WSDOT
Scour Workshop

Module 10
Scour Countermeasures

June 1st, 2023

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State Hydraulic Engineer

HQ Development Division
WSDOT

Current Duties

- Hydraulics Section
- Hydrology Section
- Stormwater Section
- Fish Passage Section

Background and Experience

- 22 years at WSDOT
- Construction Management
- Transportation Engineer
- Hydraulics Engineer

Education

- B.S. Civil Engineering (WSU)

Personal Interests

- 2 teenagers
- 1 college kid
- Lots of House Projects
- Large extended family

Casey Kramer

Principal River Engineer

Natural Waters, LLC

Current Duties

- Owner of Natural Waters, LLC
- WSDOT HQ staff augmentation team assisting State Hydraulics Engineer

Background and Experience

- Previous WSDOT State Hydraulic Engineer
- Private sector hydraulics and river engineering consultant
- Research River Engineer

Education

- B.S. Civil Engineering (Washington State University)
- M.S. River Engineering (University of Iowa – Iowa Institute of Hydraulic Research)

Personal Interests

- Spending time with family
- Rivers
- Dirt biking, Fishing, Camping, and Coaching/Watching Sports

Scour Countermeasures Overview

- Scour countermeasure minimum requirements
- Right of way coordination
- Provide summary for use of scour countermeasures
- Importance of properly designed and constructed scour countermeasures
- Scour countermeasure design requirements
- Scour countermeasure specifications
- Scour countermeasure examples
- Scour countermeasure minimum requirements
- Importance of inspection

Image Source: Casey Kramer

Scour Countermeasure Minimum Requirements

- WSDOT H_HD Template (May 2022)
  - ***PHD to document preliminary type*** *(preliminary typical section using estimated scour determined in Section 7.5 (Section 7-4.11 in WSDOT HM) and WSEs determined in Section 5.4 (Section 4-6.2.2 in WSDOT HM))* ***and extents*** *(plan view of preliminary extents upstream and downstream of crossing; and vertically from the estimated depths of scour at the scour check flood, to 1 foot above the 100-year WSE)* ***for proposed scour countermeasures to facilitate discussion if additional TCE, ROW, SFZ, etc. limits are required.***

  - *FHD to* ***document details on the countermeasure design*** *(final typical section using scour determined in Section 7.5 (Section 7-4.11 in WSDOT HM) and WSEs determined in Section 5.4 (Section 4-6.2.2 in WSDOT HM)),* ***sizing and extents*** *(plan view of final extents upstream and downstream of crossing; and vertically from the depths of scour at the scour check flood to 1 foot above the 100-year WSE). Section should also* ***document design analysis****.*

Right of Way Coordination

- Early coordination with WSDOT is critical to identify if various design elements or scour countermeasures may need additional right of way
- Assessment of potential scour countermeasure extents in relation to right of way is a critical aspect during the PHD

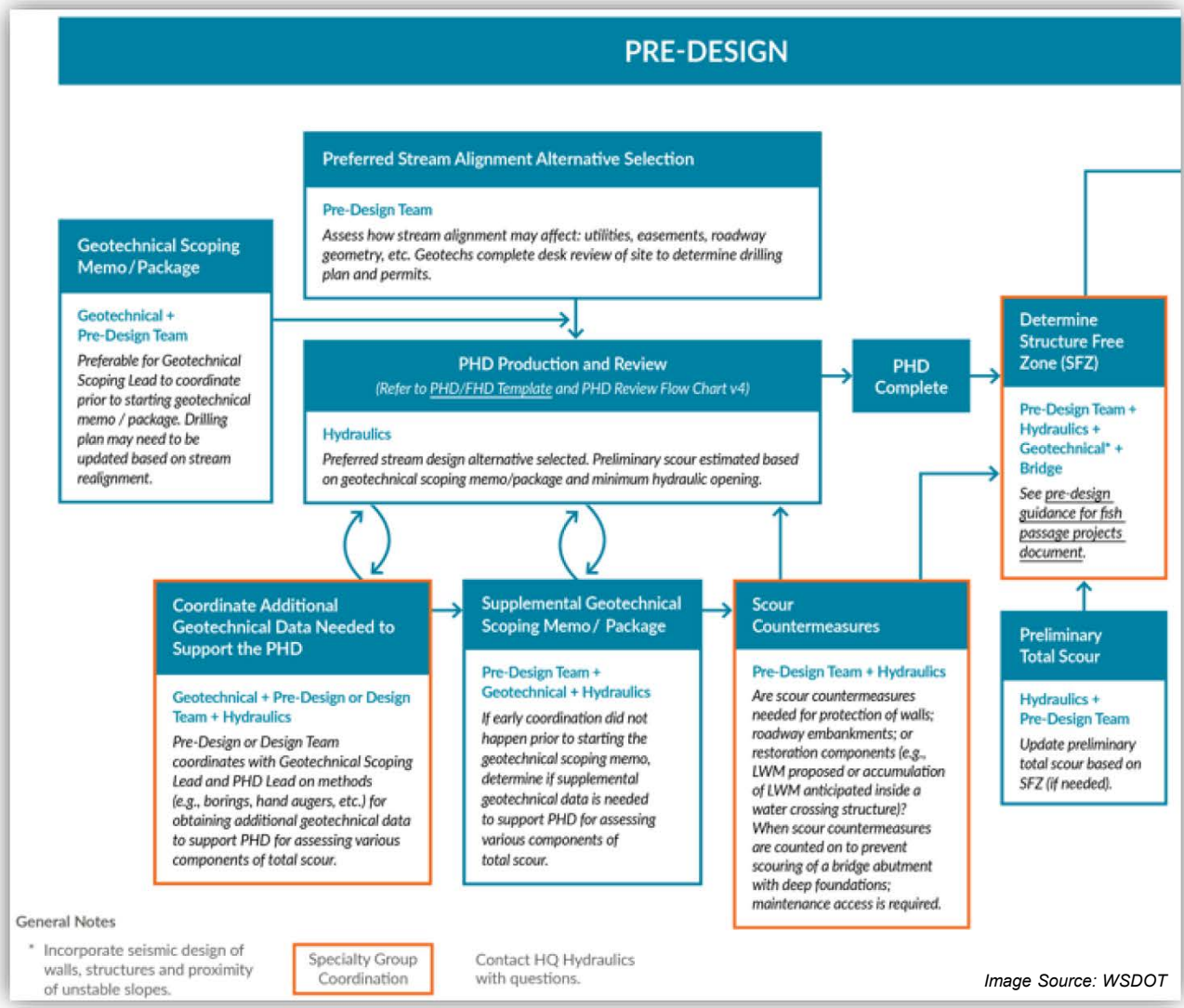


Image Source: WSDOT

Use of Scour Countermeasures

1. **Protection of existing structures**

Image Source: Casey Kramer

Use of Scour Countermeasures

2. **Protection of roadway embankments, walls or other infrastructure components**

Image Source: Casey Kramer

Use of Scour Countermeasures

3. **Large woody material or large complexity features**
   - When key pieces of LWM are placed or are material is anticipated to accumulate within water crossing

Image Source: Casey Kramer

Use of Scour Countermeasures

4. **Deep Foundations (e.g., piles and drilled shafts)**
   - Some locations based on soils and stream/bank stability may rely on scour countermeasures
   - Communication and early coordination shall happen between project, hydraulics, geotechnical and structures offices to determine scour elevations at each water crossing element
   - If used, maintenance access and clearance under a structure is required (Roadside Manual 830)

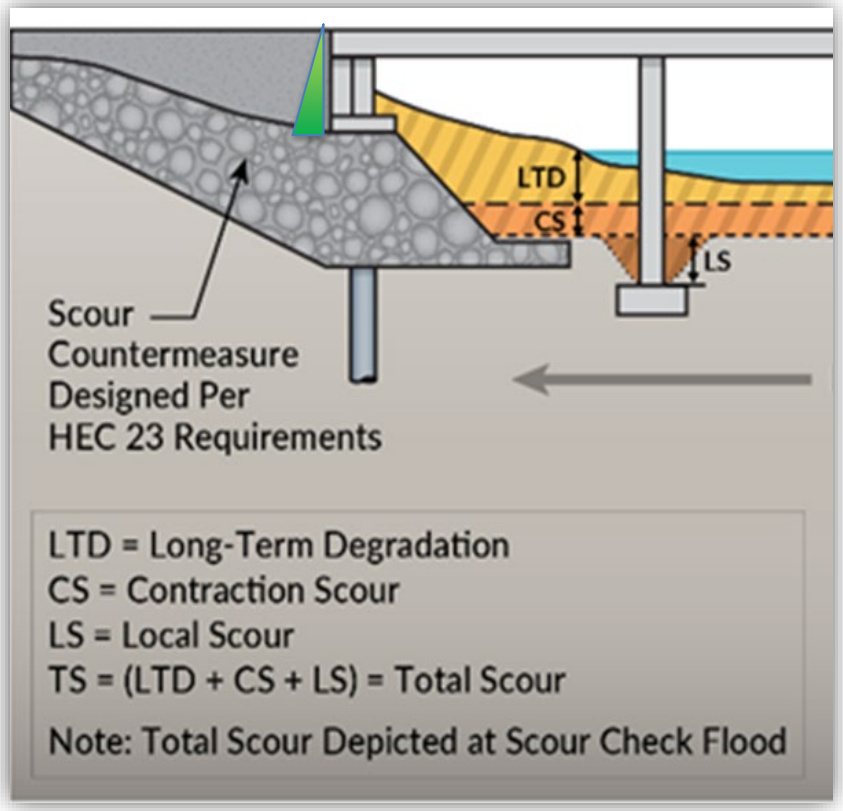
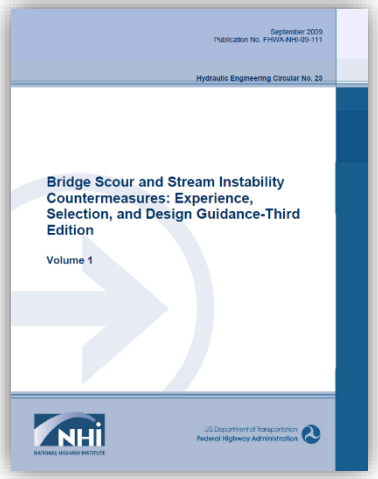


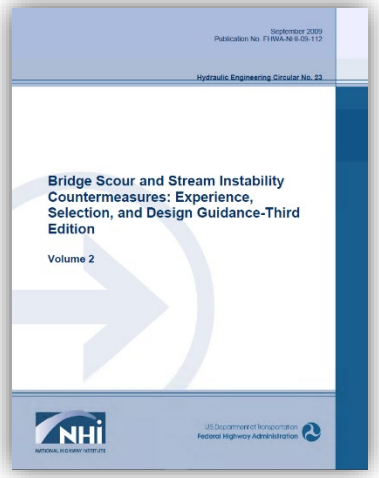
Image Source: WSDOT

Importance of Properly Designed and Constructed Scour Countermeasures

- Scour countermeasures shall be designed and constructed following:
  - HEC-23
  - FHWA TechBrief – Hydraulic Considerations for Shallow Abutment Foundations



HEC-23 Vol. 1



HEC-23 Vol. 2

FHWA TechBrief – Hydraulic Considerations for Shallow Abutment Foundations

Scour Countermeasure Design Requirements

- Portion of scour countermeasure above long-term degradation plus contraction scour at the scour check flood should be outside of the minimum hydraulic width
- Apron is required to mitigate abutment scour (FHWA TechBrief – Hydraulic Considerations for Shallow Abutment Foundations)

Figure 7-18 Scour Countermeasure Design with Deep Foundation and Calculated Abutment Scour Greater than Zero

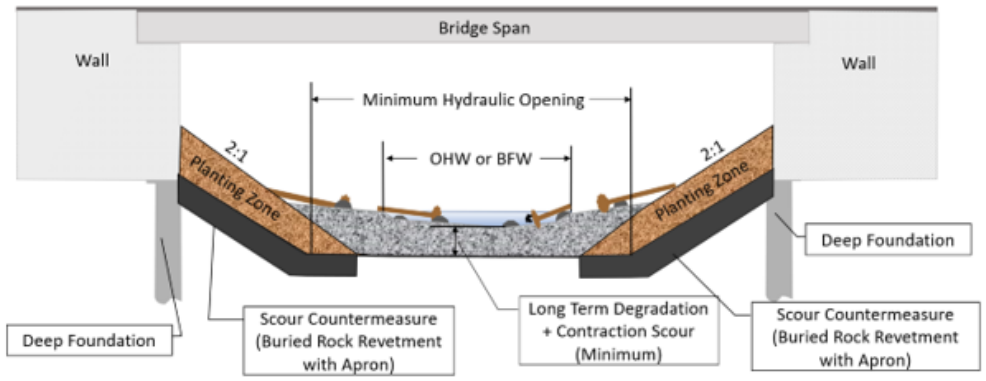


Figure 7-19 Scour Countermeasure Design with Deep Foundation and Calculated Abutment Scour of Zero

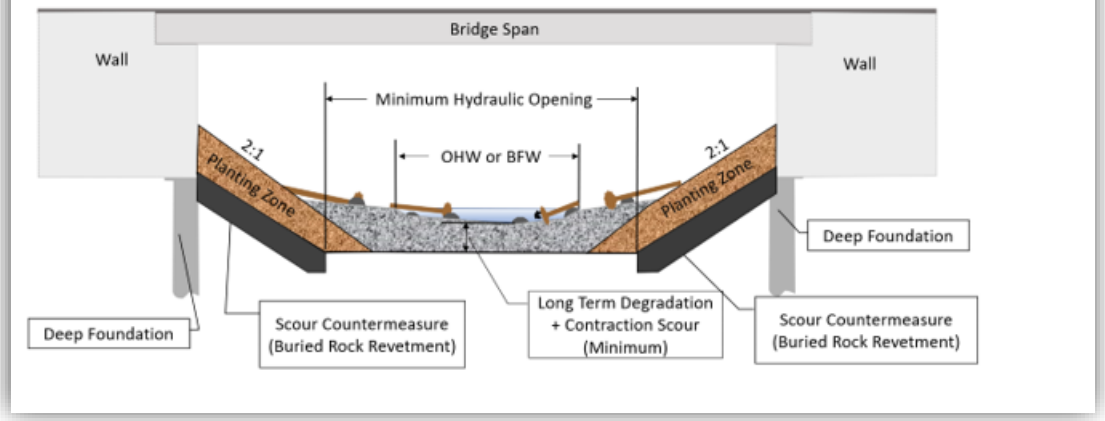


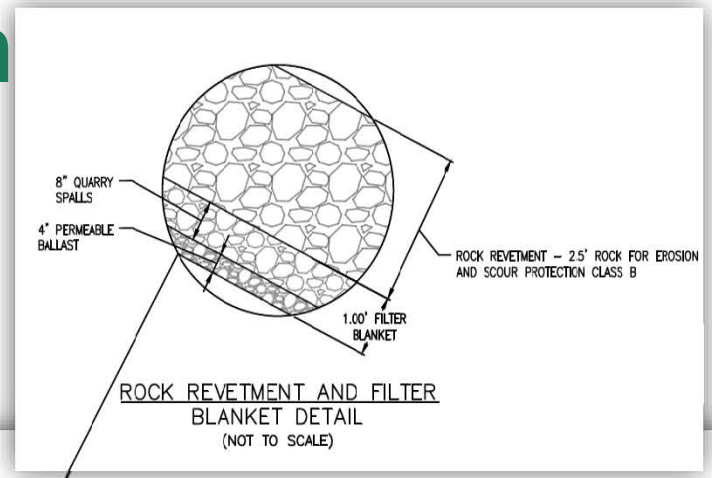
Image Sources: WSDOT

Scour Countermeasure Design Requirements

- Toe of rock revetments shall use larger fractions of rock class or a separate rock specification

- A filter is required for all scour countermeasures
  - Granular filter
  - Geotextile

- When utilizing scour countermeasures for design of deep foundations, calculated rock size (gradation) shall be increased by 1 rock class



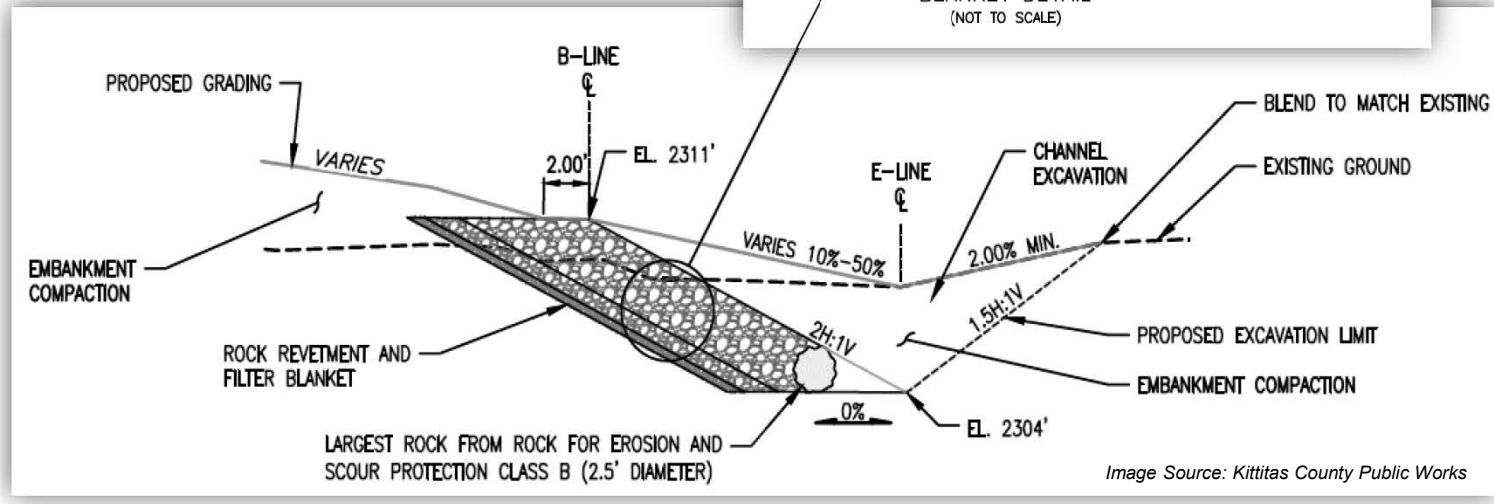


Image Source: Kittitas County Public Works

Scour Countermeasure Specifications

- WSDOT Standard Specifications 9-13.4(2)
  - Class A
  - Class B
  - Class C

- <u>DO NOT USE</u>
  - 9-13.1(2) – Heavy Loose Riprap
  - 9-13.1(3) – Light Loose Riprap

9-13.4(2) Grading Requirements of Rock for Erosion and Scour Protection

Rock for Erosion and Scour Protection will be classified as Class A, Class B, and Class C, and it shall have a "Well-Graded" structure that meets the requirements for Suitable Shape and conforms to one or more of the following gradings as shown in the Plans.

Class A	
Approximate Size (in.)[1]	Percent Passing (Smaller)
18	100
16	80-95
12	50-80
8	15-50
4	15 max.

Class C	
Approximate Size (in.)[1]	Percent Passing (Smaller)
42	100
36	80-95
28	50-80
22	15-50
14	15 max.

Class B	
Approximate Size (in.)[1]	Percent Passing (Smaller)
30	100
28	80-95
22	50-80
16	15-50
10	15 max.

[1]Approximate Size can be determined by taking the average dimension of the three axes of the rock, Length, Width, and Thickness, by use of the following calculation:

$$\frac{\text{Length} + \text{Width} + \text{Thickness}}{3} = \text{Approximate Size}$$

Rock for Erosion and Scour Protection shall be visually accepted by the Engineer. The Engineer shall determine the Suitable Shape, Approximate Size, and Grading of the load before it is placed. If so ordered by the Engineer, the loads shall be dumped on a flat surface for sorting and measuring the individual rocks contained in the load.

Image Source: WSDOT

Image Source: Casey Kramer

Scour Countermeasure Specifications

- WSDOT is working on developing a new gradation (Class D), for now coordinate with HQ hydraulics for development of a special provision

9-13.4 Rock for Erosion and Scour Protection

Rock for Erosion and Scour Protection shall be hard, sound, and durable material, free from seams, cracks, and other defects that tend to destroy its resistance to weather, and it shall consist of broken and/or processed rock. Rock for Erosion and Scour Protection shall meet the quality requirements in Section 9-13 and the grading requirements in Section 9-13.4(2). The use of recycled materials and concrete rubble is not permitted for this application.

9-13.4(1) Suitable Shape of Rock for Erosion and Scour Protection

The Suitable Shape of these rocks shall be "Angular" (having sharply defined edges) to "Subangular" (having a shape in between Rounded and Angular) for a higher degree of interlocking to provide stability to the protected area. The use of round, thin, flat, or long and needle-like shapes is not allowed. Suitable Shape can be determined by the ratio of the Length/Thickness, where the Length is the longest axis, Width is the second longest axis, and Thickness is the shortest. The Suitable Shape shall be the maximum of 3.0 using the following calculation:

$$= \leq 3.0 \text{ Suitable Shape}$$

9-13.4(2) Grading Requirements of Rock for Erosion and Scour Protection

Rock for Erosion and Scour Protection will be classified as Class A, Class B, and Class C, and it shall have a "Well-Graded" structure that meets the requirements for Suitable Shape and conforms to one or more of the following gradings as shown in the Plans.

Class A	
Approximate Size (in.)[1]	Percent Passing (Smaller)
18	100
16	80-95
12	50-80
8	15-50
4	15 max.

Class C	
Approximate Size (in.)[1]	Percent Passing (Smaller)
42	100
36	80-95
28	50-80
22	15-50
14	15 max.

Class B	
Approximate Size (in.)[1]	Percent Passing (Smaller)
30	100
28	80-95
22	50-80
16	15-50
10	15 max.

[1]Approximate Size can be determined by taking the average dimension of the three axes of the rock, Length, Width, and Thickness, by use of the following calculation:

$$\frac{\text{Length} + \text{Width} + \text{Thickness}}{3} = \text{Approximate Size}$$

Rock for Erosion and Scour Protection shall be visually accepted by the Engineer. The Engineer shall determine the Suitable Shape, Approximate Size, and Grading of the load before it is placed. If so ordered by the Engineer, the loads shall be dumped on a flat surface for sorting and measuring the individual rocks contained in the load.

Image Sources: WSDOT

Scour Countermeasure Specifications

- Toe of rock revetments shall use larger fractions of rock class or a separate rock specification
- If separate rock specification is required, use 9-13.7(1) – Rock for Rock Walls

Image Source: Casey Kramer

9-13.7 Rock for Rock Wall

9-13.7(1) Rock for Rock Walls and Chinking Material

Rock for rock walls and chinking material shall be hard, sound and durable material, free from seams, cracks, and other defects tending to destroy its resistance to weather, and shall meet the following test requirements:

Test	Test Method	Requirements
Specific Gravity, SSD	AASHTO T 85	2.55 min.
LA Wear	AASHTO T 96	50% max.
Degradation	WSDOT T 113	15 min.
Absorption	AASHTO T 85	3% max.

Rock for rock wall sizes are approximately as follows:

Rock Size	Rock Weight (lbs)	Average Dimension (in.)
Type One	50 to 200	12 to 18
Type Two	200 to 700	18 to 28
Type Three	700 to 2,000	28 to 36
Type Four	2,000 to 4,000	36 to 48
Type Five	4,000 to 6,000	48 to 54
Type Six	6,000 to 8,000	54 to 60

Image Source: WSDOT

Scour Countermeasure Specifications

- A filter is required for all scour countermeasures
- Filter allows a permeable, free-flowing interface between rock and parent material
- Filter reduces effects of piping through voids of large rock
- Methods in HEC-23 and provided in FHWA Hydraulic Toolbox shall be used
- A granular filter typically consists of:
  - 9-03.9(2) – Permeable Ballast
  - 9-12.1(5) – Quarry Spalls

9-03.9(2) Permeable Ballast

Permeable ballast shall meet the requirements of Section 9-03.9(1) for ballast except for the following special requirements.

The grading and quality requirements are:

Sieve Size	Percent Passing
2½″	99-100
2″	65-100
¾″	40-80
No. 4	5 max.
No. 100	0-2
% Fracture	75 min.

All percentages are by weight.

The sand equivalent value and dust ratio requirements do not apply.

The fracture requirement shall be at least one fractured face and will apply the combined aggregate retained on the No. 4 sieve in accordance with FOP for AASHTO T 335.

9-13.1(5) Quarry Spalls

Quarry spalls shall meet the following requirements for grading:

Sieve Size	Percent Passing
8″	100
3″	40 max.
¾″	10 max.

Image Sources: WSDOT

Scour Countermeasure Specifications

- Some projects may use a geotextile
- Coordination with the geotechnical and construction office shall occur during design of scour countermeasure
- WSDOT geotextile specifications
  - 9-33 Construction Geosynthetic

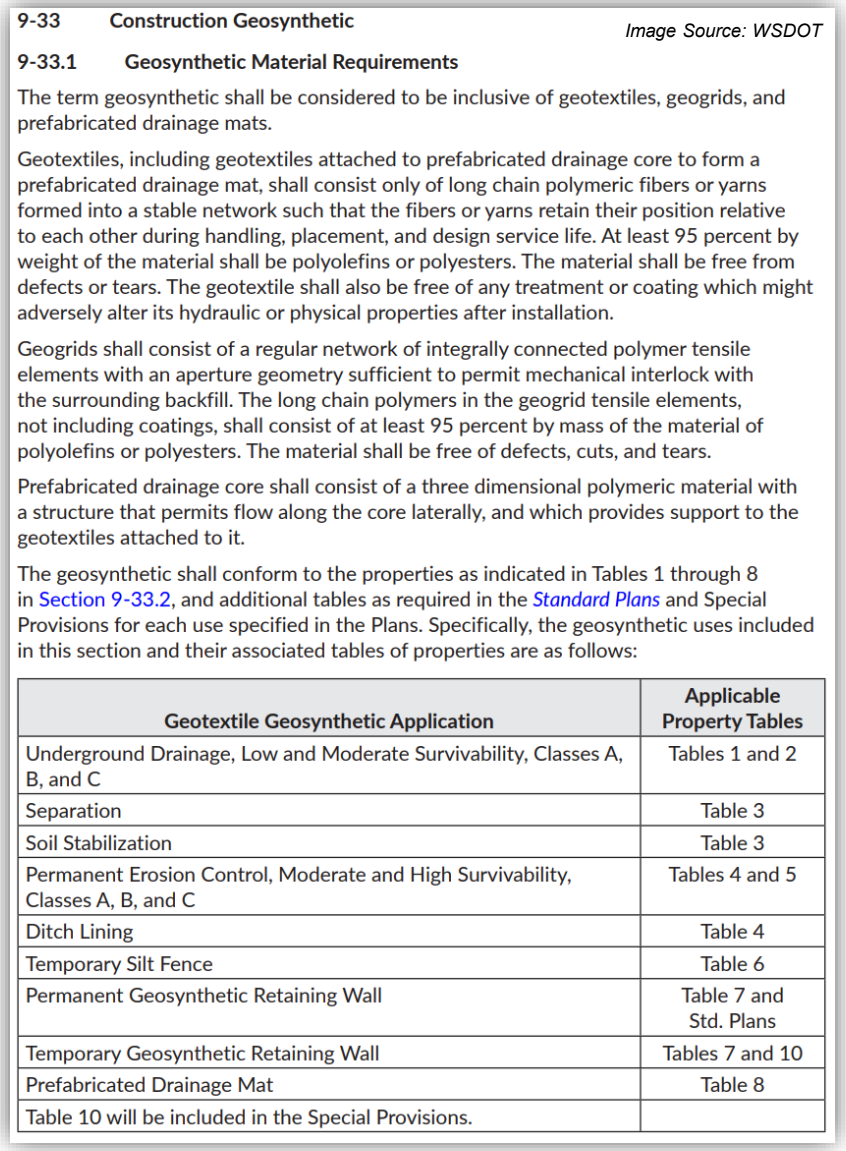


Image Source: WSDOT

9-33 Construction Geosynthetic

9-33.1 Geosynthetic Material Requirements

The term geosynthetic shall be considered to be inclusive of geotextiles, geogrids, and prefabricated drainage mats.

Geotextiles, including geotextiles attached to prefabricated drainage core to form a prefabricated drainage mat, shall consist only of long chain polymeric fibers or yarns formed into a stable network such that the fibers or yarns retain their position relative to each other during handling, placement, and design service life. At least 95 percent by weight of the material shall be polyolefins or polyesters. The material shall be free from defects or tears. The geotextile shall also be free of any treatment or coating which might adversely alter its hydraulic or physical properties after installation.

Geogrids shall consist of a regular network of integrally connected polymer tensile elements with an aperture geometry sufficient to permit mechanical interlock with the surrounding backfill. The long chain polymers in the geogrid tensile elements, not including coatings, shall consist of at least 95 percent by mass of the material of polyolefins or polyesters. The material shall be free of defects, cuts, and tears.

Prefabricated drainage core shall consist of a three dimensional polymeric material with a structure that permits flow along the core laterally, and which provides support to the geotextiles attached to it.

The geosynthetic shall conform to the properties as indicated in Tables 1 through 8 in Section 9-33.2, and additional tables as required in the *Standard Plans* and Special Provisions for each use specified in the Plans. Specifically, the geosynthetic uses included in this section and their associated tables of properties are as follows:

Geotextile Geosynthetic Application	Applicable Property Tables
Underground Drainage, Low and Moderate Survivability, Classes A, B, and C	Tables 1 and 2
Separation	Table 3
Soil Stabilization	Table 3
Permanent Erosion Control, Moderate and High Survivability, Classes A, B, and C	Tables 4 and 5
Ditch Lining	Table 4
Temporary Silt Fence	Table 6
Permanent Geosynthetic Retaining Wall	Table 7 and Std. Plans
Temporary Geosynthetic Retaining Wall	Tables 7 and 10
Prefabricated Drainage Mat	Table 8
Table 10 will be included in the Special Provisions.	

Scour Countermeasure Minimum Requirements

- WSDOT H_HD Template (May 2022)
  - ***PHD to document preliminary type*** *(preliminary typical section using estimated scour determined in Section 7.5 (Section 7-4.11 in WSDOT HM) and WSEs determined in Section 5.4 (Section 4-6.2.2 in WSDOT HM))* ***and extents*** *(plan view of preliminary extents upstream and downstream of crossing; and vertically from the estimated depths of scour at the scour check flood, to 1 foot above the 100-year WSE)* ***for proposed scour countermeasures to facilitate discussion if additional TCE, ROW, SFZ, etc. limits are required.***

  - *FHD to* ***document details on the countermeasure design*** *(final typical section using scour determined in Section 7.5 (Section 7-4.11 in WSDOT HM) and WSEs determined in Section 5.4 (Section 4-6.2.2 in WSDOT HM)),* ***sizing and extents*** *(plan view of final extents upstream and downstream of crossing; and vertically from the depths of scour at the scour check flood to 1 foot above the 100-year WSE). Section should also* ***document design analysis****.*

Scour Countermeasure Minimum Requirements

- PHD
  - Type and extents of potential scour countermeasures based on:
    - Estimated total scour downstream, upstream and through proposed water crossing
    - Constructability
    - Key pieces of LWM are placed or are anticipated to accumulate within water crossing
    - On-site visual assessment of erosion
    - 2D model results

- FHD
  - Type, sizing and extents of scour countermeasures based on:
    - Total scour downstream, upstream and through proposed water crossing
    - Constructability
    - Key pieces of LWM are placed or are anticipated to accumulate within water crossing
    - On-site visual assessment of erosion
    - 2D model results

Scour Countermeasure Examples

- WSDOT Hydraulics Manual Figure 7-18
  - Abutment Scour Calculated to be greater than zero feet – Apron required
- WSDOT Hydraulics Manual Figure 7-19
  - Abutment Scour Calculated to be zero feet – No apron required
- HEC-23 provides other options for scour countermeasures

Figure 7-18 Scour Countermeasure Design with Deep Foundation and Calculated Abutment Scour Greater than Zero

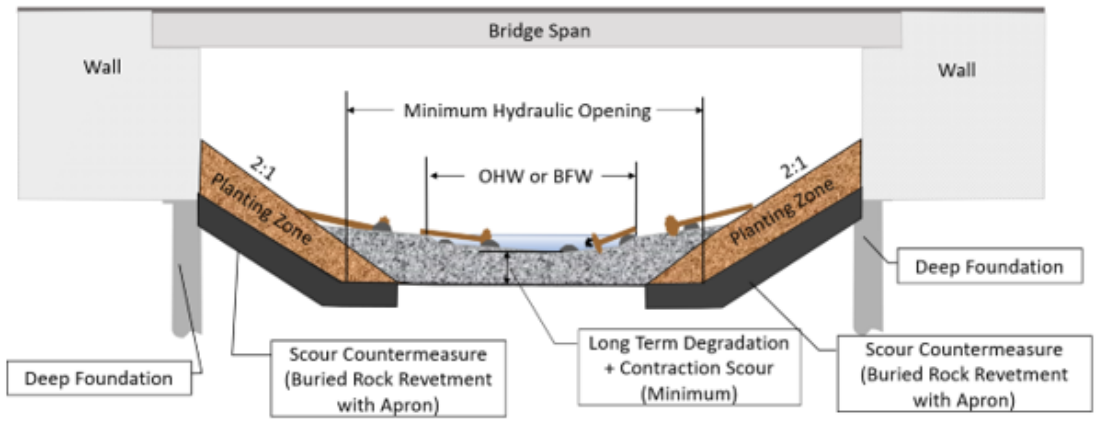


Figure 7-19 Scour Countermeasure Design with Deep Foundation and Calculated Abutment Scour of Zero

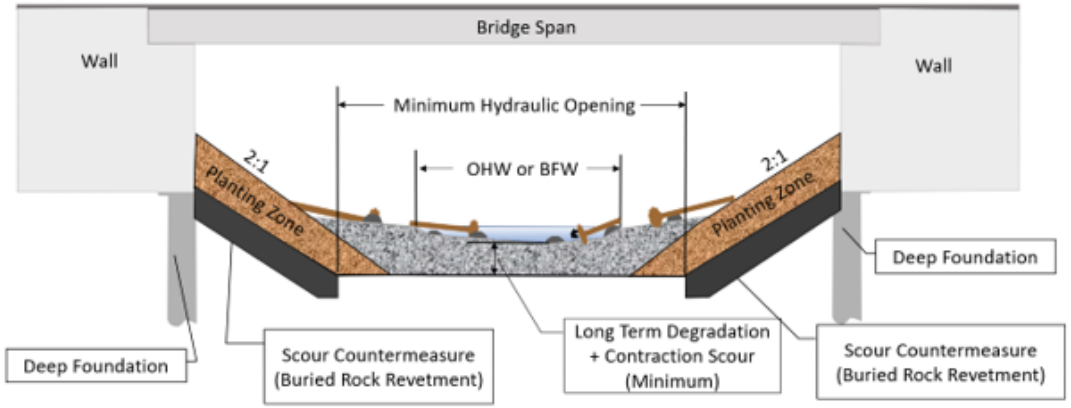


Image Sources: WSDOT

Scour Countermeasure Example

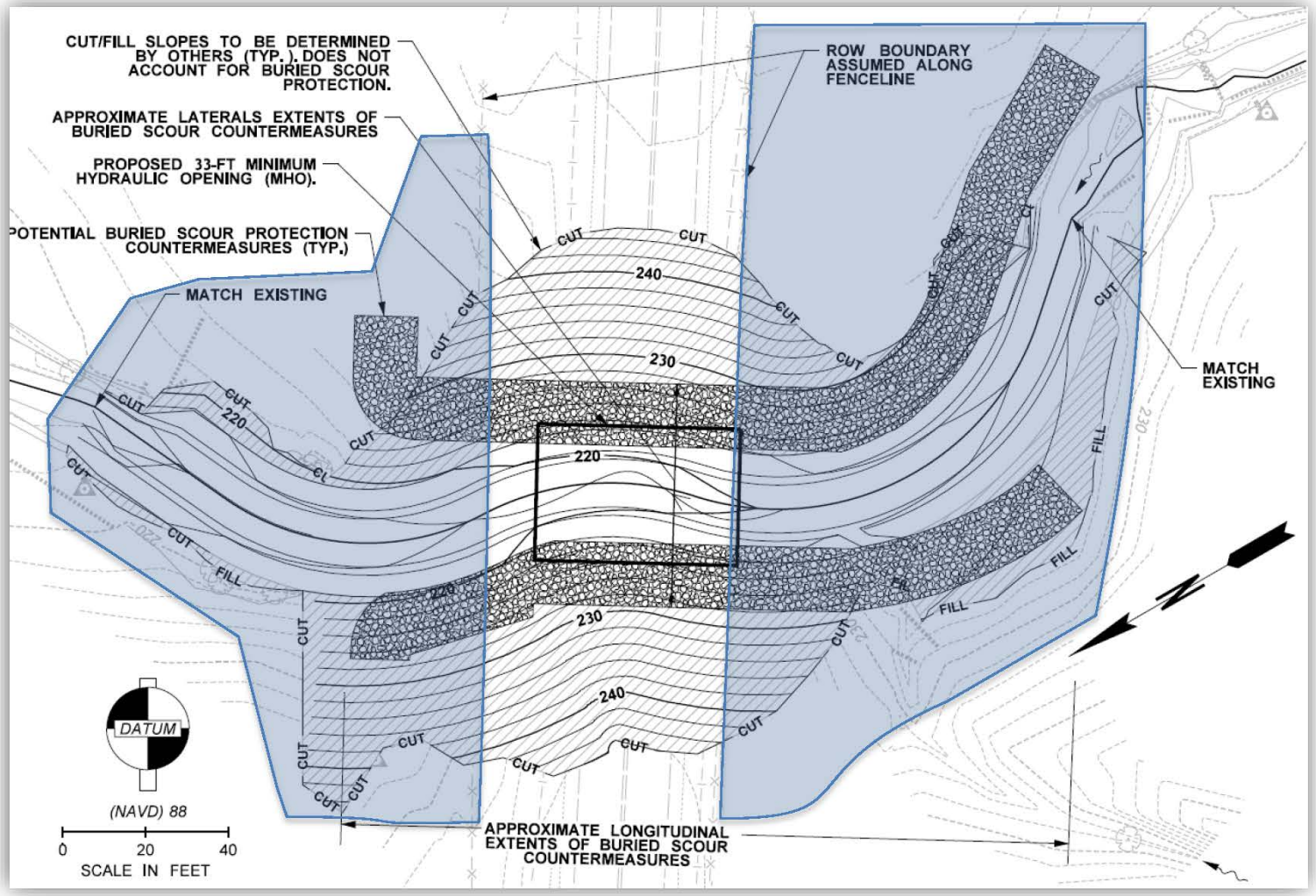
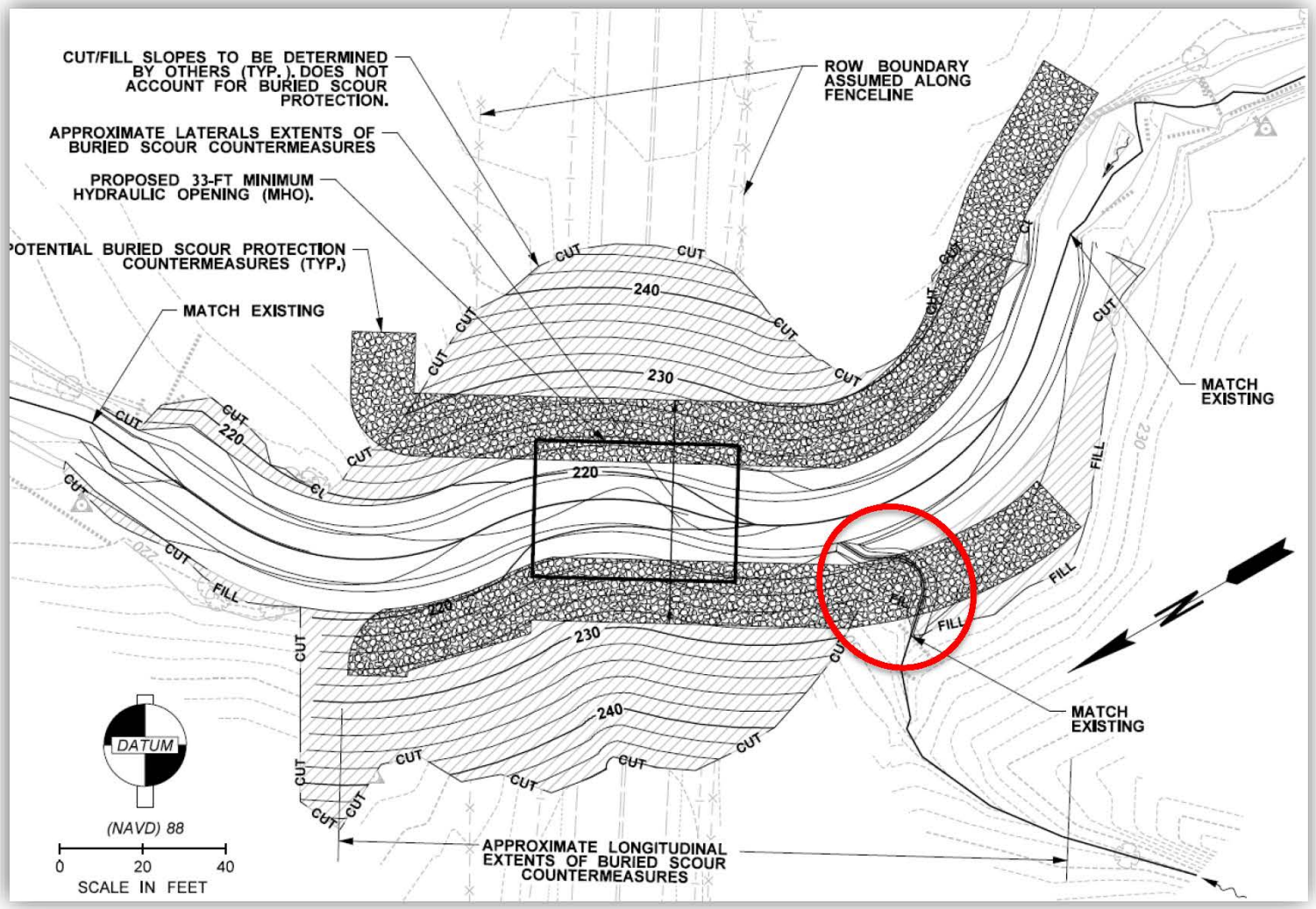


Image Source: GeoEngineers

Scour Countermeasure Example



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Scour Countermeasure Example

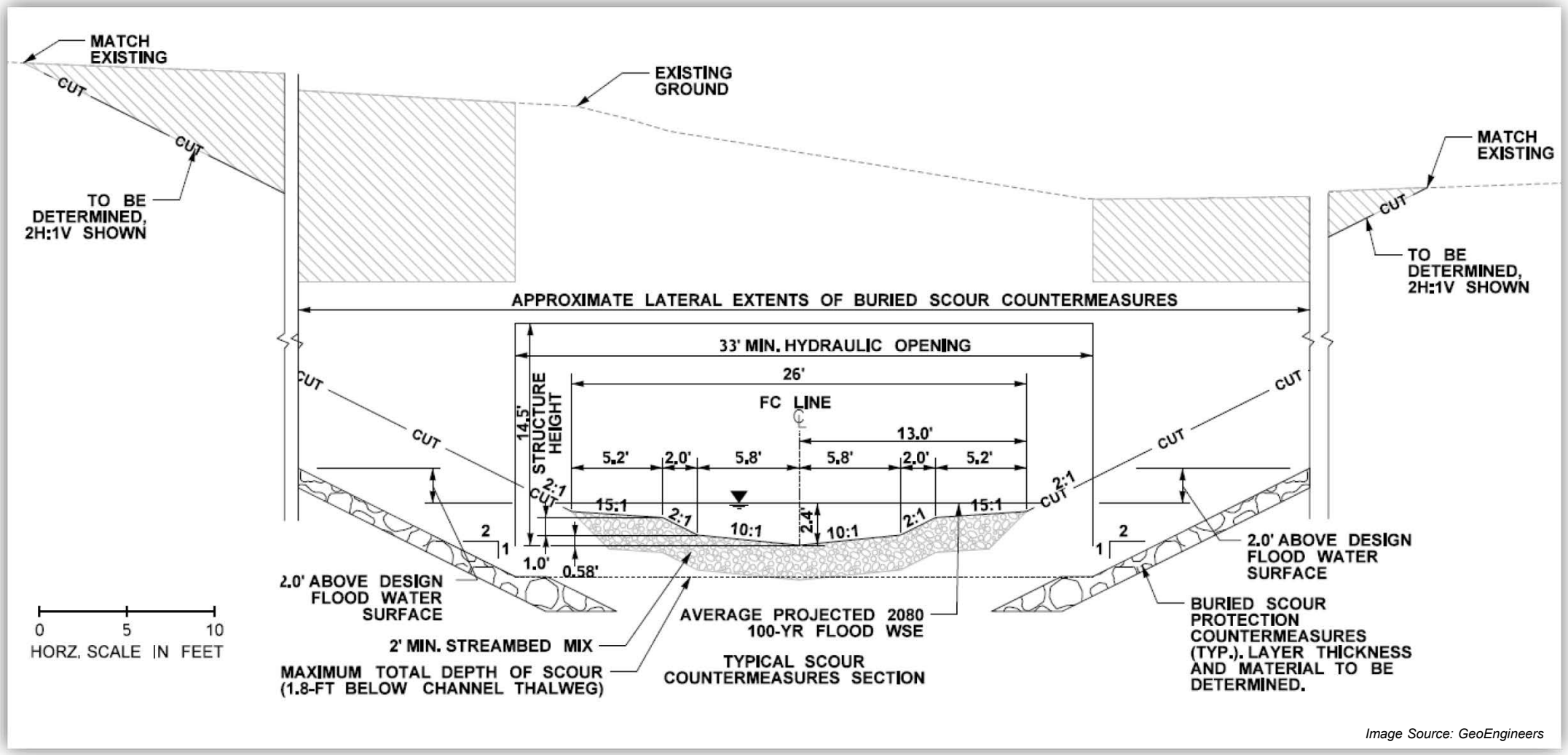

Image Source: GeoEngineers

Importance of Inspection

- Inspection during construction
  - Photo documentation
  - Rock size and extents documentation
  - Surveyed As-Builts prior to completion
  - HQ hydraulics staff on site
  - Coordination with bridge preservation office
- Inspection during bridge inspections
  - Scour countermeasure considered part of the asset it is protecting
  - Confirmation of as-built condition and changes in channel

Image Sources: Casey Kramer