I-405 MP 26.46 North Fork Perry Creek

(WDFW ID 08.0070 A 0.25):

Final Hydraulic Design Report – NDC 152

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0 Revision Log

Revision		Description
A	4/5/2024	Preliminary Submittal
B	8/25/2024	Final Submittal
0	4/9/2025	RFC Submittal
1	5/1/2026	NDC 152

1 Introduction

This notice of design change (NDC) modifies the I-405 MP 26.46 North Fork Perry Creek Final Hydraulic Design Report (FHD). It presents updated bed material gradations and updated scour analyses associated with this change. This report addendum supersedes and replaces the following tables, sections, and figures as specified below.

- Section 4.1.1 Channel Planform and Shape
  - Removed reference to previous Type I Streambed Material in text
  - Updated Figure 4-2 and Figure 4-3
- Section 4.2 Minimum Hydraulic Opening
  - Updated Figure 4-4
- Section 4.3.1 Bed Material
  - Updated discussion of streambed material gradations
  - Updated Table 4-1 and Table 4-2
  - Table 4-7 deleted
  - Subsection 4.3.1.1 retitled to Stability Analysis of Streambed Material and includes revised text
- Section 4.3.2 Channel Complexity
  - Subsection 4.3.2.3 on meander bars revised to remove reference to previous Type II Streambed Material and discuss meander bar material gradation
  - Added Table 4-4 and Table 4-5
- Section 7.2 Long-term Degradation of the Channel Bed
  - Updated armoring depth
  - Removed equilibrium slope discussion
  - Figure 7-2 deleted
- Section 7.3 Local Scour
  - Subsection 7.3.2 updated abutment scour values
- Section 7.4 Total Scour
  - Updated total scour values in text
  - Updated Table 7-1
- Section 9 Summary
  - Updated Table 9-1 potential channel degradation value
- Appendix C replaced in entirety
- Appendix D replaced in entirety
- Appendix K.a provides updated long-term degradation armor depth analysis and SRH-2D bridge scour analysis for contraction and abutment scour

Refer to revision 0 of the full FHD report for sections or references not included in this addendum.

4 Water Crossing Design

4.1 Channel Design

4.1.1 Channel Planform and Shape

The WCDG requires that the channel planform and shape mimic conditions within a reference reach. A reference reach could not be located for this project, as discussed in **Section 2.7.1**. The existing channel characteristics were determined through field survey. Outside of the influence of the existing crossings, the channel is generally uniform and straight, with pool-riffle morphology. The lack of sinuosity can be attributed to constraints imposed by the channel's proximity to urban development. The thalweg cross slopes were measured at approximately 10H:1V, with channel bank slopes rising to the BFW at approximately 1:1, both of which were used as a starting point to inform the typical riffle and pool design. **Figure 4-1** depicts the proposed channel geometry superimposed with typical existing conditions cross sections taken upstream of the I-405 crossing. These typical existing cross sections at stations (STAs) 20+60, 21+04, 21+75, 22+19, and 22+66 were taken in the region where bankfull width measurements were taken. In general, the proposed channel geometry matches the existing geometry. Aerial imagery and LiDAR were used to assess existing channel sinuosity in adjacent reaches, and this assessment was used to develop the proposed channel meandering planform. The meander belt width of the stream upstream of the crossing was measured at 30 feet.

Proposed cross slopes in riffles are 8H:1V to promote fish passage in low flows. Per stability recommendation from the geotechnical engineer, proposed riffle cross sections have 2H:1V bank slopes rising to the BFW of 11.2 feet (**Figure 4-2**).

The proposed typical pool section (**Figure 4-3**) has a wider BFW of 16.2 feet, necessary to achieve an acceptable residual pool depth of 1.5 feet and to accommodate the maximum 2H:1V bank slopes. Typical pools are pre-scoured and considered starter pools. They are expected to scour more over time as indicated by bend scour calculations in **Section 7.4.3**. Typical pool sections also include a 10H:1V bench on the inside of meander bends to mimic the formation of point bars (Cramer 2012).

The average meander spacing is approximately four times the BFW, which is consistent with project technical requirements.

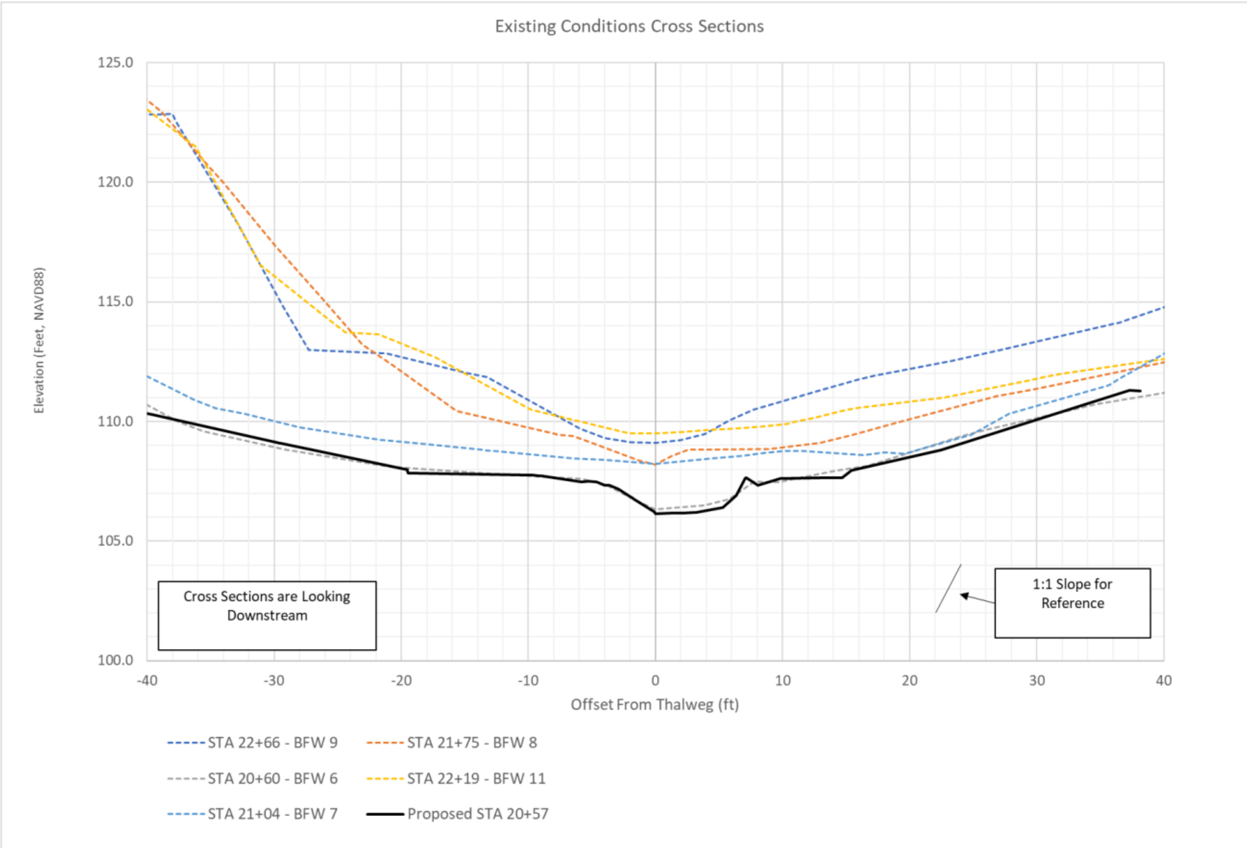

Figure 4-1: Proposed cross section superimposed with existing survey cross sections

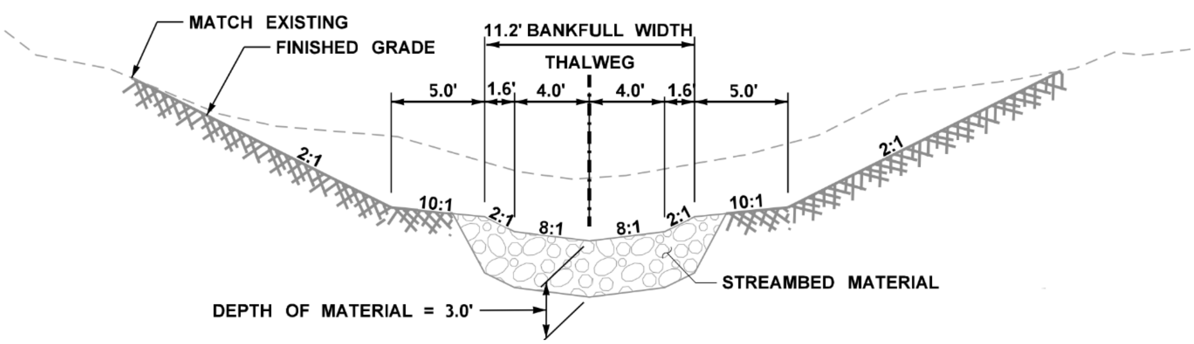

Figure 4-2: Design riffle cross section

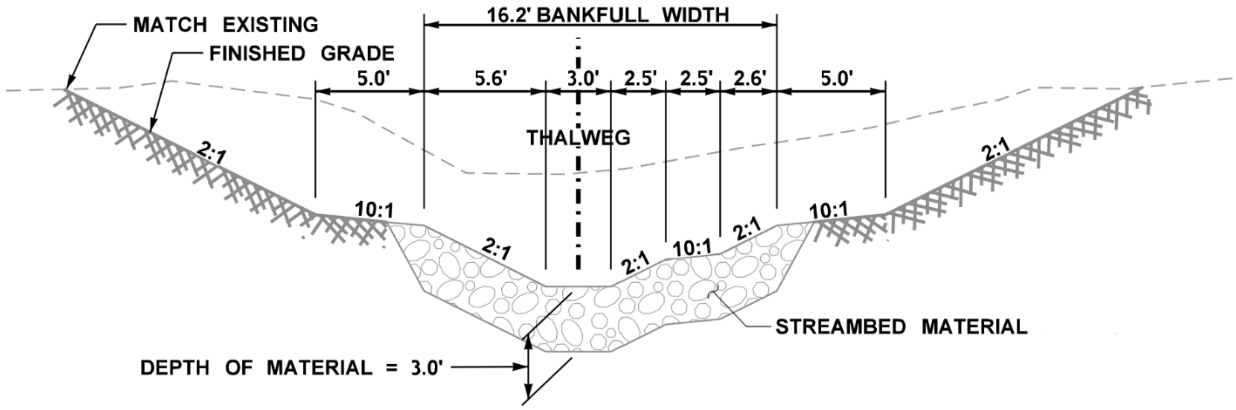

Figure 4-3: Design pool cross section

4.2 Minimum Hydraulic Opening

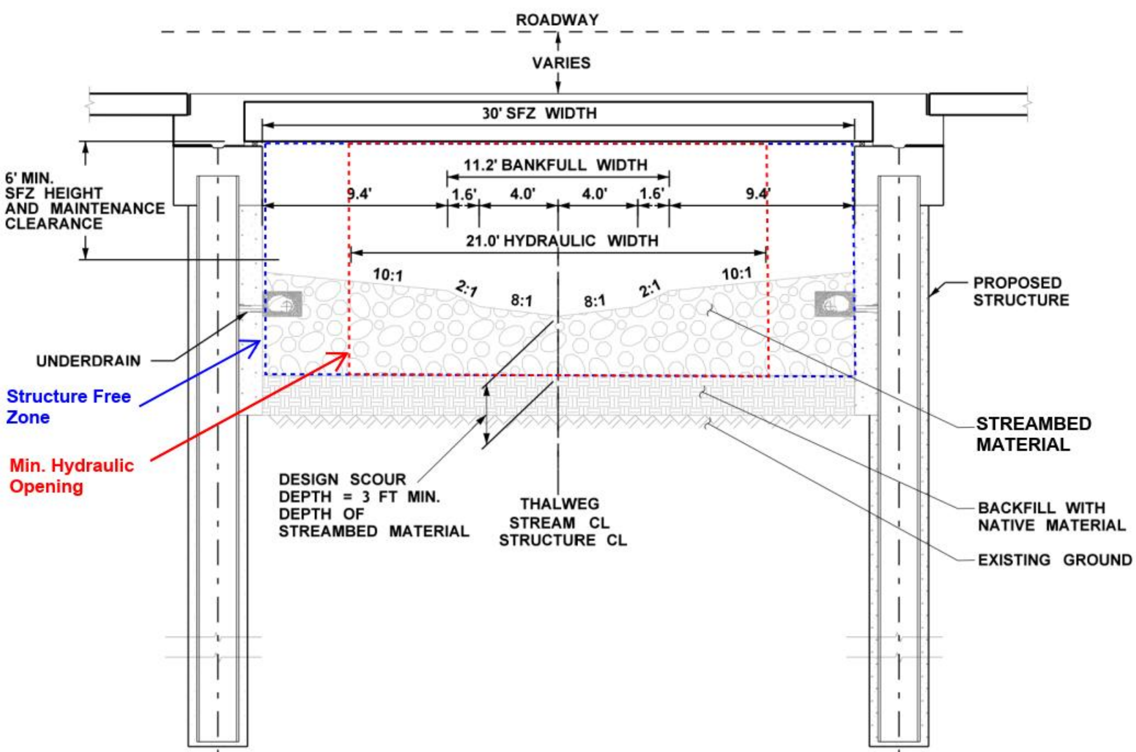

Figure 4-4: Minimum hydraulic opening illustration

4.3 Streambed Design

This section describes the streambed design developed for North Fork Perry Creek at I-405 MP 26.46.

4.3.1 Bed Material

Per contract technical requirements and stream simulation design methodology (see **Section 4.2.1**), the existing streambed material size is used to develop the proposed streambed material size. **Table 4-1** compares existing and proposed streambed material gradations. Existing streambed material was characterized by pebble counts conducted in the design reference reach (see **Section 2.7.1** and **2.7.3**). Proposed streambed material is 20% larger than existing pebble count data to provide additional streambed stability. The WSDOT standard streambed aggregate types from the Project Technical Requirements and standard specifications (WSDOT 2022b) and proportions needed to create a 10-part mix of the streambed material are listed in

Table 4-2**.**

Table 4-1: Comparison of observed and proposed streambed material gradations

Sediment Size	Existing streambed sediment diameter (inches)	Proposed streambed sediment diameter (inches)
D_{16}	0.3	0.4
D_{50}	0.7	0.8
D_{84}	1.4	1.7
D_{95}	1.8	2.2

Table 4-2: WSDOT standard specification stream aggregate mix for proposed streambed material

Aggregate Type	Parts Needed
Streambed sediment, 9-03.11(1)[a]	9
Streambed cobbles 4 inch, 9-03.11(2)[b]	1

[a]Source: Project Technical Requirements section 2.30.5.3.1
[b]Source: (WSDOT 2022b)

4.3.1.1 Stability Analysis of Streambed Material

Consistent with engineering best practices, the Hydraulics Manual (WSDOT 2022), and the Water Crossing Design Guidelines (Barnard et al. 2013), stability of the proposed bed material has been investigated. The analysis indicates that the D_{84} of the proposed streambed material is mobile at the 100-year discharge, and according to the Hydraulics Manual the system is not considered stable (see **Appendix C**).

Although sediment mobility is expected and encouraged in the crossing to mimic natural geomorphic processes, risks associated with the excessive mobility of undersized sediment should be considered. Additionally, because this crossing is considered a long culvert (see **Section 4.2.2**), and "relatively little is known about the design and performance of long stream simulation culverts" (Barnard et al. 2013), special consideration should be given to the proposed design. For example, a significant portion of the long crossing will be permanently shaded and unable to support vegetation. Without vegetation, proposed streambanks will be inherently less resistant to erosive forces than vegetated banks in the design reference reach. A risk assessment regarding mobility of streambed material is presented in **Appendix Q**. Due to the risks associated with excessive mobility of undersized sediment described in the risk assessment, the following alternatives were identified and evaluated (sorted coarsest-to-finest by bed material):

- Alternative 1: Design a roughened channel with streambed material and configuration designed to be non-deformable up to the design discharge.
- Alternative 2: Design an overcoarsened channel with D_{84} sized to be stable at the 100-year flow with channel-spanning non-deformable boulder grade controls.
- Alternative 3: Design an overcoarsened channel with D_{84} sized to be stable at the 100-year flow, channel complexity features, and a deformable bedform.
- Alternative 4: Design a channel with streambed material size within 20 percent of the existing pebble-count size, and channel complexity features.

Alternative 1 was determined to have unacceptable impacts on fish life and habitat. Large immobile material can create steep drops and form fish passage barriers. Additionally, oversized material increases void space, which can cause water to infiltrate and flow sub-surface, potentially stranding fish during low-flow periods. Roughened channels also inhibit geomorphic processes and do not meet the criteria or intent of stream-simulation design. Therefore, Alternative 1 is disregarded.

Alternative 2 would reduce the risk of undersized sediment mobility, but it would also potentially increase the risk of a fish barrier forming in the vicinity of the channel-spanning boulder grade controls. Additionally, grade separation and vertical channel stability are not identified as constraints that would require non-deformable grade control features. Therefore, Alternative 2 is disregarded.

Alternative 3 was determined to be an acceptable alternative because it reduces the risk of undersized sediment mobilization to channel banks and infrastructure, while allowing the creek to naturally respond to geomorphic processes due to the absence of rigid boulder grade controls. Habitat complexity features such as woody material, meander bars, and deformable grade control will also provide added channel stability and hydraulic diversity that will improve instream habitat for fish.

Alternative 4 was also determined to be an acceptable alternative and is consistent with the contract technical specifications.

To further assess Alternative 3 and Alternative 4, the mobility of streambed material gradations were compared at the 2-year and 25-year flows using the Modified Critical Shear Stress methodology. **Table 4-3** shows the percent of each gradation that is fine enough to be mobilized via particle entrainment.

Table 4-3: Percent of streambed material gradation susceptible to particle entrainment

Bed Material	2-year	25-year
Alternative 3: D_{84} sized for stability at 100-year flow	20.0	44.0
Alternative 4: within 20% of existing size	100.0	100.0

Both Alternative 3 and Alternative 4 present designs that are consistent with stream simulation design and allow the channel to naturally regrade. Given the mobility analysis (**Table 4-3**) and the special considerations for long culverts in the design guidance, AECOM recommends Alternative 3 for the proposed crossing. However, through coordination with WDFW and WSDOT HQ Hydraulics, it has been determined that no significant constraints exist to justify an overcoarsened channel (Alternative 3). Because the risks described in **Appendix Q** are considered acceptable to the Project's co-managers, Alternative 4 is selected for this crossing. Alternative 4 is consistent with the streambed material presented above in **Section 4.3.1**.

4.3.2 Channel Complexity

4.3.2.3 Meander Bars

Channel meandering in the proposed structure will be maintained through construction of meander bars that will enhance the instream channel diversity and encourage the stream to maintain this habitat over its design life. Meander bar spacing is designed to mimic the spacing of existing meanders in the adjacent reaches and is approximately four times the BFW. Six meander bars will be constructed in an alternating pattern on left and right banks and will protrude into the low-flow channel to encourage meandering of the channel in low-flow conditions. These meander bars will only be constructed in the crossing structure.

To maintain channel shape, the apex of the meander bar height is set to the 10-year flow depth at the structure wall and the 2-year flow depth at the nose of the bar head, closest to the thalweg. Meander bars extend subgrade to the total scour depth and occupy a substantial portion of the cross-sectional area of the channel. Meander bars do not constrict the channel width to less than the BFW.

The proposed meander bar composition follows WSDOT design guidance for three components: (1) structure head; (2) structure tail; and (3) other considerations, such as small wood material or slash placed in front of structure head rocks to encourage racking and add additional habitat complexity.

The largest fraction of meander bar material (D_{84} – D_{100}) is designed for stability at the design flood (100-year), as calculated by the Modified Critical Shear Stress methodology. The remaining meander bar gradation is designed to minimize sub-surface flow by having a well graded mix using gradation ratios found in natural streambed distributions (Barnard et al, 2013). Additionally, the proposed meander bar tail gradation is designed such that at least seventy percent by volume of the material in the tail of the structure will be larger than the D_{95} of the observed streambed material. **Table 4-4** summarizes the proposed meander bar material gradation.

A mixture of WSDOT standard streambed aggregates from the Project Technical Requirements and the WSDOT standard specifications (WSDOT 2022b) will be used to create the meander bars. The WSDOT streambed aggregate type and proportions needed to create a 10-part mix of meander bar material are listed in **Table 4-5**. The design of meander bar material gradation can be found in **Appendix C**.

Table 4-4: Proposed meander bar material gradation

Sediment Size	Meander bar material diameter (inches)
D_{16}	1.7
D_{50}	5.4
D_{84}	13.4
D_{100}	23.0

Table 4-5: WSDOT standard specification streambed aggregate mixture for meander bar material gradation

WSDOT Standard Specification Streambed Aggregate Type	Parts Needed
Streambed sediment, 9-03.11(1)[a]	3
Streambed cobbles 12 inch, 9.03.11(2)[b]	5
Type One streambed boulders, 9-03.11(3)[b]	1
Type Two streambed boulders, 9-03.11(3)[b]	1

Notes: WSDOT = Washington State Department of Transportation

[a] Source: Project technical requirement 2.30.5.3.1

[b] Source: WSDOT 2022b

The D_{100} of the proposed meander bar material gradation (**Table 4-4**) specifies the boulder size to construct the framework of the meander bar head, which are Type Two streambed boulders. The meander bar tails consists of the rest of the meander bar material gradation, which are the Type One streambed boulders and finer sediment. Slash will be incorporated in the meander bar head to increase habitat complexity. The slash will be interwoven between the meander bar head boulders and wrap around the stream channel side of the meander bar head. Meander bar material sizing calculations are included in **Appendix C**. Refer to plans in **Appendix D** for further details on the meander bar shape.

7 Final Scour Analysis

7.2 Long-term Degradation of the Channel Bed

For North Fork Perry Creek, the design allows for the channel to naturally regrade, which could come in the form of long-term degradation. Long-term degradation of the channel bed was evaluated using an armor layer analysis.

Geotechnical borings as described in **Section 7.1**, have identified a soil layer – ESU 6B – that includes cohesive materials. It likely provides more resistance to erosion than the overlying soils that mostly consist of sand, gravel, and silt. The ESU 6B consists of transitional beds (Q_{tb}) and are significantly denser than other layers and exhibited spoon refusals during explorations. This ESU is made of very stiff to hard silt and clay with some interbedded granular material. Specifically at boring NE-45-19, this ESU has a layer near an elevation of 84 feet that is identified as silty clay with sand and is described as very hard, gray, dry, and homogeneous. **Figure 7-1** shows the subsurface profile and the variation in depth of the harder ESU 6B. This layer may slow incision if it occurs, but the variation in composition and spatial extents do not support a definitive vertical limit to channel degradation over the length of the structure or outside of its extents.

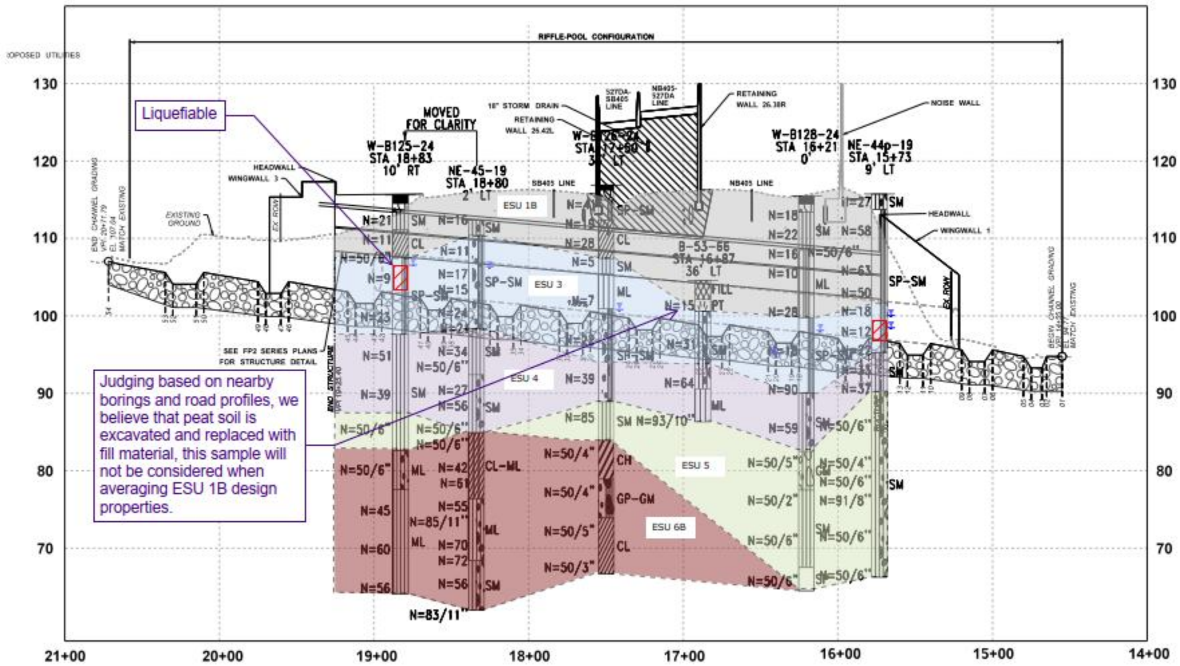

Figure 7-1: Geotechnical subsurface profile

However, in situations where the streambed material contains a sufficient quantity (>10 percent) of coarse material that is not transported by normal discharge, the best approach to compute depth of degradation is to consider the development of an armor layer (Pemberton and Lara 1984), where finer material is mobilized and transported downstream, while the remaining material inhibits vertical degradation of the streambed.

Following the procedures presented in *Hydraulic Engineering Circular No. 20 – Stream Stability at Highway Structures* (HEC-20) (Lagasse et al. 2012) and the source material (Pemberton and Lara 1984), the long-term degradation for North Fork Perry Creek was estimated using an armor layer analysis under bankfull conditions. As described in **Appendix K**, an armor layer would form in North Fork Perry Creek after 0.8 feet of degradation. This layer would likely arrest any further degradation of the streambed. Therefore, 0.8 feet is selected as the long-term degradation component of total scour.

7.3 Local Scour

7.3.2 Abutment Scour

Abutment scour was estimated using the National Cooperative Highway Research Program 24-20 approach for all flood events up to the scour design flood and scour check flood using a clear-water condition. In the FHWA Hydraulic Toolbox, a vertical wall abutment with wing walls was assumed as the abutment type (**Appendix K**). Abutment scour equations estimate 0.3 feet of scour at the scour design flood and 0.6 feet of scour at the scour check flood.

The NCHRP 24-20 method jointly evaluates contraction scour and abutment scour by applying an amplification factor to contraction scour. As outlined in HEC-18, these results (separate from those found in **Section 7.3**) represent total scour at the abutment and would not be added to contraction scour if the calculation in **Section 7.3** resulted in positive scour depths (Arneson et al. 2012).

7.4 Total Scour

For North Fork Perry Creek, there are four components of total scour: long-term degradation, contraction scour, and local scour in the form of abutment scour and bend scour.

This total scour estimate represents a conservative estimate of potential scour that could occur within the lifespan of the structure, which assumes the following scour components are additive: bend scour, long-term degradation, contraction scour, and abutment scour. Contraction was calculated to be zero. Long-term degradation, abutment scour, and bend scour are the primary components of total scour. Estimated total scour at North Fork Perry Creek is 1.4 feet for the scour design flood and 1.7 feet for the scour check flood. Further details about these calculations can be found in **Appendix K.a**.

Because the WSDOT *Hydraulics Manual* defines a minimum total scour depth of 3.0 feet, this is considered the total design scour for North Fork Perry Creek. This 3.0-foot depth is applied below the channel thalweg and horizontally to the structure walls due to the risk of lateral migration of the main channel over the lifespan of the crossing structure. As noted in **Section 7.1**, geotechnical data near the proposed structure illustrates that the material outside of the stream channel is erodible and there are not any non-erodible features present to limit the lateral migration of the channel.

Calculated total depths of scour for the scour design flood and scour check flood at the proposed North Fork Perry Creek crossing are summarized in **Table 7-1**.

Table 7-1: Calculated scour components and total scour for I-405 North Fork Perry Creek

Scour components and total scour for I-405 at North Fork Perry Creek		
Long-term degradation (feet)	0.8	
Bend scour (feet)	0.3	
	Scour design flood (2080 100-year)	**Scour check flood (500-year)**
Contraction scour (feet)	0.0	0.0
Local abutment scour (feet)	0.3	0.6
Total scour (feet)	1.4	1.7
Minimum total scour per *Hydraulics Manual*	**3.0**	**3.0**

9 Summary

Table 9-1 presents a summary of the results of this Final Hydraulic Design Report.

Table 9-1: Report summary

Stream crossing category	Element	Value	Report location
Channel degradation	Potential	0.8 feet	7.2 Long-term Degradation of the Channel Bed

Appendices

Appendix C: Streambed Material Sizing Calculations

Appendix D: Stream Plan Sheets, Profile, Details

Appendix K.a: Scour Calculations