Lower Darby Creek Hydrologic and Hydraulic Analysis Report
Philadelphia, PA

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1.0 USACE Project Summary

1.1 Introduction

To understand flooding at the confluence of Cobbs Creek and Darby Creek in the Eastwick neighborhood of Philadelphia, Pennsylvania, the United States Army Corps of Engineers (USACE) conducted a hydrologic and hydraulic study of Cobbs Creek and Darby Creek. The confluence of Cobbs Creek and Darby Creek is immediately upstream of Clearview landfill located on the western border of Eastwick Park. The USACE investigated hydrologic data and developed a hydraulic model of the creeks to investigate the factors that contribute to flooding into the neighborhood.

2.2 Hydrology

Flood frequency flow rates were computed using the United States Geological Survey's (USGS) StreamStats computer program. For Pennsylvania, the program utilizes regression equations found in the report, SIR2008-5102, Regression Equations for Estimating Flood Flows at Selected Recurrence Intervals for Ungaged Streams in Pennsylvania. Several discharge locations were selected along Darby Creek and Cobbs Creek as well as the mouths of Hermesporta Creek, Muckinipattis Creek, and Stony Creek. In an effort to be conservative, the USACE assumed that the timing of the peak flow rates would perfectly coincide. Discharges for the 2- ,5- ,10- ,50- ,100- and 500-yr events came directly from StreamStats. Flows for the 25-yr were interpolated since the program does not calculate for that return interval.

USGS gage No. 01475548 is located along Cobbs Creek on the right bank 120 feet upstream of the Access Bridge to Mt. Moriah Cemetery. The USACE incorporated data from this gage for Hurricane Irene and Tropical Storm Lee into its hydraulic analysis. Irene and Lee had reported peak discharges of 3,840 cfs and 5,800 cubic feet per second (cfs), respectively. The USACE questioned the accuracy of these discharges as it was suspected the low cord of the nearby bridge may have influenced the gage calculations during high flows.

With the USGS gage data in doubt, the USACE sought other methods to estimate discharges for these events. The other available model was a rating curve developed for the 1977 flood insurance study (FIS). Using this rating curve, the USACE estimated peak discharges of 6,625 cfs and 9,360 cfs for Irene and Lee, respectively at the gage location; which were significantly higher than the discharges reported by the USGS gage. These computed discharges were then increased by 8% to translate the flows to the upstream extent of Cobbs Creek in the HEC-RAS model. The final discharges used in the hydraulics modeling were 7,155 cfs for Hurricane Irene and 10,109 cfs for Tropical Storm Lee.

The USGS gage data and the FIS rating curve discharges were inputted into the HEC-RAS model to compare water surface elevations with high water marks recorded during Irene and Lee. The results indicated that the FIS rating curve discharges produced water surface elevations that more closely matched with the recorded high water marks. It should be noted that the USACE states that the high water marks were not surveyed and were obtained from estimated depths reported by residents.

A more detailed study of the hydrologic data was conducted by the USACE in September, 2016. The findings are reported in Darby and Cobbs Watersheds Hydrologic Study. This report sought to establish the most appropriate relationship for Darby and Cobbs Creeks. It investigated a number of hydrologic methods including FIS discharges, USGS Regression Report SIR 2009-5102, Bulletin 17B Discharge-Frequency Analysis, and Frequency Precipitation in HEC-HMS. One method developed was the creation of a flood frequency curve by merging data from the Woodland Avenue and Mt. Moriah gages along Cobbs Creek. The data were then adjusted using the rating curve for the Mt. Moriah gage found in the 1977 FIS. The USACE ultimately concluded that this method provided the most confidence for estimating discharges along Cobbs Creek.

The hydrologic report also created adjustment factors to estimate discharges along Darby Creek. Since there are no gages located along Darby Creek, a rating curve could not be developed. The USACE had less confidence in the absolute values reported by the USGS Regression. However, it found that the relative ratios of the peak discharges between Cobbs and Darby Creeks to be applicable. Using these ratios, adjustment factors were computed and applied to Cobbs Creek to estimate discharges for Darby Creek.

2.3 Hydraulics

Hydraulic computations were completed using the USACE's HEC-RAS (Version 4.1) computer program. The HEC-RAS model extends along Darby Creek from the confluence with the Delaware River to the railroad bridge by Walnut Street. It extends along Cobbs Creek from the confluence with Darby Creek to the railroad bridge by Cobbs Creek Parkway. The model also included a minor stream that wraps around the southeast edge of the Clearview Landfill and six streets to account for flooding into the Eastwick neighborhood just upstream of the confluence.

The downstream boundary condition was set to a known water surface of 2.61 feet NAVD 88. The USACE report stated that this was the mean high water mark for the Wanamaker Bridge, located on Darby Creek approximately upstream of the confluence of the Delaware River. The flow data included peak discharges to the 2- ,5- ,10- ,50- ,100- and 500-yr calculated by StreamStats and both the USGS gage data and 1977 FIS rating curve for Hurricanes Irene and Floyd.

The model is strictly one-dimensional with creeks and streets connected using junctions. The Eastwick neighborhood streets are simulated as river reaches with blocked obstructions and ineffective areas to account for buildings. Street flow in this area is actually two-dimensional with cross-street flow not being considered. In the conclusion of the report, the USACE suggested that 2D modeling should be considered.

2.0 Princeton Hydro Methods

2.1 Introduction

Princeton Hydro, LLC was tasked with continuing the hydrology and hydraulics analysis and investigating potential scenarios which could be implemented to mitigate flooding impacts. The USACE provided a one-dimensional model of the Darby and Cobbs Creeks and the report of the hydrologic assessment. After reviewing the data, it was determined that a two-dimensional hydraulic model would provide additional insight into flooding in the Eastwick neighborhood. 1D modelling is sufficient in riverine areas where flow is generally in one direction. However, in the Eastwick neighborhood and surrounding areas, flow can move down the streets or between buildings depending on the terrain. A 1D approach fails to capture these complexities. For these reasons, Princeton Hydro developed a 2D hydraulics model for the Eastwick neighborhood. This 2D model was built onto the existing 1D USACE model, as such the main river reaches use the same basic 1D model characteristics and cross sections.

Several scenarios were modelled to assess the current risks of flooding and to determine potential solutions. Many of the proposed solutions focused on improvements to the landfill area which constricts the floodplain at the confluence of Cobbs and Darby Creeks and could serve to increase water surface elevations upstream and thereby increasing the risk of flooding in the Eastwick neighborhood. The scenarios are listed in Table 2.1.

Table 2.1. 2D Modeling Scenarios

	Scenario	Notes
1	Existing Conditions	Boundary condition = 2.61 feet NAVD 88
2	Coastal Storm Surge for FEMA 1% Storm	Boundary condition = 8.54 feet NAVD 88 (Base Flood Elevation)
3	Coastal Storm Surge for NOAA SLOSH Category One storm	Boundary condition = 6.80 feet NAVD 88 (Maximum of Maximum – MoM)
4	Remove Hook Rd (S 84th St.) Constriction	Removed bridge, embankments remained
5	Remove Clearview landfill and restore to floodplain	Manipulated DEM, Floodplain elevation=4' NAVD88
6	Baseline: Remove Clearview landfill and restore to floodplain and Hook Rd constriction	Combine scenarios #4 and #5
7	Using a similar footprint of the USACE proposed levee	Levee Elevation = 20 feet NAVD88
8	Create floodplain along Cobbs Creek left overbank upstream of the Darby-Cobbs confluence at pinch point	Manipulated DEM, pinch point floodplain bench elevation = 4 feet NAVD88
9	Remove 75 feet of left overbank and restore to floodplain along the length of Clearview landfill	Manipulated DEM, channel floodplain bench elevation = 4 feet NAVD88

2.2 Hydrology

One of the requirements of 2D modeling within HEC-RAS is the input of unsteady flow data. An unsteady analysis was not conducted in the original USACE study. For the hydrologic study, the USACE did develop a HEC-HMS model for the application of frequency precipitation in determining flood frequency. However, due to a lack of data, especially for greater return periods, the USACE expressed uncertainty with the calibration of the model.

USGS gage No. 01475548 on Cobbs Creek at Mt. Moriah Cemetery is the best available recorded hydrologic data available. As noted earlier, the USACE expressed uncertainty with the reported discharges at higher flow events. However, the USACE hydrology study concluded that utilizing the USGS gage data adjusted with the 1997 FIS rating curve provided the greatest certainty.

Princeton Hydro decided to use the Tropical Storm Lee event as the basis of the unsteady analysis. The USGS recorded discharges for this event between September 5, 2011 to September, 11 2011, as shown in Figure 2.1. Tropical Storm Lee produced enough precipitation (6.5 – 8 inches) to correlate with high a frequency precipitation (approximately 50yr event) and it produced high enough discharges to initiate flooding into the Eastwick neighborhood. The USACE also included Tropical Storm Lee in its initial flood analysis and reported high water marks from the event were used to calibrate discharges.

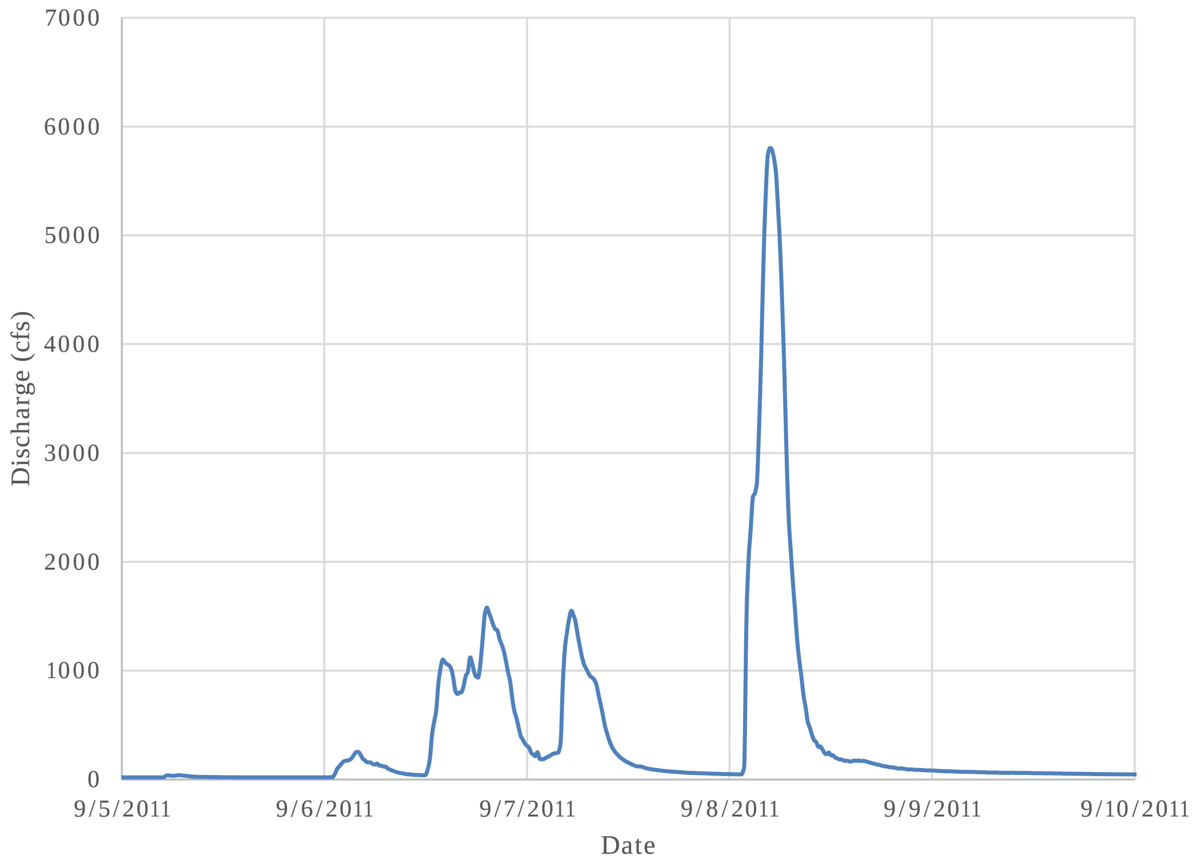


Figure 2.1. USGS Gage No. 01475548 reported discharges on Cobbs Creek

Hurricane Irene impacted the Philadelphia area days prior to Tropical Storm Lee. Its impact on the Cobbs Creek discharges can be seen from September 6 to September 7, 2011. Tropical Storm Lee landed in Philadelphia shortly after midnight on September 8, 2011. The recorded peak discharge at the Cobbs Creek gage was 5,800 cfs.

As mentioned earlier, the USACE hydrology study found greater confidence in using the USGS gage data along with the 1977 FIS rating curve. Therefore, the peak discharges needed to be scaled up for this model. It was assumed that the general shape of the hydrograph recorded at the USGS gage was accurate. An adjustment factor of 1.743 was applied to all time periods during the tropical storm event. This adjustment factor is the ratio of USACE computed Tropical Storm Lee peak discharge (10,109 cfs) and the USGS reported discharge (5,800 cfs).

Since there are no gages located along Darby Creek, the USACE developed a relationship between Cobbs and Darby Creeks in its hydrologic study. It was recommended to estimate Darby Creek discharges by multiplying the Cobbs Creek discharges by an adjustment factor. This adjustment factor was based on the SteamStats frequency flows at Darby Creek divided by the flows at Cobbs Creek. Princeton Hydro assumed that the hydrograph for Darby Creek had a similar shape and time series as the Cobbs Creek hydrograph. The final computed discharges for Darby Creek are the adjusted Cobbs Creek discharges multiplied by 1.39. The same method was used to compute discharges for Hermesporta Creek, Muckinipattis Creek, and Stony Creek. Discharge adjustment factors are show in Table 2.2.

Table 2.2. Stream Discharge Adjustment Factors

Stream	Adjustment Factor
Cobbs Creek	1.743*
Darby Creek	1.395**
Hermesporta Creek	0.18***
Muckinipattis Creek	0.34***
Stony Run	0.27***

* Ratio of USACE computed Tropical Storm Lee peak discharge and USGS gage peak (10,109cfs/5,800cfs)
**From USACE Hydrology Study; Adjustment factor for 50-year frequency
***Ratio of peak discharges from Stream Stats

This methodology assumed that all the streams have similar hydrographs and peak at the same time. In reality, this is very likely untrue. However, due to a lack of data on Darby Creek and other minor streams, these are the best assumptions that could be made. This resulted in conservative water surface elevations in the hydraulic analysis. The stream hydrographs for Tropical Storm Lee is displayed in Figure 2.2. These hydrographs were used as the input flow data for all scenarios in the hydraulic modeling.

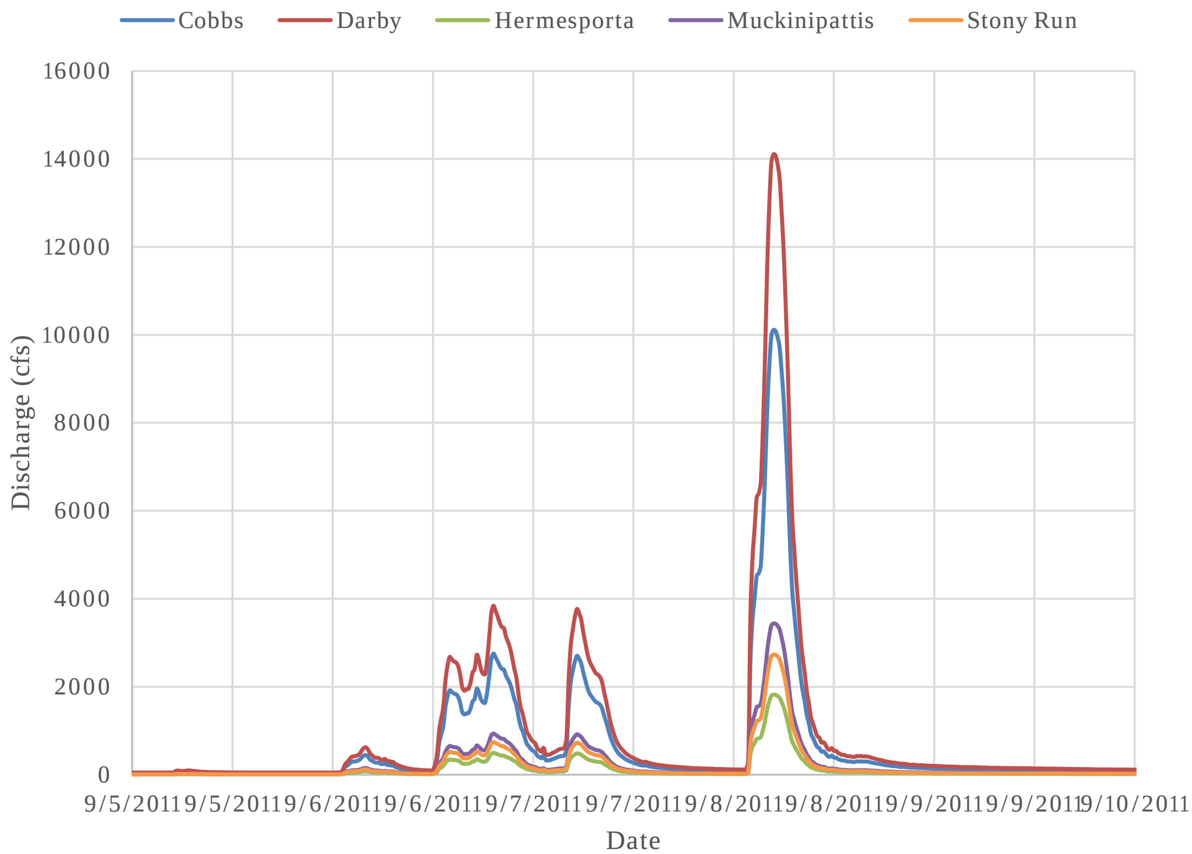


Figure 2.2. Computed Stream Hydrograph for Hurricane Irene and Tropical Storm Lee

2.3 Hydraulics

2.3.1 Updating 1D Model

Princeton Hydro sought to preserve as much of the original USACE HEC-RAS model as possible. Since the flooding into Eastwick east of Cobbs Creek would be computed with 2D methods, the stream on the east side of Clearview landfill and street conveyances were removed from the 1D HEC-RAS model. For existing conditions, cross section lengths, manning's n values, bank points, ineffective flow areas, and terrain data were maintained from the USACE model.

The terrain source for the USACE HEC-RAS model was from 2013. Princeton Hydro had access to 2015 1 meter LiDAR terrain data. The two terrain datasets were compared and while the overbanks matched, the stream bottoms were significantly lower in the HEC-RAS model compared to the 2015 LiDAR. This is likely due to the 2015 LiDAR capturing the water surface instead of the stream bottoms. For this reason, it was decided to maintain the channel geometry from the USACE HEC-RAS model instead of using the more recent terrain data. However, both terrain data sources were extremely similar in the overbank areas as would be assumed due to the fact that they were collected only two years apart.

2.3.2 Unsteady Flow Analysis

The hydrographs for Tropical Storm Lee shown in Figure 2.2 were input as the boundary conditions for the unsteady flow data. For the boundary condition, the most downstream cross section of Darby Creek was set as a stage hydrograph with a water surface elevation at 2.61 feet at all time intervals, with the exception of scenarios 2 and 3 as noted above in Table 2.1. It was assumed that the downstream stage would not change significantly over time since it ties in with the larger Delaware River. Elevation 2.61 feet was derived from the USACE steady flow model and it is based off mean high water marks on Wanamaker Bridge.

2.3.3 Developing 2D Flow Area

Combined 1D and 2D Models

Traditional one-dimensional modeling in HEC-RAS was sufficient for modeling the riverine portions of Cobbs and Darby Creeks where the flow generally moves in one direction. The flooding into the Eastwick neighborhood is more complex with multidirectional flow moving down streets and between buildings. Recent versions of HEC-RAS have the capability to perform two-dimensional hydraulic routing. Instead of modeling the streets in 1D like the riverine portions, a 2D flow analysis provided a clearer picture of the direction and extent of the flooding. The final product was a combined 1D model for the stream segments with a 2D flood area for the Eastwick neighborhood as shown below in Figure 2.3. A detailed map of the cross sections is also provided in Appendix A.

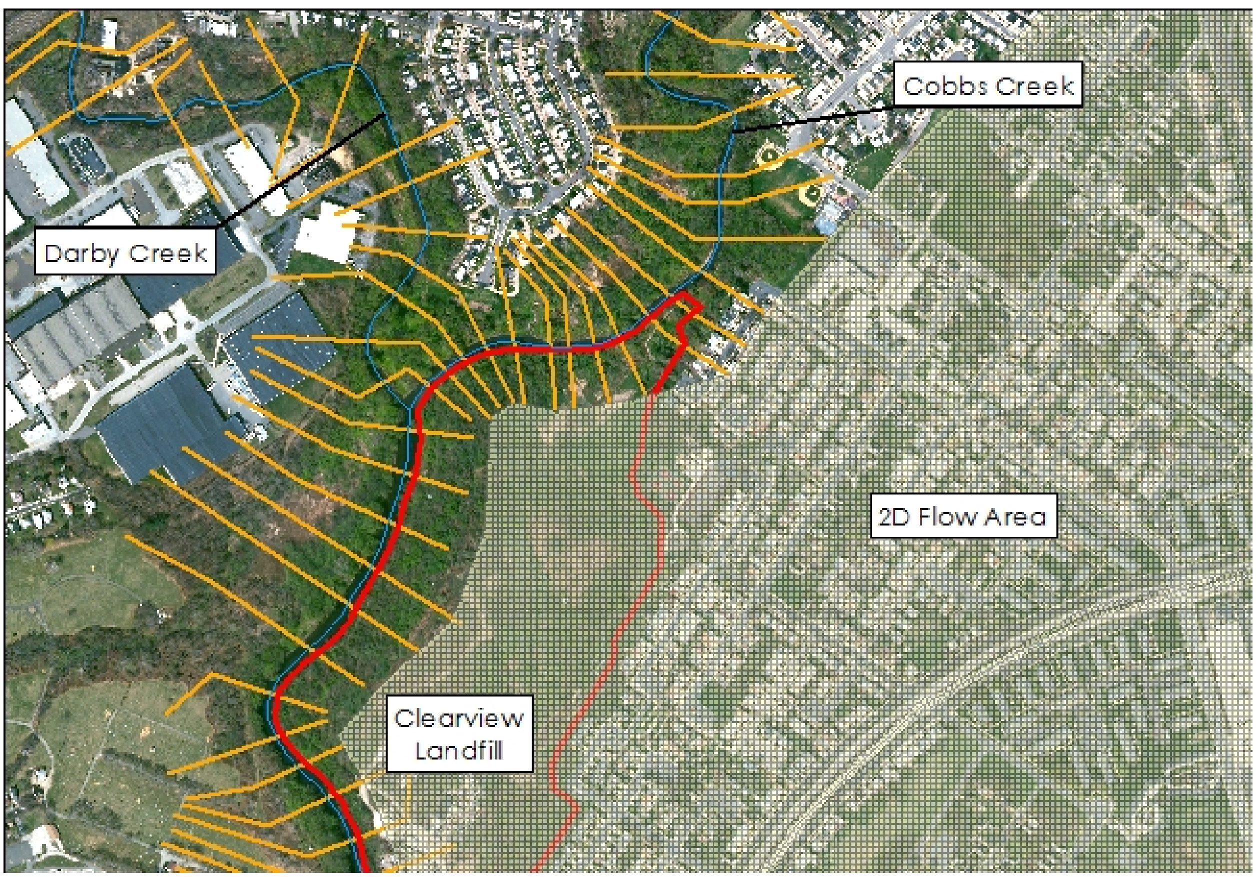


Figure 2.3. 1D/2D Tie-in at Eastwick neighborhood.

2D Computational Mesh

Unlike in 1D modeling where computations are made at each cross section, 2D modeling utilizes a grid and terrain raster data to complete hydraulic computations. For this study, Princeton Hydro used the 2015 1 meter LiDAR as its terrain source for the 2D flow area and for mapping the floodplains. Using the HEC-RAS RAS Mapper tool, the LiDAR raster was imported into HEC-RAS. The 2D area boundary was drawn by hand in Geometric Data editor. The boundary was drawn to be consistent with the edges of the 1D cross sections.

Once the 2D flow area was drawn, a cell size must be selected. Calculations are made within each individual cell. Each cell contains only one representative elevation value and roughness coefficient. Small cell sizes are required for finer resolution to account for changes in land use, buildings, etc. However, smaller cell sizes result in longer run times and significantly reduced model stability. Therefore, there is a balance between model resolution and practical aspects of the modeling. Initially, cell sizes of 5’x5’ and 10’x10’ were selected, however these cell sizes resulted in model instability. This is a common issue in 2D modeling and larger cell sizes are recommended to improve stability. Ultimately, a cell size of 25’X25’ was selected for the existing conditions and most of the alternative scenarios. This cell size provided adequate resolution to represent ground conditions without introducing model instability. Figure 2.4 shows the 2D flow area and terrain data along with the cross sections from the original USACE model within HEC-RAS.

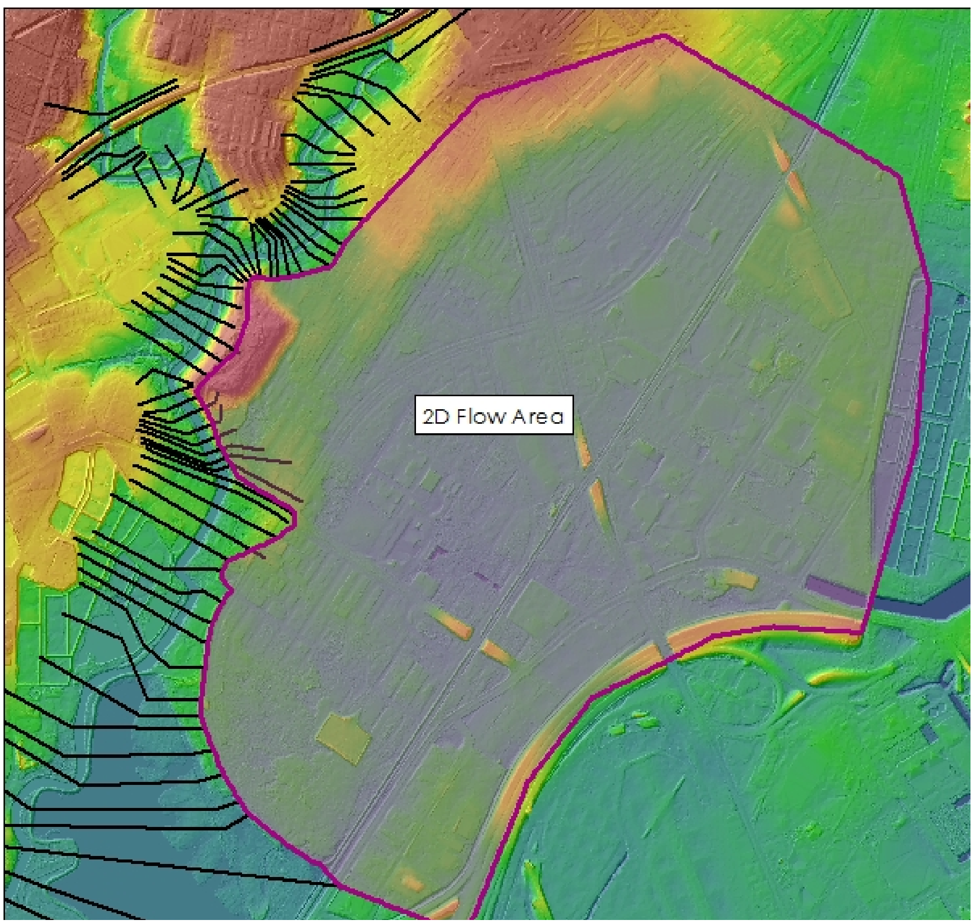


Figure 2.4. HEC-RAS 2d Flow Area

1D/2D Tie-in

1D and 2D flow elements connected together through the Lateral Structure Function in HEC-RAS. Although there is no actual physical lateral structure, the function is used to tie-in the 1D cross sections with the 2D terrain. For the existing conditions, a lateral structure was placed between cross sections 743 and 1676 on Cobbs Creek. This is the location of the source of flooding into the Eastwick neighborhood. Results from the 1D modeling suggested that there may also be flooding in the vicinity of the John Heinz Wildlife Refuge. Therefore, another lateral structure was inserted between stations 19804 and 25220 on Darby Creek. For some of the proposed scenarios, additional lateral structures were inserted to observe changes in flooding locations.

The station-elevation data for the lateral weir embankment was pulled directly from the 2015 1 meter LiDAR along the lateral structure centerline. Weir widths were set to 0.01 feet and the weir coefficient was set to 0.1. In this way, the lateral structure simulates the actual terrain between the 1D and 2D areas thereby allowing flow between the 1D cross sections and the 2D model mesh. A detailed overview of the 1D cross sections and the 2D mesh is provided in Figure 2.5, and the hydraulic model cross sections in Appendix A.

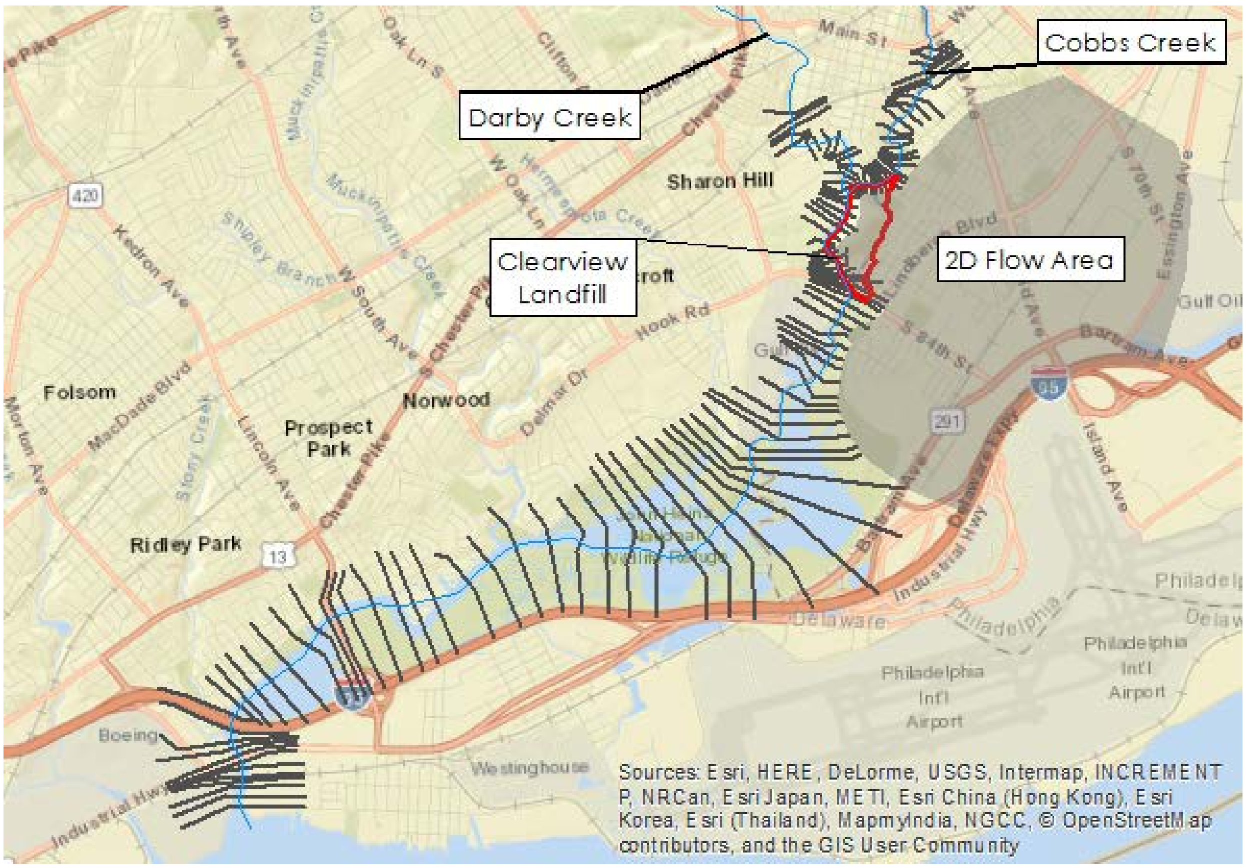


Figure 2.5. Combined 1D/2D HEC-RAS Model for Cobbs Creek and Darby Creek.

Landcover

Manning's n values were assigned to the 2D cells through the New Land Cover tool in the RAS Mapper. The landcover source used was the 2004 Impervious Surfaces coverage from the City of Philadelphia Water Department. Although 13 years old, this dataset was the best resolution available and observations in more recent imagery indicated that the landcover had not significantly changed. Manning's n values were assigned to each land cover type in the Land Cover to Manning's n (2D Flow Areas Only) table in the HEC-RAS Geometry editor. As is commonly applied, buildings were assigned extremely high n values to essentially be simulated as obstructions to flow, this is also important considering buildings were removed from the LiDAR terrain source. Table 2.3 displays the Manning's n values used.

Table 2.3 Terrain and Manning's n values.

Landcover	Manning's n
No Data	0.06
Alleys	0.017
Asphalt/Concrete Slabs/Patios	0.017
Building Center Polygons	750
Buildings	750
Driveways	0.017
Forest	0.1
Inground Pools	0.013
Institutional	500
Large Concrete/Asphalt Ditches	0.017
Marsh	0.1
Medians	0.017
Parking	0.017
Parking Islands	0.06
Pedestrian Bridge	0.017
Ponds	0.04
Railroad Ballast	0.07
Railroad Bridge	0.07
Shoulder	0.017
Sidewalks	0.015
Streams wider than 15'	0.045
Tanks	750
Travel way Bridge	0.017
Travelways	0.017
Turf	0.06

It must be noted that current versions of HEC-RAS can only assign one Manning's n value to each 2D cell. Future versions will allow for cells to have multiple n values. With a 25'x25' cell size, small terrain features are unlikely to be captured in the hydraulic computations.

Model Runs

Once the 2D flow area was generated, the combined 1D/2D models were ran to compute water surface elevations along the creeks and in the Eastwick neighborhood. Computations along Cobbs and Darby Creeks are strictly 1D. Once the water surface elevations are high enough to exceed the boundaries of the 1D cross sections, flow computations are initiated in the 2D flow area. The terrain and landcover dictated the depth and direction of flow. Since these simulations were unsteady, flooding extents could be observed at different time periods. In the RAS Mapper, the floodplains were animated; giving a clear illustration of the flooding extents, depths and direction over time.

2.3.4 Scenarios Discussion

The following discussion presents the results from the model runs for each scenario. Maps representing the maximum floodplain extents, water depths, and water surface elevations are included at the end of the section, and Appendix B. Summary tables of the water surface elevations for Cobbs and Darby Creeks

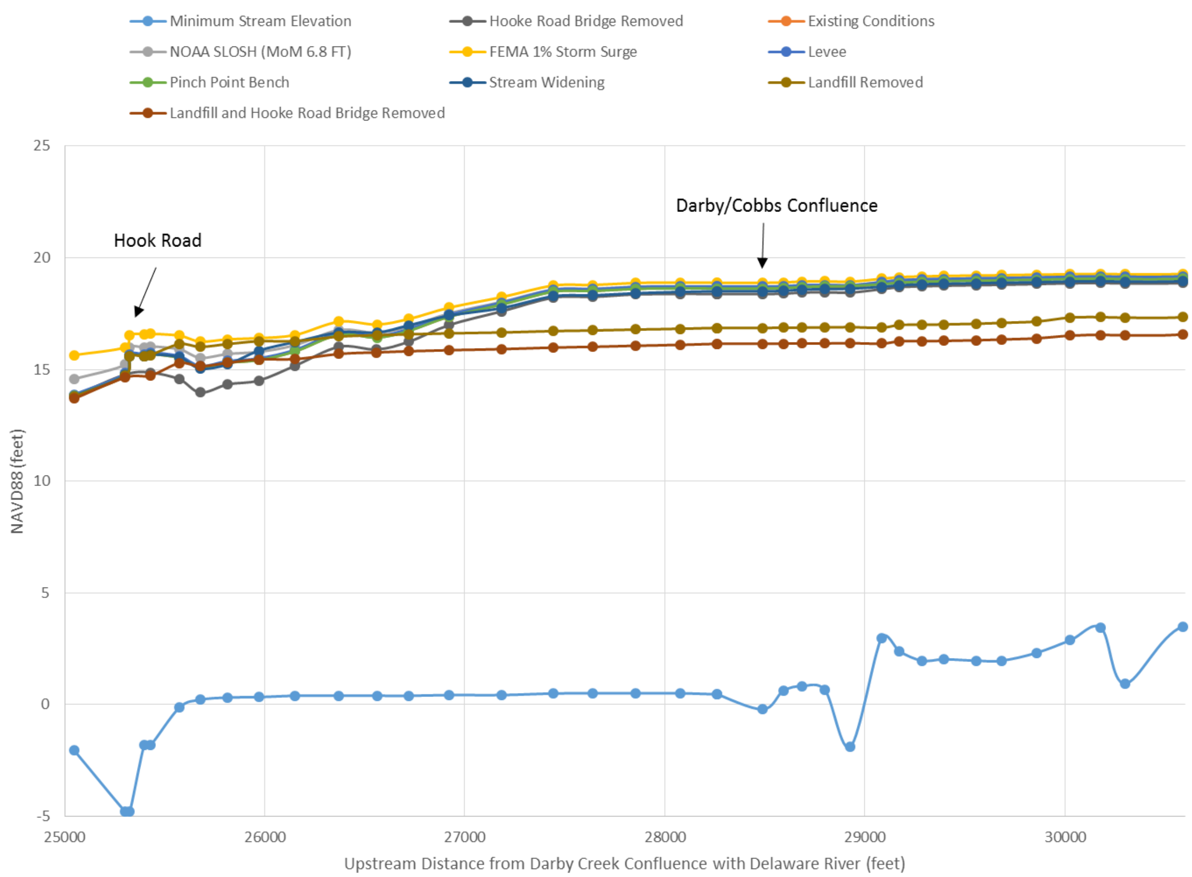


Figure 2.6 Water Surface Profiles for Each Scenario on Cobbs and Darby Creeks
Note: This graph contains profiles for areas adjacent to Eastwick neighborhood

can be found in Appendix C. These tables only contain results for the 1D portions of Cobbs and Darby Creeks adjacent to the Eastwick neighborhood. Figure 2.6 displays a comparison of the water surface profiles for each scenario and is discussed in detail below.

1. Existing Conditions

Figure 2.7 displays the maximum extents of the floodplain for the existing conditions. As shown, flooding into Eastwick begins immediately upstream of Clearview landfill. Compared to the landfill and areas further north, Eastwick is located at a relatively low elevation which is only a few feet higher than the Cobbs Creek left overbank area, making the neighborhood particularly vulnerable to flooding. A minimum ground elevation at the 1D/2D boundary is approximately 11.5 feet NAVD88. When water levels in Cobbs Creek exceed this elevation, flooding is initiated into Eastwick. The flow generally moves into Eastwick from northwest to southeast. Flooding is not restricted to the streets as the floodplain moves between the homes located along Saturn Place and Venus Place. The floodwater then begins to move southward before moving southeast towards Lindbergh Boulevard. By the time water elevations in Cobbs Creek recede, flooding has extended all the way to Grovers Avenue on the southeast side of Lindbergh Boulevard.

In addition, the 2D modeling revealed flooding along South 86th Street downstream of the Hook Road crossing. This location was not considered as a flood risk area in the original 1D model. This was another added benefit to 2D modeling by identifying flood risk areas without the need for additional stream reaches and cross sections created by the user.

The water surface profile from the HEC-RAS output indicates that coastal conditions, such as tidal stage of the Delaware, is the major influence for much of Darby Creek. This influence extends to Hook Road. Upstream of the Hook Road crossing coastal influences are much less significant.

Compared to the original USACE model which attempted to simulate flow down the neighborhood streets in 1D, the 2D model is able to better capture the complexities of the terrain and landcover and give a clearer picture of flooding in this area. The existing conditions served as a baseline for which to compare all potential solutions.

2. Coastal Storm Surge for FEMA 1% Storm

Due to its proximity to the Delaware River, in additional to typical riverine flooding, Cobbs and Darby Creeks are prone to coastal storm-related influences. The previous USACE study and the existing conditions model are based on a mean high water elevation for its downstream boundary condition. During a coastal storm surge, water elevations in the Delaware River can be significantly higher which result in higher water elevations in Cobbs and Darby Creeks. The purpose of this scenario was to assess the influence of coastal storm surges on the flooding in Eastwick. It should be noted that for these simulations the cell size for the 2D flow area were increased to 35’X35’ to improve model stability. Like with existing conditions, the Tropical Storm Lee hydrograph was used as the input flow data.

The FEMA 1% storm base flood elevation at the confluence of Darby Creek and the Delaware River is 8.54 feet NAVD88; significantly higher than the 2.61 feet mean high water elevation. Despite a 5.93 feet water surface elevation increase at the downstream boundary condition, the FEMA 1% storm surge only resulted in a 0.2 feet to 0.25 feet water surface elevation increase along Cobbs Creek. This supports the conclusion that coastal influences are not substantial upstream of the Hook Road Bridge crossing. Even though water surface elevations in Cobbs Creek did not increase as much as expected, the model results indicate that the modest increase in water elevation did result in additional flooding in the Eastwick neighborhood. As displayed in Figure 2.8, the peak flooding extents now extends past Grovers Avenue to 84th Street and Maria Lanza Boulevard. Due to the relatively flat and low-lying terrain, the flood risk to Eastwick is sensitive to even small changes in the riverine water surface elevations.

This scenario demonstrates that coastal influences need to be considered when developing resiliency improvements for this area. Coastal flooding will have the most impact to areas downstream of Hook Road but as this scenario has shown, high coastal flood elevations will continue to have influences further upstream and even small water level increases in Cobbs Creek can greatly impact the number of homes and businesses at risk to flooding.

3. Coastal Storm Surge for NOAA SLOSH Category One storm

This scenario is similar to Scenario 2 but using coastal elevations estimated by NOAA. NOAA’s Sea, Lake, and Overland Surges from Hurricanes (SLOSH) modular ocean model estimates a maximum water surface elevation of 6.8 feet NAVD88 at the Delaware River for a Category One Storm, Maximum of Maximum. Surprisingly, the change in water surface elevations compared to the existing conditions were less than

0.1 feet along Cobbs Creek as shown in Table A1.3. Figure 2.9 displays only a small expansion to the floodplain.

Comparing Scenario 1 and Scenario 3, the difference in water surface elevations on Cobbs Creek was only 0.1 feet but Scenario 3 had a more expansive floodplain. This again demonstrated how even small changes in the riverine water surface elevations can greatly affect the total area flooded in Eastwick. This also suggested that coastal storm surges will not have significant impacts on flooding into Eastwick until coastal flood elevations exceed an elevation of approximately 6.5 feet NAVD88.

4. Remove Hook Road Constriction

The Hook Road Bridge marks the upstream extent of significant coastal influence and is a major constriction point on Darby Creek. It was hypothesized that its removal might lower flood elevations enough to significantly reduce impacts to the Eastwick neighborhood. The bridge was removed from the 1D portion of the combined model to determine how much of an influence it had on the water surface elevations. Table A1.4 and Figure 2.10 display the water surface elevations and floodplain at Eastwick, respectively.

As the data show, the Hook Road Bridge had minimal impact on the water surface elevations. Water surface elevation reductions were greatest immediately upstream of the bridge. However, these reductions decreased further upstream with only a 0.25 feet reduction on Cobbs Creek. This was not a large enough reduction to prevent water from overtopping the banks of Cobbs Creek. The removal of the bridge alone, or the modification of the crossing to increase its conveyance, is unlikely to notably decrease the risk to flooding in Eastwick.

5. Remove Clearview Landfill

An obvious constriction to the floodplain is Clearview landfill at the confluence of Cobbs and Darby Creeks. The landfill is approximately 870 feet wide, 1800ft long, and has a top elevation approximately 75 feet higher than the floodplain. Its removal would create a wider floodplain downstream of the confluence and result in lower water surface elevations further upstream.

Beginning with the 2015 1 meter LiDAR dataset, the terrain in the landfill footprint was adjusted to an elevation of 4 feet NAVD 88. This approximates the floodplain to its original elevation and lowers it below the elevation of the Eastwick neighborhood. Since it is recommended that the 1D/2D boundary occur at a high point in the terrain, the cross sections were extended on the river left side to new high points at the Eastwick/landfill boundary. The adjusted cross section and terrain were then imported into the combined 1D/2D HEC-RAS model. The lateral weir was also extended further downstream to allow for water to move from the 1D to the 2D area east of the landfill area.

Figure 2.11 displays the floodplain with the landfill removed. Its removal did reduce water surface elevations between 1.8 feet and 2.0 feet on Cobbs Creek as shown in Table A1.5, enough to prevent flooding into Eastwick from the upstream side of the confluence. However, interestingly more severe flooding is now occurring to areas adjacent to the landfill. Under the existing conditions, the landfill itself acts as a barrier to flooding. Its removal may relieve some residents but put others at risk.

6. Baseline: Remove Clearview Landfill and Hook Road Bridge Constriction

This scenario is a combination of Scenarios 4 and 5. In viewing historical maps, it was clear that the floodplain had been constricted by the development of the landfill and the Hook Road Bridge. Removal of these features would help better understand the flooding elevations and extents that existed prior to these significant alterations. It also helped determine how significant these features are to the overall flooding in the area. As expected, this scenario produced the lowest water surface elevations out of all the scenarios. Compared to existing current conditions, water elevations were about 2.5 feet lower. However, as shown in Figure 2.12, the area adjacent to the landfill would still experience flooding due to the landfill's removal. The removal of the Hook Road Bridge lowered elevations by 0.5 feet to 1 feet compared to just removing the landfill. This reduction is significant but not enough to prevent flood waters overtopping into Eastwick.

7. Levee Protection

The original proposal by the USACE was the construction of a 500-yr event levee on the left bank of Cobbs Creek between the landfill and playground on 77th Street. The levee assumed a crest elevation of 20 feet NAVD88 with 1:3 side slopes and a 10 foot wide crest. The model with the levee was not provided to Princeton Hydro. A concern was that the levee may block flooding into Eastwick but could potentially raise water surface elevations which might increase flood impacts to neighborhoods on the right (west) bank of Cobbs Creek. Mapping of the USACE existing conditions model showed that the apartment buildings on Tribet Place are within the floodplain for the Tropical Storm Lee events.

To model this scenario in a combined 1D/2D model, the lateral structure that connects the 1D and 2D flow areas at Eastwick was raised to 20 feet NAVD88 to match the crest height of the proposed USACE levee crest height. The weir width was increased to 10 feet and weir coefficient set to two to match specifications outlined in the USACE report.

The inclusion of the levee protects the Eastwick neighborhood from flooding originating from Cobbs Creek, as depicted in Figure 2.13. Like with the USACE model, the two apartment buildings on the right bank of Cobbs Creek are inundated under existing conditions in the combined 1D/2D model; however, as shown in Figure 2.13, there were no significant changes in the floodplain encroachment to the neighborhoods on the right bank of Cobbs Creek and no additional properties were impacted. The addition of the levee only raised water surface elevations by approximately 0.07 feet along Cobbs Creek for the Tropical Storm Lee event. The hydraulic modeling has shown that the levee is the only scenario studied to create full flood protection for Eastwick.

8. Create floodplain along Cobbs Creek left overbank upstream of the Darby-Cobbs confluence

The removal of the entire landfill is unlikely, and as previous scenarios have shown, its high elevations act as a barrier to flooding for portions of Eastwick. Removal of limited areas of the landfill are likely more feasible. The floodplain is most constricted at the northern tip of the landfill just upstream of the confluence. For this scenario, the 2015 1 meter LiDAR was manipulated to remove a portion of the northern landfill and replace it with a 4 feet NAVD88 floodplain bench.

Figure 2.14 displays the floodplain for this scenario. The replacement of the northern tip of the landfill with a floodplain bench had minimal impact on the flooding into Eastwick. Water surface elevations were less than 0.1 feet lower in the riverine portions in comparison to the existing conditions. This was not significant enough of an impact to prevent flooding into Eastwick and out of the flood risk area.

9. Remove 75 feet of left overbank and restore to floodplain along the length of Clearview Landfill

This scenario is similar to Scenario 8 but removed more of the landfill and extends the floodplain bench further downstream. In this scenario, 25 feet to 75 feet of the landfill on the left overbank was removed and replaced with a floodplain bench at elevation 4 feet NAVD88. The floodplain bench extends approximately 4,200 feet from river station 26,123 at Hook Road on Darby Creek to river station 1335 on Cobbs Creek. The widening of the floodplain allowed for less constrictive conveyance while still maintaining the flood protection provided by the landfill.

Scenario 9 ultimately yielded minimal improvements. Water surface elevations only dropped by approximately 0.1 feet. As shown in Figure 2.15, Eastwick is still inundated under these conditions. The results of Scenarios 8 and 9 indicate that greater reductions to the landfill footprint are necessary in order to achieve meaningful decreases in flooding.

3.0 Summary of Results and Conclusions

Beginning with the USACE 1D HEC-RAS model, Princeton Hydro took advantage of the HEC-RAS 2D modeling capabilities to develop a combined 1D/2D model for Cobbs and Darby Creeks. The 2D approach proved to be a valuable tool in assessing flooding from Cobbs Creek into the Eastwick neighborhood of Philadelphia. A summary of the water surface elevations for each scenario is shown in Appendix A. Full floodplain maps can be found in Appendix B.

It was observed that Darby Creek is significantly influenced by coastal conditions up to Hook Road. The modeling revealed that coastal flood elevations are unlikely to have a significant impact to Eastwick flooding below coastal flood elevations 7 feet NAVD88. Above 7 feet NAVD88, coastal influences have a notable impact on the hydraulic conditions of Cobbs Creek and may expose Eastwick to greater flood risks.

Many of the scenarios focused on improving floodplain conveyance through reductions to Clearview landfill. The landfill is hydraulically significant as it constricts flows immediately downstream of the Cobbs and Darby Creeks confluence. The results of the hydraulic modeling revealed that modest reductions to the landfill area produced minimal reductions in flooding. Removal of the entire landfill did reduce water surface elevations enough to prevent flooding into Eastwick upstream of the confluence. However, the landfill currently acts as a flooding barrier and its complete removal would expose other areas of Eastwick to flooding.

With a proposed crest elevation of 20 feet NAVD88, the levee was capable of blocking off flooding into Eastwick for the modelled Tropical Storm Lee scenario. Two apartment buildings located on Tribet Place in the neighborhood on the right banks of Cobbs Creek are already at risk to flooding in existing conditions. The proposed levee risked inundating the neighborhood even further. However, the addition of the levee did not significantly increase water surface elevations enough to pose a greater risk of flooding to neighborhoods on the right overbank of Cobbs Creek. Out all the proposed scenarios, only the levee provided full protection to Eastwick while not adversely affecting other areas along Cobbs Creek.

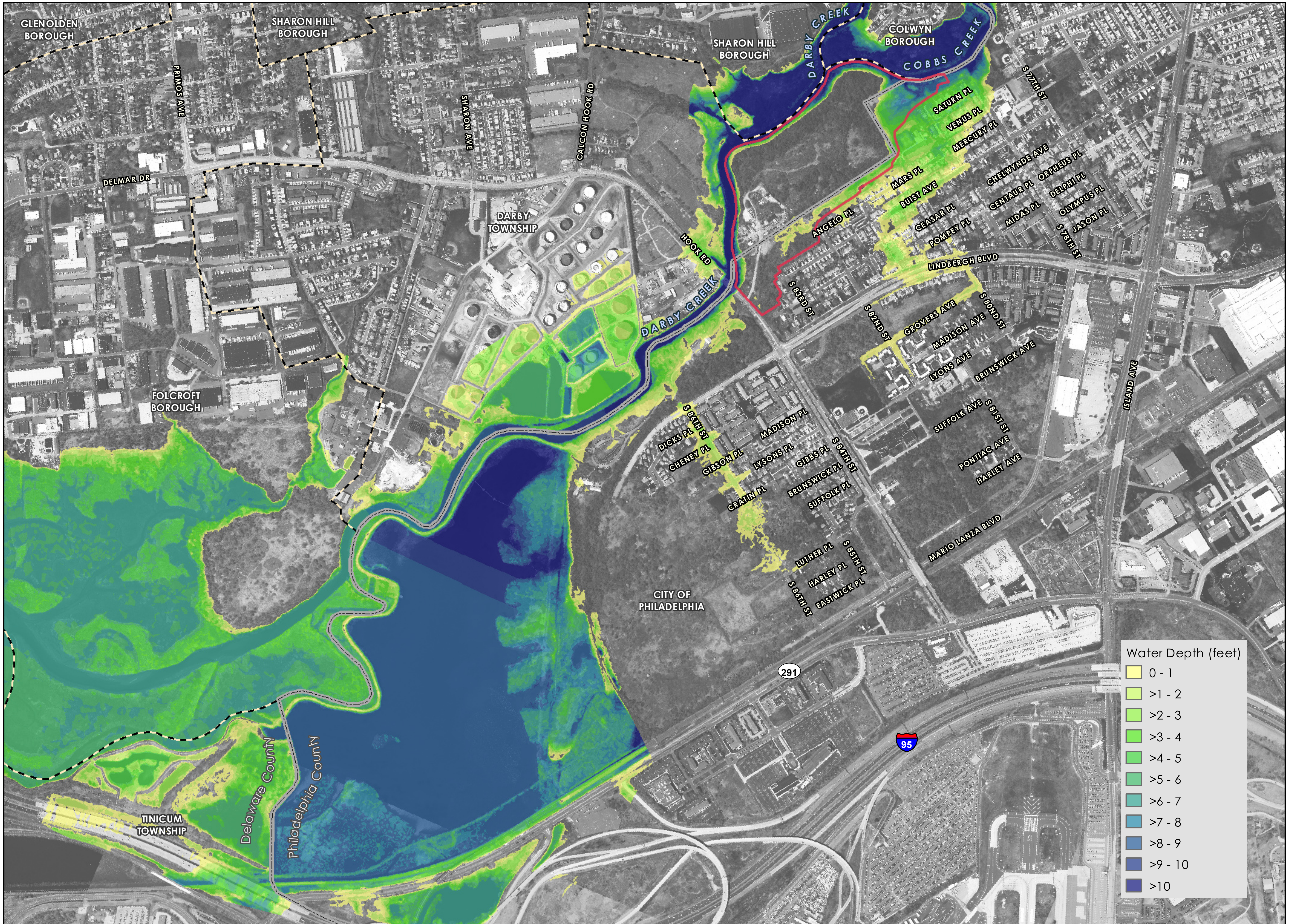
4. References

HEC (2016). “HEC-RAS River Analysis System – 2D Modeling User’s Manual, Version 5.0”. USACE Hydrologic Engineering Center, Davis, CA, February 2016.

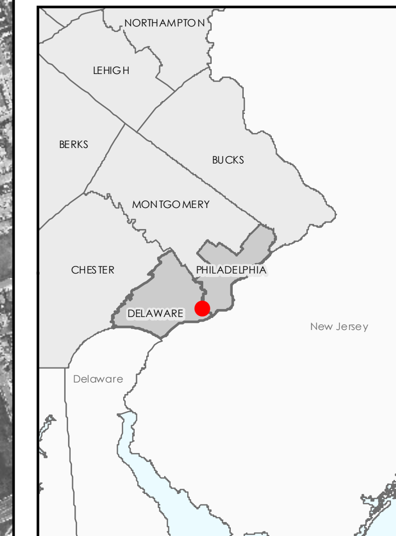
HEC (2016). “Hydraulic Reference Manual, Version 5.0”. USACE Hydrologic Engineering Center, Davis, CA, February 2016.

USACE (2014). “Eastwick Stream Modeling and Technical Evaluation – Technical Report”. Philadelphia, Pennsylvania.

USACE (2016). “Darby and Cobbs Watersheds Hydrologic Study”. Philadelphia, Pennsylvania.



LOCATION MAP



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1 inch = 1,000 feet

0 500 1,000 Feet

FIGURE 2.7
WATER DEPTH
EXISTING CONDITIONS

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

- County Boundary
- Municipal Boundary
- Clearview Landfill Existing Limits

NOTES:

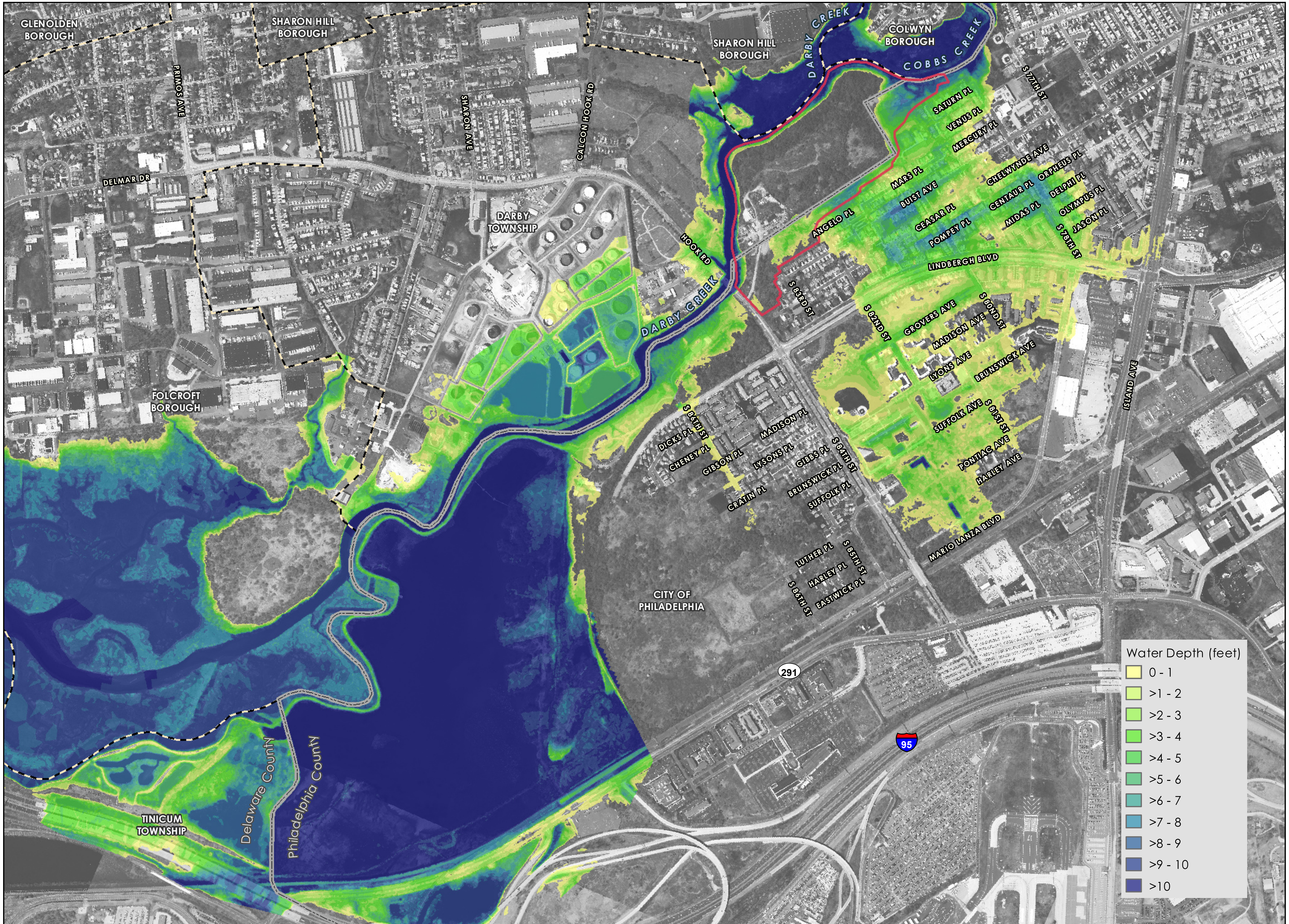
1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

3. Elevations reference North American Vertical Datum 1988 (NAVD88).

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

File: P:\1626\Projects\1626001\GIS\MXD\Flood_Maps\2.8_FEMA_100yr_Depth.mxd, 3/21/2017, Drawn by thopper, Copyright Princeton Hydro, LLC.



LOCATION MAP

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0 500 1,000 Feet

FIGURE 2.8
WATER DEPTH
COASTAL STORM SURGE
FOR FEMA 1% STORM

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

- County Boundary
- Municipal Boundary
- Clearview Landfill Existing Limits

NOTES:

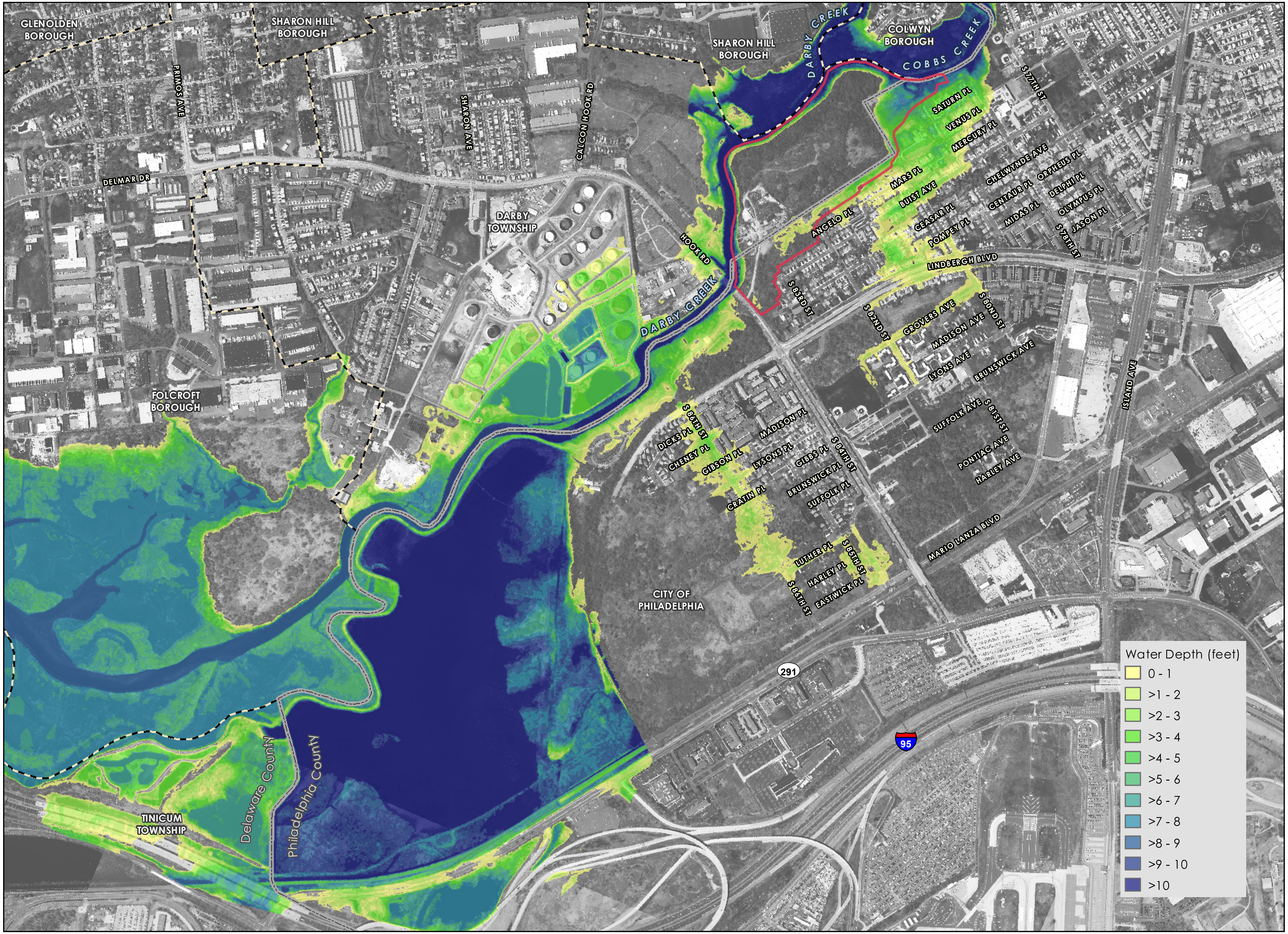
1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

3. Elevations reference North American Vertical Datum 1988 (NAVD88).

4. FEMA Base Flood Elevation (BFE): 8.54 feet.

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet



LOCATION MAP

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1 inch = 1,000 feet

0 500 1,000 Feet

FIGURE 2.9 WATER DEPTH COASTAL STORM SURGE FOR NOAA SLOSH CATEGORY ONE STORM

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

- County Boundary
- Municipal Boundary
- Clearview Landfill Existing Limits

NOTES:

1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

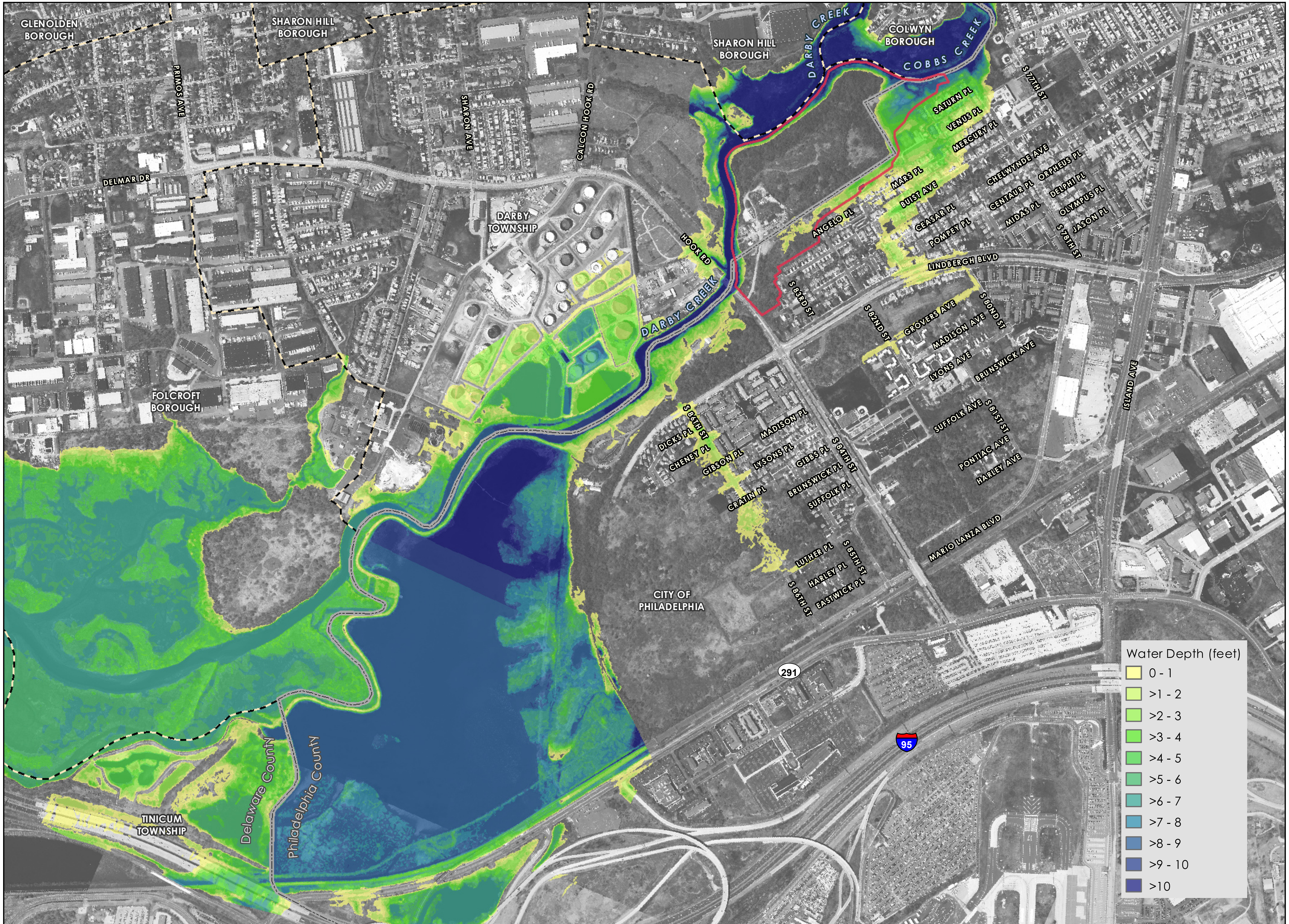
2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

3. Elevations reference North American Vertical Datum 1988 (NAVD88).

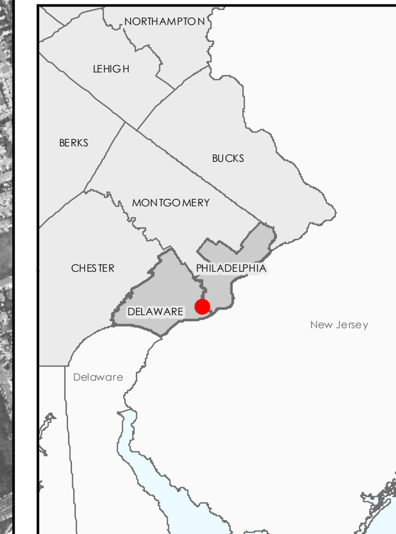
4. NOAA SLOSH Category One Storm Maximum of Maximum (MoM) elevation: 6.8 feet.

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

File: P:\1626\Projects\1626001\GIS\MXD\Flood_Maps\2.10_Remove_HookRd_Depth.mxd, 3/21/2017, Drawn by thopper, Copyright Princeton Hydro, LLC.



LOCATION MAP



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0 500 1,000 Feet

FIGURE 2.10
WATER DEPTH
REMOVE HOOK ROAD CONSTRICTION

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

- County Boundary
- Municipal Boundary
- Clearview Landfill Existing Limits

NOTES:

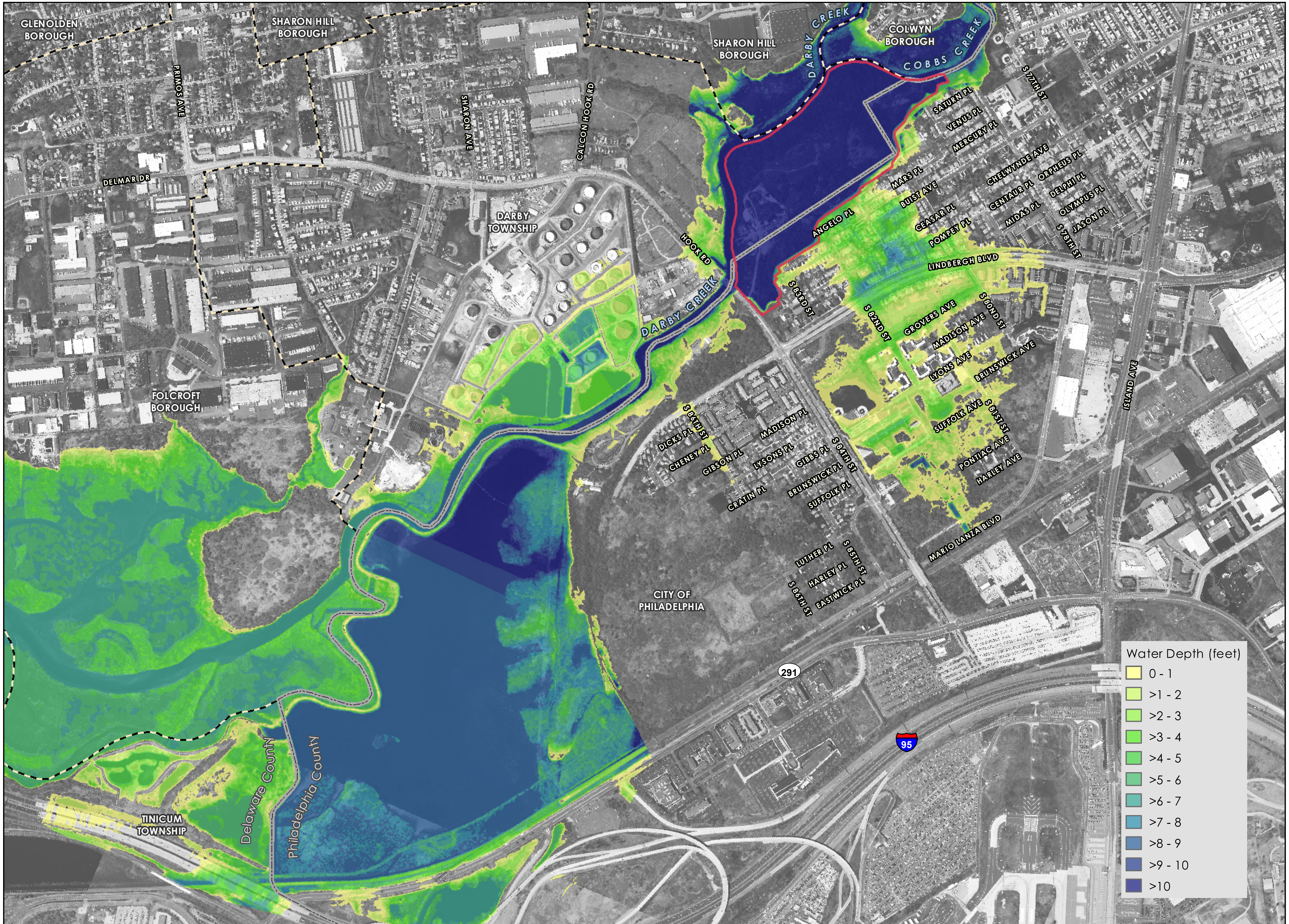
1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

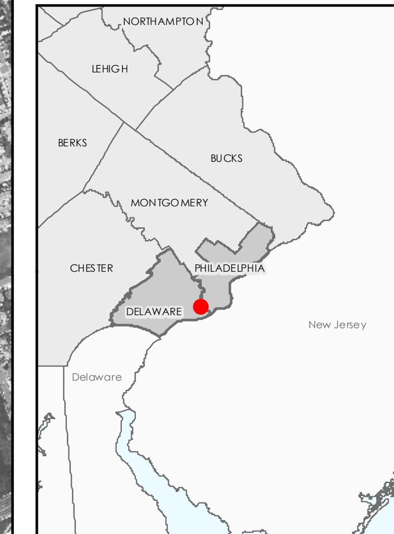
3. Elevations reference North American Vertical Datum 1988 (NAVD88).

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

File: P:\1626\Projects\1626001\GIS\MXD\Flood_Maps\2.11_Remove_Landfill_Depth.mxd, 3/23/2017, Drawn by thopper, Copyright Princeton Hydro, LLC.



LOCATION MAP



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0 500 1,000 Feet

FIGURE 2.11 WATER DEPTH REMOVE CLEARVIEW LANDFILL AND RESTORE TO FLOODPLAIN

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

- County Boundary
- Municipal Boundary
- Clearview Landfill Existing Limits

NOTES:

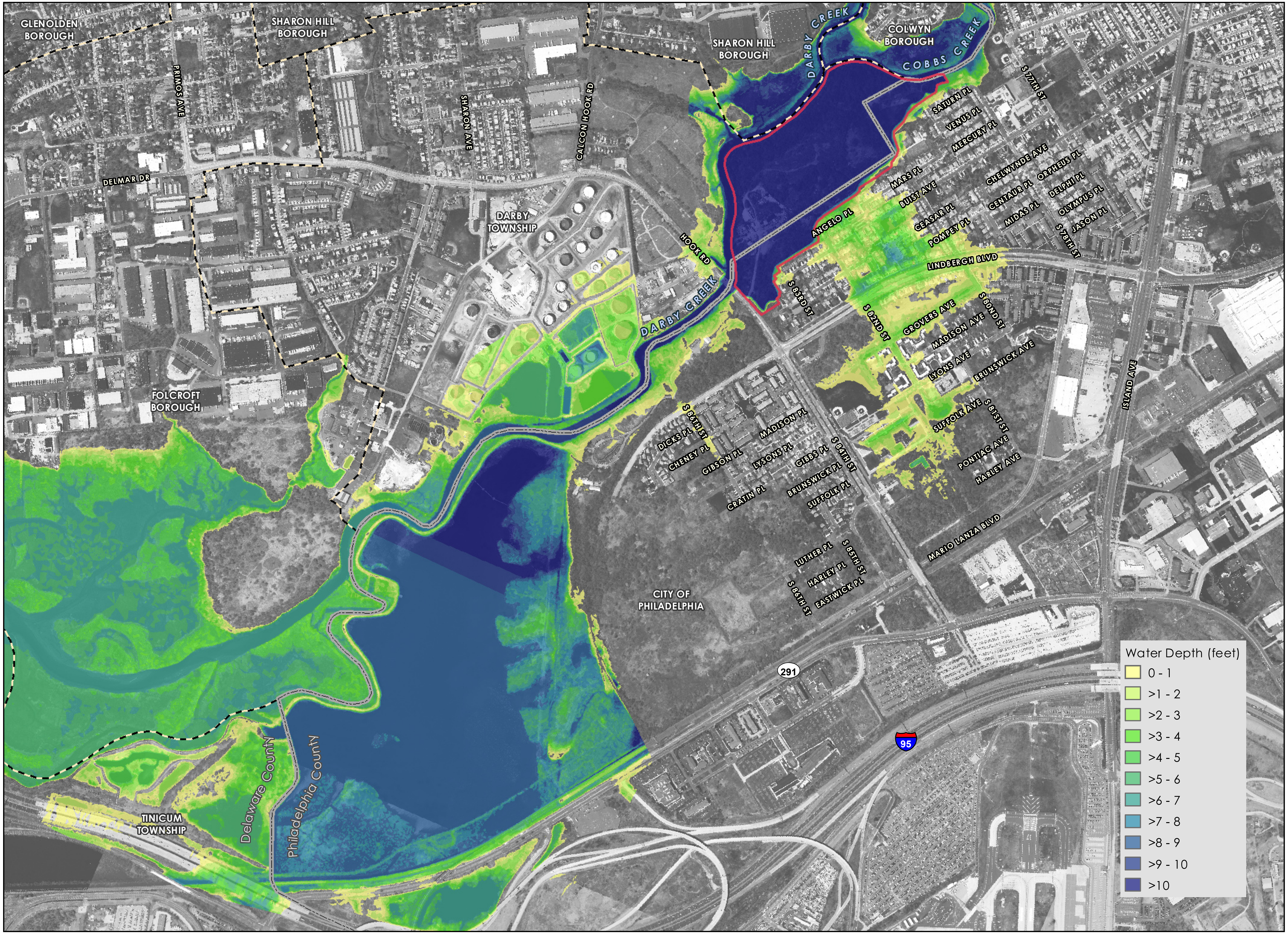
1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

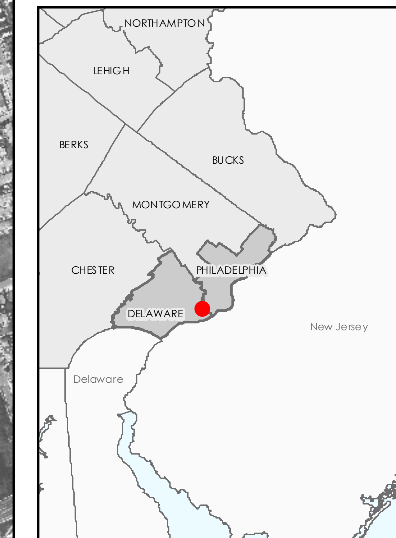
3. Elevations reference North American Vertical Datum 1988 (NAVD88).

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

File: P:\1626\Projects\1626001\GIS\MXD\Flood_Maps\2.12_Baseline_Remove_HookRd&Landfill_Depth.mxd, 3/23/2017, Drawn by thopper, Copyright Princeton Hydro, LLC.



LOCATION MAP



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0 500 1,000 Feet

FIGURE 2.12
WATER DEPTH
BASELINE:
REMOVE CLEARVIEW LANDFILL AND RESTORE TO FLOODPLAIN AND HOOK ROAD BRIDGE CONSTRICTION

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

- County Boundary
- Municipal Boundary
- Clearview Landfill Existing Limits

NOTES:

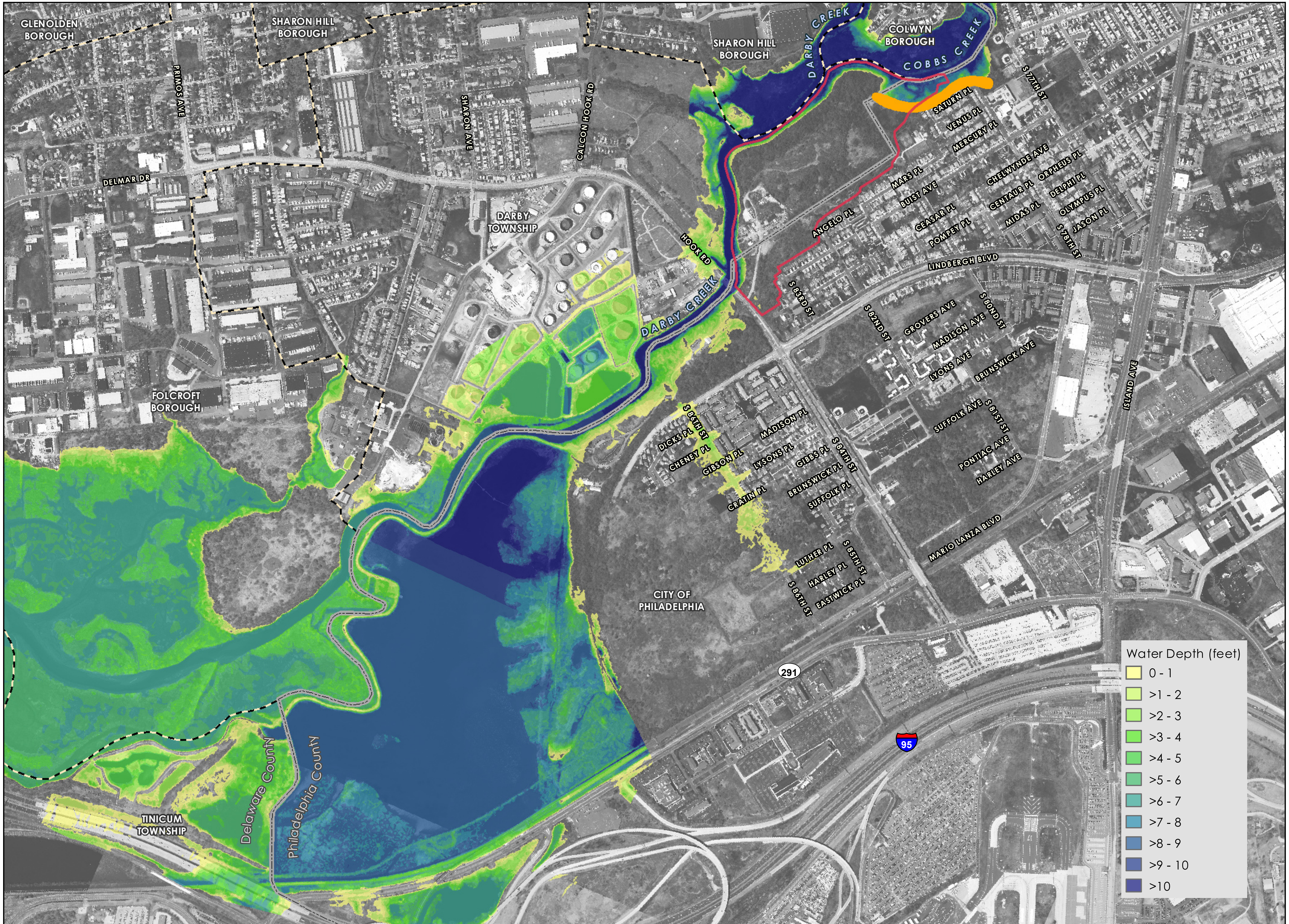
1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

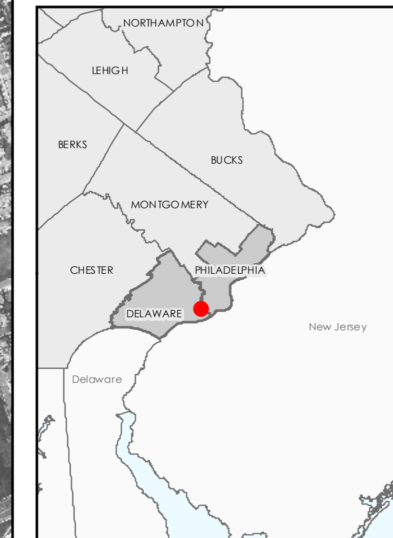
3. Elevations reference North American Vertical Datum 1988 (NAVD88).

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

File: P:\1626\Projects\1626001\GIS\MXD\Flood_Maps\2.13_Levee_Depth.mxd, 3/23/2017, Drawn by thopper, Copyright Princeton Hydro, LLC.



LOCATION MAP



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1 inch = 1,000 feet

0 500 1,000 Feet

FIGURE 2.13
WATER DEPTH
LEVEE PROTECTION

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

- County Boundary
- Municipal Boundary
- Clearview Landfill Existing Limits
- Proposed Levee (not to scale)

NOTES:

1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

3. Elevations reference North American Vertical Datum 1988 (NAVD88).

4. Proposed levee location obtained from USACE 2014 Technical Report "Eastwick Stream Modeling and Technical Evaluation." Levee crest elevation: 20 feet, max width: 10 feet

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

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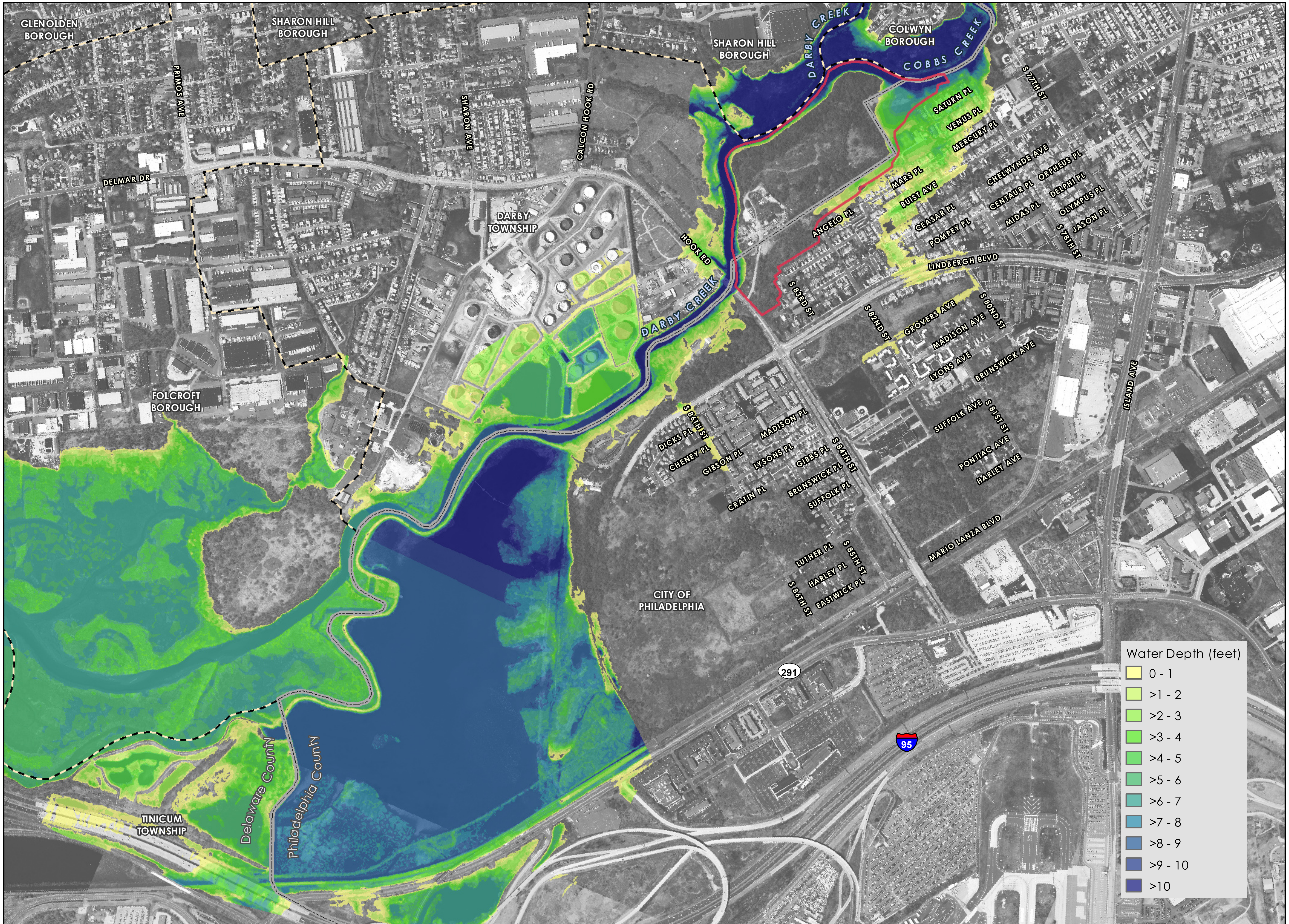

LOCATION MAP

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1 inch = 1,000 feet

0 500 1,000 Feet

FIGURE 2.14
WATER DEPTH
CREATE FLOODPLAIN ALONG COBBS CREEK LEFT OVERBANK UPSTREAM OF THE DARBY-COBBS CONFLUENCE

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

County Boundary
Municipal Boundary
Clearview Landfill Existing Limits

NOTES:

1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

3. Elevations reference North American Vertical Datum 1988 (NAVD88).

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

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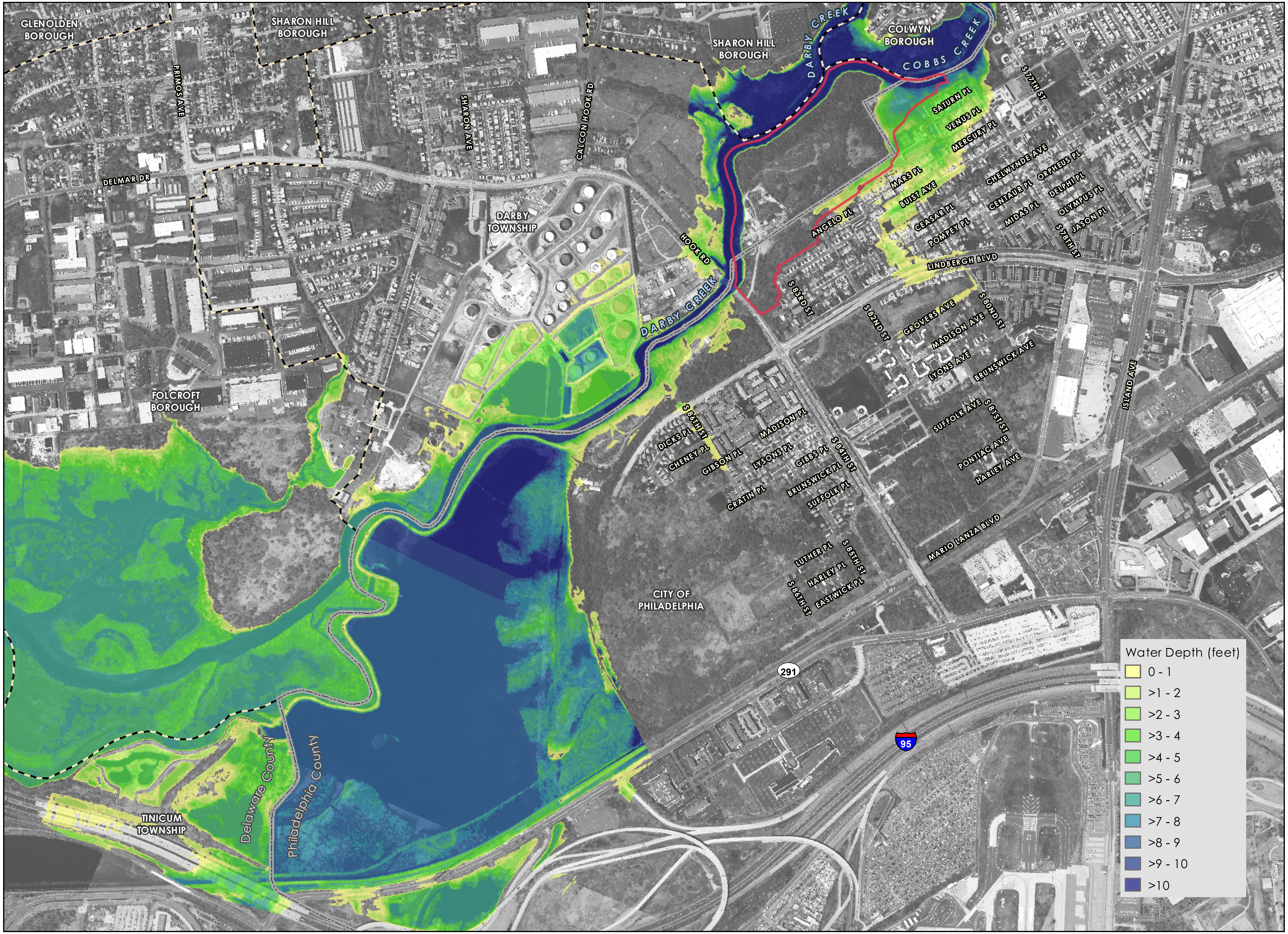
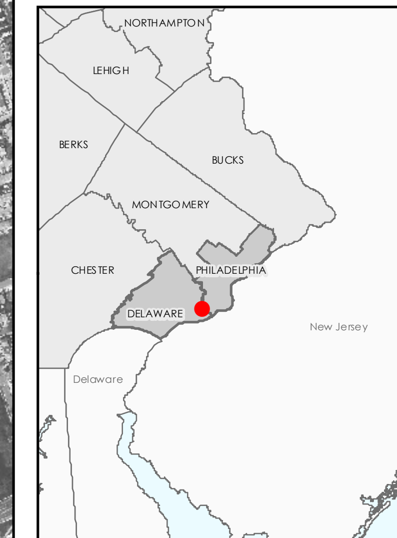


LOCATION MAP



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1 inch = 1,000 feet

0 500 1,000 Feet

FIGURE 2.15
WATER DEPTH
REMOVE 75 FEET OF LEFT OVERBANK AND RESTORE TO FLOODPLAIN

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

- County Boundary
- Municipal Boundary
- Clearview Landfill Existing Limits

NOTES:

1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

3. Elevations reference North American Vertical Datum 1988 (NAVD88).

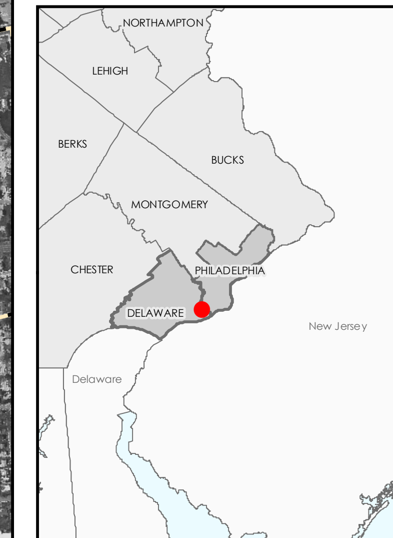
Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

Appendix A

Hydraulic Model Maps

File: P:\1626\Projects\1626001\GIS\MXD\Flood_Maps\A.1_CrossSections_Downstream.mxd, 3/27/2017, Drawn by thopper, Copyright Princeton Hydro, LLC.

LOCATION MAP



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1 inch = 1,250 feet
0 625 1,250
Feet

FIGURE A.1 HYDRAULICS MODEL MAP DOWNSTREAM

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend
- HEC-RAS Cross Section
- County Boundary
- Municipal Boundary

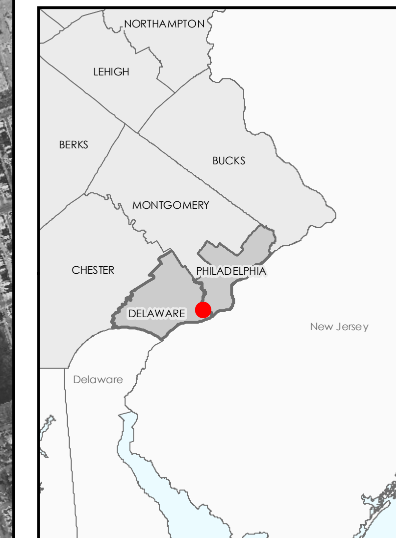
NOTES:

1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

2. Cross sections developed by Princeton Hydro for Hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1).

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

LOCATION MAP



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1 inch = 1,250 feet
0 625 1,250 Feet

FIGURE A.2
HYDRAULICS MODEL MAP
UPSTREAM

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend
- HEC-RAS Cross Section
- County Boundary
- Municipal Boundary

NOTES:

1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

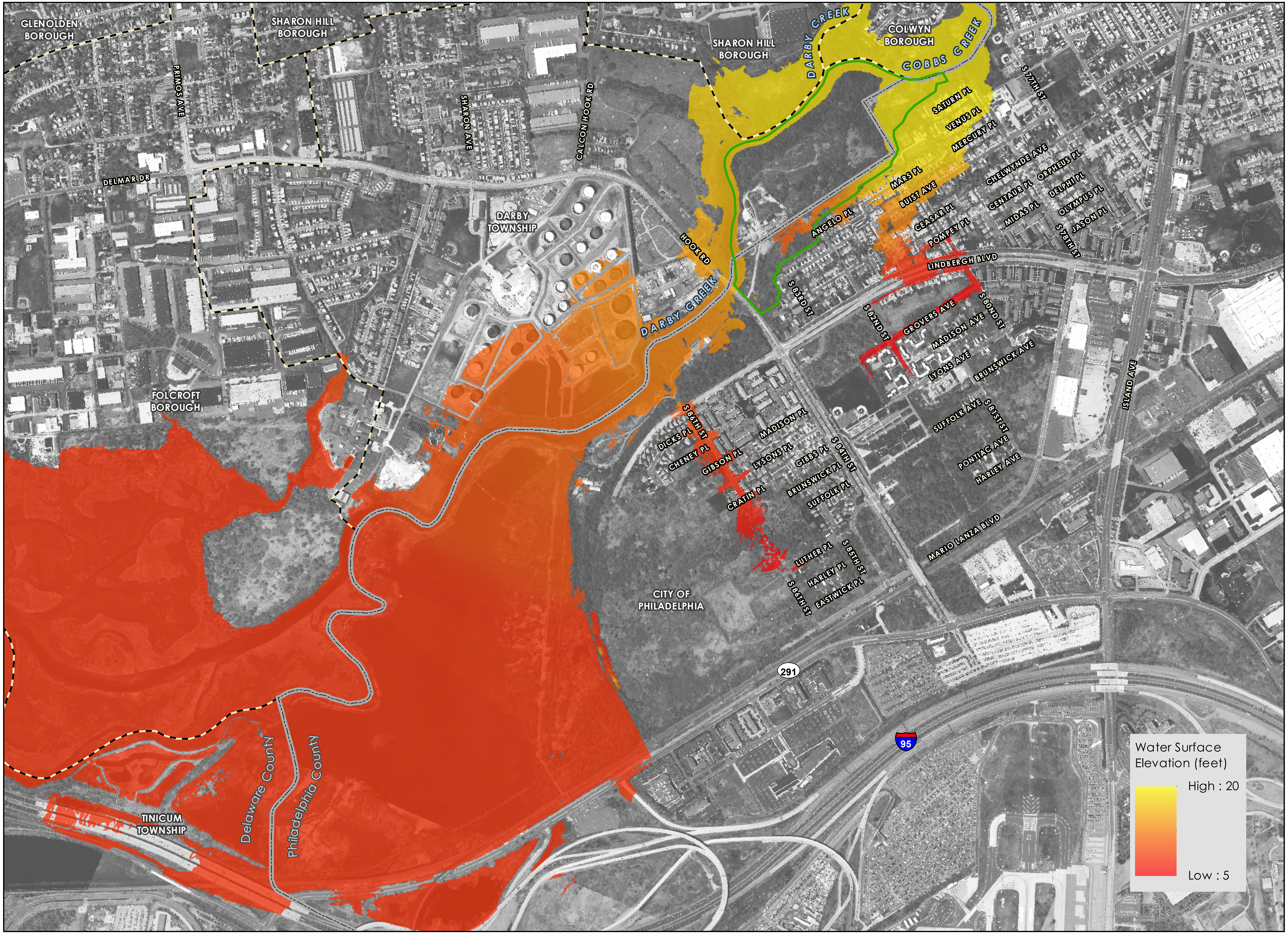
2. Cross sections developed by Princeton Hydro for Hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1).

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

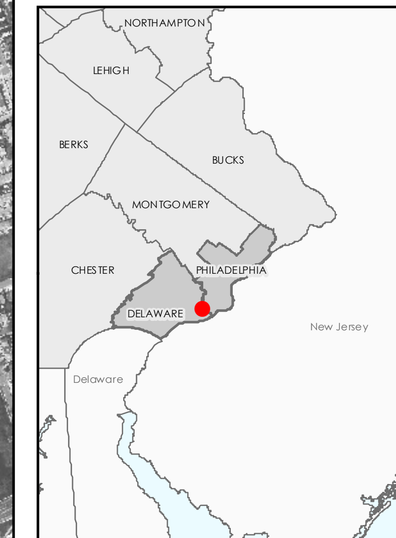
APPENDIX B

WATER SURFACE ELEVATION MAPS

File: P:\1626\Projects\1626001\GIS\MXD\Flood_Maps\B.1_Existing_WSEL.mxd, 3/21/2017, Drawn by thopper, Copyright Princeton Hydro, LLC.



LOCATION MAP



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1 inch = 1,000 feet

0 500 1,000 Feet

FIGURE B.1
WATER SURFACE ELEVATION
EXISTING CONDITIONS

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

County Boundary

Municipal Boundary

Clearview Landfill Existing Limits

NOTES:

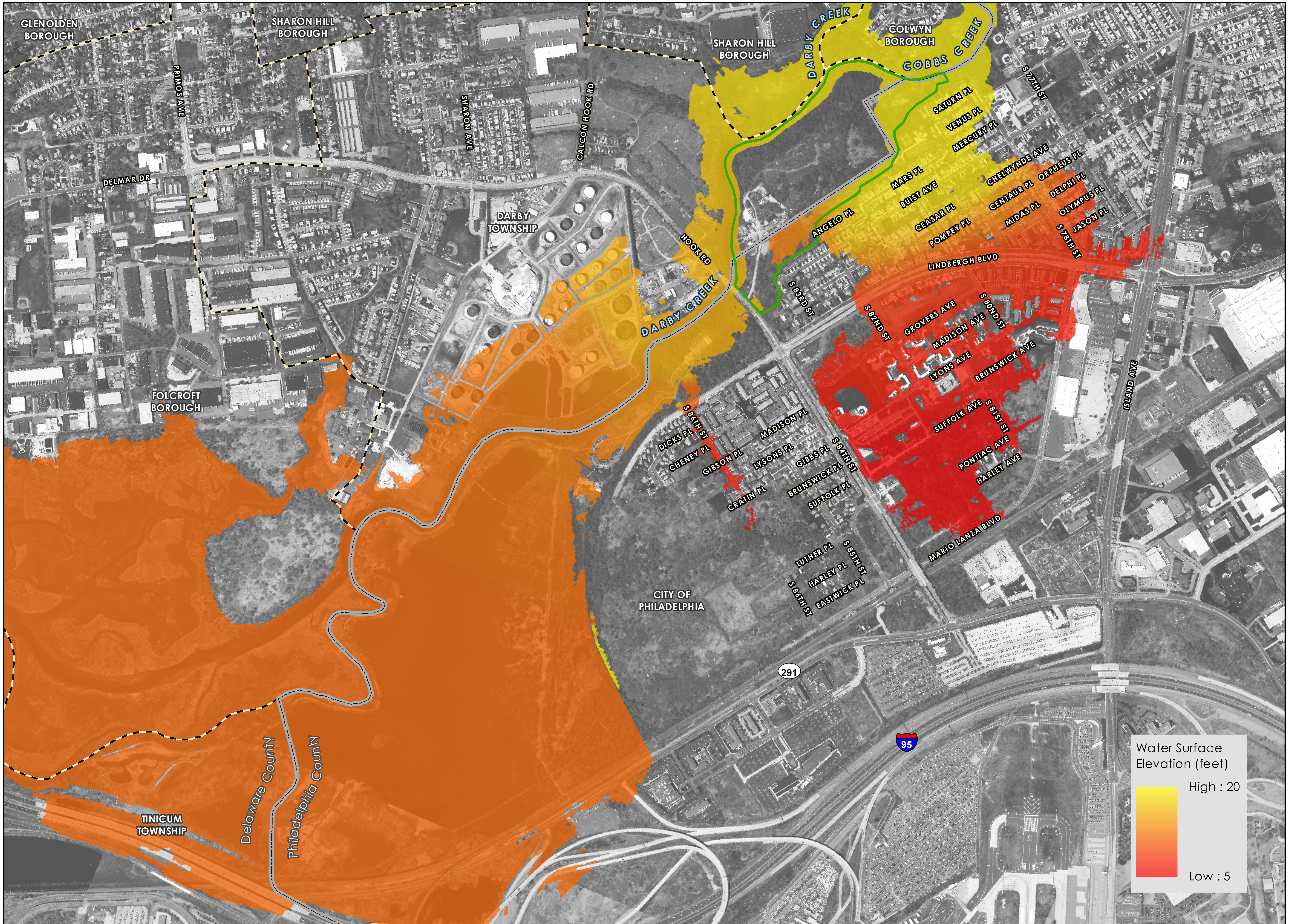
1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

3. Elevations reference North American Vertical Datum 1988 (NAVD88).

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

File: P:\1626\Projects\1626001\GIS\MXD\Flood_Maps\B.2_FEMA_100yr_WSEL.mxd, 3/21/2017, Drawn by thopper, Copyright Princeton Hydro, LLC.



LOCATION MAP

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1 inch = 1,000 feet

0 500 1,000 Feet

FIGURE B.2
WATER SURFACE ELEVATION
COASTAL STORM SURGE
FOR FEMA 1% STORM

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

- County Boundary
- Municipal Boundary
- Clearview Landfill Existing Limits

NOTES:

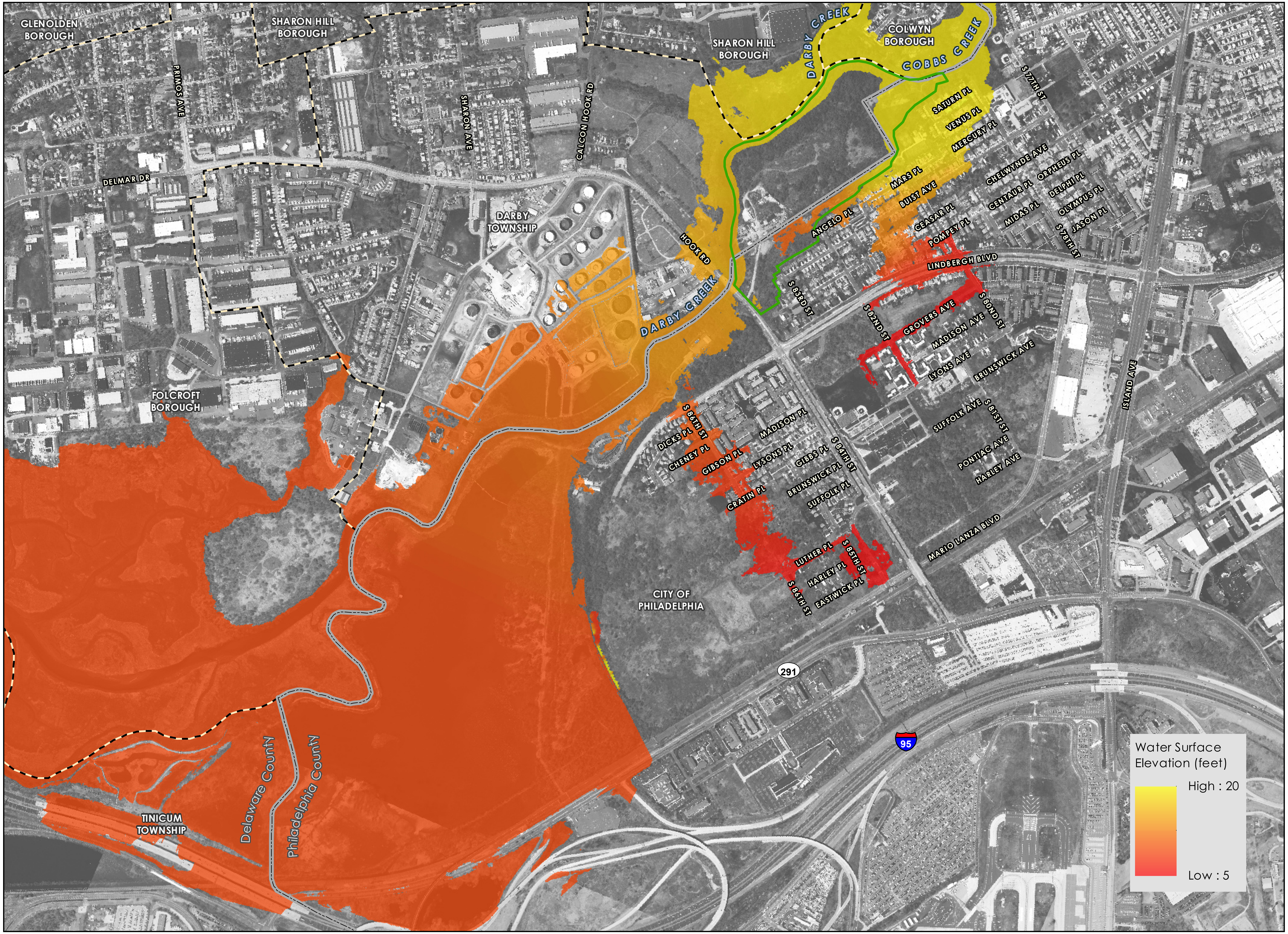
1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

3. Elevations reference North American Vertical Datum 1988 (NAVD88).

4. FEMA Base Flood Elevation (BFE): 8.54 feet.

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet



LOCATION MAP

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

1 inch = 1,000 feet

0 500 1,000 Feet

FIGURE B.3
WATER SURFACE ELEVATION COASTAL STORM SURGE FOR NOAA SLOSH CATEGORY ONE STORM

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

- County Boundary
- Municipal Boundary
- Clearview Landfill Existing Limits

NOTES:

1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

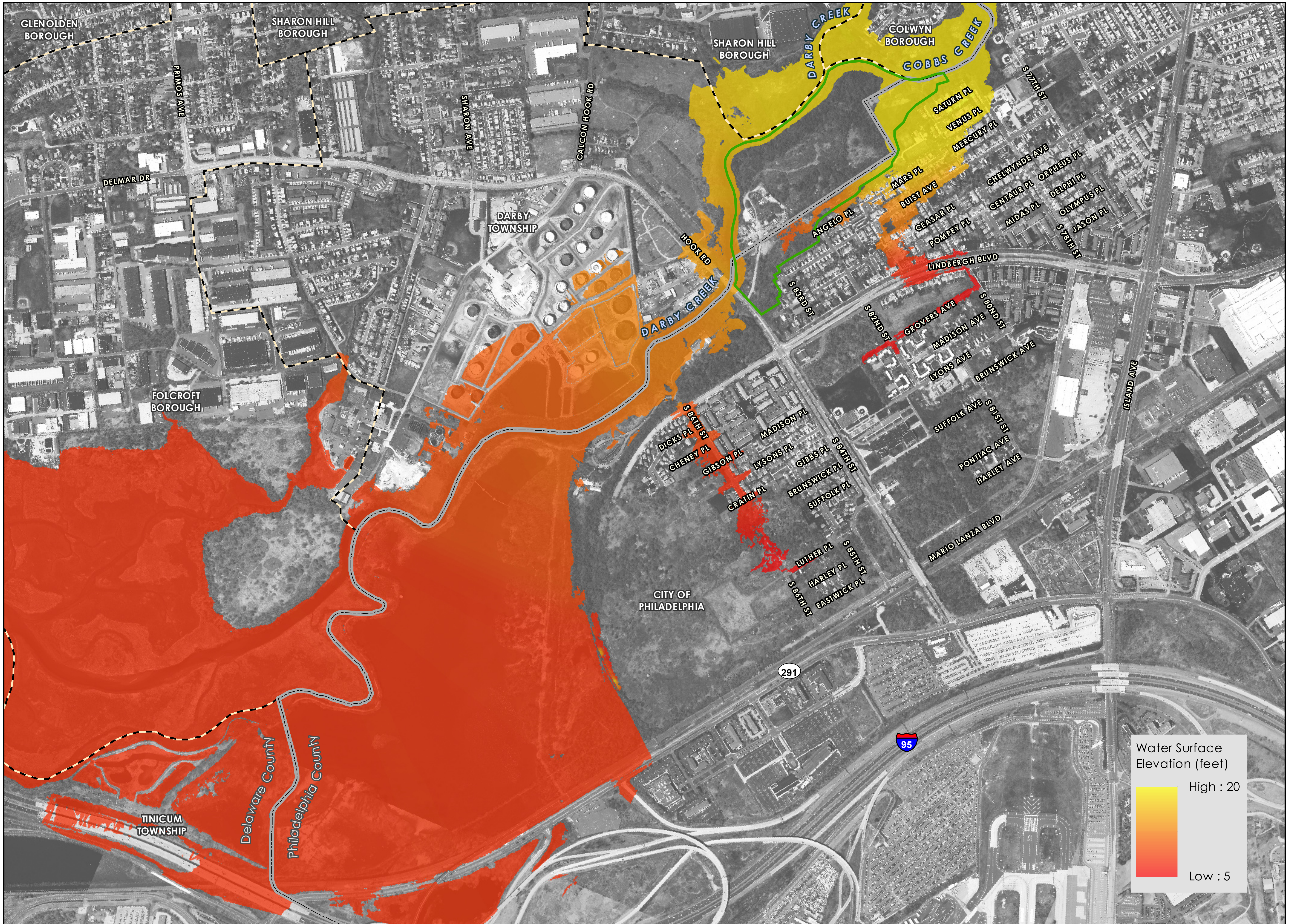
2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

3. Elevations reference North American Vertical Datum 1988 (NAVD88).

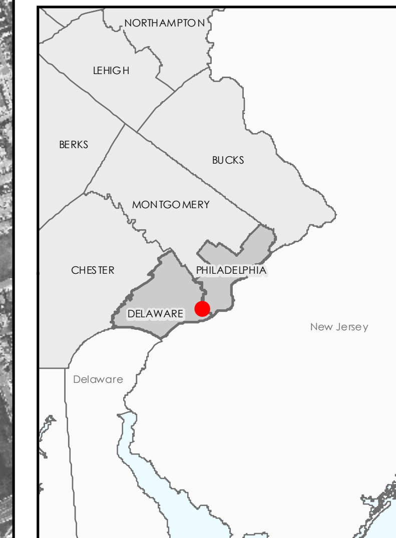
4. NOAA SLOSH Category one Storm Maximum of Maximum (MoM) elevation: 6.8 feet.

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

File: P:\1626\Projects\1626001\GIS\MXD\Flood_Maps\B.4_Remove_HookRd_WSEL.mxd, 3/21/2017, Drawn by thopper, Copyright Princeton Hydro, LLC.



LOCATION MAP



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P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

1 inch = 1,000 feet

0 500 1,000 Feet

FIGURE B.4
WATER SURFACE ELEVATION REMOVE HOOK ROAD CONSTRICTION

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

- County Boundary
- Municipal Boundary
- Clearview Landfill Existing Limits

NOTES:

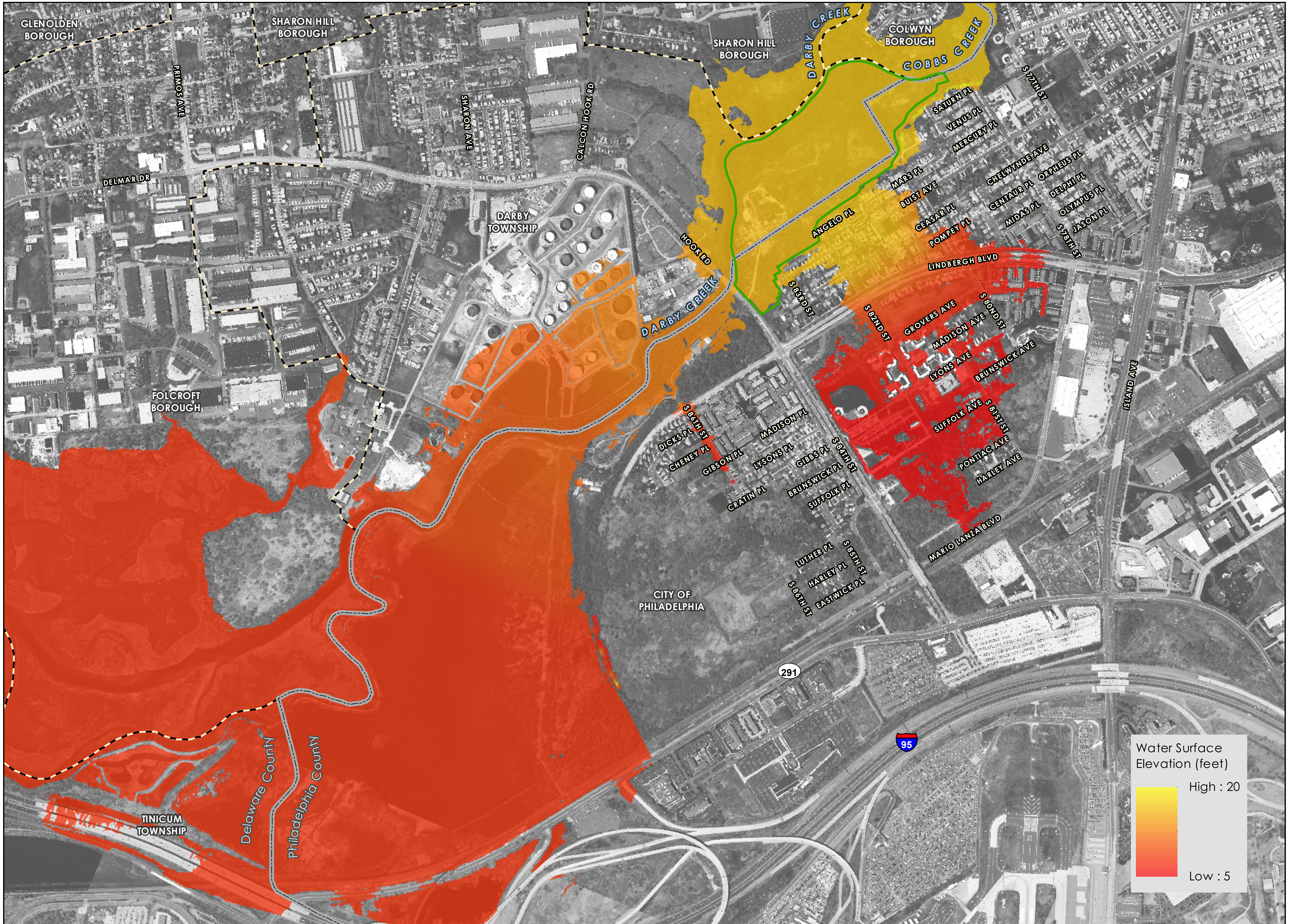
1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

3. Elevations reference North American Vertical Datum 1988 (NAVD88).

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

File: P:\1626\Projects\1626001\GIS\MXD\Flood_Maps\B.5_Remove_Landfill_WSEL.mxd, 3/24/2017, Drawn by thopper, Copyright Princeton Hydro, LLC.



LOCATION MAP

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

1 inch = 1,000 feet
0 500 1,000 Feet

FIGURE B.5
WATER SURFACE ELEVATION
REMOVE CLEARVIEW LANDFILL AND RESTORE TO FLOODPLAIN

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend
- County Boundary
- Municipal Boundary
- Clearview Landfill Existing Limits

NOTES:

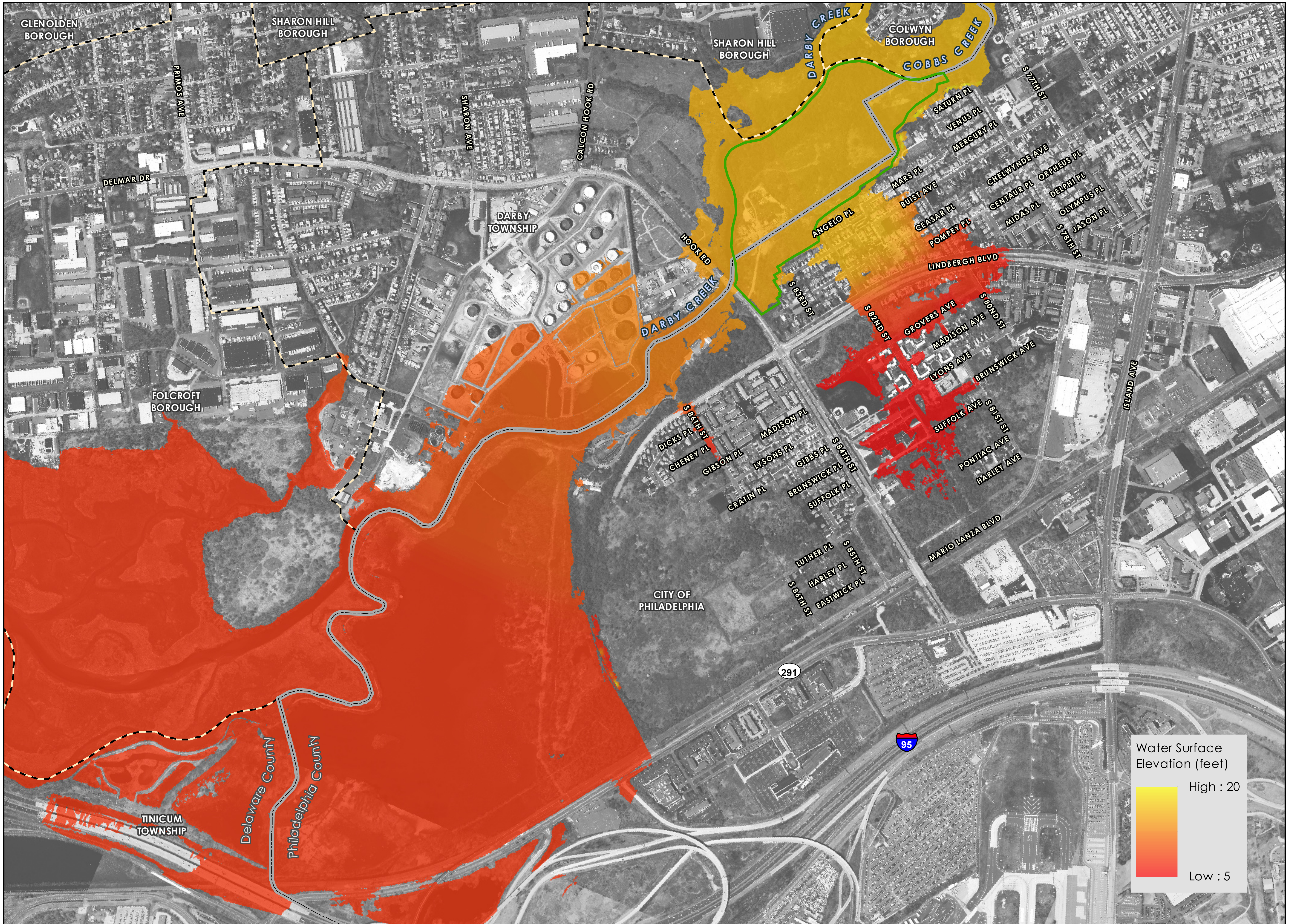
1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

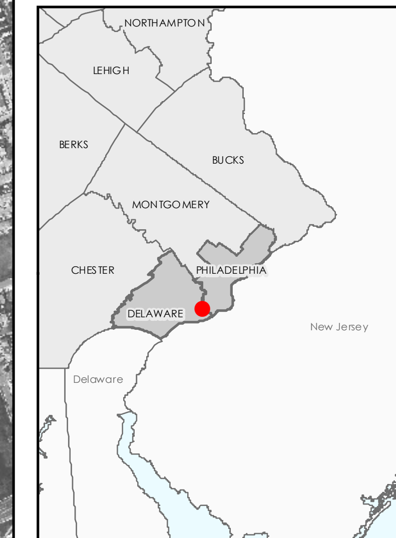
3. Elevations reference North American Vertical Datum 1988 (NAVD88).

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

File: P:\1626\Projects\1626001\GIS\MXD\Flood_Maps\B.6_Baseline_Remove_HookRd&Landfill_WSEL.mxd, 3/24/2017, Drawn by thopper, Copyright Princeton Hydro, LLC.



LOCATION MAP



PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

1 inch = 1,000 feet

0 500 1,000 Feet

FIGURE B.6
WATER SURFACE ELEVATION BASELINE:
REMOVE CLEARVIEW LANDFILL AND RESTORE TO FLOODPLAIN AND HOOK ROAD BRIDGE CONSTRICTION

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

- County Boundary
- Municipal Boundary
- Clearview Landfill Existing Limits

NOTES:

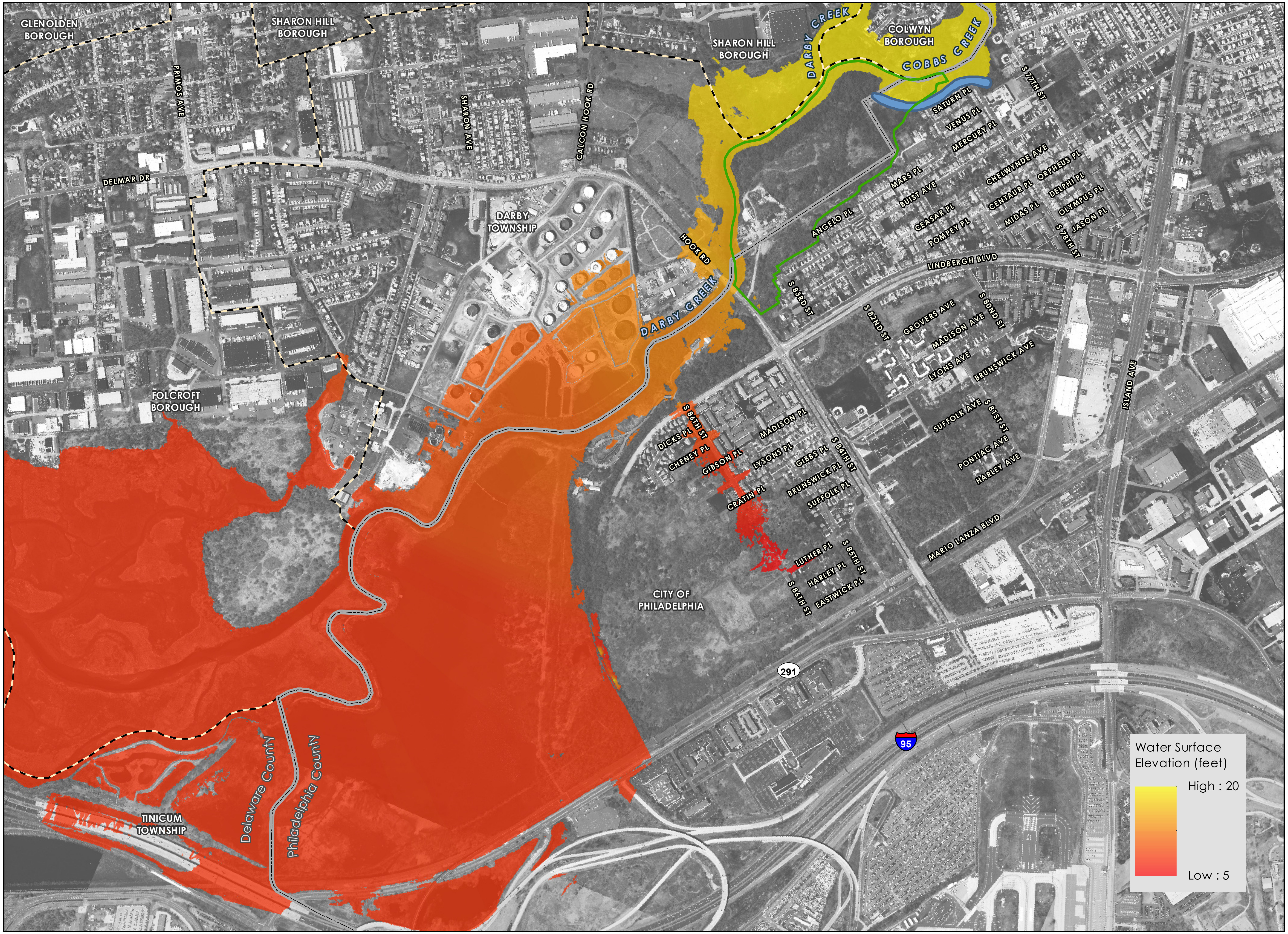
1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

3. Elevations reference North American Vertical Datum 1988 (NAVD88).

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

File: P:\1626\Projects\1626001\GIS\MXD\Flood_Maps\B.7_Levee_WSEL.mxd, 3/24/2017, Drawn by thopper, Copyright Princeton Hydro, LLC.



LOCATION MAP

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

1 inch = 1,000 feet

0 500 1,000 Feet

FIGURE B.7
WATER SURFACE ELEVATION
LEVEE PROTECTION

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

- County Boundary
- Municipal Boundary
- Clearview Landfill Existing Limits
- Proposed Levee (not to scale)

NOTES:

1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

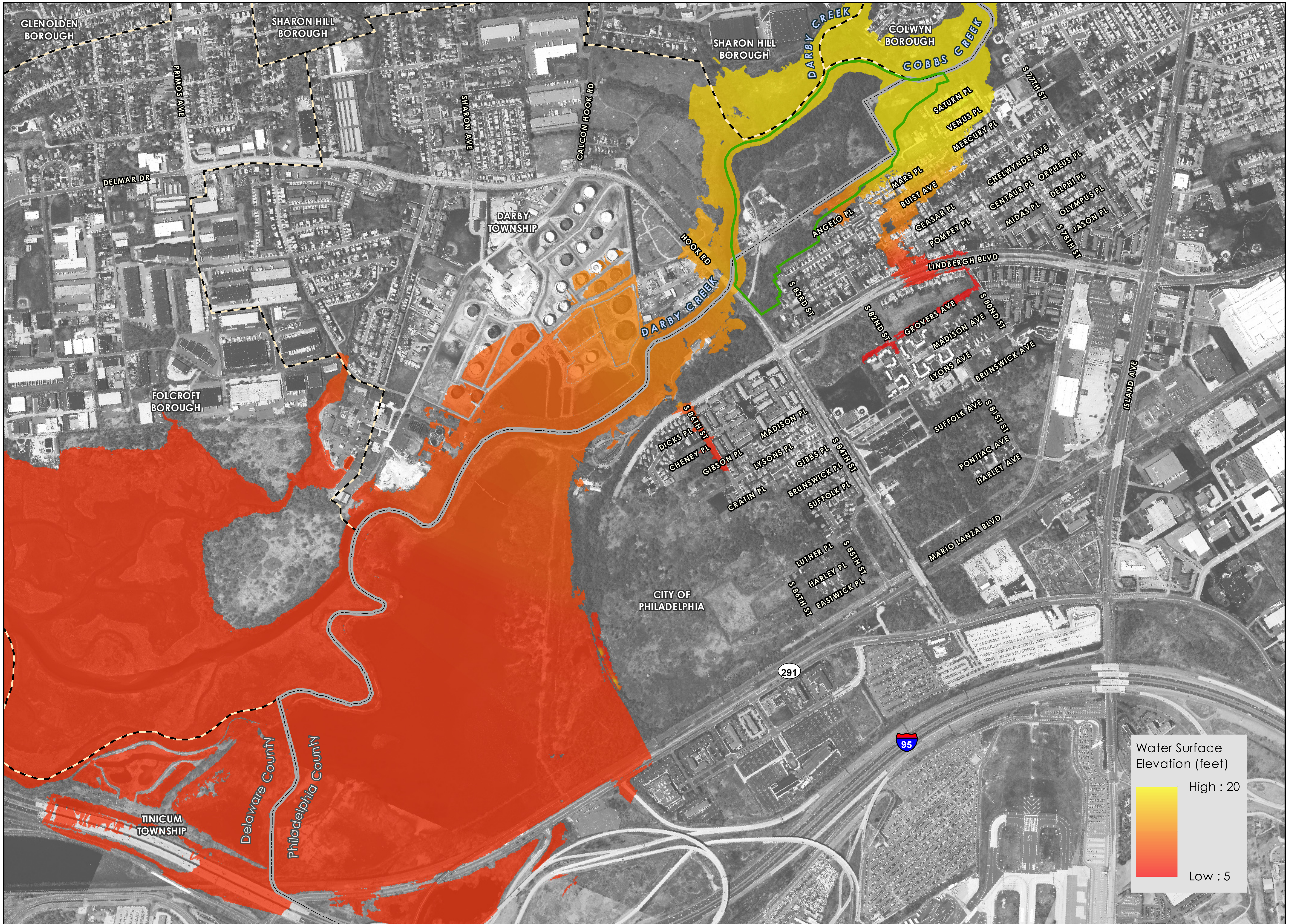
2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

3. Elevations reference North American Vertical Datum 1988 (NAVD88).

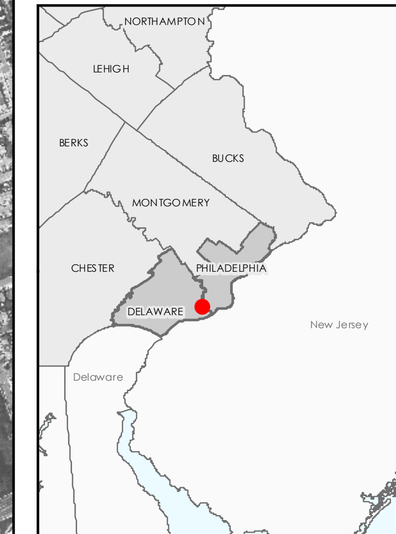
4. Proposed levee location obtained from USACE 2014 Technical Report "Eastwick Stream Modeling and Technical Evaluation." Levee crest elevation: 20 feet, max width: 10 feet

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

File: P:\1626\Projects\1626001\GIS\MXD\Flood_Maps\B.8_Left_Overbank_Floodplain_WSEL.mxd, 3/21/2017, Drawn by thopper, Copyright Princeton Hydro, LLC.



LOCATION MAP



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P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

1 inch = 1,000 feet

0 500 1,000 Feet

FIGURE B.8
WATER SURFACE ELEVATION
CREATE FLOODPLAIN ALONG COBBS CREEK LEFT OVERBANK UPSTREAM OF THE DARBY-COBBS CONFLUENCE

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

- County Boundary
- Municipal Boundary
- Clearview Landfill Existing Limits

NOTES:

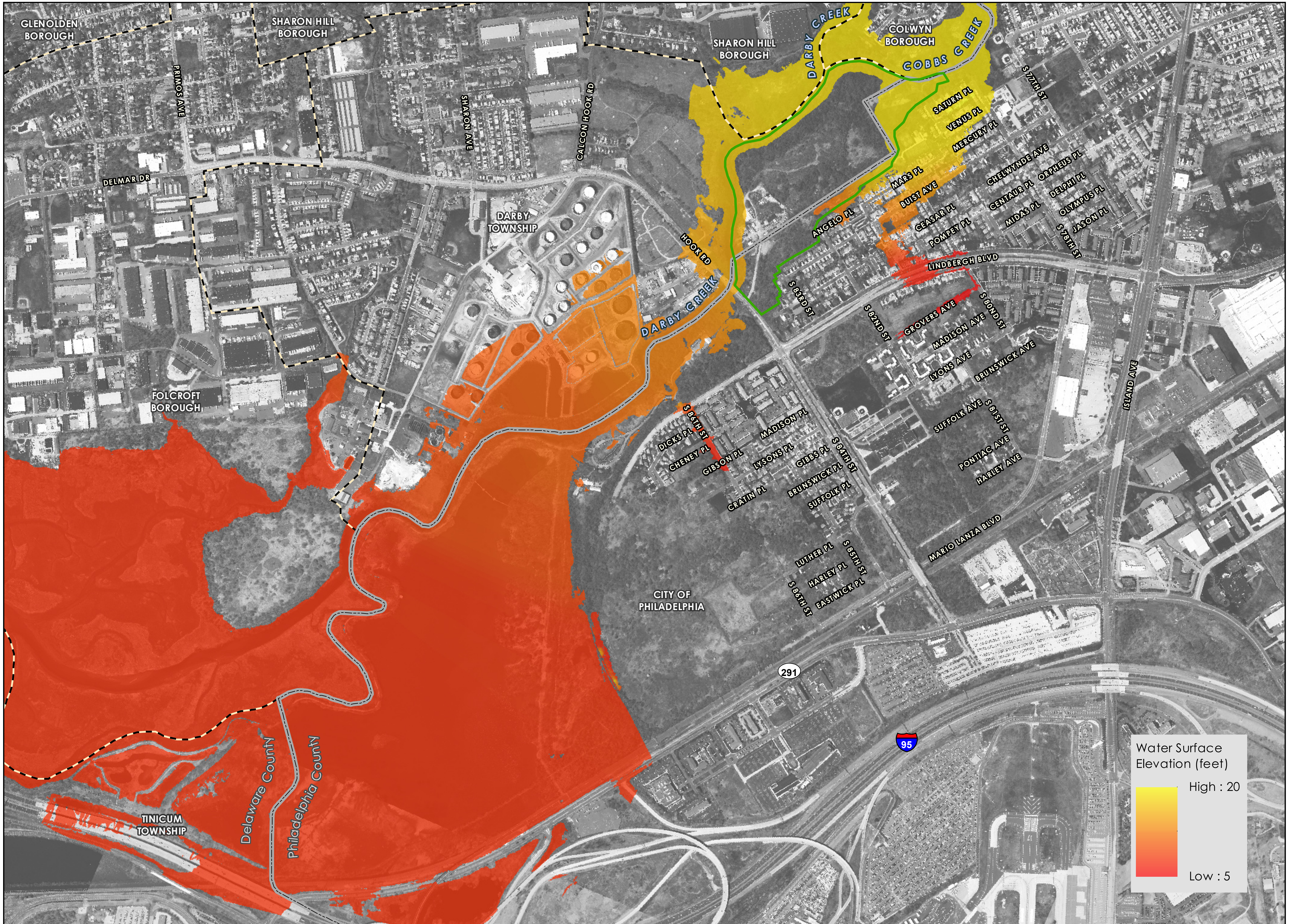
1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

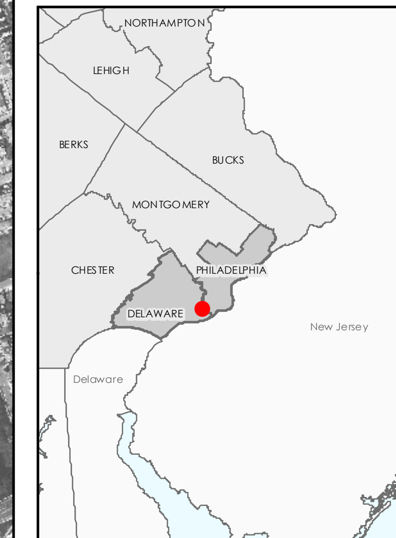
3. Elevations reference North American Vertical Datum 1988 (NAVD88).

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

File: P:\1626\Projects\1626001\GIS\MXD\Flood_Maps\B.9_Remove_25ft_75ft_Landfill_WSEL.mxd, 3/21/2017, Drawn by thopper, Copyright Princeton Hydro, LLC.



LOCATION MAP



PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

1 inch = 1,000 feet

0 500 1,000 Feet

FIGURE B.9 WATER SURFACE ELEVATION REMOVE 75 FEET OF LEFT OVERBANK AND RESTORE TO FLOODPLAIN

LOWER DARBY CREEK AREA
WILLIAM PENN FOUNDATION GRANT
PHILADELPHIA &
DELAWARE COUNTIES
PENNSYLVANIA

Legend

- County Boundary
- Municipal Boundary
- Clearview Landfill Existing Limits

NOTES:

1. DVRPC 2015 orthoimagery, county boundaries, and municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).

2. Water Depths and WSELs derived from unsteady 2D hydraulic modeling analysis performed in USACE HEC-RAS (version 4.1) by Princeton Hydro for Tropical Storm Lee (total precipitation 6.5 - 8 inches), ~ 50-yr event.

3. Elevations reference North American Vertical Datum 1988 (NAVD88).

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

APPENDIX C

WATER SURFACE ELEVATION TABLES

Table C.1. Scenario Reference Table

	Scenario	Notes
1	Existing Conditions	Boundary condition = 2.61 feet NAVD 88
2	Coastal Storm Surge for FEMA 1% Storm	Boundary condition = 8.54 feet NAVD 88 (Base Flood Elevation)
3	Coastal Storm Surge for NOAA SLOSH Category One storm	Boundary condition = 6.80 feet NAVD 88 (Maximum of Maximum – MoM)
4	Remove Hook Rd (S 84th St.) Constriction	Removed bridge, embankments remained
5	Remove Clearview landfill and restore to floodplain	Manipulated DEM, Floodplain elevation=4' NAVD88
6	Baseline: Remove Clearview landfill and restore to floodplain and Hook Rd constriction	Combine scenarios #4 and #5
7	Using a similar footprint of the USACE proposed levee	Levee Elevation = 20 feet NAVD88
8	Create floodplain along Cobbs Creek left overbank upstream of the Darby-Cobbs confluence at pinch point	Manipulated DEM, pinch point floodplain bench elevation = 4 feet NAVD88
9	Remove 75 feet of left overbank and restore to floodplain along the length of Clearview landfill	Manipulated DEM, channel floodplain bench elevation = 4 feet NAVD88

Table C.2. Comparison of Water Surface Elevations for Existing Conditions and FEMA 1% Coastal Storm Surge

Stream	River Station	WSE (NAVD88)		Difference (feet)
		Scenario 1	Scenario 2	
Cobbs	**1949**	19.1	19.29	0.19
Cobbs	**1830**	19.12	19.27	0.15
Cobbs	**1676**	19.11	19.29	0.18
Cobbs	**1508**	19.07	19.26	0.19
Cobbs	**1335**	19.04	19.23	0.19
Cobbs	**1207**	19.02	19.22	0.2
Cobbs	**1046**	19	19.2	0.2
Cobbs	**935**	18.98	19.18	0.2
Cobbs	**822**	18.94	19.15	0.21
Cobbs	**734**	18.85	19.07	0.22
Cobbs	**579**	18.71	18.95	0.24
Cobbs	**451**	18.72	18.96	0.24
Cobbs	**338**	18.71	18.95	0.24
Cobbs	**243**	18.66	18.91	0.25
Cobbs	**141**	18.64	18.89	0.25
Darby	**28957**	18.64	18.89	0.25
Darby	**28769**	18.65	18.9	0.25
Darby	**28546**	18.63	18.88	0.25
Darby	**28334**	18.53	18.8	0.27
Darby	**28138**	18.5	18.77	0.27
Darby	**27878**	17.93	18.25	0.32
Darby	**27617**	17.39	17.78	0.39
Darby	**27414**	16.75	17.27	0.52
Darby	**27254**	16.45	17.03	0.58
Darby	**27065**	16.58	17.15	0.57
Darby	**26846**	15.83	16.56	0.73
Darby	**26665**	15.44	16.41	0.97
Darby	**26509**	15.32	16.36	1.04
Darby	**26372**	15.1	16.26	1.16
Darby	**26267**	15.54	16.53	0.99
Darby	**26123**	15.71	16.61	0.9
Darby	**Hook Road**			
Darby	**25997**	14.78	16.01	1.23
Darby	**25742**	13.83	15.66	1.83

Table C.3. Comparison of Water Surface Elevations for
Existing Conditions and NOAA SLOSH Category One Coastal Storm Surge

Stream	River Station	WSE (NAVD88)		Difference (feet)
		Scenario 1	Scenario 3	
Cobbs	**1949**	19.1	19.17	0.07
Cobbs	**1830**	19.12	19.19	0.07
Cobbs	**1676**	19.11	19.18	0.07
Cobbs	**1508**	19.07	19.14	0.07
Cobbs	**1335**	19.04	19.12	0.08
Cobbs	**1207**	19.02	19.1	0.08
Cobbs	**1046**	19	19.08	0.08
Cobbs	**935**	18.98	19.05	0.07
Cobbs	**822**	18.94	19.02	0.08
Cobbs	**734**	18.85	18.93	0.08
Cobbs	**579**	18.71	18.79	0.08
Cobbs	**451**	18.72	18.81	0.09
Cobbs	**338**	18.71	18.8	0.09
Cobbs	**243**	18.66	18.75	0.09
Cobbs	**141**	18.64	18.73	0.09
Darby	**28957**	18.64	18.73	0.09
Darby	**28769**	18.65	18.74	0.09
Darby	**28546**	18.63	18.72	0.09
Darby	**28334**	18.53	18.62	0.09
Darby	**28138**	18.5	18.6	0.1
Darby	**27878**	17.93	18.04	0.11
Darby	**27617**	17.39	17.52	0.13
Darby	**27414**	16.75	16.93	0.18
Darby	**27254**	16.45	16.65	0.2
Darby	**27065**	16.58	16.78	0.2
Darby	**26846**	15.83	16.1	0.27
Darby	**26665**	15.44	15.8	0.36
Darby	**26509**	15.32	15.71	0.39
Darby	**26372**	15.1	15.54	0.44
Darby	**26267**	15.54	15.92	0.38
Darby	**26123**	15.71	16.05	0.34
Darby	**Hook Road**			
Darby	**25997**	14.78	15.23	0.45
Darby	**25742**	13.83	14.59	0.76

Table C.4. Comparison of Water Surface Elevations and for Existing Conditions and Hook Road Bridge Removal

Stream	River Station	WSE (NAVD88)		Difference (feet)
		Scenario 1	Scenario 4	
Cobbs	**1949**	19.1	18.87	-0.23
Cobbs	**1830**	19.12	18.89	-0.23
Cobbs	**1676**	19.11	18.88	-0.23
Cobbs	**1508**	19.07	18.84	-0.23
Cobbs	**1335**	19.04	18.81	-0.23
Cobbs	**1207**	19.02	18.79	-0.23
Cobbs	**1046**	19	18.77	-0.23
Cobbs	**935**	18.98	18.74	-0.24
Cobbs	**822**	18.94	18.7	-0.24
Cobbs	**734**	18.85	18.61	-0.24
Cobbs	**579**	18.71	18.46	-0.25
Cobbs	**451**	18.72	18.47	-0.25
Cobbs	**338**	18.71	18.46	-0.25
Cobbs	**243**	18.66	18.41	-0.25
Cobbs	**141**	18.64	18.4	-0.24
Darby	**28957**	18.64	18.4	-0.24
Darby	**28769**	18.65	18.4	-0.25
Darby	**28546**	18.63	18.38	-0.25
Darby	**28334**	18.53	18.27	-0.26
Darby	**28138**	18.5	18.24	-0.26
Darby	**27878**	17.93	17.62	-0.31
Darby	**27617**	17.39	17.01	-0.38
Darby	**27414**	16.75	16.26	-0.49
Darby	**27254**	16.45	15.91	-0.54
Darby	**27065**	16.58	16.03	-0.55
Darby	**26846**	15.83	15.18	-0.65
Darby	**26665**	15.44	14.52	-0.92
Darby	**26509**	15.32	14.35	-0.97
Darby	**26372**	15.1	13.98	-1.12
Darby	**26267**	15.54	14.58	-0.96
Darby	**26123**	15.71	14.87	-0.84
Darby	**Hook Road**			
Darby	**25997**	14.78	14.78	0
Darby	**25742**	13.83	13.83	0

Table C.5. Comparison of Water Surface Elevations for Existing Conditions and Clearview Landfill Removal

Stream	River Station	WSE (NAVD88)		Difference (feet)
		Scenario 1	Scenario 5	
Cobbs	**1949**	19.1	17.31	-1.79
Cobbs	**1830**	19.12	17.33	-1.79
Cobbs	**1676**	19.11	17.31	-1.8
Cobbs	**1508**	19.07	17.14	-1.93
Cobbs	**1335**	19.04	17.08	-1.96
Cobbs	**1207**	19.02	17.04	-1.98
Cobbs	**1046**	19	17.01	-1.99
Cobbs	**935**	18.98	17	-1.98
Cobbs	**822**	18.94	16.98	-1.96
Cobbs	**734**	18.85	16.86	-1.99
Cobbs	**579**	18.71	16.89	-1.82
Cobbs	**451**	18.72	16.88	-1.84
Cobbs	**338**	18.71	16.87	-1.84
Cobbs	**243**	18.66	16.86	-1.8
Cobbs	**141**	18.64	16.86	-1.78
Darby	**28957**	18.64	16.86	-1.78
Darby	**28769**	18.65	16.82	-1.83
Darby	**28546**	18.63	16.78	-1.85
Darby	**28334**	18.53	16.74	-1.79
Darby	**28138**	18.5	16.71	-1.79
Darby	**27878**	17.93	16.65	-1.28
Darby	**27617**	17.39	16.61	-0.78
Darby	**27414**	16.75	16.57	-0.18
Darby	**27254**	16.45	16.52	0.07
Darby	**27065**	16.58	16.47	-0.11
Darby	**26846**	15.83	16.27	0.44
Darby	**26665**	15.44	16.26	0.82
Darby	**26509**	15.32	16.13	0.81
Darby	**26372**	15.1	16	0.9
Darby	**26267**	15.54	16.13	0.59
Darby	**26123**	15.71	15.64	-0.07
Darby	**Hook Road**			
Darby	**25997**	14.78	14.72	-0.06
Darby	**25742**	13.83	13.77	-0.06

Figure C.6. Comparison of Water Surface Elevations for
Existing Conditions and Removal of Clearview Landfill and Hook Rd Constriction

Stream	**River Station**	**WSE (NAVD88)**		**Difference (feet)**
		Scenario 1	**Scenario 6**	
Cobbs	**1949**	19.1	16.54	-2.56
Cobbs	**1830**	19.12	16.56	-2.56
Cobbs	**1676**	19.11	16.52	-2.59
Cobbs	**1508**	19.07	16.4	-2.67
Cobbs	**1335**	19.04	16.35	-2.69
Cobbs	**1207**	19.02	16.31	-2.71
Cobbs	**1046**	19	16.28	-2.72
Cobbs	**935**	18.98	16.27	-2.71
Cobbs	**822**	18.94	16.26	-2.68
Cobbs	**734**	18.85	16.15	-2.7
Cobbs	**579**	18.71	16.17	-2.54
Cobbs	**451**	18.72	16.16	-2.56
Cobbs	**338**	18.71	16.15	-2.56
Cobbs	**243**	18.66	16.15	-2.51
Cobbs	**141**	18.64	16.14	-2.5
Darby	**28957**	18.64	16.14	-2.5
Darby	**28769**	18.65	16.1	-2.55
Darby	**28546**	18.63	16.06	-2.57
Darby	**28334**	18.53	16.01	-2.52
Darby	**28138**	18.5	15.98	-2.52
Darby	**27878**	17.93	15.91	-2.02
Darby	**27617**	17.39	15.87	-1.52
Darby	**27414**	16.75	15.82	-0.93
Darby	**27254**	16.45	15.77	-0.68
Darby	**27065**	16.58	15.7	-0.88
Darby	**26846**	15.83	15.47	-0.36
Darby	**26665**	15.44	15.46	0.02
Darby	**26509**	15.32	15.31	-0.01
Darby	**26372**	15.1	15.15	0.05
Darby	**26267**	15.54	15.29	-0.25
Darby	**26123**	15.71	14.73	-0.98
Darby	**Hook Road**			
Darby	**25997**	14.78	14.65	-0.13
Darby	**25742**	13.83	13.71	-0.12

Table C.7. Comparison of Water Surface Elevations for Existing Conditions and Levee

Stream	River Station	WSE (NAVD88)		Difference (feet)
		Scenario 1	Scenario 7	
Cobbs	**1949**	19.1	19.16	0.06
Cobbs	**1830**	19.12	19.18	0.06
Cobbs	**1676**	19.11	19.16	0.05
Cobbs	**1508**	19.07	19.13	0.06
Cobbs	**1335**	19.04	19.11	0.07
Cobbs	**1207**	19.02	19.09	0.07
Cobbs	**1046**	19	19.07	0.07
Cobbs	**935**	18.98	19.04	0.06
Cobbs	**822**	18.94	19.01	0.07
Cobbs	**734**	18.85	18.93	0.08
Cobbs	**579**	18.71	18.78	0.07
Cobbs	**451**	18.72	18.8	0.08
Cobbs	**338**	18.71	18.79	0.08
Cobbs	**243**	18.66	18.74	0.08
Cobbs	**141**	18.64	18.72	0.08
Darby	**28957**	18.64	18.72	0.08
Darby	**28769**	18.65	18.73	0.08
Darby	**28546**	18.63	18.71	0.08
Darby	**28334**	18.53	18.61	0.08
Darby	**28138**	18.5	18.58	0.08
Darby	**27878**	17.93	18	0.07
Darby	**27617**	17.39	17.46	0.07
Darby	**27414**	16.75	16.82	0.07
Darby	**27254**	16.45	16.51	0.06
Darby	**27065**	16.58	16.65	0.07
Darby	**26846**	15.83	15.89	0.06
Darby	**26665**	15.44	15.51	0.07
Darby	**26509**	15.32	15.39	0.07
Darby	**26372**	15.1	15.17	0.07
Darby	**26267**	15.54	15.61	0.07
Darby	**26123**	15.71	15.77	0.06
Darby	**Hook Road**			
Darby	**25997**	14.78	14.84	0.06
Darby	**25742**	13.83	13.89	0.06

Table C.8. Comparison of Water Surface Elevations for
Existing Conditions and Proposed Floodplain at Confluence

Stream	River Station	WSE (NAVD88)		Difference (feet)
		Scenario 1	Scenario 8	
Cobbs	**1949**	19.1	19.07	-0.03
Cobbs	**1830**	19.12	19.09	-0.03
Cobbs	**1676**	19.11	19.08	-0.03
Cobbs	**1508**	19.07	19.04	-0.03
Cobbs	**1335**	19.04	19.02	-0.02
Cobbs	**1207**	19.02	19	-0.02
Cobbs	**1046**	19	18.97	-0.03
Cobbs	**935**	18.98	18.95	-0.03
Cobbs	**822**	18.94	18.91	-0.03
Cobbs	**734**	18.85	18.84	-0.01
Cobbs	**579**	18.71	18.76	0.05
Cobbs	**451**	18.72	18.74	0.02
Cobbs	**338**	18.71	18.72	0.01
Cobbs	**243**	18.66	18.66	0
Cobbs	**141**	18.64	18.64	0
Darby	**28957**	18.64	18.64	0
Darby	**28769**	18.65	18.65	0
Darby	**28546**	18.63	18.63	0
Darby	**28334**	18.53	18.53	0
Darby	**28138**	18.5	18.5	0
Darby	**27878**	17.93	17.92	-0.01
Darby	**27617**	17.39	17.39	0
Darby	**27414**	16.75	16.75	0
Darby	**27254**	16.45	16.44	-0.01
Darby	**27065**	16.58	16.57	-0.01
Darby	**26846**	15.83	15.83	0
Darby	**26665**	15.44	15.44	0
Darby	**26509**	15.32	15.32	0
Darby	**26372**	15.1	15.09	-0.01
Darby	**26267**	15.54	15.53	-0.01
Darby	**26123**	15.71	15.7	-0.01
Darby	**Hook Road**			
Darby	**25997**	14.78	14.77	-0.01
Darby	**25742**	13.83	13.83	0

Table C.9 Comparison of Water Surface Elevations for Existing Conditions and Proposed Stream Widening

Stream	River Station	WSE (NAVD88)		Difference (feet)
		Scenario 1	Scenario 9	
Cobbs	**1949**	19.1	18.96	-0.14
Cobbs	**1830**	19.12	18.97	-0.15
Cobbs	**1676**	19.11	18.96	-0.15
Cobbs	**1508**	19.07	18.92	-0.15
Cobbs	**1335**	19.04	18.9	-0.14
Cobbs	**1207**	19.02	18.88	-0.14
Cobbs	**1046**	19	18.86	-0.14
Cobbs	**935**	18.98	18.83	-0.15
Cobbs	**822**	18.94	18.79	-0.15
Cobbs	**734**	18.85	18.72	-0.13
Cobbs	**579**	18.71	18.64	-0.07
Cobbs	**451**	18.72	18.62	-0.1
Cobbs	**338**	18.71	18.59	-0.12
Cobbs	**243**	18.66	18.54	-0.12
Cobbs	**141**	18.64	18.52	-0.12
Darby	**28957**	18.64	18.52	-0.12
Darby	**28769**	18.65	18.49	-0.16
Darby	**28546**	18.63	18.43	-0.2
Darby	**28334**	18.53	18.33	-0.2
Darby	**28138**	18.5	18.3	-0.2
Darby	**27878**	17.93	17.76	-0.17
Darby	**27617**	17.39	17.43	0.04
Darby	**27414**	16.75	16.99	0.24
Darby	**27254**	16.45	16.67	0.22
Darby	**27065**	16.58	16.67	0.09
Darby	**26846**	15.83	16.25	0.42
Darby	**26665**	15.44	15.86	0.42
Darby	**26509**	15.32	15.25	-0.07
Darby	**26372**	15.1	15.05	-0.05
Darby	**26267**	15.54	15.56	0.02
Darby	**26123**	15.71	15.7	-0.01
Darby	**Hook Road**			
Darby	**25997**	14.78	14.77	-0.01
Darby	**25742**	13.83	13.82	-0.01