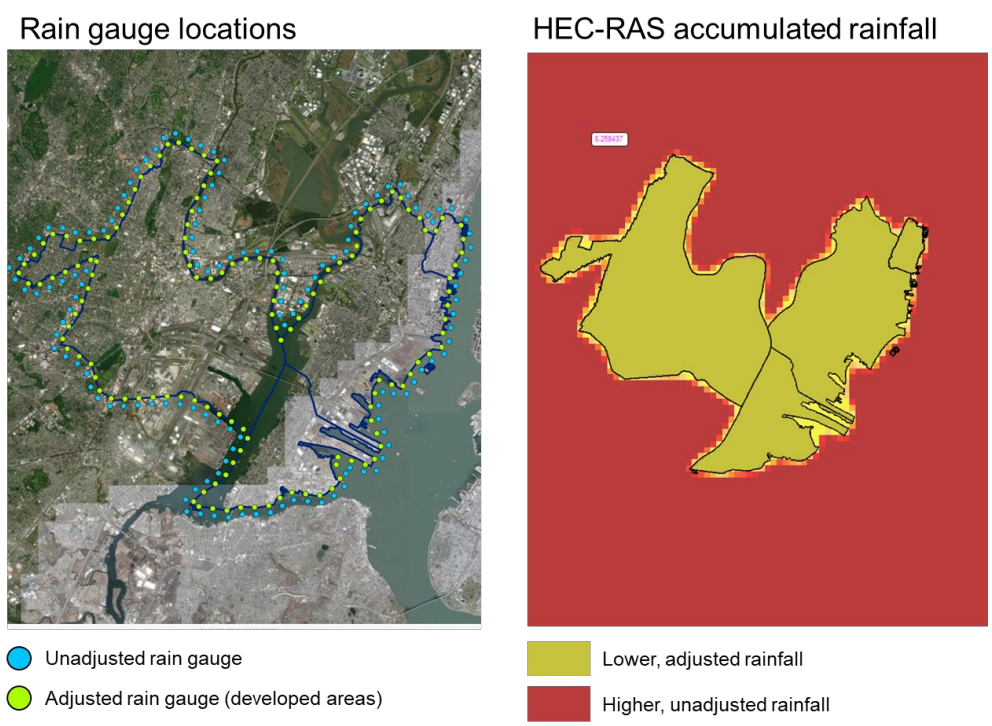

Figure 4 – (Left) Rain gauges used to create spatially-varying rainfall input in HEC-RAS; (Right) Resulting rainfall distribution computed in the model.

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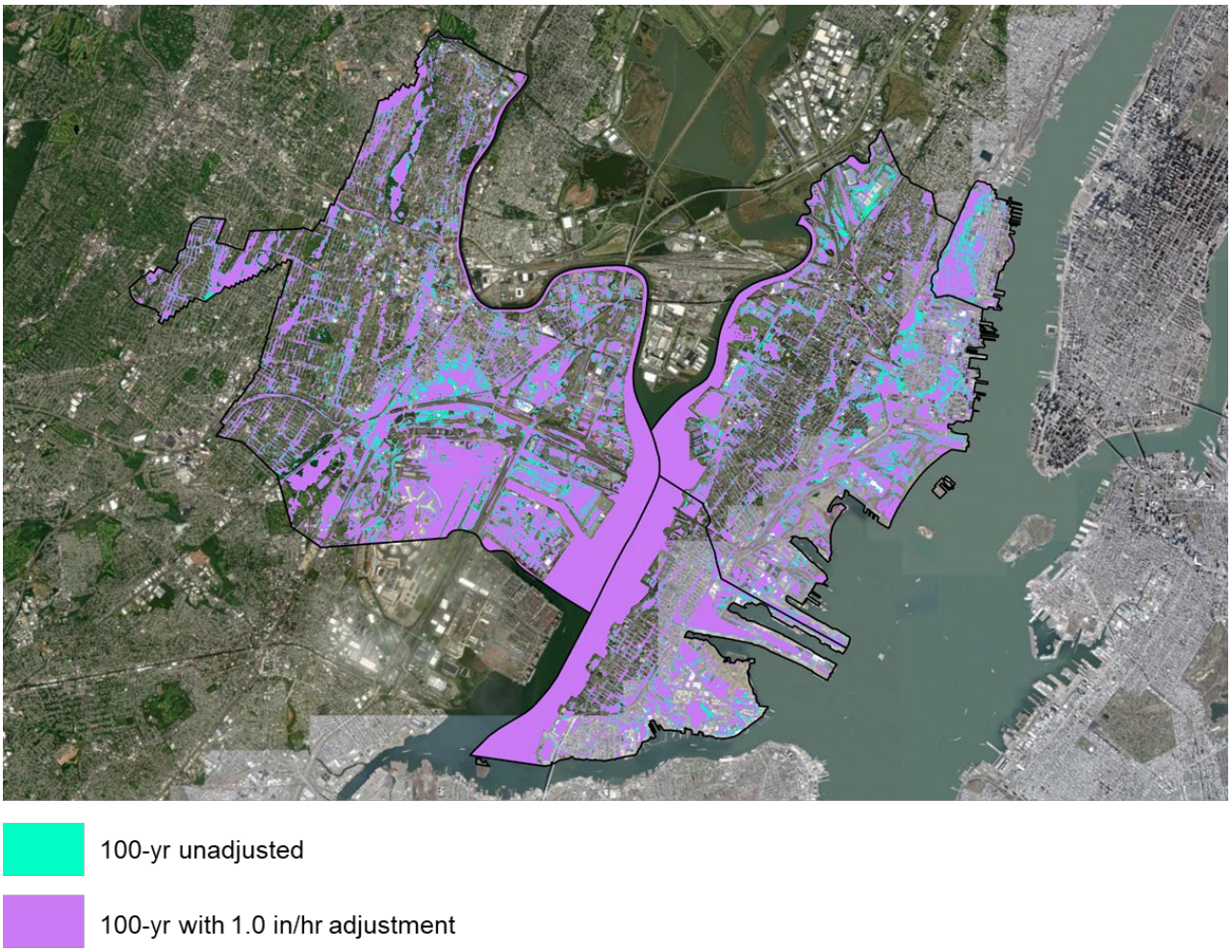


Figure 5 - Change in the 100-year, 24-hr floodplain extents with and without the storm sewer capacity rainfall adjustment

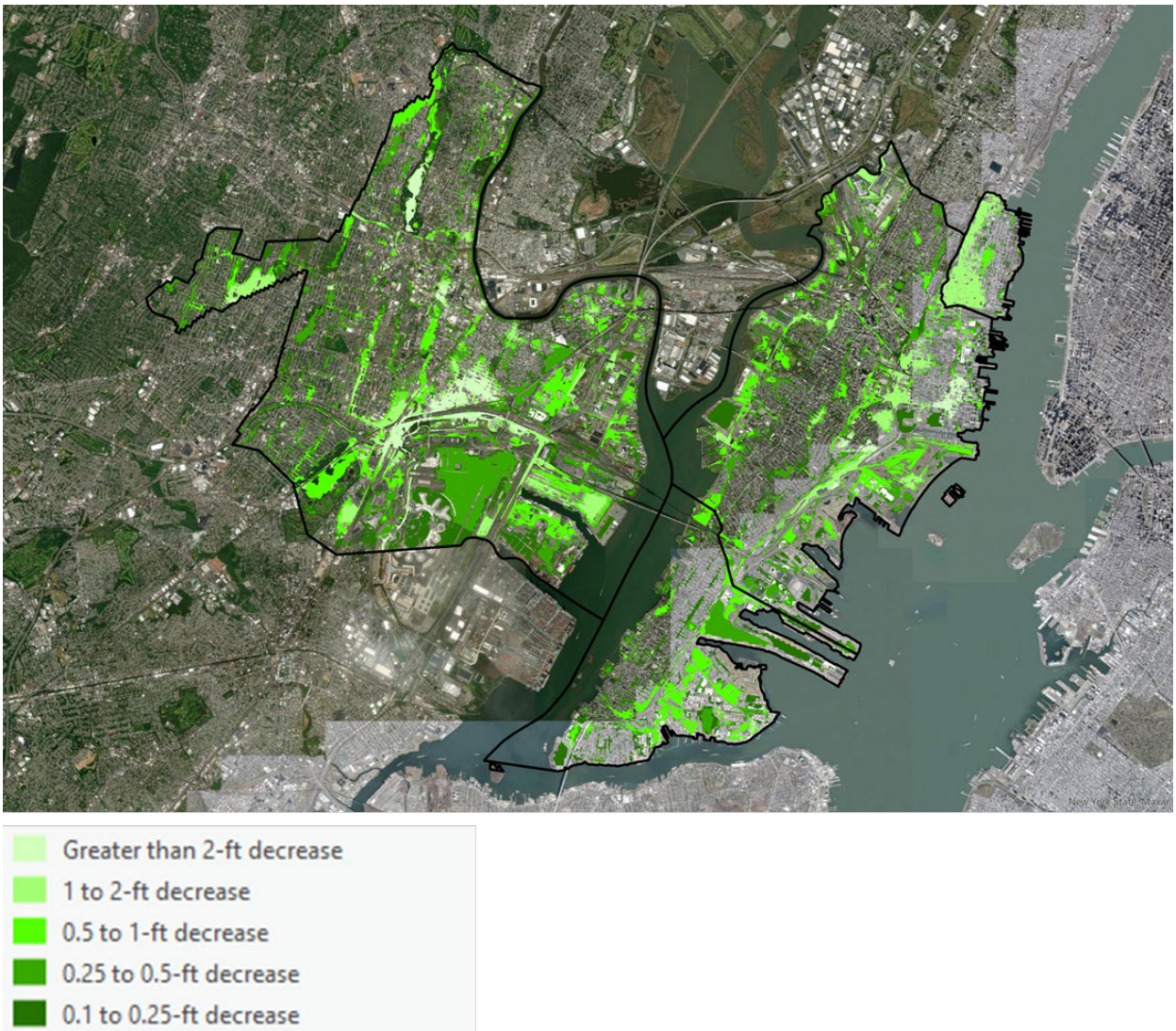


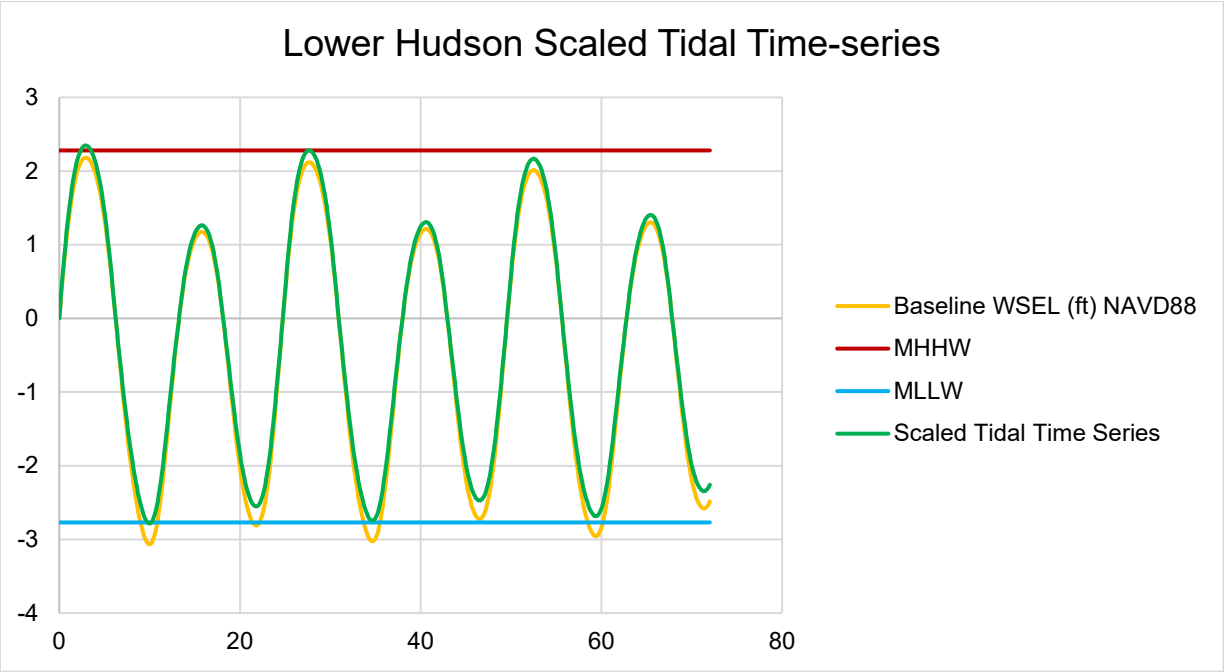
Figure 6 - Change in the 100-year, 24-hr flood depth with and without the storm sewer capacity adjustment

Attachment A:

Tidal Documentation for Resilient New Jersey (NENJ)

Tidal Time-series Data

- A separate tidal time-series boundary condition is provided for each model domain. Each time-series has a unique MHHW and a MLLW for the model domain based off different NOAA tidal gauges and harmonic constituent sites, as well as MHHW and MLLW values obtained from VDATUM.
- The tidal time-series were developed by scaling a representative tidal time-series at a NOAA gauge or harmonic constituent site to span MHHW to MLLW based on the percent difference between the maximum of the second highest peak and second lowest trough in the baseline tidal cycle. See graph below for an example of the scaled tidal time-series for the Lower Hudson model.
- The 2070 tidal time-series were created by adding 2.4 ft to each model's present day scaled tidal time-series.



- **Lower Hudson**
  - Representative tidal time-series obtained from NOAA station: The Battery, NY - Station ID: 8518750 (tidal gauge)
  - Baseline tidal time-series data range: 01/01/21 to 04/01/21
  - Start date used for the beginning of baseline tidal cycle 01/01/21 06:12 EST
  - MHHW: 2.28 ft, NAVD88, MLLW: -2.77 ft, NAVD88

        - Source: NOAA Battery Gauge datums

- **Hackensack, Passaic**
    - Representative tidal time-series obtained from NOAA station: Bergen Point West Reach, NY - Station ID: 8519483 (tidal gauge)
    - Baseline tidal time-series data range: 01/01/21 to 04/01/21
    - Start date used for the beginning of baseline tidal cycle 01/01/21 06:18 EST
    - Baseline tidal time-series converted from MSL to NAVD88 by adding -0.176 ft, according to VDATUM
    - MHHW: 2.73 ft, NAVD88, MLLW: -3.04 ft, NAVD88
        - Source: VDATUM at model boundary condition location

- **Sandy Hook Staten Island**
    - Representative tidal time-series obtained from NOAA station: Sandy Hook, NJ - Station ID: 8531680
    - Baseline tidal time-series data range: 01/01/21 to 04/01/21
    - Start date used for the beginning of baseline tidal cycle 01/01/21 05:54 EST
    - MHHW: 2.41 ft, NAVD88, MLLW: -2.82 ft, NAVD88
        - Source: NOAA Sandy Hook Gauge datums

Sandy Time-series Data

- Hurricane Sandy time-series boundary conditions were developed for the Hackensack/Passaic and the Raritan River using observed WSEL data from temporary storm tide gauges as well as permanent locations. For the Lower Hudson and the Sandy Hook Staten Island domains, Sandy's inundation will be mapped using observed highwater mark data, so no Sandy time-series boundary conditions were developed.
- The 2070 Sandy time-series were created by adding 2.4 ft to the present-day Sandy time-series.
- Both Sandy time-series span from 10/29/12 00:00 to 10/30/12 23:54

- **Hackensack, Passaic**
    - Baseline Sandy storm tide time-series obtained from NOAA station: Bergen Point West Reach, NY - Station ID: 8519483 (tidal gauge)
    - Baseline time-series converted from MSL to NAVD88 by adding -0.176 ft, according to VDATUM
    - The time series was then scaled down from the peak at the Bergen Point Gauge of 11.6 ft, NAVD88 to 11.4 ft, NAVD88 on a percent difference basis. 11.4 ft, NAVD88 is the estimated height of Sandy's storm surge at the Hackensack/Passaic confluence with Newark Bay (see figure below.)

Nearest USGS Sandy high water marks to the Hackensack/Passaic confluence are shown as brown diamonds. The two values were spatially interpolated to approximate the elevation during Hurricane Sandy at the confluence of 11.4 ft, NAVD88 (blue rectangle).