APPENDIX F – STRUCTURAL

for

RIO GUAYANILLA, GUAYANILLA, PR

2018 SUPPLEMENTAL APPROPRIATIONS

FLOOD RISK MANAGEMENT STUDY

March 2020

US Army Corps of Engineers®
Chicago District

USACE. 2019. Rio Guayanilla, Guayanilla, PR Flood Risk Management Study. Draft Integrated Feasibility Report Environmental Assessment. U.S. Army Corps of Engineers, Chicago District, 231 S. LaSalle Street, Suite 1500, Chicago, Illinois 60604. June 2019.

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Attached Plates

S-101 Diversion Structure Gravity Dam Plan, Elevation, and Section
S-102 Diversion Structure Single Wall Plan, Elevation, and Section
S-103 Diversion Structure Double Wall Plan, Elevation, and Section
S-301 Typical Structural Sections and Details

Overview

1.1 Purpose

Develop a feasibility level design based on baseline concept structures developed by the PDT for determining preliminary project costs.

1.2 References

1. ACI 318-14, Building Code Requirements for Structural Concrete and Commentary.
2. EM 1110-2-2104 Strength Design for Reinforced Concrete Hydraulic Structures, 11/30/2016
3. EM 1110-2-2100 Stability Analysis of Concrete Structures, 12/1/2005
4. EM 1110-2-2007 Structural Design of Concrete Lined Flood Control Channels
5. EM 1110-2-2504 Design of Sheet Pile Walls
6. EM 1110-2-2200 Gravity Dam Design
7. EM 1110-2-6053 Earthquake Design and Evaluation of Concrete Hydraulic Structures
8. EM 1110-2-1806 Earthquake Design and Evaluation for Civil Works Projects

1.3 Structural Features

a) A Reinforced Concrete Engineered Channel
b) A Sheet Pile Flood Wall
c) A Cast-In-Place Concrete Diversion Structure with a formed opening

2.0 Feature Design Discussion

2.1 Reinforced Concrete Engineered Channel

2.1.1 General Channel Design Guidance

Per Reference (d) a paved engineered channel shall have a main channel paving thickness of 8 to 10 inches and 6 to 8 inches for the slope paving. Both paving slabs shall have one layer of reinforcement typically either #4, #5, or #6 bars with the longitudinal reinforcing located at or slightly above the center of the slab. The paving shall be continuously reinforced with no expansion joints except at the intersection of two channels, and where the paving abuts other structures. Reinforcing shall run through construction joints. The concrete strength, f'c, shall be 3000 psi at 28 days. The slope paving slabs shall be thickened at the upper ends of the slope paving to anchor the paving into the subgrade.

Drainage systems for channels formed in soil should be placed beneath paving slabs on bottoms of channels to relieve excessive hydrostatic pressures. The drainage system beneath the side slope paving typically does not need to extend higher than one-half the channel depth due to natural drawdown of the water table near a channel. A closed drainage system is the suggested drainage system for a channel as large as the required channel. This system consists of drainage blankets, collector drains, collector manholes, and outlet drains which drain into the channel. The outlet drains are provided with check valves to prevent the backflow of water from the channel into the drainage system.

2.1.2 Channel Geometry

The channel geometry is based on hydraulic analysis. The channel will be a trapezoidal channel with a flat main channel bottom. The channel will be approximately 13,000 feet long. The main channel paving will be 100 feet wide and the slope paving width will vary with the area topography to maintain a 2 to 1 side slope.

2.1.3 Current Feasibility Channel Structure.

The current feasibility channel varies slightly form the standard design guidance. All paving is assumed to be 1 foot thick and reinforced with two layers of #6 bars. The depth of the slab and the reinforcing was chosen based on the uncertainties of the channel site. A detailed site investigation during the next project phase should result in a smaller section with less reinforcing by following the design guidance in paragraph 2.1. No drainage system was assumed, but should be incorporated in the next phase.

2.2 Sheet Pile Flood Wall

2.2.1 General Sheet Pile Flood Wall Design Guidance

The sheet pile flood wall shall be designed per Reference (e) and supplemental guidance. The wall shall be checked for stability (local and global) and structural strength. The sheet pile shall have a "Z" profile. The wall shall be capped with a steel channel. In addition to a stability check the wall should be checked for seepage. If the wall's tip elevation terminates in a granular soil the length of the pile may have to be increased to reach an impervious, clay, soil layer. Also based on guidance developed after Hurricane Katrina the maximum exposed height of the wall from the ground surface to the top of the wall is limited to 10 feet.

2.2.2 Sheet Pile Flood Wall Geometry

There is approximately 650 linear feet of steel sheet pile flood wall. The average height of the walls is approximately 2.25 feet. The lowest wall height is 1.0 foot and the highest is 4.7 feet. The heights of the wall were developed through hydraulic analysis and site topography. The wall alignment was chosen to minimize the required height of the walls.

2.2.3 Current Feasibility Sheet Pile Wall

The current feasibility wall assumes a PZ27 sheet pile section 30 feet long with a steel channel cap. This design was developed earlier on in the project when the flood walls were substantially higher. By inspection this wall works for the wall geometry outlined in paragraph 2.2.2.

2.3 Concrete Diversion Structure

2.3.1 General Gravity Dam Design Guidance.

Per Reference (f) gravity dams should be founded on bedrock. This is a mass concrete structure which requires specialized concrete placement procedures. Other requirements/features:

a. Skin reinforcement will be required and will form a cage around the face of the dam. It is assumed that the steel will be #6 bars at 12 inches in both directions with 4 inches of cover. This steel will help with surface crack control.

b. The diversion opening will be reinforced and split into three 8'-0" wide bays. Without a detailed structural analysis assume #8 bars @ 6 inches longitudinally across the roof of the openings and 12 inches in the transvers direction. This is based on engineering judgment.
c. A site concrete batch plant will be required to provide the volume of concrete required during lift placement.
d. Lifts will be in 5 foot depths placed in 18 to 20 inch layers.
e. The heat generated as cement hydrates requires careful temperature control during placement of mass concrete and for several days after placement.
f. The structure width can be stepped back as more of the structure is embedded into the embankment.
g. A more detailed Structural and Geotechnical investigation and analysis will need to be performed during the development of the next phase of plans and specification development.
h. The concrete strength, f'c, shall be 3000 psi at 28 days.

2.3.2 Current Feasibility Diversion Structure

The current feasibility diversion structure, based on hydraulic and geotechnical stability analysis, is a concrete gravity dam 14 feet thick, 162 feet long and 21 feet high from the invert elevation of the diversion opening. The opening is 8 feet high by 24 feet wide and will be located at the low point of the channel. As stated above in paragraph 3.3.1 gravity dams should be founded on bedrock. However, bedrock in the area of this structure is approximately 69 feet down. Therefore the structure would end up being quite massive given the elevation of the bedrock. Since this isn't a true dam it is possible that the structure could be founded on steel piles. Based on engineering judgment the foundation should consist of 34 HP12x63 piles spaced at 10'-0" centers and 50 feet long. Also the structure will extend 2 feet below the opening invert so the total height of the structure will be 23 feet to allow proper embedment of the H-pile tops. See Plate S-101 for details.

2.3.3 Alternative Diversion Structure.

An alternative diversion structure which employs simpler construction methods, is a concrete U wall channel structure. The diversion opening will be formed by opposing 21 foot tall concrete walls 24 feet apart with a single or double constricting wall running down the from the top of the structure to 8 feet above the structural apron slab. A footing will run behind the walls and the structure will be backfilled with impervious fill. The structure will be designed per the Requirements of Reference (a) and Reference (b). The concrete strength, f'c, shall be 4000 psi at 28 days. This structure is modeled after a control structure designed and built successfully for the Little Calumet River flood control project in Indiana. See Plates S-102 & S-103 for details.

3.0 Design Recommendations

3.1 Reinforced Concrete Engineered Channel

Refine the current design by following the channel design guidance outlined in paragraph 2.1.1. Reduce the thickness of the slabs and use a single layer of reinforcement. Coordinate the drainage system design with Geotechnical. See plate S-301.

3.2 Sheet Pile Flood Wall

Based on the current wall heights the sheet pile section can be reduced from a PZ27 to PZ22. Given the low height of these walls it is likely the design embedment will hinge on seepage cutoff instead of stability. Also given the low heights it may be impossible to get design results since the analysis relies on iterations of force that ultimately end up converging but with low height walls there is generally not enough of a driving load/force on the wall to allow the iteration to converge. Geotechnical should perform a global stability check. See plate S-301.

3.3 Concrete Diversion Structure

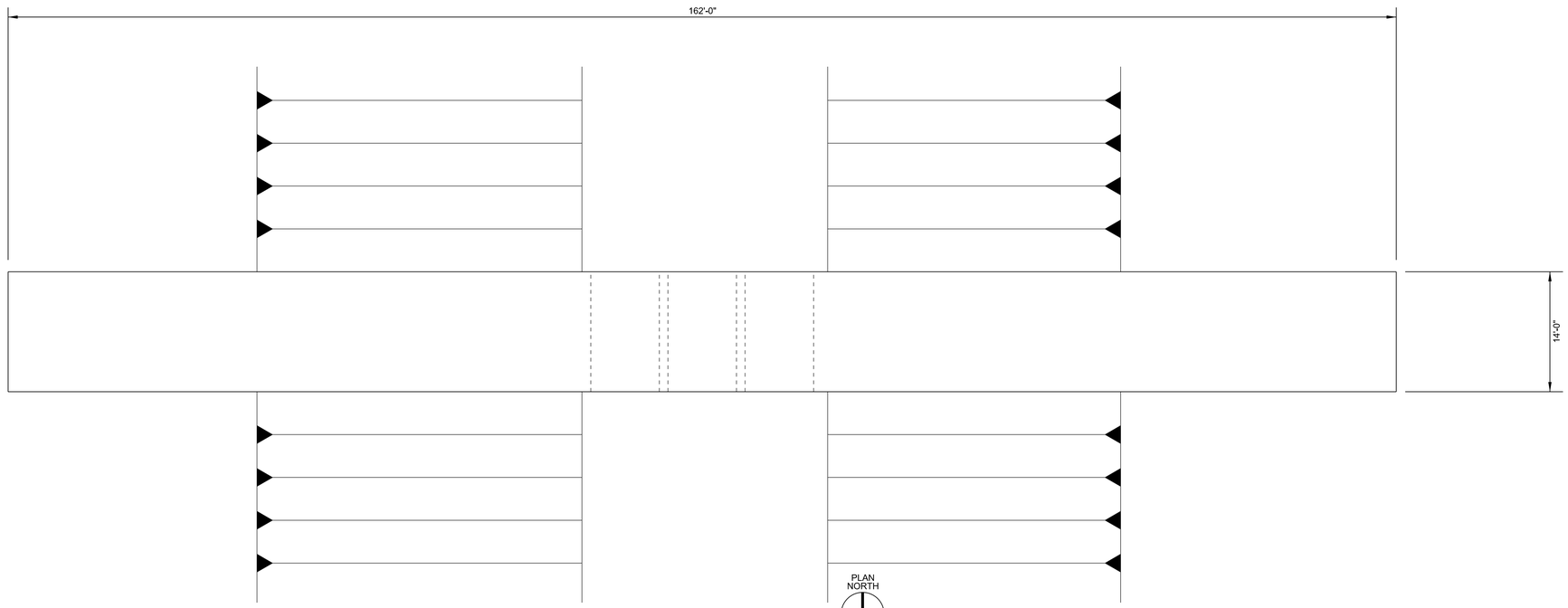
Use the alternative diversion structure layout. This foundation slab for this structure will spread the structure load out over the site and will not require steel H-Piles for support. The concrete placement for this structure will not require extensive temperature control just normal quality control procedures for concrete placement in hot weather. . See Plates S-102 & S-103 for details.

3.4 Concrete Production

It has been determined that the nearest ready mix plant is about 40 minutes away from the project site. Given the volume of concrete required for both concrete structures a site batched concrete plant should be looked into.

3.5 Earthquake Loading

Further investigation is necessary during the design phase for earthquake loading considerations. USGS Seismic Hazard map referenced in EM 1110-2-1806 shows the entire Puerto Rico Island “high” for seismic hazard. A site specific seismic analyses may be required where earthquake loading controls the design. Site specific seismic analyses must be completed in accordance to EM 1110-2-1806. Earthquake loads design requirements shall be in accordance with EM 1110-2-2104 and EM 1110-2-6053. The final results of the site specific seismic analyses must be used as the basis for making earthquake loading design decisions.



D4 PLAN
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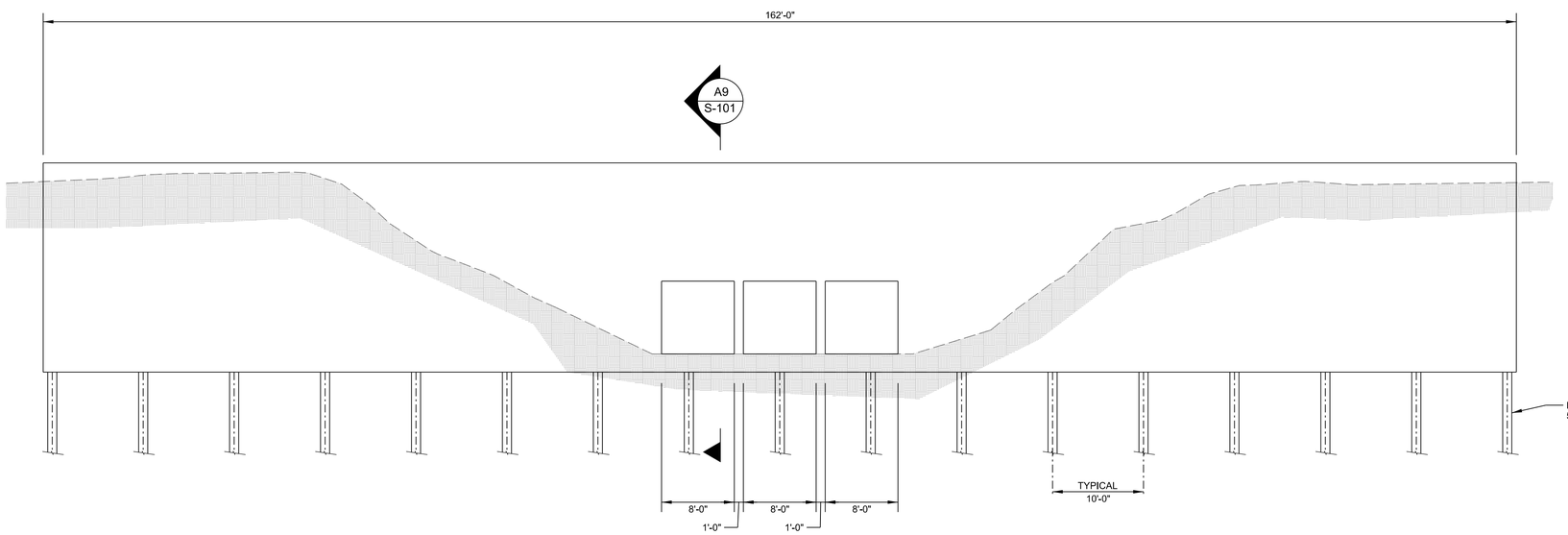

A4 ELEVATION
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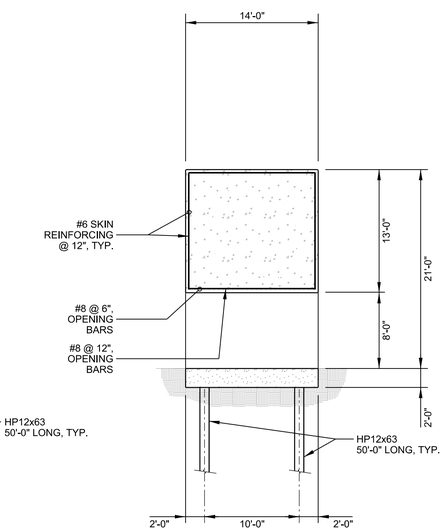

A9 SECTION
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RIO GUAYANILLA
GUAYANILLA, PUERTO RICO

DIVERSION STRUCTURE
GRAVITY DAM
PLAN, ELEVATION, AND SECTION

SHEET ID
S101

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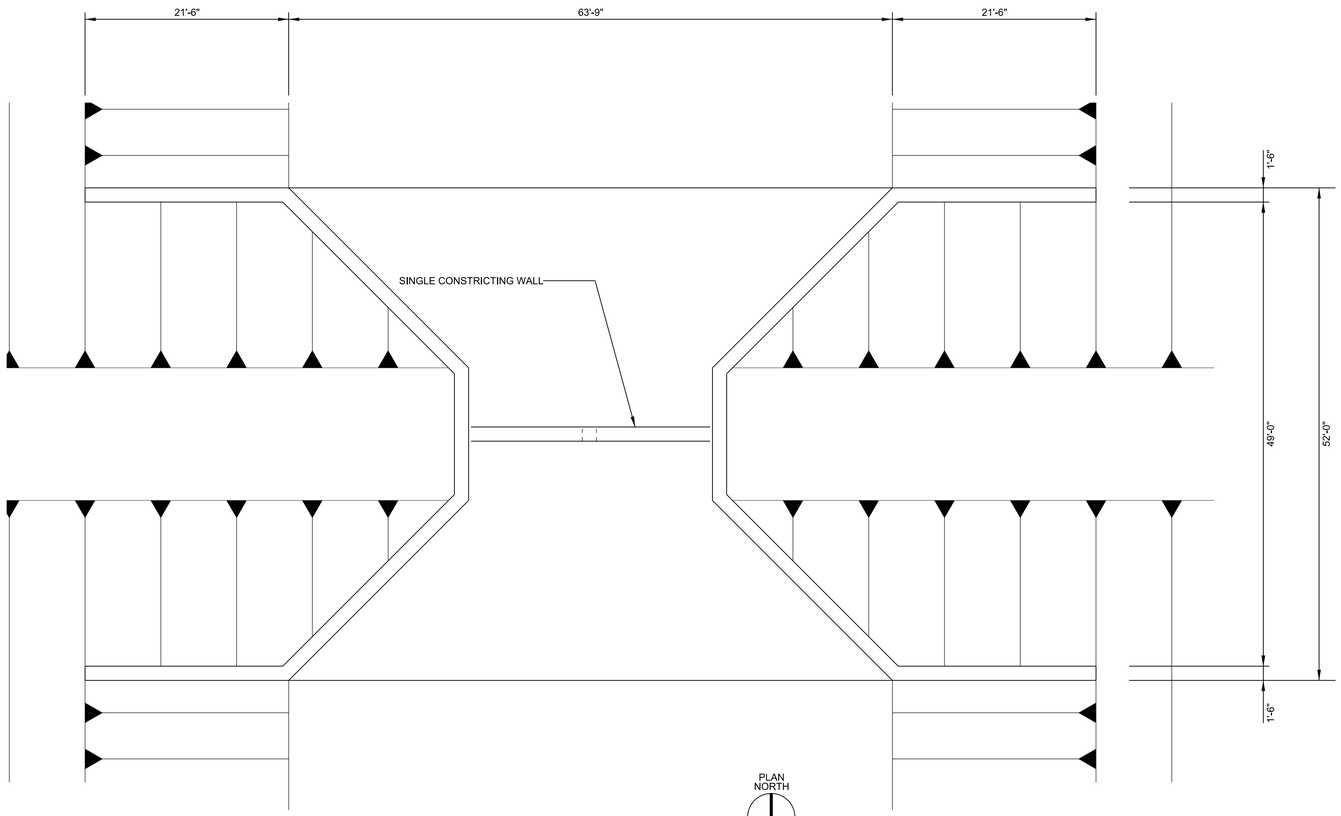

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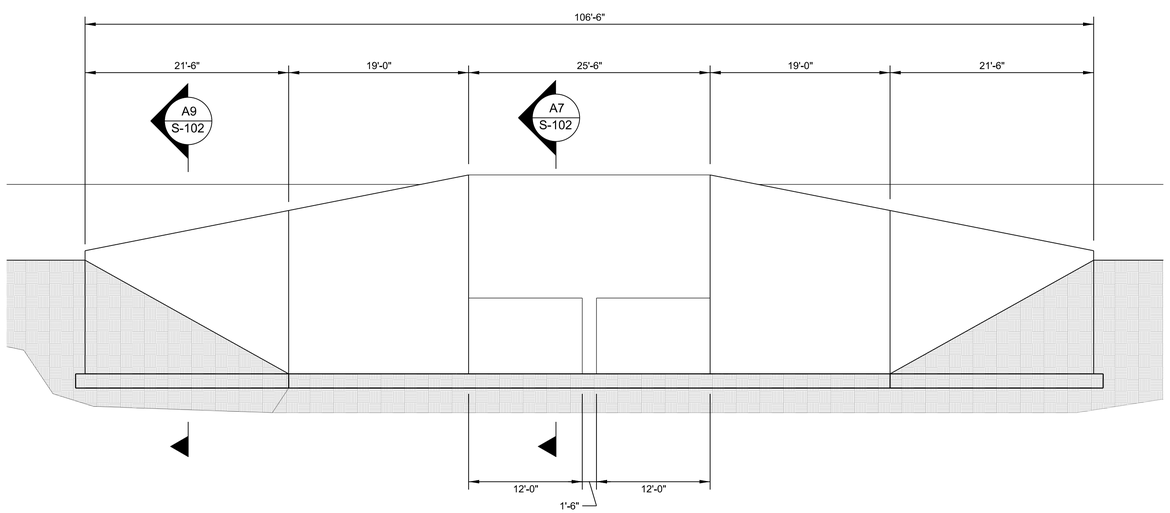

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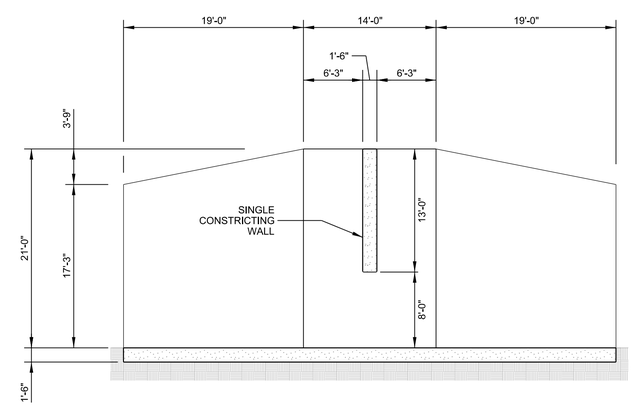

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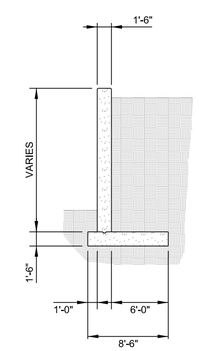

A9 SECTION
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DIVERSION STRUCTURE
SINGLE WALL
PLAN, ELEVATION, AND SECTION

SHEET ID
S102

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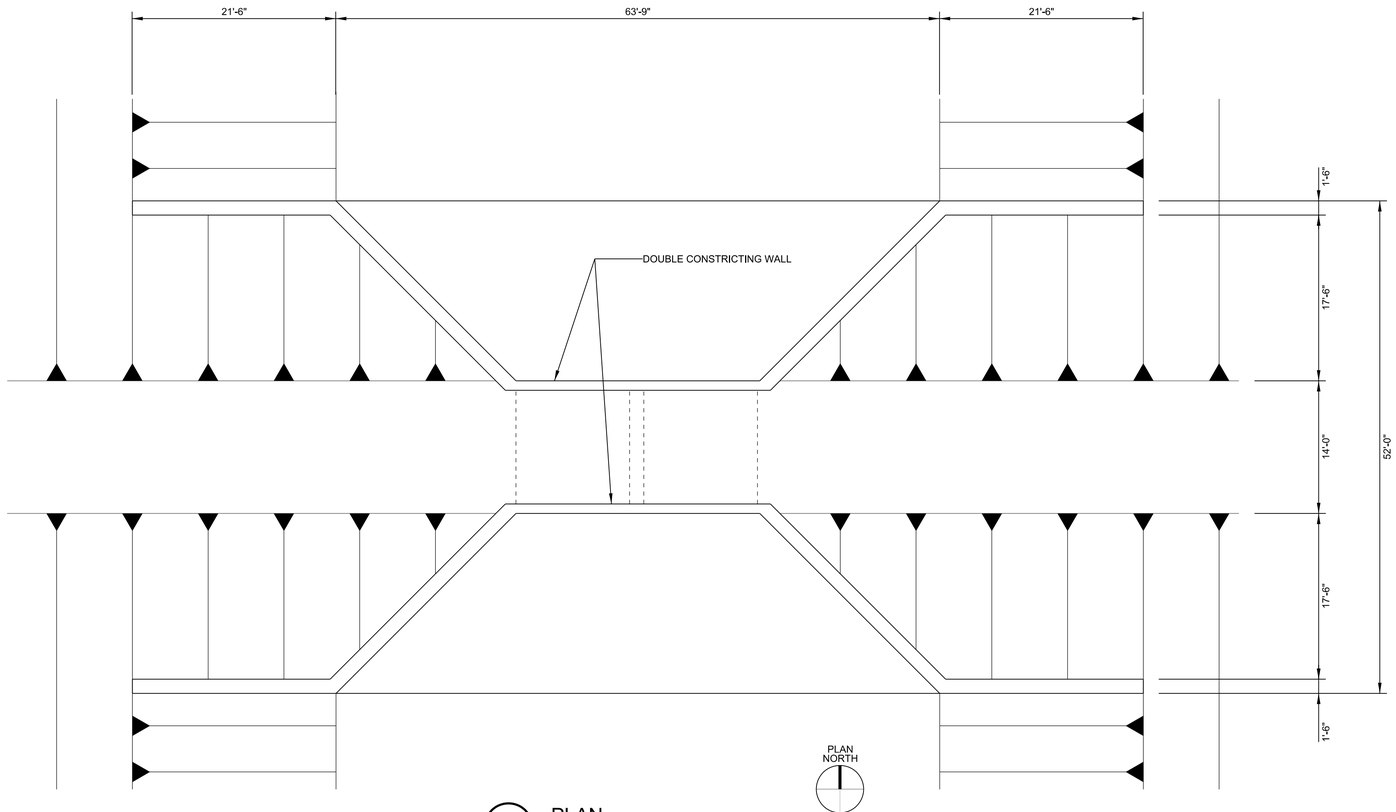

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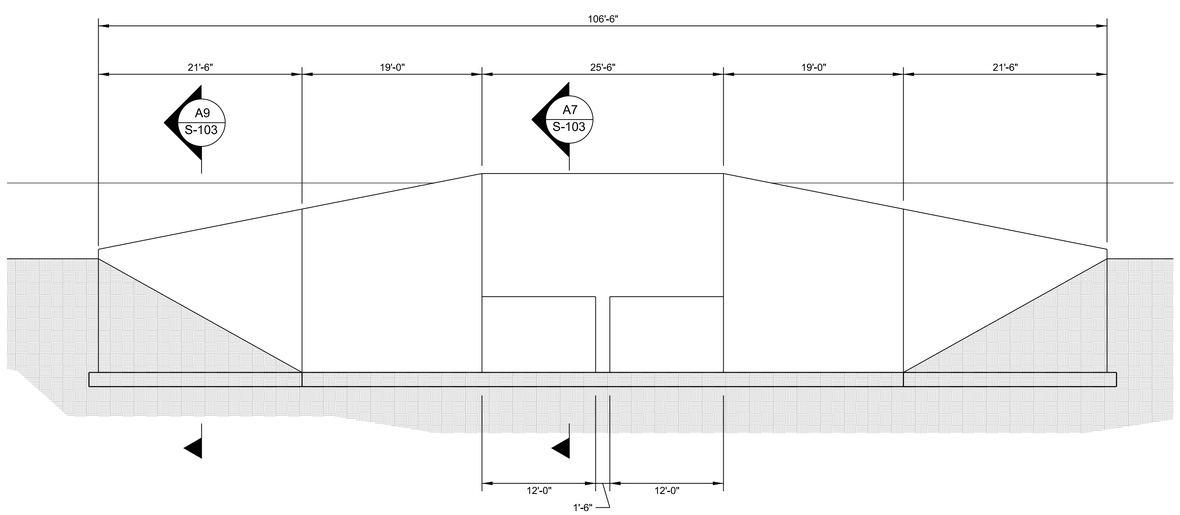

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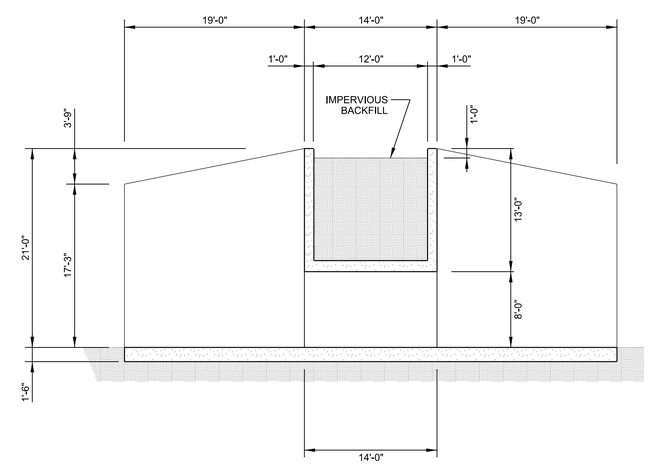

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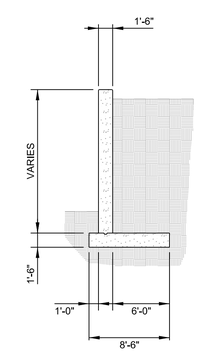

A9 SECTION
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DIVERSION STRUCTURE
DOUBLE WALL
PLAN, ELEVATION, AND SECTION

SHEET ID
S103

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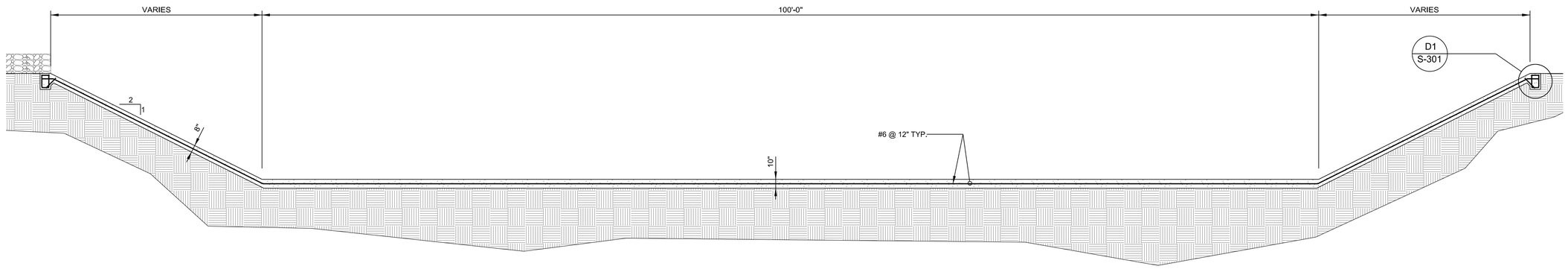

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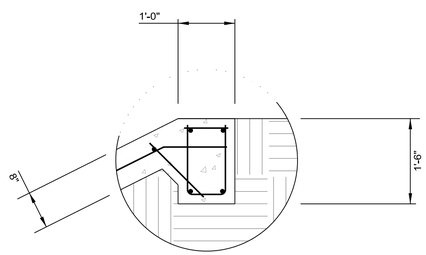

D1 TYPICAL PAVING END DETAIL
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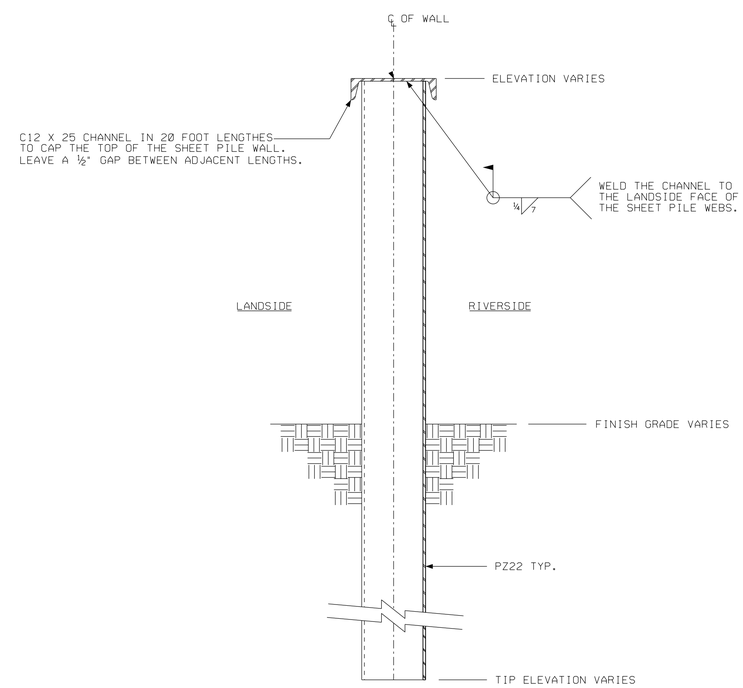

A7 STEEL SHEET PILE FLOOD WALL
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