# APPENDIX A:

# ENGINEERING

# North Shore Riverfront Ecosystem Restoration
# Engineering Appendix

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# 1 STUDY AREA - EXISTING CONDITIONS


**Figure 1: Aerial View of Study Area (Source: Google Earth, 2015)**

The Study Area (shown in Figure 1) Existing Conditions are described in the various Sections of this Appendix. A generalized plan of the Existing Conditions is provided in Section 4.1 of this Appendix. Stationing references included in this Section are for general location purposes only and are based on the preliminary baseline information shown on the referenced Existing Condition plans.

## 1.1 SOILS AND GEOLOGY

### 1.1.1 Geology and Physiography

Bedrock underlaying the Study Area is Pennsylvanian-aged and belongs to the Glenshaw Formation of the Conemaugh Group and is comprised mainly of claystone, sandstone, and shale. The site is within the alluvial flood plain of the Allegheny and Ohio Rivers. The soils at the site consist of the Urban Land series according to the USDA Soil Survey. These soils are classified as soils having been altered by significant disturbance and development.

Further information on bedrock characteristics are available from test boring information included in two previously completed reports: a Geotechnical Report for the Rivers Casino Hotel (Civil & Environmental Consultants, Inc. (2013). *Geotechnical Report: Rivers Casino Hotel.* Pittsburgh.) and a Geotechnical Engineering Report for the North Shore River Front Park (A&A Consultants, 2000). These test borings were located between approximately Stations 5+00 and 25+00.

The Study Area has encountered heavily industrialized activity for over 100 years. This activity resulted in the deposition of slag and coal waste products ranging up to 30 feet in thickness at some locations along and adjacent to the North Shore. Based on the core boring information referenced above, black oil-stained sand and silt and coal tar was observed at depths ranging between 20 and 50 feet below the ground surface. Underlying the fill materials are alluvial sands and gravels extending to depths of about 60 feet. In borings performed for the Rivers Casino Hotel project, bedrock was encountered at depths of about 65 feet—an elevation of about 663 ft.

### 1.1.2 Hydric Soils

Based on the available information provided by the Sponsor and their subconsultants, there are likely no hydric soils in the area due to urbanization. However, within the geological context, sediment within the Ohio River could be classified as hydric soil.

## 1.2 STRUCTURAL

### 1.2.1 Buildings or Permanent Structures in Study Area

A number of various “structures” are located along the Study Area alignment. An abandoned/deteriorated 2-story commercial office building is located on top of slope near Stations 40+00 of the Area alignment. The West End Bridge abutments are located between Station 35+00 and 35+40. Two U-shaped masonry wall structures (bunkers) consisting of hollow masonry walls (10 courses high) exist adjacent to and on the river side of the trail walkway. The first bunker is located approximately between stations 33+20 and 33+50. The second bunker is located approximately between stations 33+80 and 34+52. Hardscape, or man-made and / or placed items, are located from approximately Stations 6+10 to 6+90, and Stations 21+00 to 21+90.

A permanently-moored submarine (USS Requin) and an associated dock structure (mooring cell) are located at approximately Stations 9+80 to 11+00. The mooring cell for the USS Requin is located at approximately Station 9+50. The “RiverQuest” vessel and associated temporary dock are located approximately between Stations 11+00 to 11+80.

There are three ALCOSAN owned and operated combined sewer overflow (CSO) outfall structures within the project site: O-40, O-41, and O-43. CSO structure O-43 is located at approximately Station 11+40. CSO structure O-41 is located at approximately Station 30+80. CSO structure O-40 is located at approximately 35+80. See Figure 2.

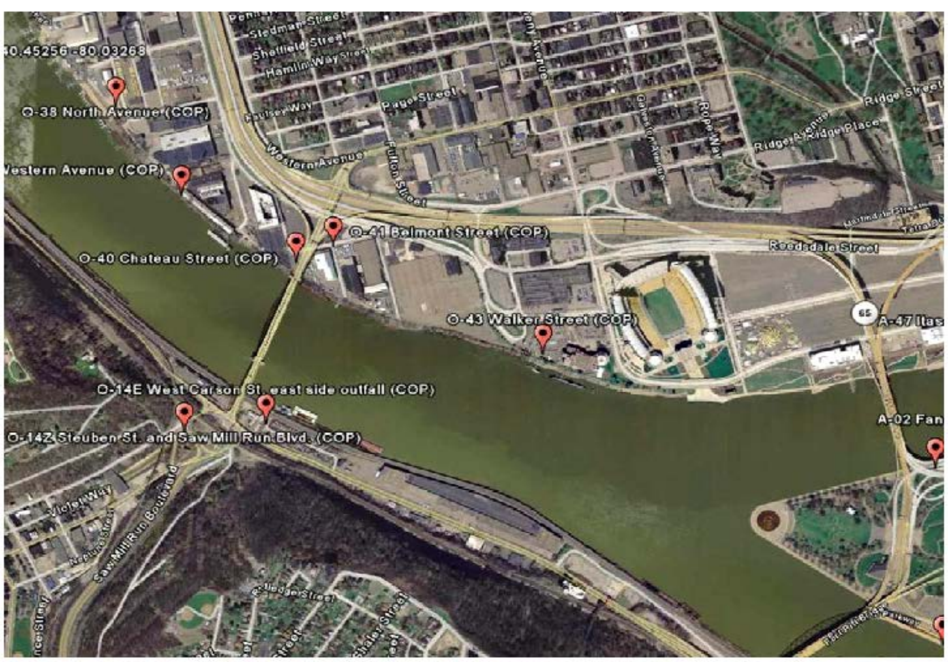


**Figure 2: ALCOSAN CSO Locations within Study Area**

There is large rip-rap material armoring the river bank between Stations 13+00 to 21+00. Additionally, relatively new sheet piling (associated with the Carnegie Science center construction) extends approximately three feet above the water surface and is located from Station 21+00 to 25+20. Older sheet piling (with an unknown construction project association) extends approximately 10 feet above the water surface is located between Station 25+20 and 26+00. A vertical concrete wall (associated with prior industrial riverfront development) is located from Station 28+70 to 30+60. A deteriorating, concrete capped dock (also associated with prior industrial riverfront development) is located at approximately Station 31+00. Additional older sheet piling extends about 10 feet above the water surface and is located approximately between Stations 32+40 and 34+60.

Finally, the West End Bridge concrete abutment is located between Stations 34+60 and 35+30. The abutment foundation stationing was not physically located but appears to extend 20 to 30 feet both upstream and downstream of the abutment station locations.

### 1.2.2 Below Ground Structures

Subsurface utilities exist in the Study Area. No permanent structures other than the storm sewer outfalls and those identified with the CSOs appear to exist within the Study Area.

## 1.3 WATER RESOURCES

### 1.3.1 Surface Water

The Study Area is located on the right bank of the Ohio River, just below the confluence of the Allegheny and Monongahela Rivers at Pittsburgh ("The Point"). It is located within the navigation pool created by Emsworth Lock and Dam, which is situated approximately 6.2 miles downstream of the Point. Emsworth Lock and Dam is operated to maintain a normal pool elevation of 710 feet NGVD29 near Pittsburgh. Water surface elevations near the study area are within ±1 foot of this elevation 90% of the year. Significant flood events can affect the study area as a result of elevated flows on the Allegheny River, Monongahela River, or a combination of the two. The trail known as the North Shore Riverwalk begins to flood when the river is near elevation 714 ft NGVD29 and businesses on the lower North Side are affected by flood waters near flood stage elevation 719ft NGVD29.

Note: Ohio River pool elevations are referenced to a legacy vertical datum thought to be NGVD29. The geodetic conversion from NGVD29 to NAVD88 vertical datum is -0.52 feet (Vertcon, http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html, accessed 8 February 2016).

The Upper Ohio River is US Geological Survey (USGS) Hydrologic Unit Code 05030101 (HUC-8). The Study Area is within the HUC-12 of 050301010303 (Ohio River-Montour Run), which has an area of almost 33 square miles that is 50% forest, 35% developed, 7% open water and 6% agricultural.

The contributing area to the Ohio River near the Point is approximately 19,100 square miles. The Allegheny River watershed is approximately 11,720 square miles (61%) and the Monongahela River watershed is approximately 7,380 square miles (39%) of this total watershed area.

The Ohio River channel is 1000-1200 feet wide along the Study Area with a water depth at normal pool of up to 30 feet. Existing right bank side slopes range from 2:1 to 6:1 (horizontal: vertical).

### 1.3.2 Groundwater

Groundwater has been found to be located at approximately 710 feet NGVD29, which is the approximate normal pool elevation of the Ohio River. Previous reports have noted groundwater flow appears to be directed toward the south into the Ohio River (CEC – Environmental Report, 2013).

### 1.3.3 Flood Plains

Most of the Study Area is within the 100-year floodplain.

The floodplain within the study area is terraced with a lower floodplain along the right bank varying in width from 600-1200 feet at elevations ranging from 720-730. The upper floodplain terrace along the right bank varies in width from 3000-4000 feet at elevations ranging from 740-800. The right bank floodplain is highly developed with industrial, commercial, and recreational businesses occupying the lower terrace while the upper floodplain terrace is primarily residential.

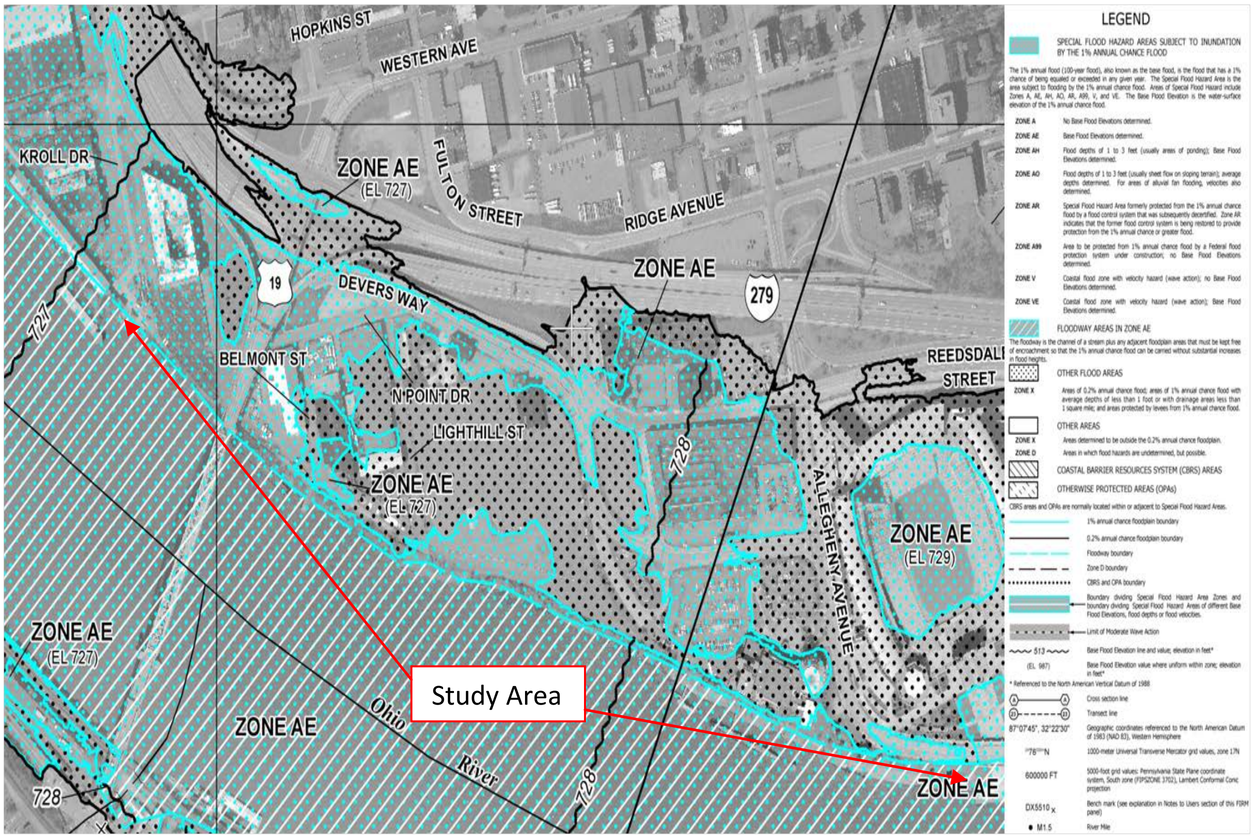


**Figure 3: Flood Plain Map of Study Area (Source: FEMA)**

### 1.3.4 Wetlands

There are no wetlands in the Study Area except for riparian areas at the river-land interface.

# 2 ENGINEERING CONSIDERATIONS RELATED TO MANAGEMENT MEASURES

## 2.1 GENERAL DISCUSSION

### 2.1.1 Determination of Project Area Limits

The future project area within the Study Area is limited by several factors, including, real estate, existing encumbrances, hydraulic and hydrological limitations, and geostructural capacity of soil and rock. The future project limits are primarily restricted in plan-view (see map), however cross sections were also developed as part of the Feasibility Study and provide an alternative view of the plans.

## 2.2 GEOTECHNICAL CONSIDERATIONS

### 2.2.1 Slope and Soil Strength

The slopes of material associated with any restoration measures and their ultimate configuration depends, in part, on the strength characteristics of the geomaterials. The strength properties of in-situ soils and engineered geomaterials were considered to provide a framework from which cross-section geometries could be developed. Soils with higher shear strengths generally allow for construction of steeper slopes which are stable. Cohesive soils are generally assessed according to the undrained shear strength to assess the slope stability. The shear strength of granular soils are usually well-represented by the internal friction angle and often allow steeper stable slopes. Riprap or other engineered materials can provide stability at even steeper slopes while earth retaining structures (e.g. walls) can provide support for vertical geometries. Preliminary estimates of the shear strength of existing (in-situ) soils and engineered geomaterials were used to determine the steepest angle at which a stable slope could be supported. It is important to understand that other factors, particularly pore water pressures, can significantly affect the effective strength of soil and should be considered in design.

The slope angle at which a chosen material is stable will determine how far inland an embankment of given height will extend. A shallow slope (say 4 feet horizontal for every 1 foot vertical), would extend 80 feet inland for a 20-foot high embankment. Where steeper slopes are required, engineered geomaterials or retaining walls will allow less encroachment into the areas behind the riverbank. Riprap of appropriate size/weight and placed at sufficient thickness in the river could provide additional surface on which terraces or level areas could be developed.

### 2.2.2 Soil Correlations

Soils strength was roughly estimated using correlations based on material classification and standard penetration test (SPT) blow counts. Most of the material in the top 10-20 feet consists of silty gravels classified by the Unified Soil Classification System (USCS) as GM, poorly-graded gravels classified as GP, and some organic silts and inorganic clays classified as OL and CL, respectively as shown in Figure 4. Using the friction angle of granular backfills correlation chart from EM 1110-2-2502 (U.S. Army Corps of Engineers, 1989), a conservative range of friction angles was determined for each material type (Figure 5). These friction angles were further refined using Meyerhof's (Meyerhof, 1956) correlation between SPT-N value and friction angle as shown in Figure 5.

**Table 1 - SPT - Friction Angle Correlation**

| Depth | B12 | B14 | B15 | B7 | B8 | R7 |
|---|---|---|---|---|---|---|
| 2.5 | 13 | 42 | 56 | 14 | 17 | 7 |
| 5 | 16 | 14 | 25 | 8 | 53 | 30 |
| 7.5 | 10 | 5 | 50 | 4 | 6 | 10 |
| 10 | 3 | 5 | 50 | 4 | 4 | |
| Blowcount - $N_{ave}$ | 11 | 17 | 45 | 8 | 20 | 16 |
| Internal Friction Angle - ϕ | 35 | 35 | 40 | 30 | 37 | 35 |
| Slope angle (°) - α for SF=1.2 | 30 | 30 | 35 | 26 | 32 | 30 |
| Slope – Horizontal:Vertical | 1.7:1 | 1.7:1 | 1.4:1 | 2.1:1 | 1.6:1 | 1.7:1 |

Note that SPT correlated values are only applicable to cohesionless, granular materials and are, at best, close approximations of internal friction angles. If cohesive soils are encountered in significant quantities or at critical locations, additional testing will be required to assess the undrained shear strength of that material.

The soil strength, as represented by the internal friction angle, was used to determine the maximum stable slope configuration using in-situ materials. The slope was determined to be stable when an infinite slope stability analysis resulted in a factor of safety of 1.1 or greater. More rigorous limit-equilibrium slope stability analyses should be performed for preliminary and final designs. Consideration for and applicable factor of safety should also be included in the design process.


**Figure 4: Existing Core Boring Information along Study Area**

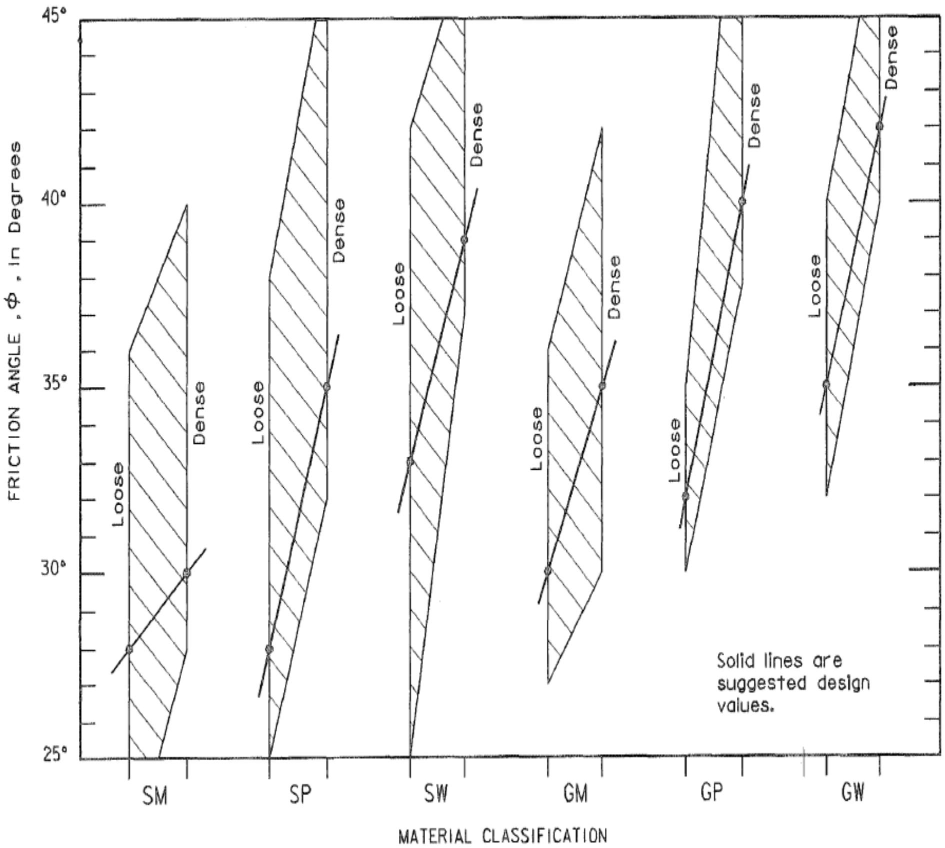


Figure 2-9. Friction angle of granular backfills



**Figure 5: Friction angle of Granular Backfills**

## 2.3 WATER RESOURCE CONSIDERATIONS

### 2.3.1 Discharge Frequency Analysis

The effective Federal Emergency Management Agency (FEMA) *Flood Insurance Study for Allegheny County, Pennsylvania* (FEMA, 2014) provides a source of discharge frequency values for the Ohio River at the confluence of the Allegheny and Monongahela Rivers. These values were generated by the USACE in 1977. A preliminary discharge frequency analysis based on Bulletin 17B, *USGS Guidelines for Determining Flood Flow Frequency* (USGS, 1981) procedures using the HEC-SSP software program (USACE HEC, October 2010) was developed for this effort. Data was taken from the Ohio River at Sewickley, PA gage (USGS, 2014), which provides peak discharge values for water years 1934-2014. Only values from water years 1967-2014 were used in the analysis, since the largest USACE Pittsburgh District reservoir (Kinzua Dam and Allegheny Reservoir) was put into operation in January 1966. Both the FEMA FIS and HEC-SSP values are summarized in the table and figure below.

**Table 2: Discharge Frequency Data for the Ohio River near Pittsburgh**

| Frequency (years) | Frequency (ACE)[1] | Frequency (%) | Discharge (cfs) | |
|---|---|---|---|---|
| | | | FEMA FIS (1977) | HEC-SSP (1967-2014) |
| 1 | 1.0 | 99 | n/a | 101,000 |
| 2 | 0.5 | 50 | n/a | 166,000 |
| 5 | 0.2 | 20 | n/a | 218,000 |
| 10 | 0.1 | 10 | 282,000 | 257,000 |
| 50 | 0.02 | 2 | 362,000 | 363,000 |
| 100 | 0.01 | 1 | 394,000 | 417,000 |
| 500 | 0.002 | 0.2 | 480,000 | 572,000 |

[1] ACE = Annual Chance Exceedance

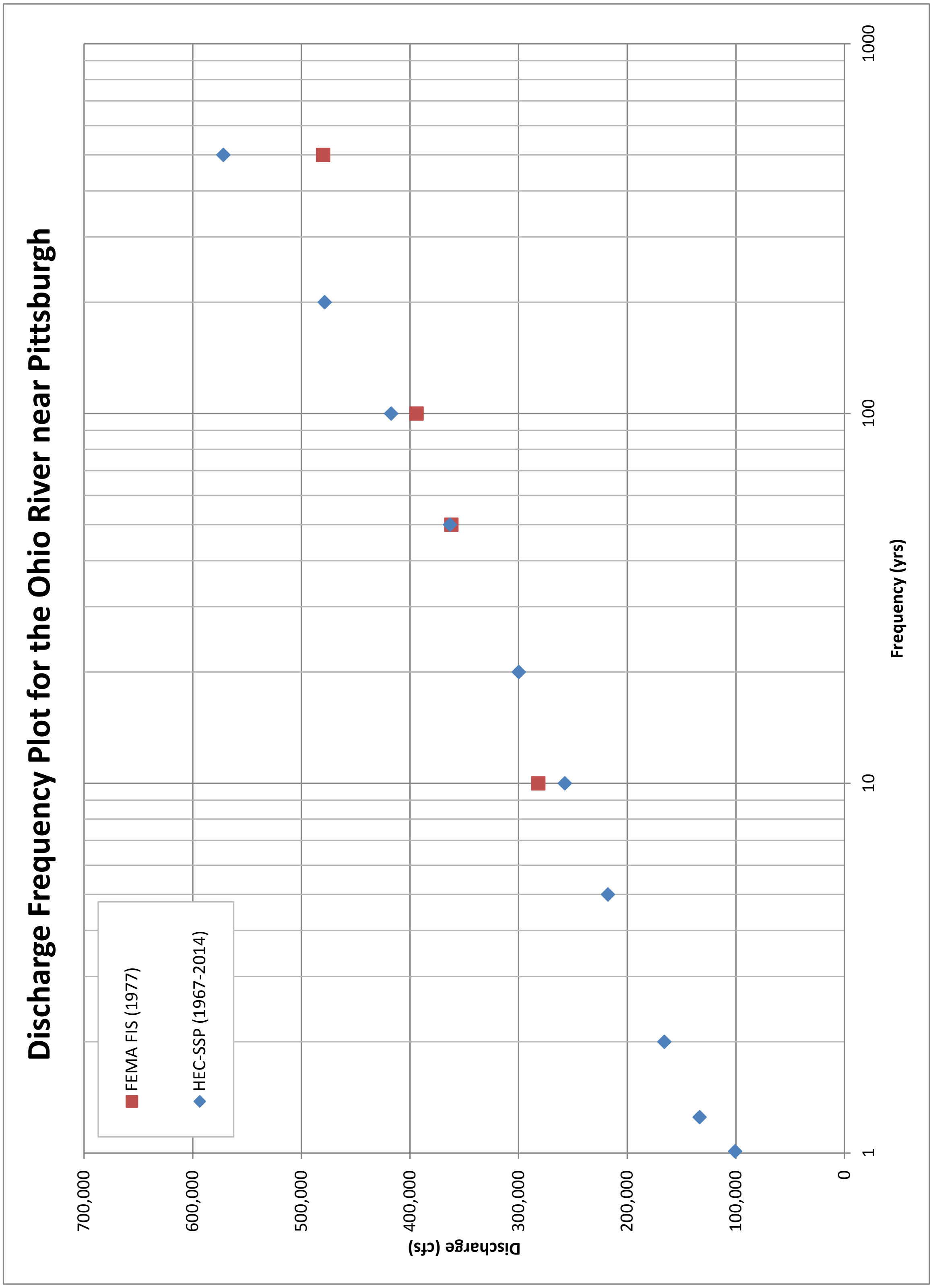


**Figure 6: Discharge Frequency Plot for the Ohio River near Pittsburgh**

### 2.3.2 Elevation Frequency Analysis

Elevation frequency values are also available for the Study Area, based on FEMA FIS flood profiles (FEMA, 2014) and USACE Ohio River frequency profiles (USACE, 1977). A preliminary elevation frequency analysis using the HEC-SSP software program (USACE HEC, October 2010) was developed for this effort. Data was taken from the Ohio River at Pittsburgh, PA, National Weather Service (NWS) records (NWS, 2015), which provide peak stage values from 1902-2015. Only values from water years 1967-2015 were used in the analysis, since the largest USACE Pittsburgh District reservoir (Kinzua Dam and Allegheny Reservoir) was put into operation in January 1966. HEC-RAS (USACE HEC, August 2015) steady flow hydraulic modeling of the HEC-SSP discharge frequency data was also used to provide another set of elevation frequency data for comparison with the statistical frequency analysis. The FEMA FIS flood profiles, USACE Ohio River frequency profiles, HEC-SSP values, and Pittsburgh District HEC-RAS modeling results are summarized in the table and figure below.

**Table 3: Elevation Frequency Data for the Ohio River near Pittsburgh**

| Frequency (years) | Frequency (ACE)[1] | Frequency (%) | Elevation (ft NGVD29) | | | |
|---|---|---|---|---|---|---|
| | | | FEMA FIS Flood Profiles | USACE Ohio River Frequency Profiles | HEC-SSP (1967-2015) | HEC-RAS Modeling |
| 1 | 1.0 | 99 | n/a | n/a | 713.0 | 712.8 |
| 2 | 0.5 | 50 | n/a | n/a | 716.0 | 714.9 |
| 5 | 0.2 | 20 | n/a | n/a | 719.2 | 720.9 |
| 10 | 0.1 | 10 | 723.0 | 723.1 | 721.5 | 725.0 |
| 50 | 0.02 | 2 | 727.5 | 727.7 | 726.8 | 733.0 |
| 100 | 0.01 | 1 | 729.5 | 729.5 | 729.1 | 736.2 |
| 500 | 0.002 | 0.2 | 734.0 | 734.2 | 734.7 | 744.4 |

[1] ACE = Annual Chance Exceedance

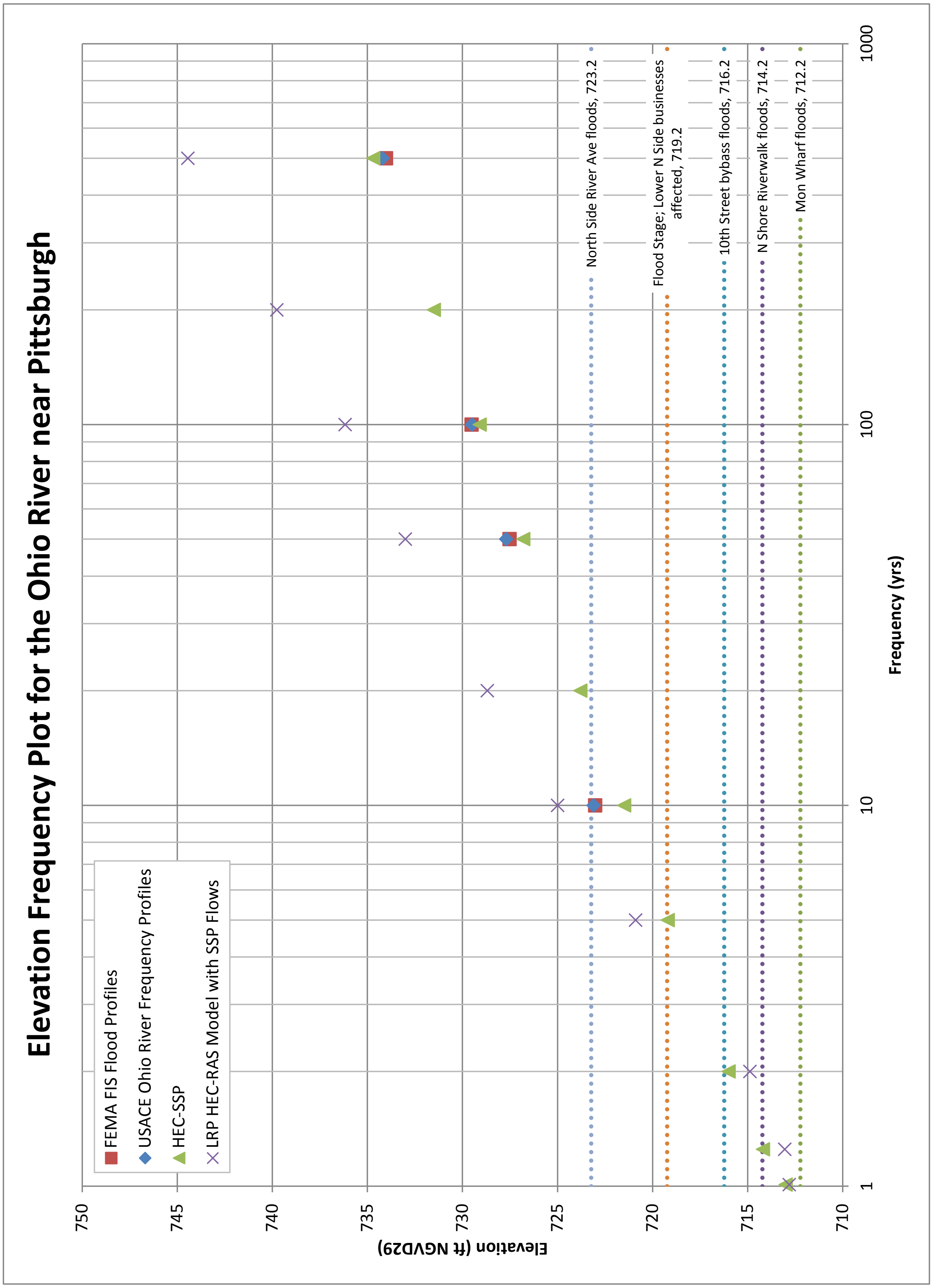


**Figure 7: Elevation Frequency Plot for the Ohio River near Pittsburgh**

### 2.3.3 Elevation Duration Analysis

A preliminary elevation duration analysis was also completed for this effort using the software program HEC-DSSVue (USACE HEC, January 2015). Daily and hourly observed stage data for Point State Park at Pittsburgh (USGS, 2015) from 01OCT1995 through 30SEP2015 was used in the analysis and converted to mean daily stages. Stage was then converted to elevation based on a gage zero elevation of 694.23 ft NGVD29. A plot of results is provided on the next page.

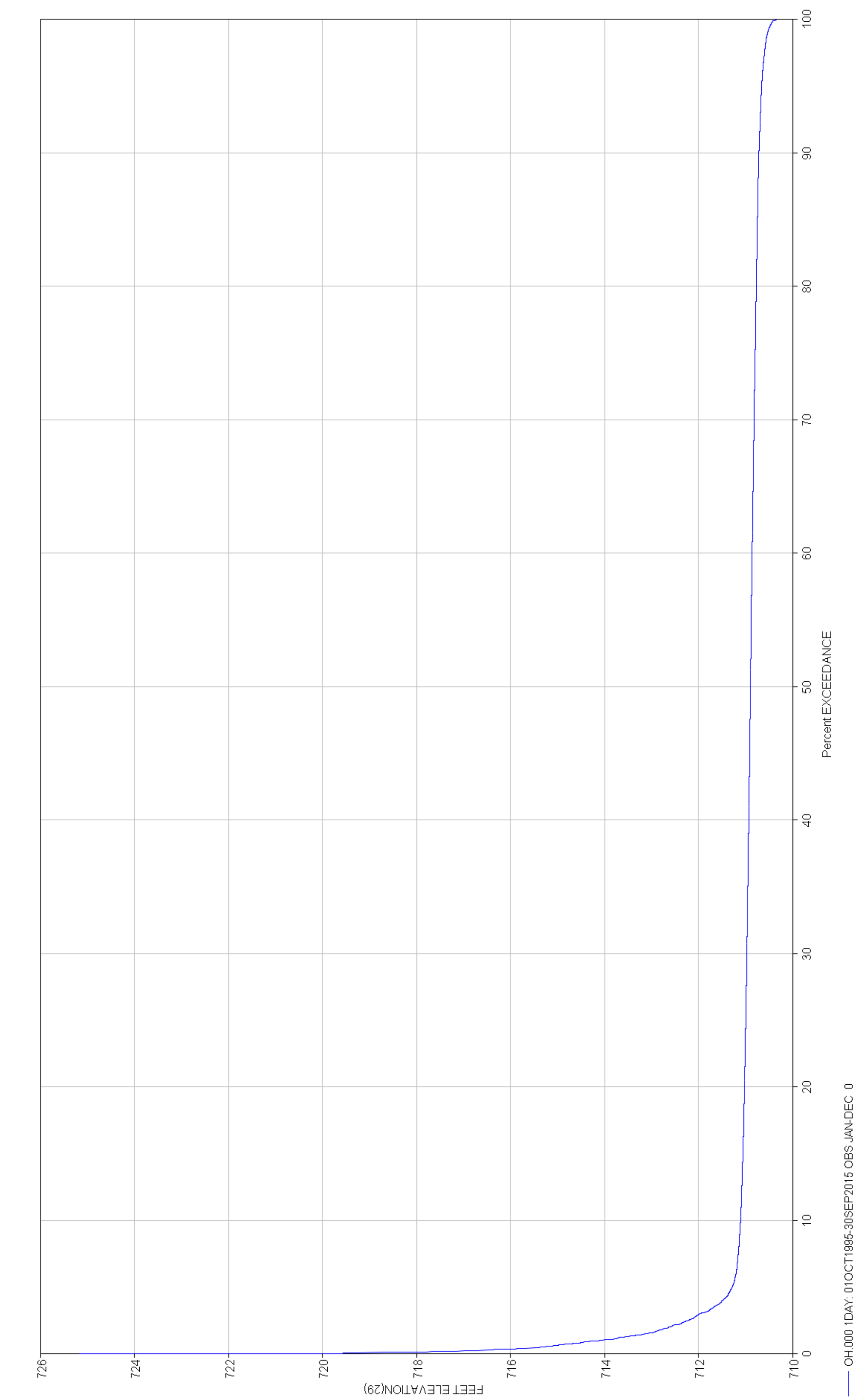


**Figure 8: Elevation Duration Plot for the Ohio River near Pittsburgh**

### 2.3.4 Hydraulic Modeling

The Pittsburgh District HEC-RAS model for the Ohio River was used to evaluate expected water surface elevations, velocities and shear stress through the Study Area. The HEC-RAS model utilized for this preliminary analysis is a one-dimensional, steady flow model. The model extends from Lock and Dam 4 (Natrona) on the Allegheny River and Lock and Dam 2 (Braddock) on the Monongahela River, downstream to Pike Island Lock and Dam on the Ohio River.

Figure 9 presents a snapshot of the HEC-RAS model cross sections through the Study Area.

The HEC-SSP discharge frequency flows described in Section 3.3.1 were used as steady flow input to the model. Cross sections through the Study Area correspond to HEC-RAS stations 14+26, 26+40, 38+02, and 42+77. This stationing represents approximate feet downstream of the confluence of the Allegheny and Monongahela Rivers.

To evaluate the effects of project alternatives for this feasibility study, blocked obstructions were placed along the right bank of the Ohio River through the study area. The obstructions were assumed to be at a top elevation of 715 and extend horizontally from the right bank with a vertical side slope in the river. This is a simplistic representation of the proposed project geometry, but can provide the product delivery team with an estimate of the relative impacts of various extents of horizontal bank obstruction. Blocked obstructions “trials” of 50, 100, 150, 200, and 250 feet were evaluated for this effort. Potential impacts to water surface elevation, velocity, and shear stress are summarized in the following sections.

Based on the Ohio River Navigation Charts, the centerline of the navigation channel through the Study Area is a minimum of 400 feet from the right bank of the Ohio River. The navigation channel is 300 feet wide (150 feet on either side of the centerline), which places the edge of the navigation channel a minimum of 250 feet from the right bank of the Ohio River through the study area. Therefore, 250 feet was used as the maximum extent of the blocked obstruction for HEC-RAS modeling. This represents the furthest the project features can extend into the river without direct impact to the navigation channel.

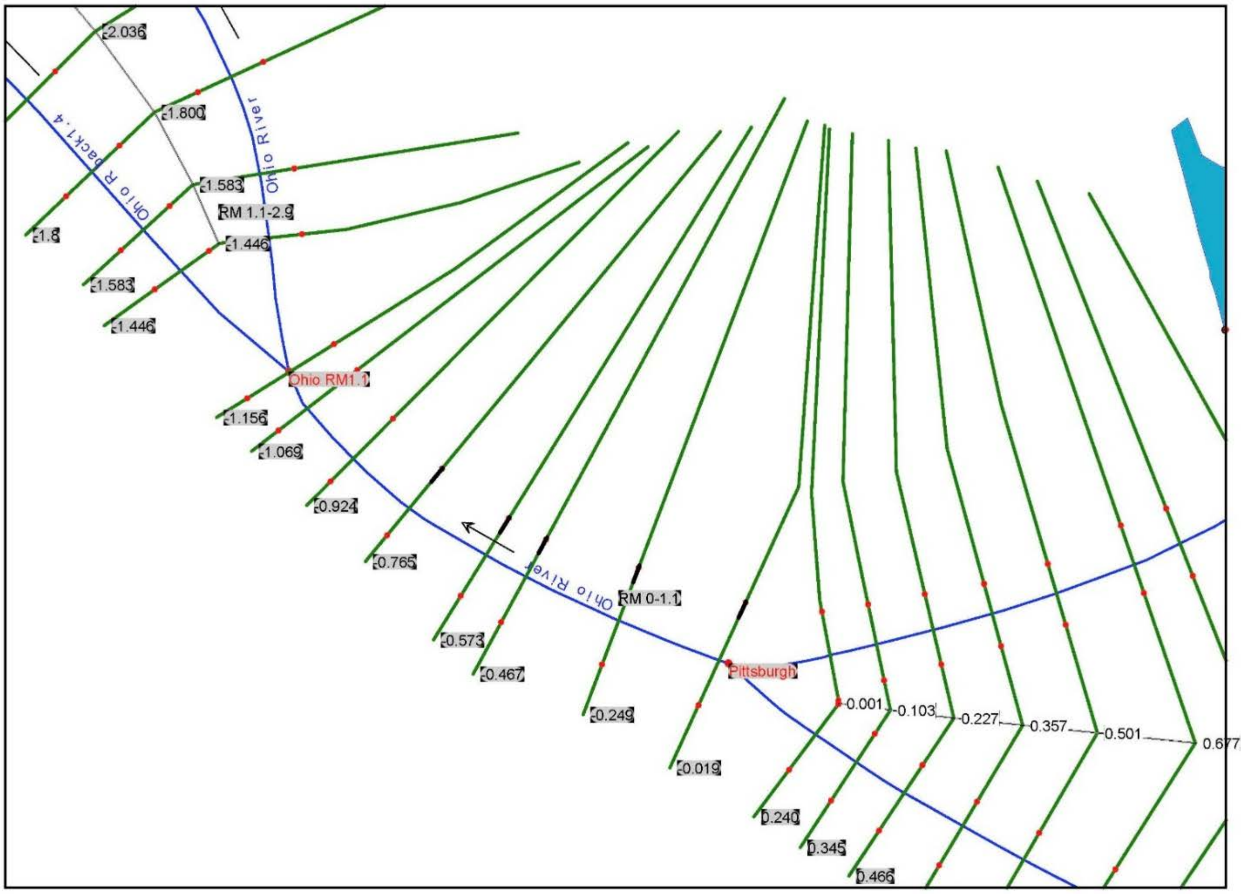


**Figure 9: HEC-RAS Cross Sections through the Study Area**

### *2.3.4.1 Water Surface Elevation*

The one-dimensional HEC-RAS model computes a uniform water surface elevation at each cross section. Water surface elevations were tabulated for each cross section through the Study Area and each steady flow plan. The results from the existing conditions geometry were compared to the results from each blocked obstruction trial using the difference between the two conditions. The maximum increase in water surface elevation for each trial is summarized in the table below. An increase in water surface elevation of 0.1 feet was considered as an impact threshold. Therefore, based on water surface elevation impacts, a distance of 100 feet or less is recommended for any feature that will protrude into the river from the right bank of the Ohio River. Figure 10 provides a comparison of HEC-RAS water surface profiles for the existing conditions plan ("SSP Freq Exist") and 100-foot blocked obstruction plan ("SSP Freq Concept").

**Table 4: Maximum Increase in Water Surface Elevation for Each Modeling Trial**

| Trial | Blocked Obstruction Width (feet) | Maximum Increase in Water Surface Elevation (feet) |
|---|---|---|
| 1 | 50 | 0.03 |
| 2 | 100 | 0.07 |
| 3 | 150 | 0.15 |
| 4 | 200 | 0.24 |
| 5 | 250 | 0.38 |

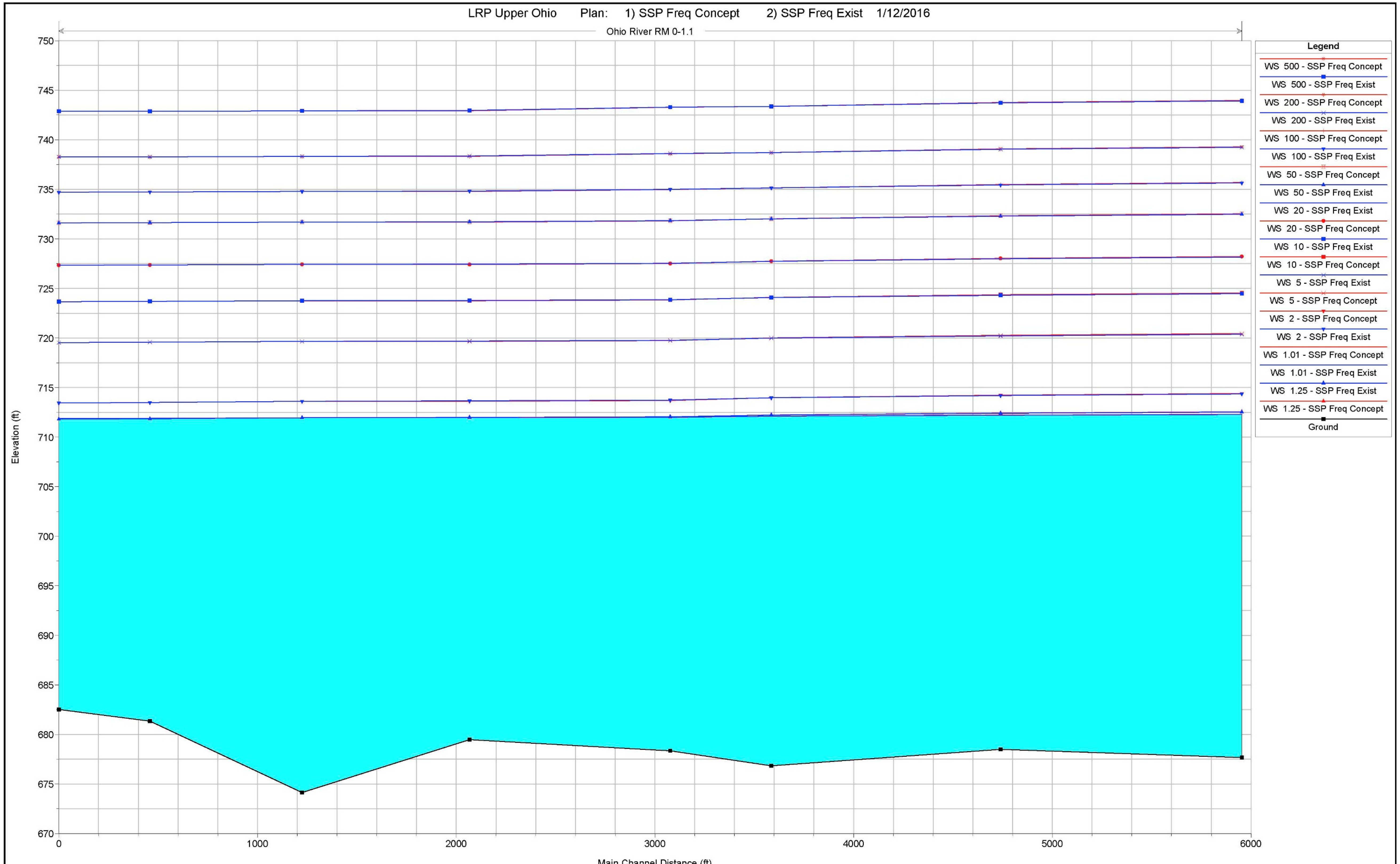


**Figure 10: HEC-RAS Water Surface Profile Comparison (Existing Conditions vs. 100-ft Blocked Obstruction)**

#### 2.3.4.2 Velocity

The HEC-RAS model computes average channel, right overbank, and left overbank velocities. Bank stations are positioned based on changes in cross section geometry and roughness. Average channel velocity has been reported for this analysis because most of the project features will be located below and riverward of the bank stations. The average channel velocity was tabulated for each cross section through the study area and each steady flow plan. The results from the existing conditions geometry were compared to the results from each blocked obstruction trial using the percent increase in the two conditions. The maximum percent increase in velocity for each trial is summarized in the table below. An increase in velocity of 10% was considered as an impact threshold. This 10% threshold is considered by the modeler as an acceptable level of increase based on the model approach used. Therefore, based on average channel velocity impacts, a distance of 100 feet or less is recommended for any feature that will protrude into the river from the right bank of the Ohio River.

**Table 5: Maximum Percent Increase in Average Channel Velocity for Each Modeling Trial**

| Trial | Blocked Obstruction Width (feet) | Maximum Percent Increase in Average Channel Velocity |
|---|---|---|
| 1 | 50 | 2% |
| 2 | 100 | 6% |
| 3 | 150 | 12% |
| 4 | 200 | 20% |
| 5 | 250 | 30% |

EM 1110-2-1601, *Hydraulic Design of Flood Control Channels* (USACE, 1994), presents information on maximum permissible mean channel velocities for various types of channel material; as well as governing equations for determining stone stability velocities as a function of stone diameter ($D_{50}$). This information is summarized in the figure below and plotted with the HEC-RAS average channel velocities for sections through the study area.

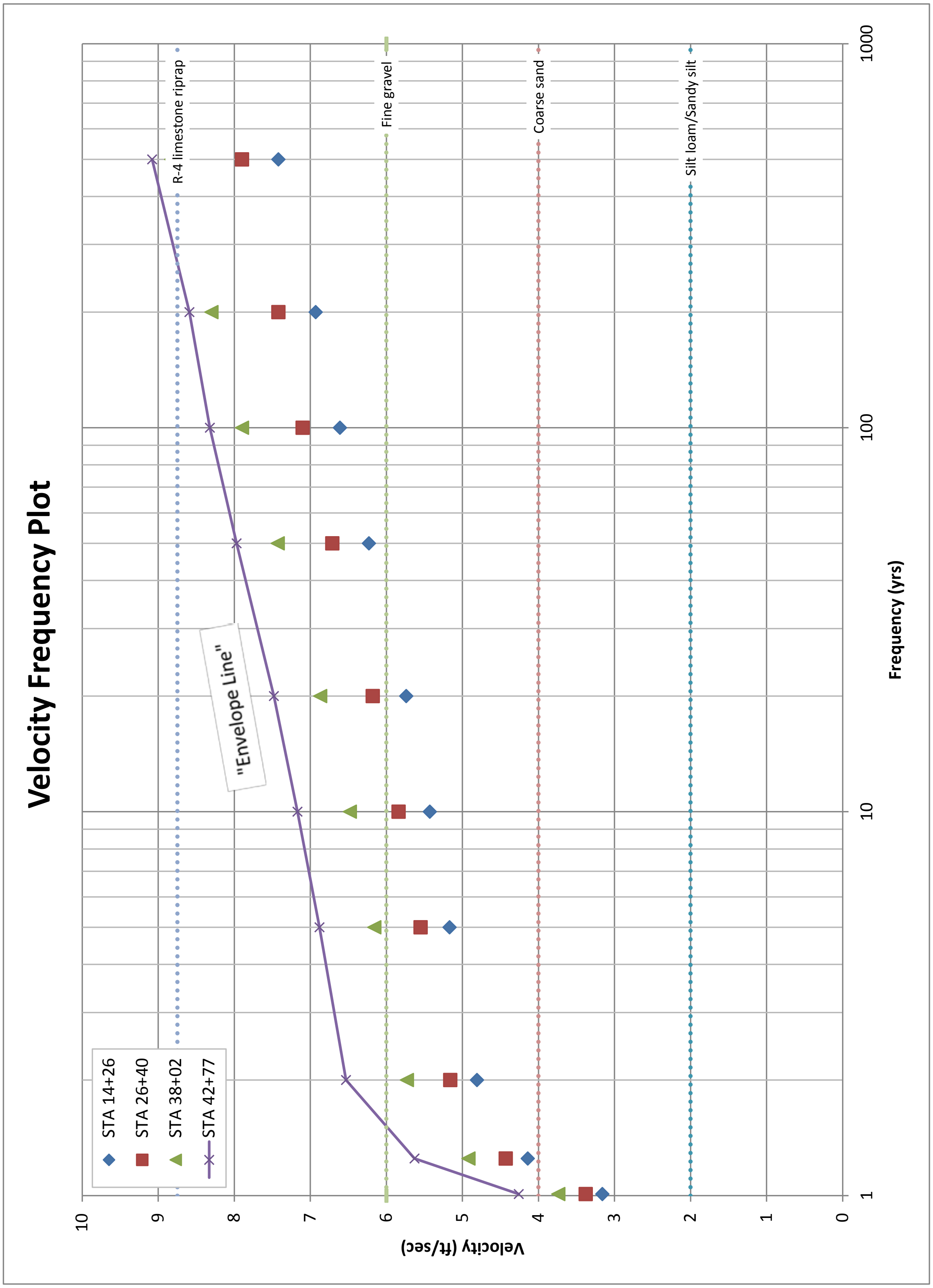


**Figure 11: Velocity Frequency Plot for the Ohio River near Pittsburgh**

#### *2.3.4.3 Shear Stress*

The HEC-RAS model computes average channel, right overbank and left overbank shear stress. Average channel shear stress has been reported for this analysis because most of the project features will be located below and riverward of the bank stations. The average channel shear stress was tabulated for each cross section through the study area and each steady flow plan. The results from the existing conditions geometry were compared to the results from each blocked obstruction trial assuming a threshold value of 0.4 lb/ft2 of shear stress. This is approximately the shear stress that will mobilize coarse gravel. The frequency event above this threshold value (0.4 lb/ft2) for each trial is summarized in the table below. A frequency event of 100 years (1% ACE) was considered as an impact threshold. Therefore, based on shear stress impacts, a distance of 150 feet or less is recommended for any feature that will protrude into the river from the right bank of the Ohio River.

**Table 6: Frequency Event above the Shear Stress Threshold for Each Modeling Trial**

| Trial | Blocked Obstruction Width (feet) | Frequency Event above Shear Stress Threshold |
|---|---|---|
| Existing | 0 | 500 year (0.2% ACE) |
| 1 | 50 | 500 year (0.2% ACE) |
| 2 | 100 | 500 year (0.2% ACE) |
| 3 | 150 | 200 year (0.5% ACE) |
| 4 | 200 | 50 year (2% ACE) |
| 5 | 250 | 2 year (50% ACE) |

#### *2.3.4.4 Model Improvements*

Significant hydraulic model improvements are recommended for the design phase. A two-dimensional model is recommended to evaluate localized effects of the selected project features. Updated LiDAR and bathymetric data should be used to generate the two-dimensional terrain grid. Unsteady flow events should be generated and simulated to more accurately represent conditions during a range of flood events.

Note: The latest version of HEC-RAS has two-dimensional, unsteady flow modeling capabilities that have not been utilized for this feasibility-level effort.

### 2.3.5 Engineering Recommendations

The water resources analysis presented above results in the following engineering recommendations for the alternatives analysis:

- A distance of 100 feet or less is recommended for any feature that will protrude into the river from the right bank of the Ohio River. This distance should have negligible impacts on the water surface elevation, velocity, and shear stress through the study area. Impacts will need to be verified with more detailed hydraulic modeling during the design phase of the Project.
- For backwater or notched dikes extending above the water surface, a top elevation of 713 feet NGVD29 is recommended; this represents a 99% elevation ACE (1yr frequency) or 1.6% annual duration exceedance. It is anticipated that this elevation will be exceeded at least once per year and for an average of 6 days per year.
- Larger diameter gravels that will withstand a two year overtopping frequency (~6 feet/second) are recommended as substrate modification material.
- R-4 limestone riprap has a maximum permissible velocity of ~8.7 feet/second; this represents a ~0.5% velocity ACE [200 year frequency], which may be suitable for long term bank stabilization.
- A two-dimensional unsteady flow HEC-RAS model, using actual location and dimensions of obstructions proposed, should be performed during the design phase of the Project to evaluate the localized effects of the selected project features (measures). Attention shall be given to the applicable regulatory guidelines related to water surface elevation increase thresholds.

## 2.4 STRUCTURAL CONSIDERATIONS

### 2.4.1 General

Currently, only one permanent building "structure" exists within the Study Area planned for restoration activities or improvement. This structure is located at Station 41+00 near the downstream limit of the Study Area. The structure is located between the Three Rivers Trail and the riverbank. It was previously used as office space. At this time, there appears to be no plans for demolition of this structure. Therefore no consideration is given in the Report to this item.

### 2.4.2 Ancillary Structures

What does exist within the Study Area however, are ancillary structural items associated with utilities, road infrastructure and prior constructed riverfront development. These items specifically include ALCOSAN CSO discharge pipes and headwalls, Pittsburgh Water and Sewer stormwater pipes and outfalls, the West End Bridge abutment (and foundation) and miscellaneous hardscape items such as sheet pile walls, mooring cells, a pier and temporary docks.

### 2.4.3 Inclusion of Existing Structures in Recommended Plan

It is the intent of the sponsor to include compatible recreation features as part of the Recommended Plan. A portion of these recreation features involves repurposing some riverfront hardscape. Specifically, such repurposing is proposed in the form of cutting and removing portions of existing sheet pile (above current river surface elevation) and potentially using an existing pier structure as a scenic overlook. These concepts have been discussed at the feasibility level ONLY and more investigation related to structural integrity, stability and other engineering characteristics will need to be performed as each of the preferred alternative measures are approved as part of the final Project scope.

Additionally, care should be taken relative to any work in the Study Area that may disturb the aforementioned items. Specific attention should be paid to any easements for such items and the required offsets listed by the Agencies in charge of the infrastructure items. Future design and implementation of any of the recommended restoration measures should include all these considerations.

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(NWS, 2015) National Weather Service. NWS Advanced Hydrologic Prediction Service. Ohio River at Pittsburgh, http://water.weather.gov/ahps2/hydrograph.php?wfo=pbz&gage=pttp1

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(USACE HEC, January 2015) USACE Hydrologic Engineering Center. HEC-DSSVue Version 2.5, January 2015

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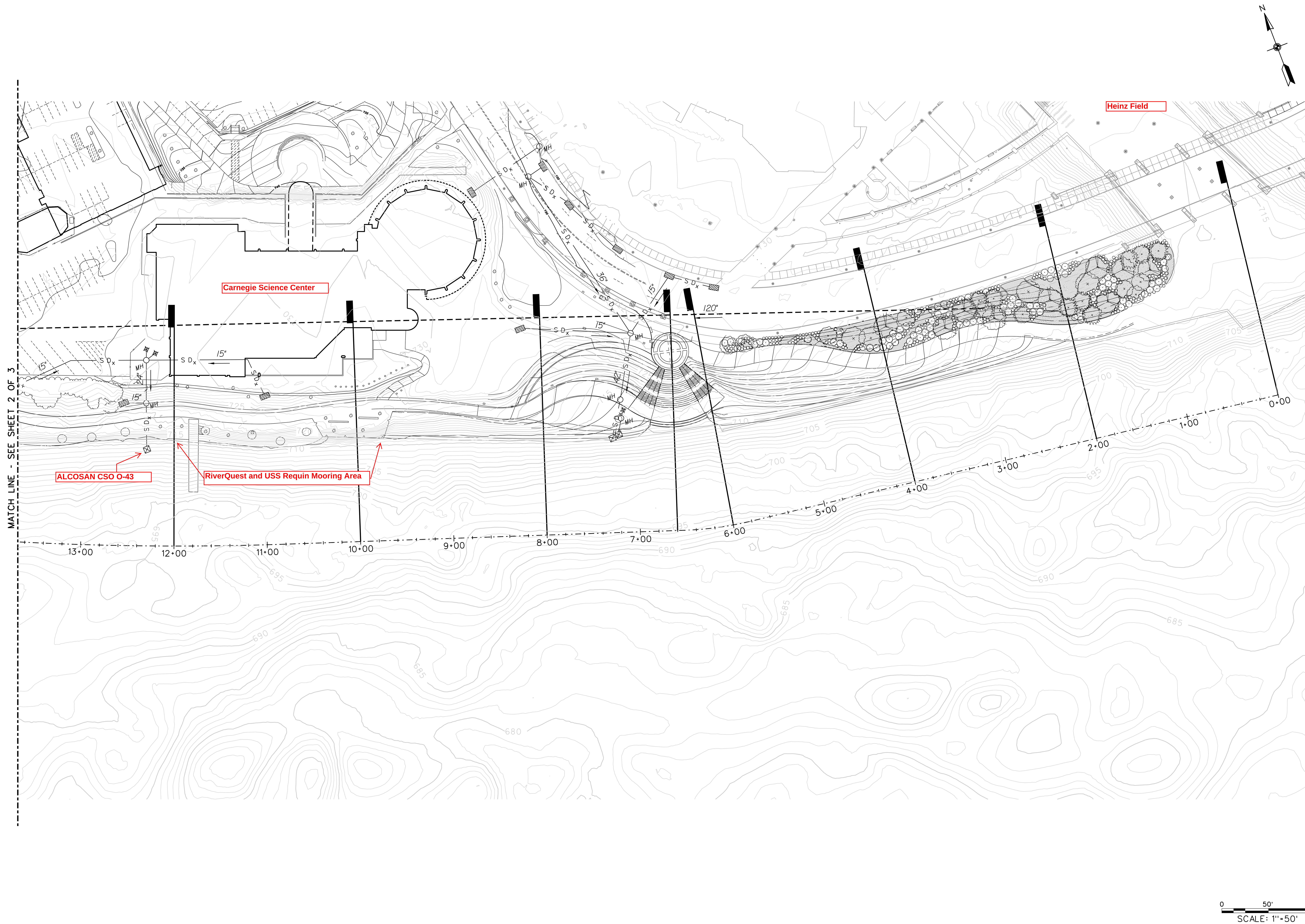
(USGS, 2015) US Geological Survey. USGS Water Data for Pennsylvania. USGS 03085152 Monongahela R at Point State Park at Pittsburgh, http://waterdata.usgs.gov/usa/nwis/uv?03085152

# 4 ATTACHMENTS

## 4.1 Existing Condition Plans




US ARMY CORPS OF ENGINEERS
PITTSBURGH DISTRICT

| MARK | DESCRIPTION | DATE | APPR |
|---|---|---|---|

| MARK | DESCRIPTION | DATE | APPR |
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U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
PITTSBURGH, PA

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CKD BY:
SUBMITTED BY:
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CONTRACT NO.:
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OHIO RIVER - SECTION 206
NORTH SHORE - CITY OF PITTSBURGH
AQUATIC ECOSYSTEM RESTORATION PROJECT
FEASIBILITY STUDY

SHEET IDENTIFICATION NUMBER
1 of 3

PRELIMINARY

IP_PWPdms37483\Plan Sheet 1 of 3.dgn
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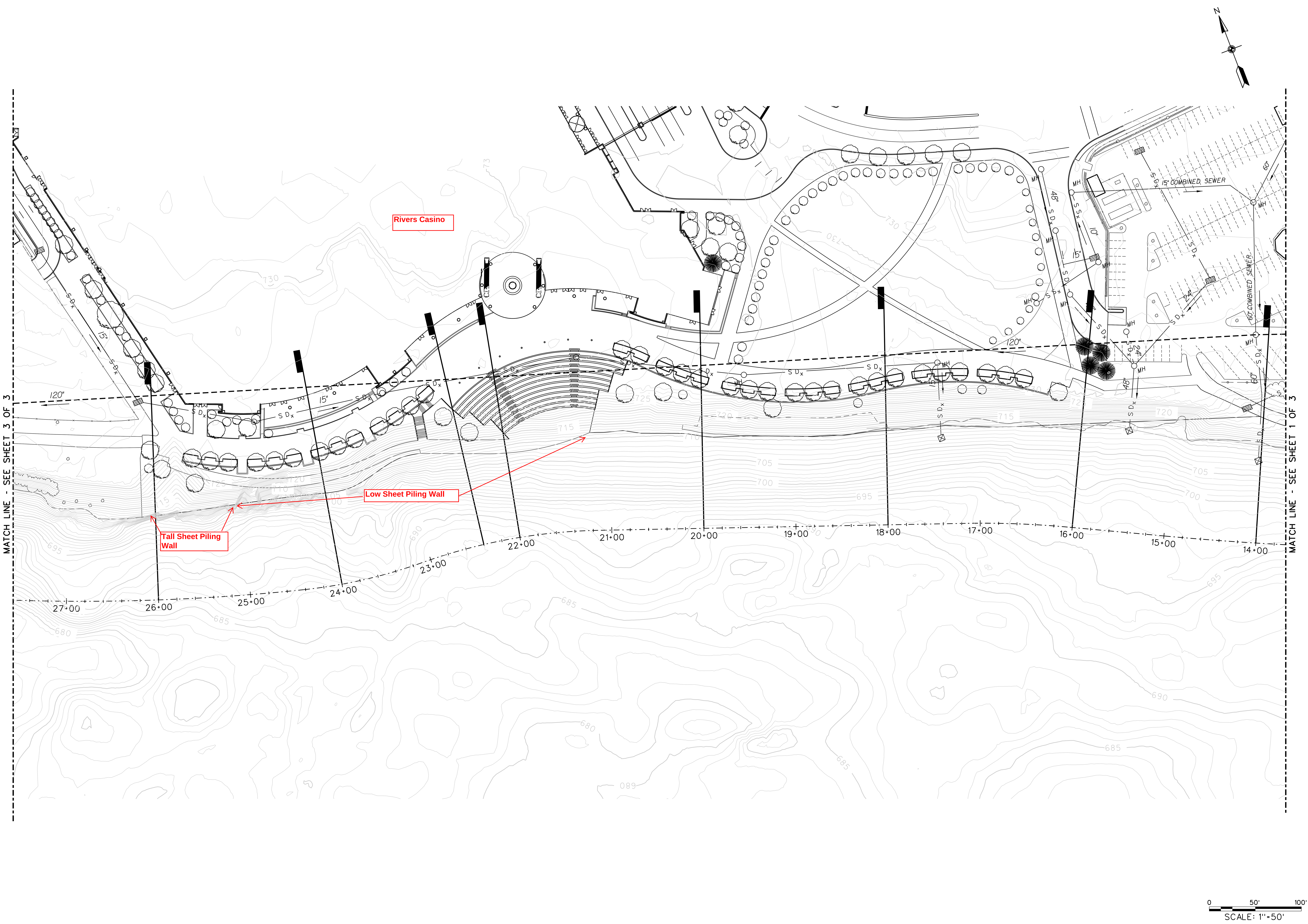


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OF ENGINEERS
PITTSBURGH DISTRICT

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U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
PITTSBURGH, PA

OHIO RIVER - SECTION 206
NORTH SHORE - CITY OF PITTSBURGH
AQUATIC ECOSYSTEM RESTORATION PROJECT
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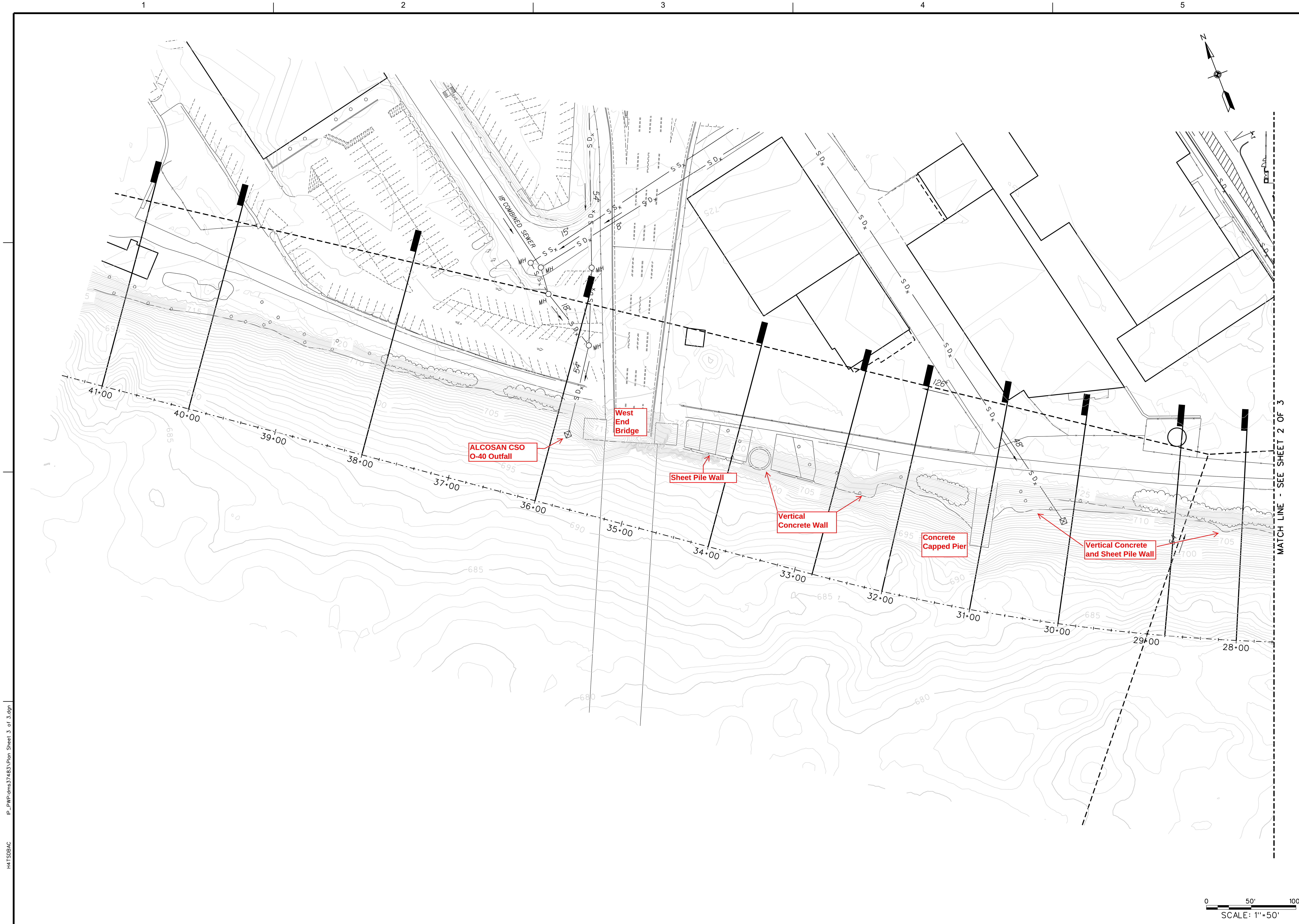


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PITTSBURGH DISTRICT

| MARK | DESCRIPTION | DATE | APPR |
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U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
PITTSBURGH, PA

DESIGNED BY: | DATE:
DWN BY: B. CRATTY | CKD BY: | SOLICITATION NO.:
SUBMITTED BY: | CONTRACT NO.:
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OHIO RIVER - SECTION 206
NORTH SHORE - CITY OF PITTSBURGH
AQUATIC ECOSYSTEM RESTORATION PROJECT
FEASIBILITY STUDY

SHEET IDENTIFICATION NUMBER
3 of 3

PRELIMINARY

## 4.2 Selected Alternative Plan


HEINZ FIELD
CONSTRUCTED WETLAND
SAFETY BENCH, TYPICAL
AQUATIC BENCH, TYPICAL
POOL/MARSH, TYPICAL
RIVERS CASINO
CARNEGIE SCIENCE CENTER
WEST END BRIDGE
EXISTING SHORELINE, TYPICAL
NEW SHORELINE
NEW SHORELINE
KAYAK LAUNCH FEATURE
PARALLEL NOTCHED DIKES, TYPICAL
USS REQUIN
PARALLEL NOTCHED DIKES, TYPICAL
41+00
40+00
38+00
36+00
34+00
32+70
32+00
31+00
30+00
28+70
28+00
26+00
24+00
22+40
22+00
20+00
18+00
16+00
14+00
12+00
10+00
8+00
6+60
6+00
4+00
2+00
0+00


SELECTED ALTERNATIVE PLAN SHOWING AQUATIC RESTORATION MEASURES AND PRELIMINARY BASELINE
HEINZ FIELD
CONSTRUCTED WETLAND AREA
CARNEGIE SCIENCE CENTER
RIVERS CASINO
INVASIVE REMOVAL & REVEGETATION, TYPICAL
INVASIVE REMOVAL & REVEGETATION, TYPICAL
RESHAPED BANK, TYPICAL
NEW SHORELINE, TYPICAL
SLOPE, TYPICAL
SUBSTRATE MODIFICATIONS, TYPICAL
KAYAK LAUNCH FEATURE, TYPICAL
PARALLEL DIKE, TYPICAL
SLOPE, TYPICAL
SUBSTRATE MODIFICATIONS, TYPICAL
PARALLEL DIKE, TYPICAL
SLOPE, TYPICAL
SUBSTRATE MODIFICATIONS, TYPICAL
41+00
40+00
38+00
36+00
34+00
32+70
32+00
31+00
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28+70
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26+00
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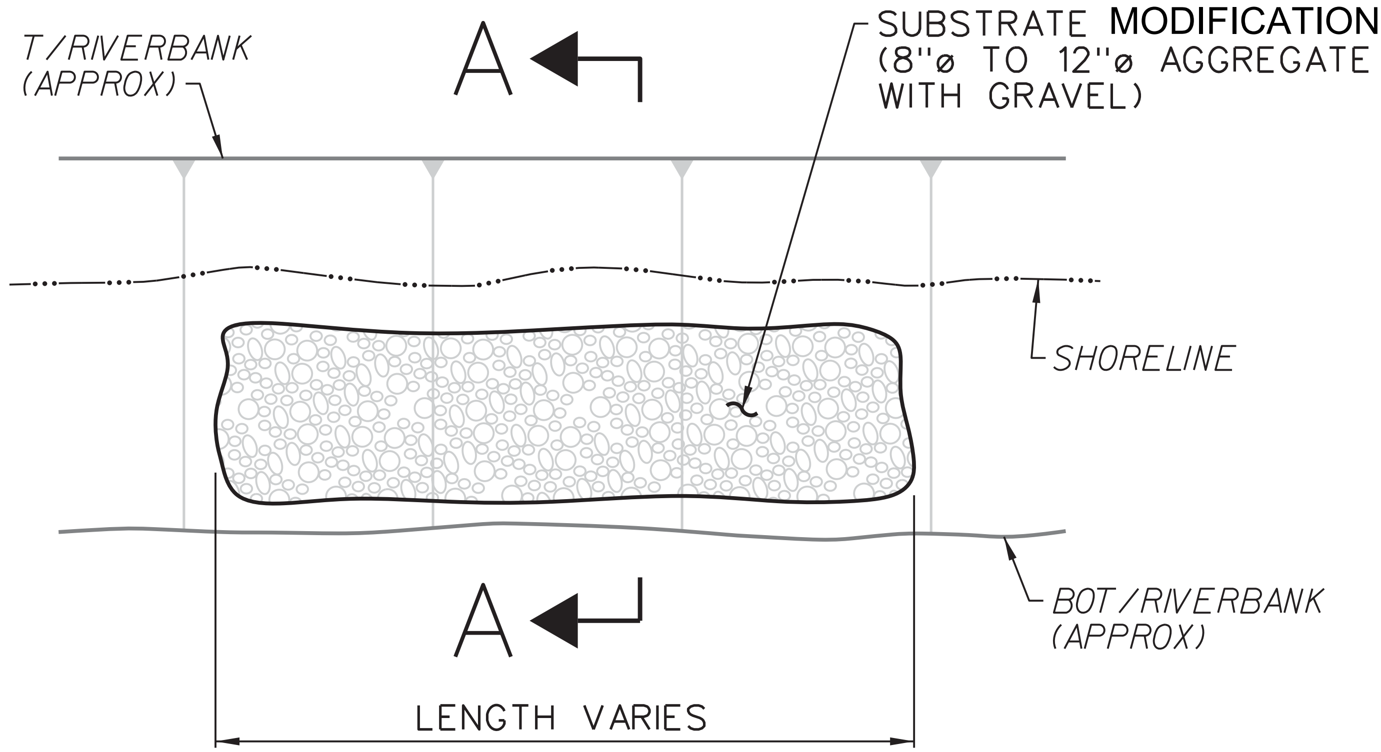
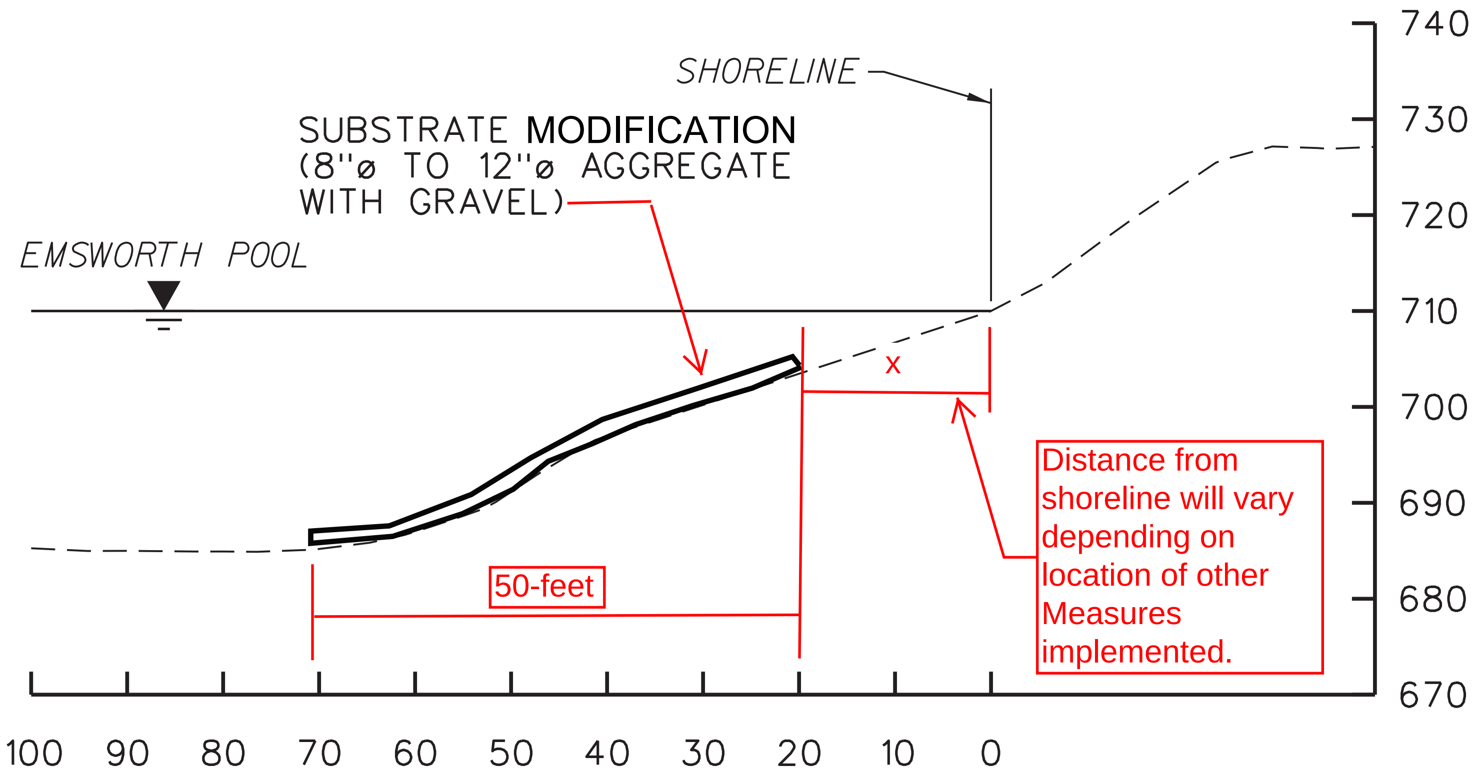
## 4.3 Miscellaneous Details



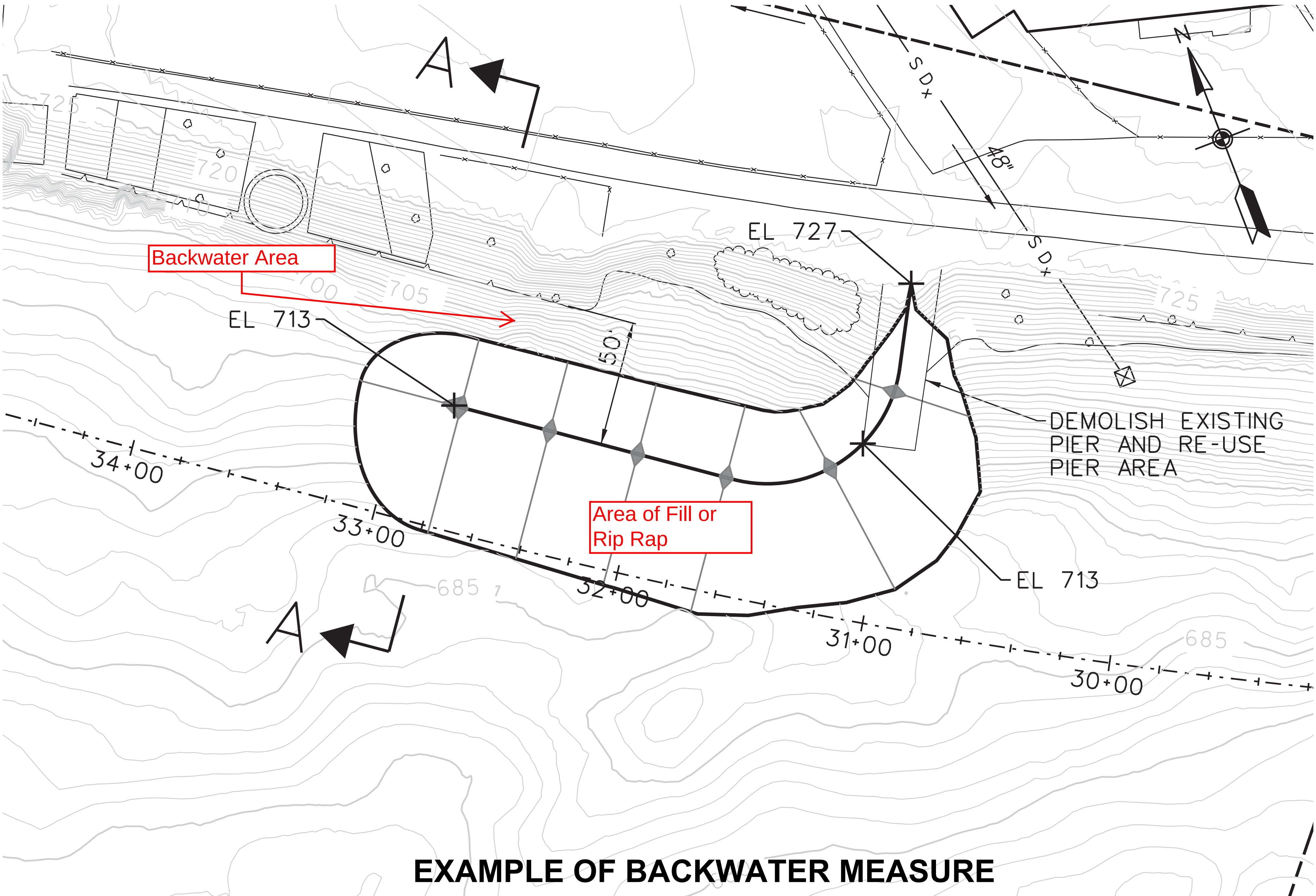

PLAN VIEW




SECTION A-A

**EXAMPLE OF**
**SUBSTRATE MODIFICATION MEASURE**
**Plan and Section Views**

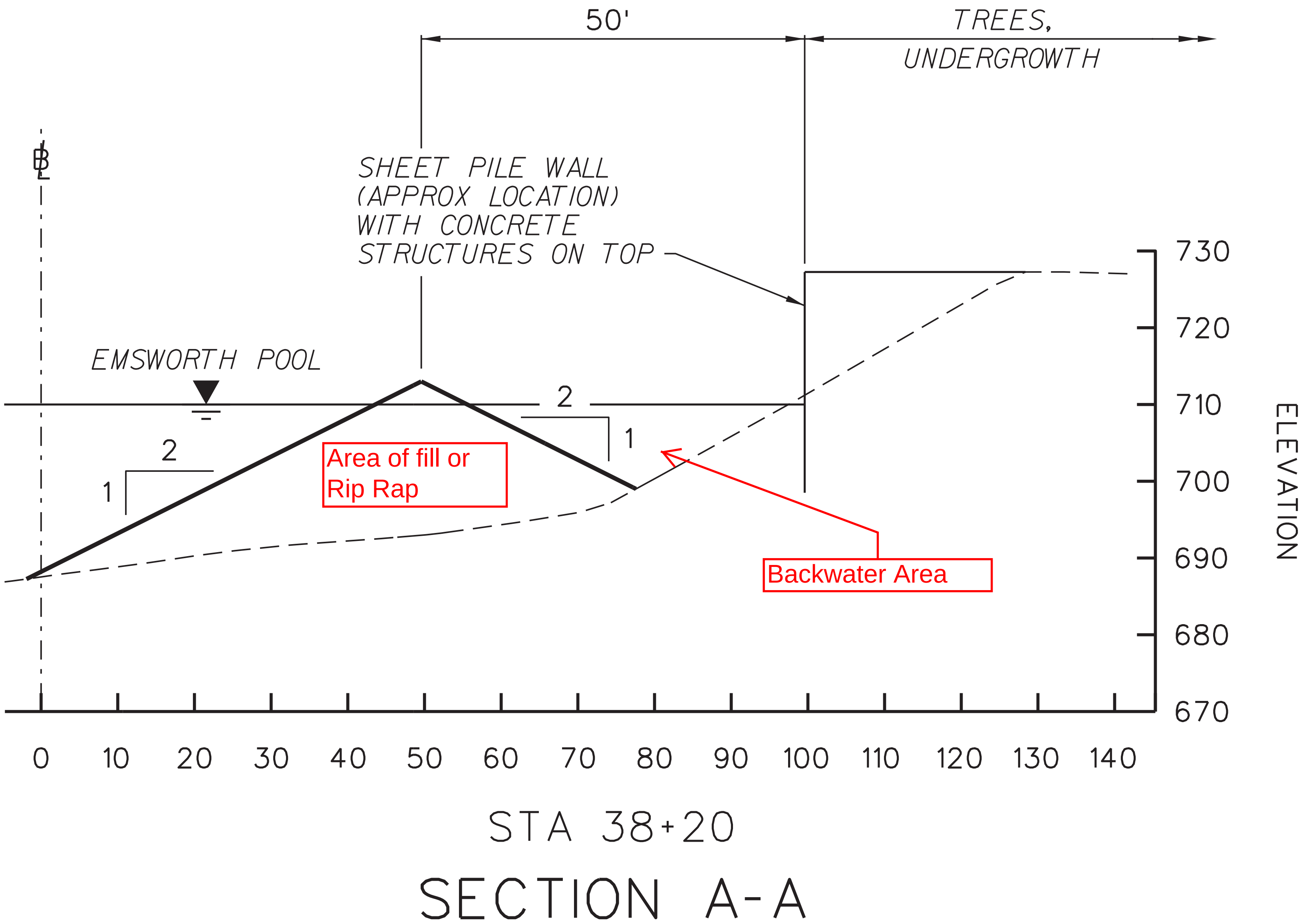
Not to Scale




## EXAMPLE OF BACKWATER MEASURE

### Plan View

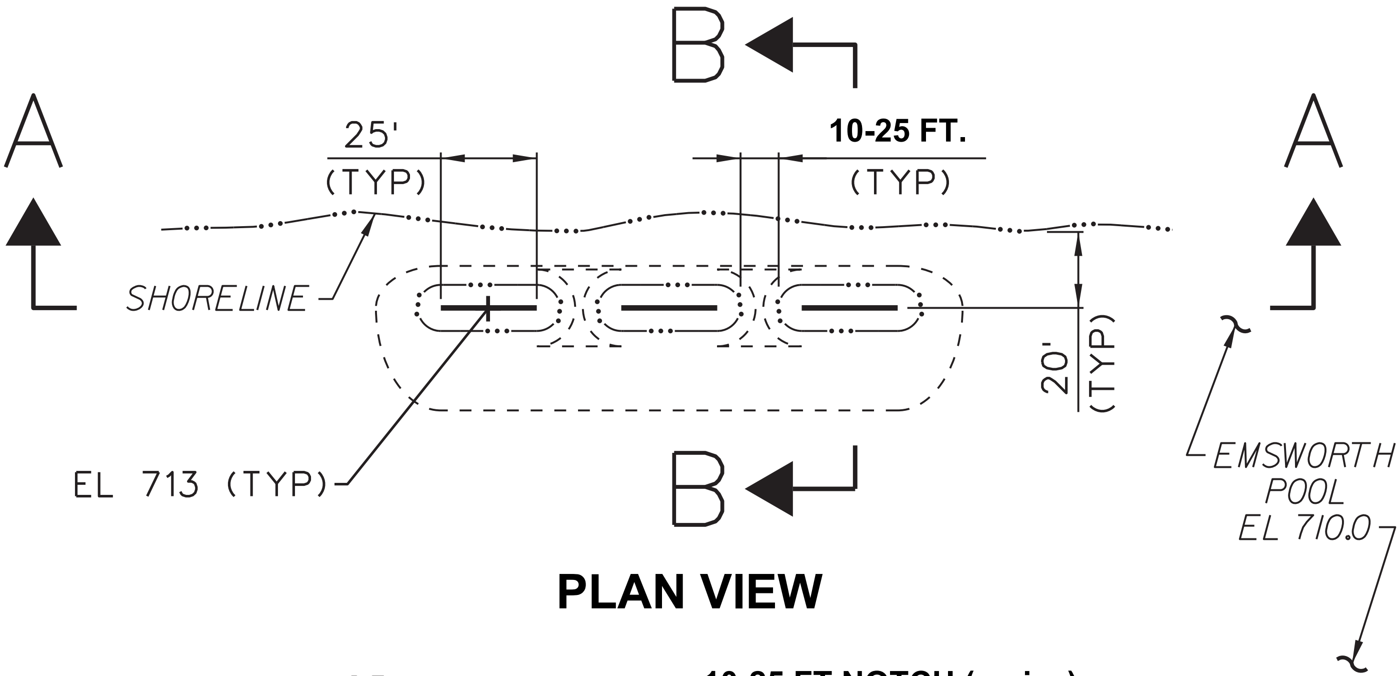
**Not to Scale**



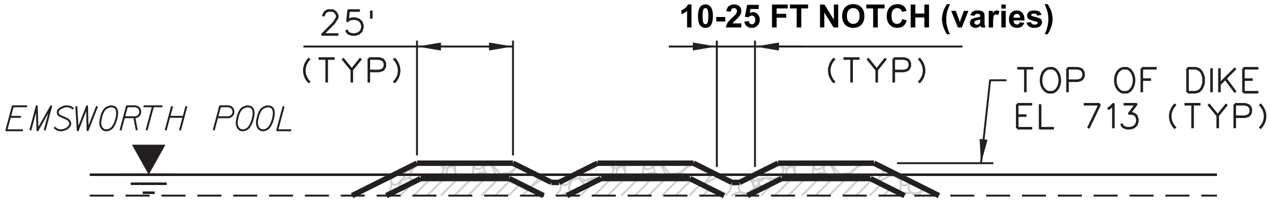

**EXAMPLE OF BACKWATER MEASURE**

**Section View**

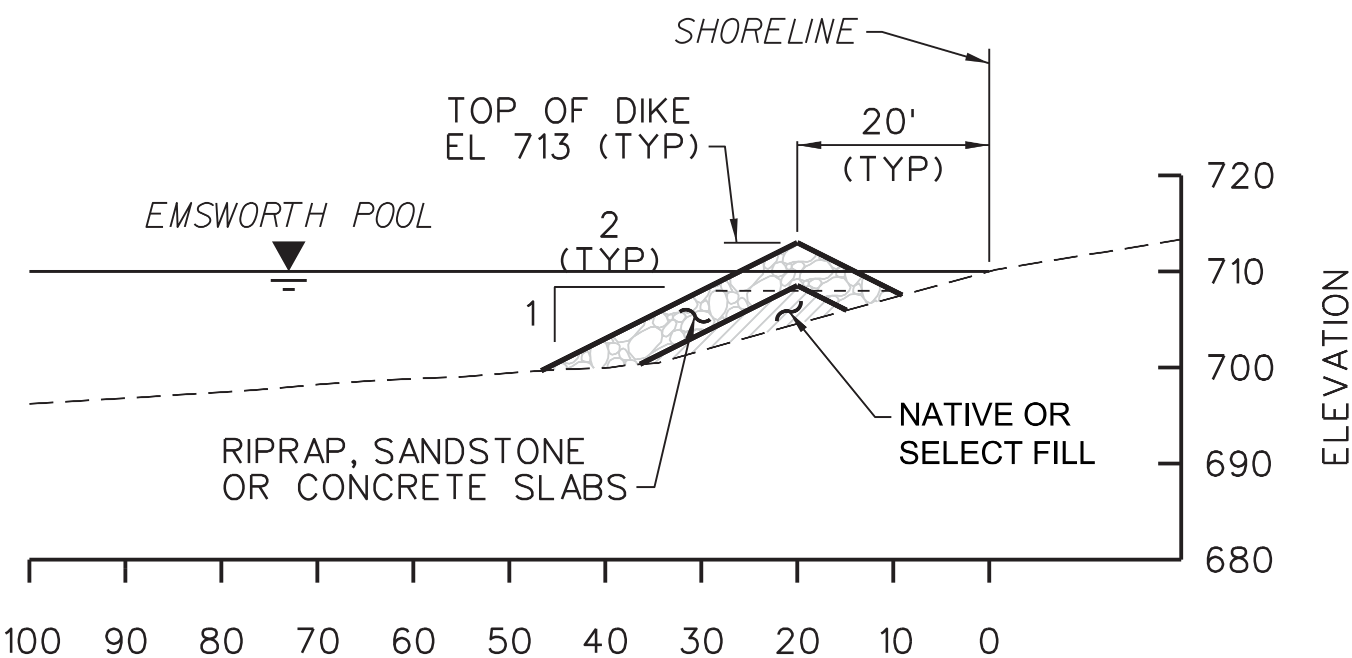
**Not to Scale**




**PLAN VIEW**



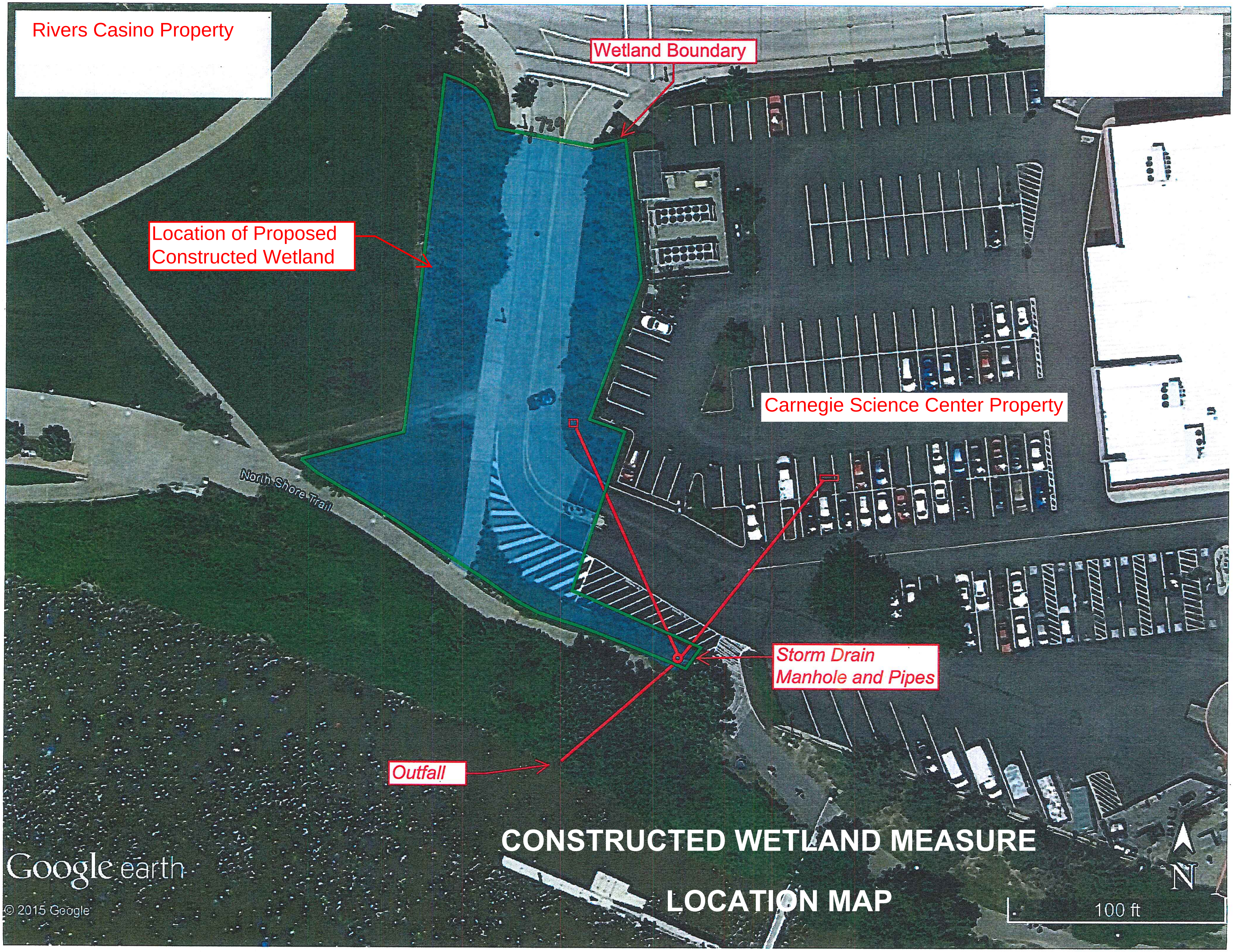

**SECTION A - A**

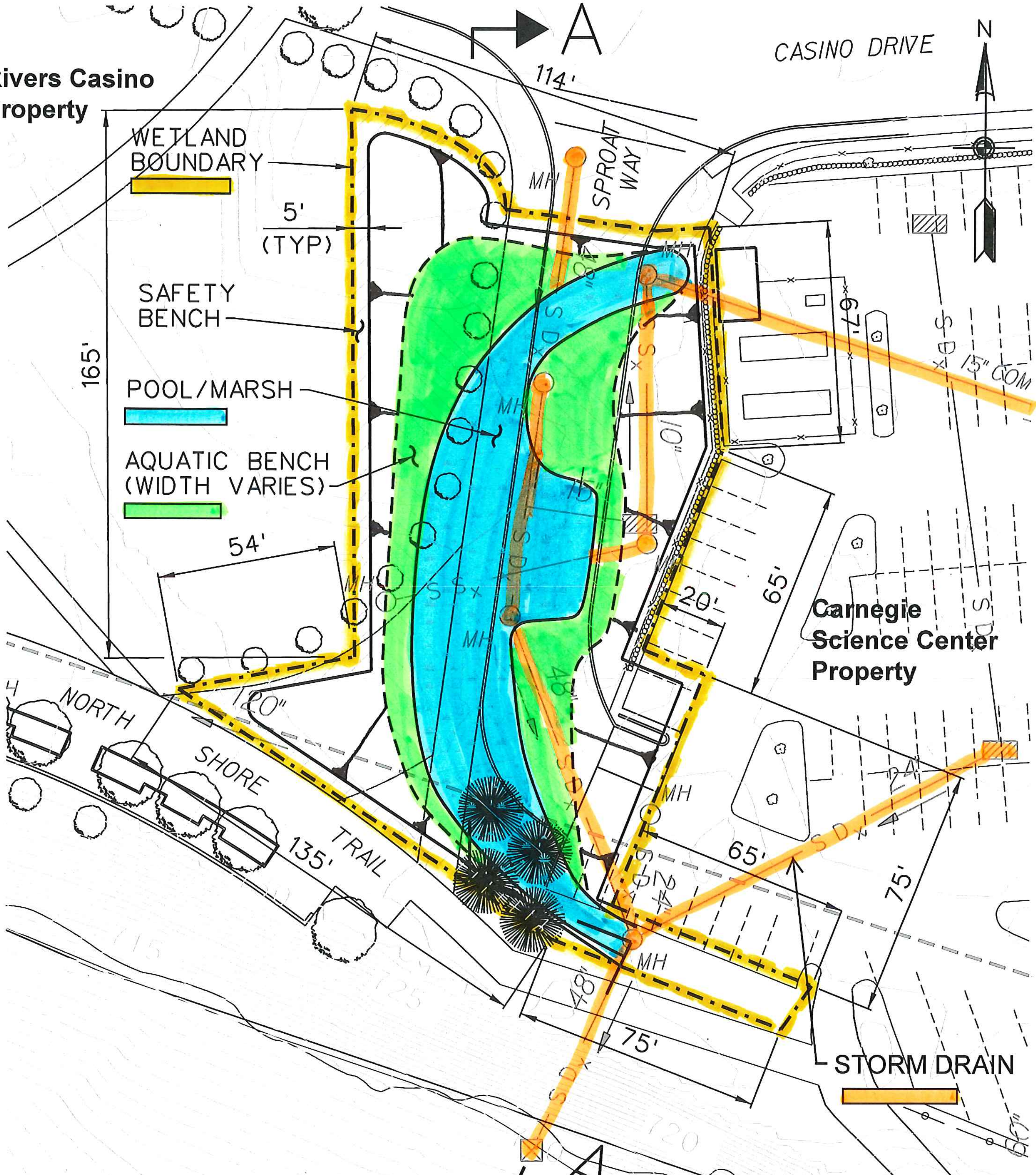



**SECTION B - B**

**EXAMPLE OF NOTCHED DIKE**
**MEASURE PARALLEL TO SHORE**
**<u>Plan and Section Views</u>**

Not to Scale

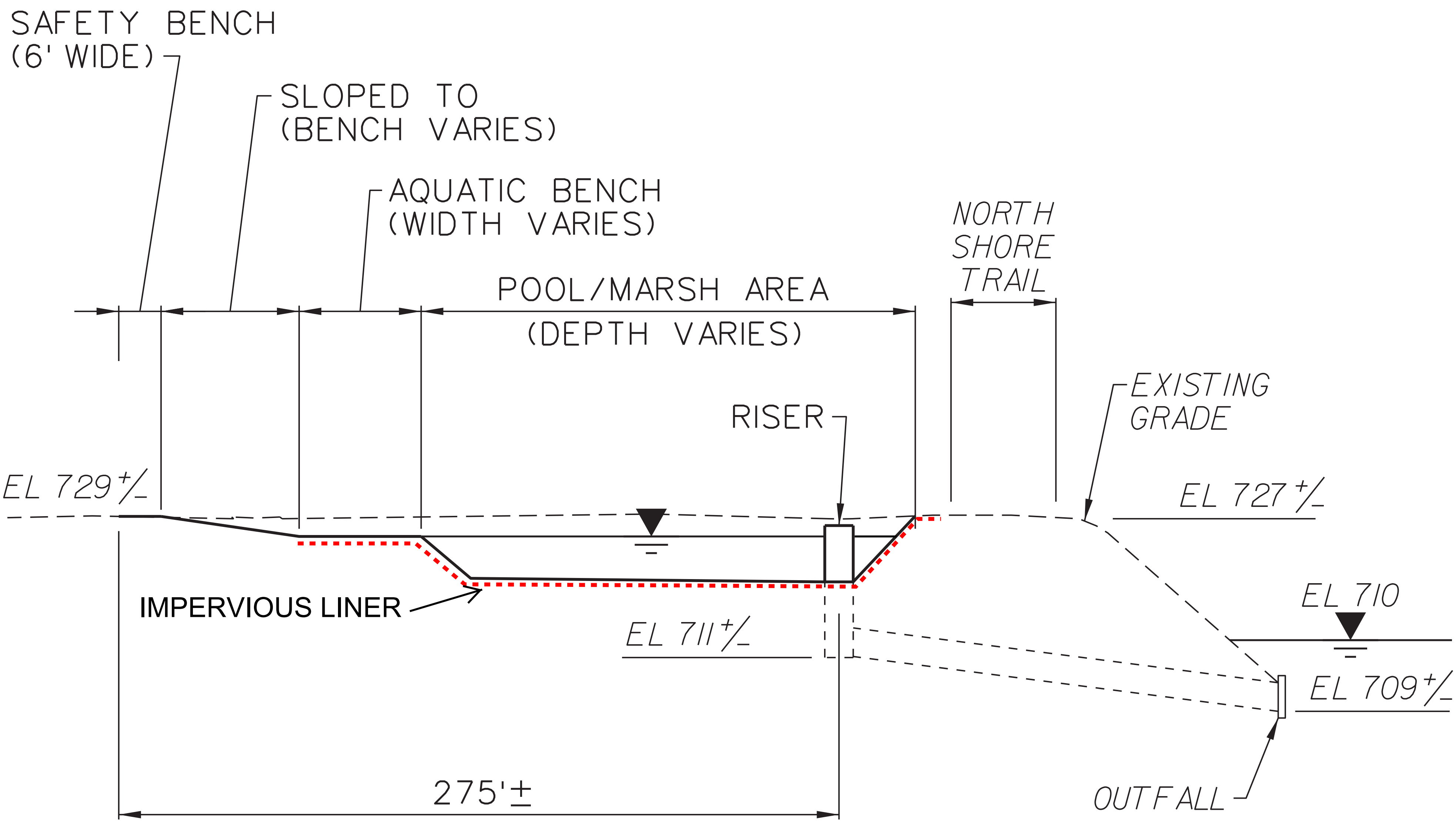

Rivers Casino Property
Wetland Boundary
Location of Proposed Constructed Wetland
Carnegie Science Center Property
North Shore Trail
Storm Drain Manhole and Pipes
Outfall
CONSTRUCTED WETLAND MEASURE
LOCATION MAP
Google earth
© 2015 Google
N
100 ft




# EXAMPLE OF CONSTRUCTED WETLAND MEASURE

## PLAN VIEW

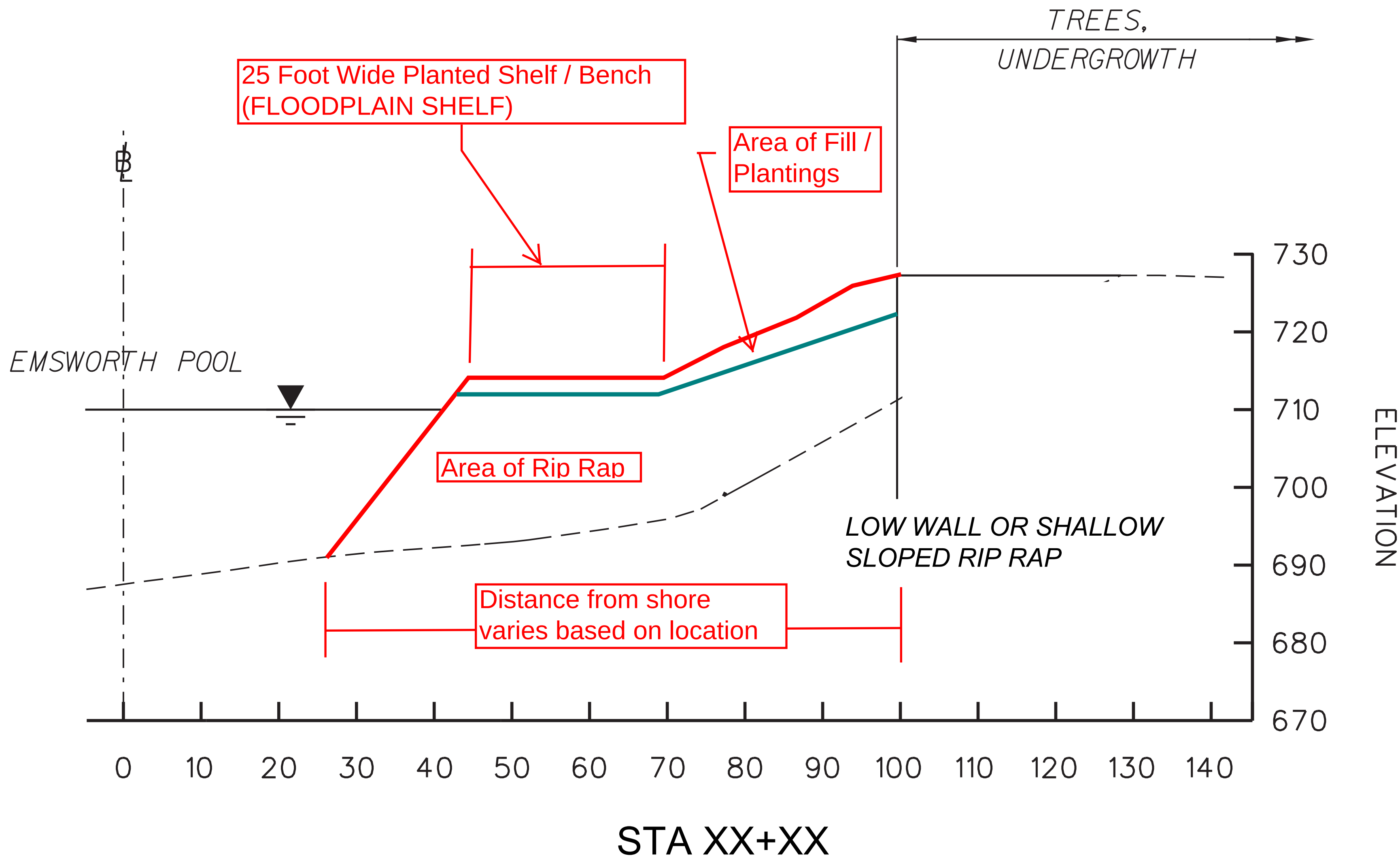
Not To Scale




**CONSTRUCTED WETLAND MEASURE**

**SECTION A-A**

**Not to Scale**

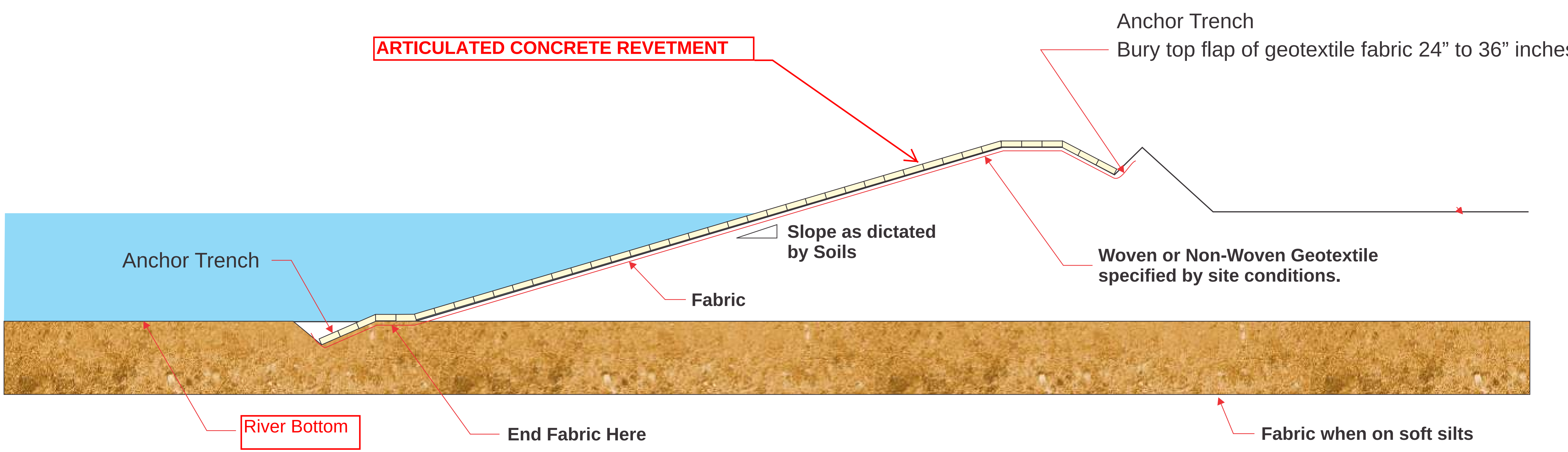



**EXAMPLE OF FLOODPLAIN**
**SHELF MEASURE**

**Section View**

**Not to Scale**

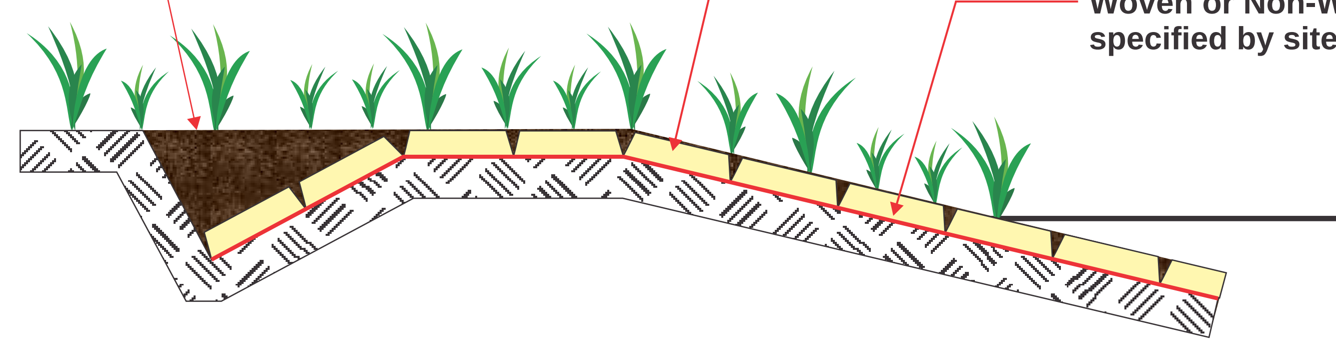
# Slope Protection | Land and Shore Erosion Control LLC.




| Client | Scale: N.T.S. | Drawing Updates | Designer | Date | Contact Information | |
|---|---|---|---|---|---|---|
| Tri-Lock Interlocking Concrete Matrix | | - | - | - | Midwest Construction Products<br>17370 Alico Center Rd.<br>Ft. Myers, FL 33967<br>Tel: (800) 532-2381 | Midwest Construction Products<br>www.midwestconstruct.com |

# Typical Tri-Lock Application

**Photo Showing Installation of Articulated Concrete Revetment**




**Articulated Concrete Revetment**

**Typical Cross Section**

**EXAMPLE OF CONCRETE REVETMENT**
**for**
**KAYAK LAUNCH FEATURE**

| Client | Scale: N.T.S. | Drawing Updates | Designer | Date | Contact Information | |
|---|---|---|---|---|---|---|
| Tri-Lock Interlocking Concrete Matrix | | - | - | - | Midwest Construction Products<br>17370 Alico Center Rd.<br>Ft. Myers, FL 33967<br>Tel: (800) 532-2381 | Midwest Construction Products<br>www.midwestconstruct.com |