MOTT MACDONALD

Technical Note

Project:	PennEast		
Our reference:	353754	**Your reference:**	Mud Run Slope
Prepared by:	D Chandler	**Date:**	September 24, 2019
Approved by:	M Wilcox	**Checked by:**	D Hartman
Subject:	Mud Run Slope Restoration		

1 Purpose

The purpose of this document is to present possible slope restoration methodologies at the proposed pipeline crossing of Mud Run Creek in Hickory Run State Park, Pennsylvania. These slope restoration methodologies are intended to minimize the risk of slope failure adjacent to Mud Run, and to address comment #37 in the technical deficiency letter from the Pennsylvania Department of Environmental Protection (PADEP) dated July 3, 2019. Representatives from PennEast and Mott MacDonald met onsite with a contractor that specializes in slope stabilization to evaluate the site conditions and discuss options. The overall engineering objective of restoring the slope at Mud Run is the long-term resiliency of the pipeline and to avoid the need to perform repeated maintenance or restoration procedures during the operation of the pipeline.

2 Topography and Geology

The northern side of Mud Run is at a gradient of approximately 35^{o} (70%) and is approximately 100 feet high. The south side of the crossing is at a gradient of approximately 17^{o} (30%) and is unlikely to require use of any special restoration methods.

The ground conditions on the slope consist of a thin cover of clayey soil over shallow bedrock. The bedrock consists of interbedded sandstone, siltstone and conglomerate. These geological conditions were observed in crossing-specific boreholes and are typical of the mapped geological unit – Duncannon Member of the Catskill Formation. The Rock Quality Designation (RQD) values with in the rock mass were highly variable, ranging from low (highly fractured) to very high (virtually intact).

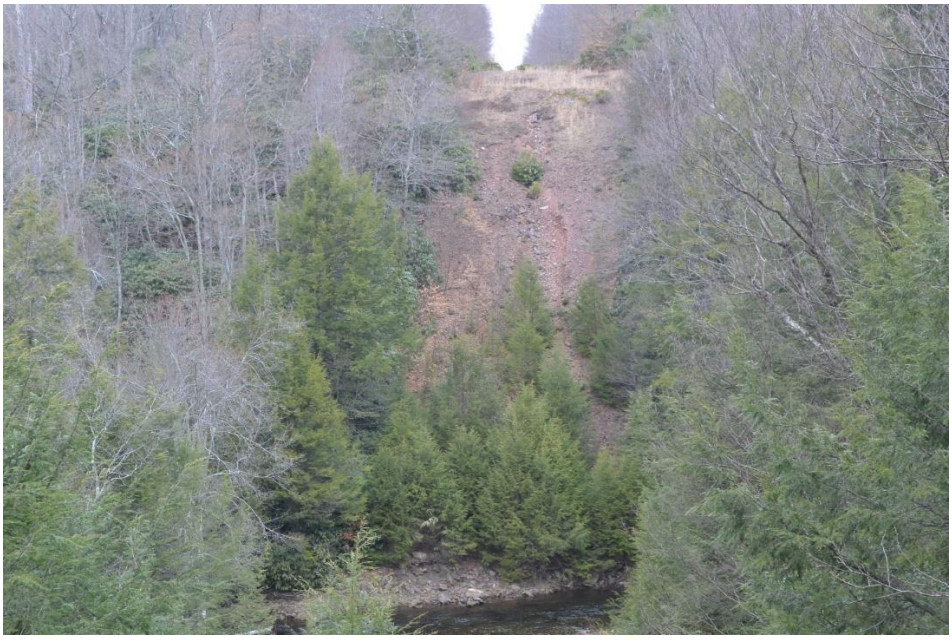
Laboratory testing upon samples obtained during project site investigation drilling obtained Uniaxial Compressive Strength values ranging from 5.1ksi to 23.3ksi, with an average value of 13.6ksi. It is noted that the weakest rock layers were not lab tested as drilling would recover samples too small for lab testing.

Figures 1 and 2, below, provide images of the slope. Note that the PennEast pipeline is to be constructed to the left (west) of the existing Buckeye pipeline right-of-way (ROW).

Figure 1: Looking in a north easterly direction, at the northern side of the Buckeye ROW showing exposed shallow bedrock on slope. February 2017.

Source: Mott MacDonald

Figure 2: Looking in a north westerly direction along the Buckeye ROW. February 2017.



Source: Mott MacDonald

3 Typical Soil and Erosion Control Measures

Erosion and Sediment Control (E&S) drawing sheets 000-03-09-01 through 000-03-09-09 contain 34 typicals detailing construction methods which the Contractor will be required to follow during construction of the pipeline; these are known as the E&S Best Management Practices (BMPs). These details include many methods relevant to slope stability and protection. The reader should be familiar with these drawing sheets before progressing to the more specialized methodologies. These E&S BMPs have been proven on various prior projects to be practical and effective means of controlling soil erosion and slope stabilization during construction and in restored condition.

PennEast is committed to the responsible installation and resilient operation of the pipeline. To assist in meeting this objective, PennEast will have geotechnical engineers and inspectors onsite during construction and restoration of this slope. At certain locations along this slope and/or where conditions exceed the applicability of the standard construction details, additional slope restoration provisions will be developed and implemented. The Geohazard Mitigation Plan includes typicals 12A, 13A and 135 through 138. These typicals present examples of additional engineered slope retention and drainage measures. These additional slope retention measures will be utilized where appropriate for the conditions faced.

4 Recommendations for the North Slope of Mud Run

PennEast is providing further specific detail regarding which method is anticipated to be utilized at the crossing of Mud Run.

4.1 Practical Slope Restoration Scenario- Trench Plug Drainage

One of the leading causes of slope failure is water saturation and hydrostatic pressure as groundwater accumulates on the uphill side of traditional trench plugs. The objective of this practical slope restoration method is to reduce hydrostatic pressures accumulating within the trench by conveying groundwater to the surface and into water bars. Trench plug drainage will be implemented on the north slope of Mud Run, and when combined with the E&S BMPs, this represents a robust restoration approach.

The following steps are associated with this scenario:

1. It is anticipated that shallow rock will be encountered during the excavation of the trench. Rock will be excavated using mechanical excavators.
2. The pipe will be welded and coated before being lowered into the trench.
3. Trench plugs will be installed with drainage pipes penetrating the base.
4. The drainage pipes will be aligned to daylight to surface beyond the crest of the next trench plug.
5. The trench will be backfilled with imported well-draining geotechnical materials (angular gravel) to within 12 inches of the natural ground surface. The upper 12 inches will be covered with native topsoil / soil material from near by the slope location to maintain the natural local soils conditions.
6. Waterbars will be located immediately down slope of the drainage pipe daylights / trench plugs.
7. Vegetative matting (bamboo matting) will be placed on the surface and will be staked-in with living stakes. The surface will be seeded based on seed mix specifications.
8. It is not anticipated that high flows will occur out of the drainage pipes. No ground water springs have been observed at this slope. The trench plug drainage is intended to prevent undesirable hydraulic forces accumulating in the trench. It is considered likely that flows will be ephemeral and low volume.

The final visual appearance will be a fully vegetated pipeline ROW with waterbars. Small drainage pipes will periodically discharge into these waterbars. It is anticipated that vegetation will fully cover the ROW and drainage outlets after several of growing seasons.

See Figures 12A and 13A of the geohazard mitigation plan for details on drained trench plugs.

4.2 Additional Slope Restoration Provision A - Soil Nails

PennEast will consider the following additional slope restoration Provision A (if deemed necessary after the slope is exposed during the tree cutting and trenching phases). Please note this additional provision is considered unlikely based upon a current understanding of the slope and geological conditions.

The objective of this slope restoration method is to physically restrain the surficial soils via connection to deeper high strength materials. The soils nails are anchored into strong rocks at depth, the nail face plates are tensioned and this restrains the surficial soils. This method can be implemented without the removal of the failing soils which can often be a hazardous task. This may be implemented if practical drainage alone is not sufficient to restore a long-term stable slope.

There is a low likelihood that this scenario will be needed at Mud Run.

The following steps are associated with this scenario:

1. The trench excavation at this slope will encounter low strength materials (weak soils / extremely weak and fractured rock).
2. The trench sides will be angled and benched at a safe angle for the soils present.
3. The pipe will be welded, coated and lowered in to the trench.
4. The trench plugs and drainage will be installed as detailed in section 4.1.
5. The trench will be backfilled with imported well-draining geotechnical materials (angular gravel) to within 12 inches of the natural ground surface. The upper 12 inches will be covered with topsoil.
6. Vegetative matting will be installed across the slope.
7. Threaded soil nails will be drilled through the loose soils until bedrock is reached. Soil nails will be grouted. Soil nails will be trimmed to protrude 8 inches from the surface.
8. A wire surface mesh with holes approximately 6 inches wide will be installed across the slope over the soil nails and vegetative matting.
9. Face plates and nuts will be installed on to the soil nails and the nuts will be torqued until the mesh is pulled tight against the surface.
10. The surface will be seeded which will grow up from the vegetative cover to obscure the wire mesh. It is anticipated that vegetation will fully cover the wire mesh after several of growing seasons.

See Figures 136, 136A & 136B of the geohazard mitigation plan for details depicting Provision A.

4.3 Additional Slope Restoration Provision B - Reinforced soils slope

PennEast will consider the following additional slope restoration Provision B (if deemed necessary after the slope is exposed during the tree cutting and trenching phases). Please note this additional provision is considered unlikely based upon a current understanding of the slope and geological conditions.

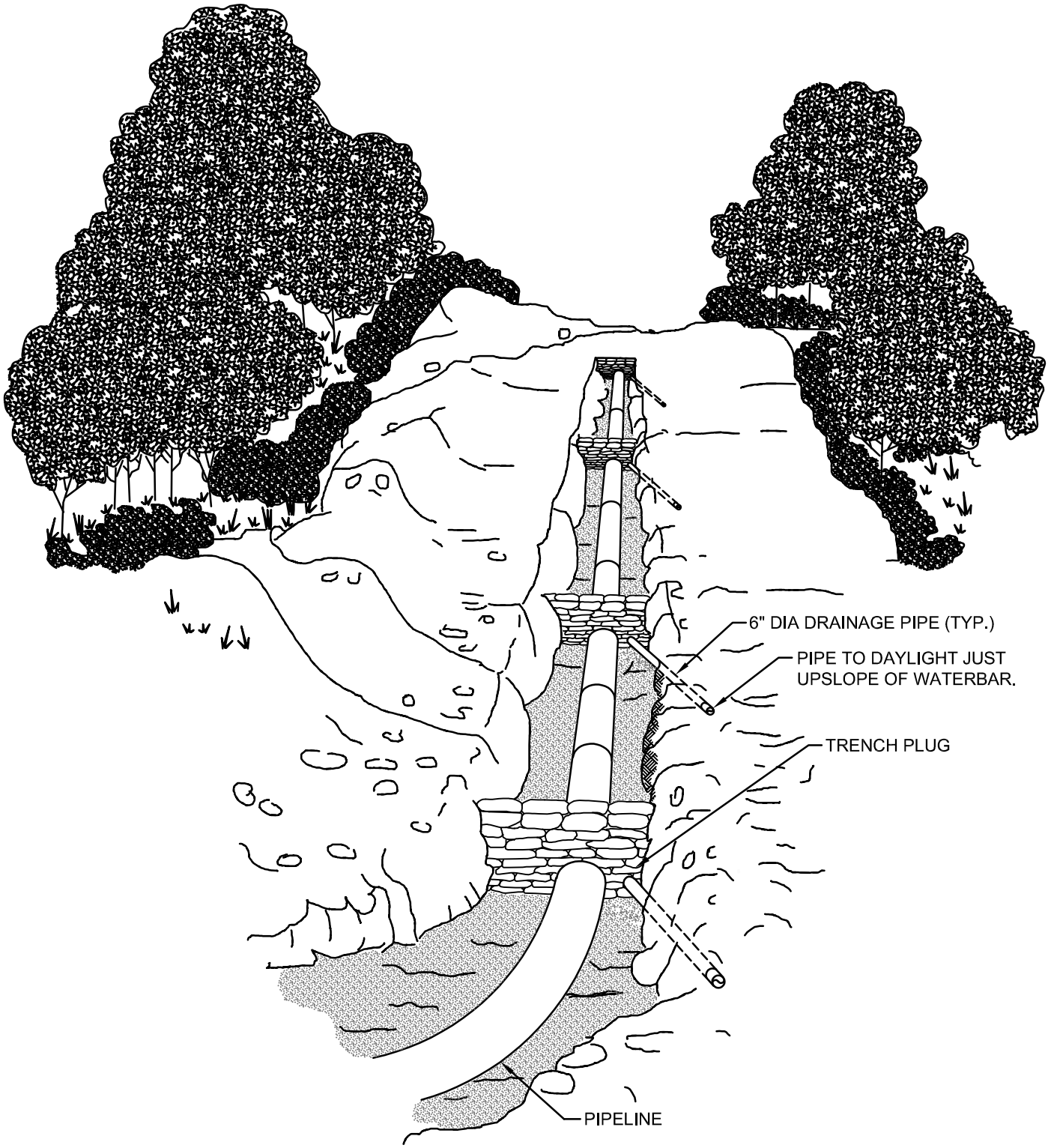
The objective of the reinforced soil slope is to add tensional capacity to the soils via the introduction of synthetic layers. This forms a resilient cover across the slope with a natural vegetative appearance. This method may be used in the reconstruction of the slope if significant thickness of soils were removed during construction due to low strength and stability.

There is a very low likelihood that this scenario will be needed at Mud Run.

The following steps are associated with this scenario:

1. The trench excavation at this slope will encounter low strength materials (weak soils / extremely weak and fractured rock) requiring a significant amount of material to be removed for pipeline installation.
2. The trench sides will be angled and benched at a safe angle for the soils present.
3. The pipe will be welded, coated and lowered in to the trench.
4. The trench plugs and drainage will be installed as detailed in 4.1.
5. A geo mesh will be used to construct a reinforced soil slope using lifts of 18 inches. The geo mesh will provide tensional capacity to the soil's mass while allowing free drainage and plants to grow through the surface of the slope.
6. The slope lifts will be constructed of native materials with granular angular gravels used only at the interface between geo mesh layers.

See Figure 137 of the Geohazard Mitigation Plan for details depicting Provision B.



NOTE:

1. INSTALL TRENCH PLUG DRAINAGE PIPES 1 SAND BAG ABOVE BASE OF TRENCH.
2. RUN DRAINAGE PIPES DOWNSLOPE TO DAYLIGHT BEYOND NEXT TRENCH PLUG WITHIN TRENCH FOOTPRINT, OR CAN BE TERMINATED BEFORE NEXT TRENCH PLUG IF OUTSIDE TRENCH FOOTPRINT.
3. DRAINAGE PIPES SHOULD DAYLIGHT JUST UPSLOPE OF WATER BARS.

NOT TO SCALE

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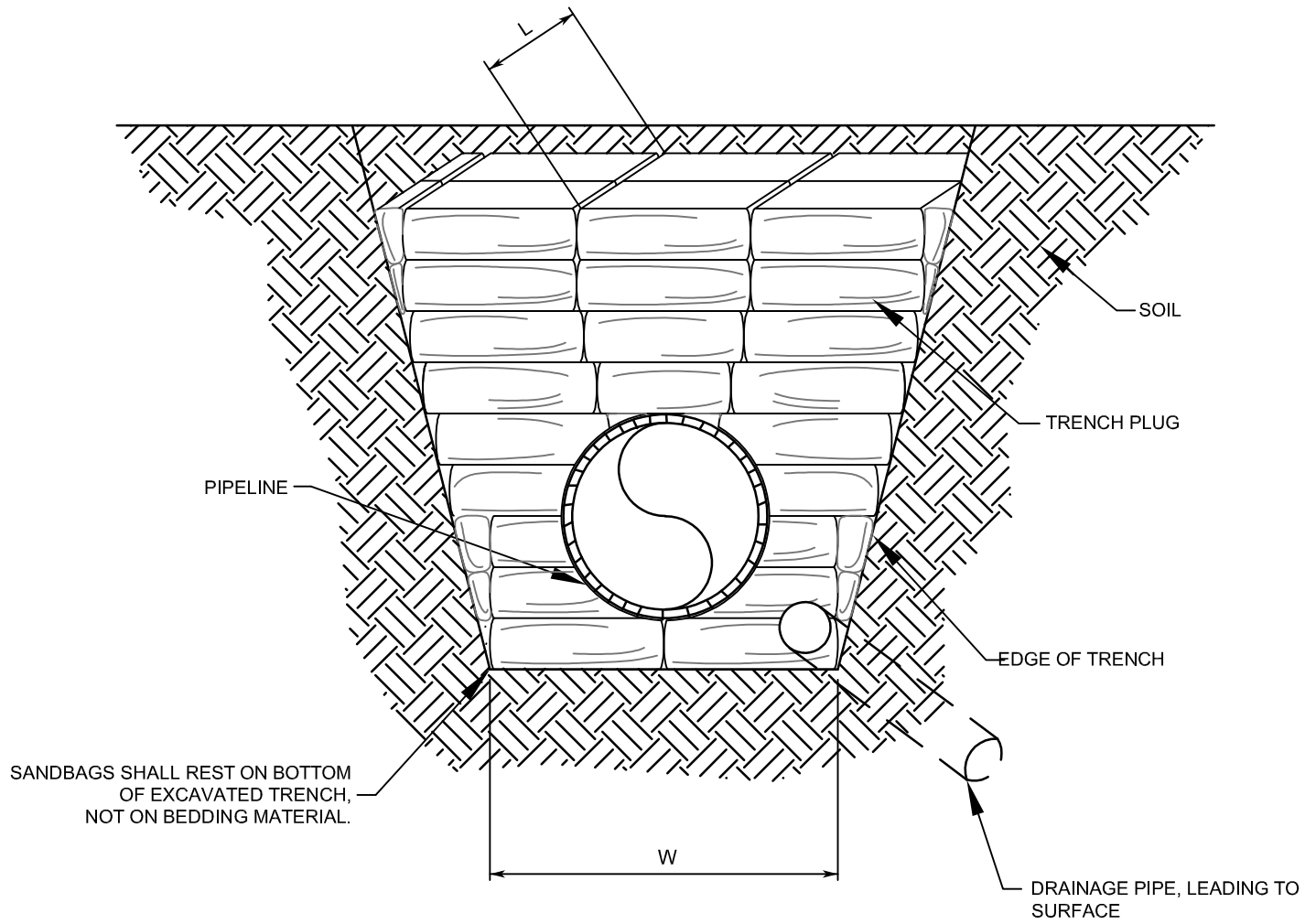
PennEast PIPELINE

PENNEAST PIPELINE PROJECT

DRAINED TRENCH PLUGS
FOLLOWING PIPELINE INSTALLATION

FIGURE 12A



W = TRENCH WIDTH
L = 24" MINIMUM

NOT TO SCALE

						PennEast PIPELINE	PENNEAST PIPELINE PROJECT
							DRAINED TRENCH PLUG DETAIL
							FIGURE 13A
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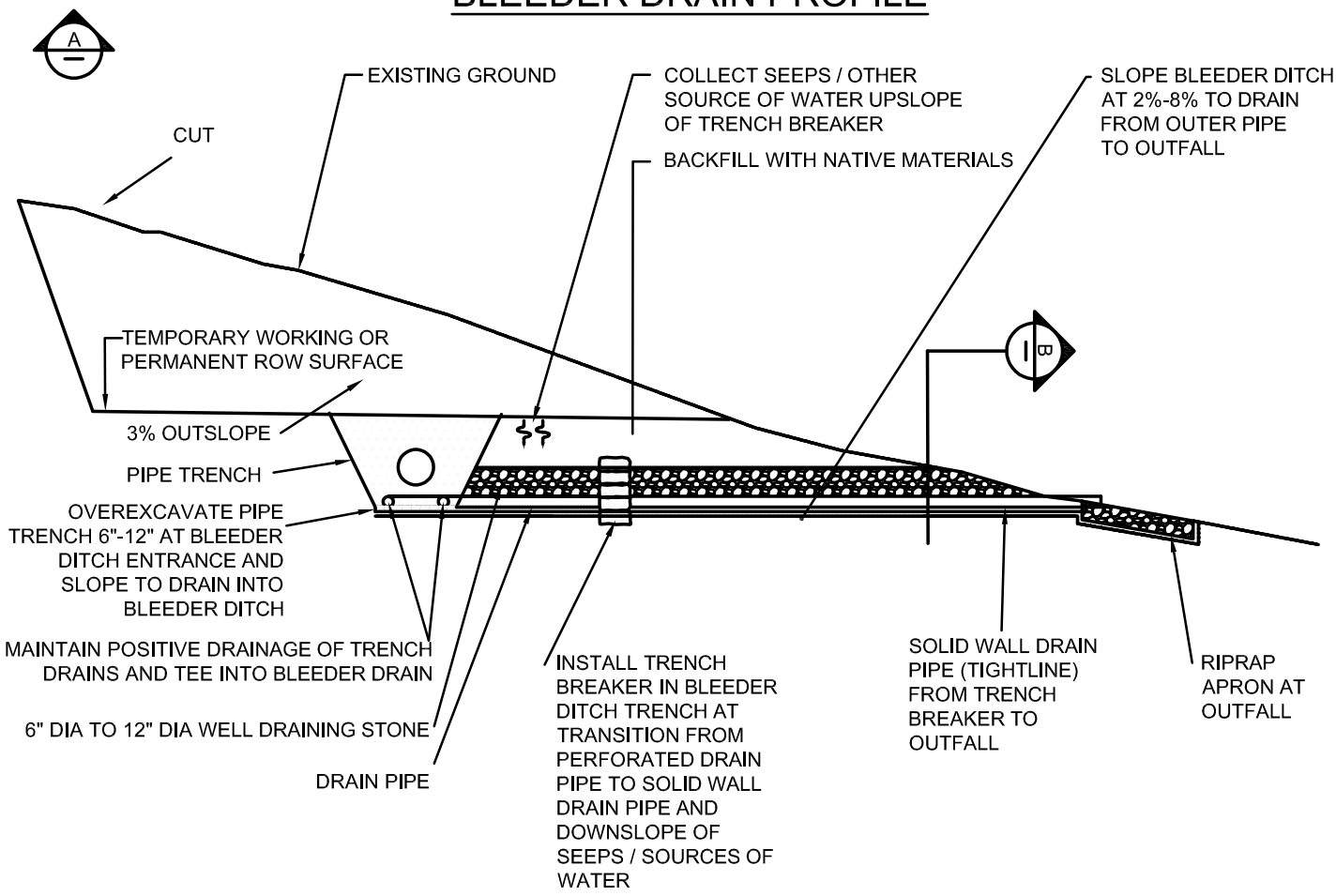
BLEEDER DRAIN PROFILE



TYPICAL APPLICATION

1. PIPE CONSTRUCTION ACROSS HEAVILY SATURATED GROUND WITH SLOPE STABILITY ISSUES OBSERVED BEFORE OR DURING CONSTRUCTION.
2. SIDE SLOPE CONSTRUCTION.

X CROSS SECTION ALIGNMENT

NOTES

1. TYPICAL DETAIL ONLY. ACTUAL CONSTRUCTION LAYOUT TO BE ADJUSTED AS APPROPRIATE AND APPROVED FOR SITE CONDITIONS AND DESIGN.
2. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
3. INSTALL BLEEDER DITCH IN SIDESLOPE SCENARIOS AT 100 FT INTERVALS AT LOW POINTS IN THE PIPELINE TRENCH OR AS NEEDED TO COLLECT SEEPS, SOURCES OF WATER, OR OTHER DRAINS.
4. NATIVE MATERIALS MAY BE USED DOWNSLOPE OF BLEEDER DITCH TRENCH BREAKERS INSTEAD OF DRAINFILL PROVIDED THAT NATIVE BACKFILL MATERIALS ARE FREE-DRAINING AND NO SEEPS OR SOURCES OF WATER ARE IDENTIFIED DOWNSLOPE OF THE PIPE TRENCH.
5. LENGTH OF BLEEDER DRAIN WILL VARY AS NEEDED TO MAINTAIN POSITIVE DRAINAGE IN DITCH TO OUTFALL.
6. SEE FIGURE 135A.

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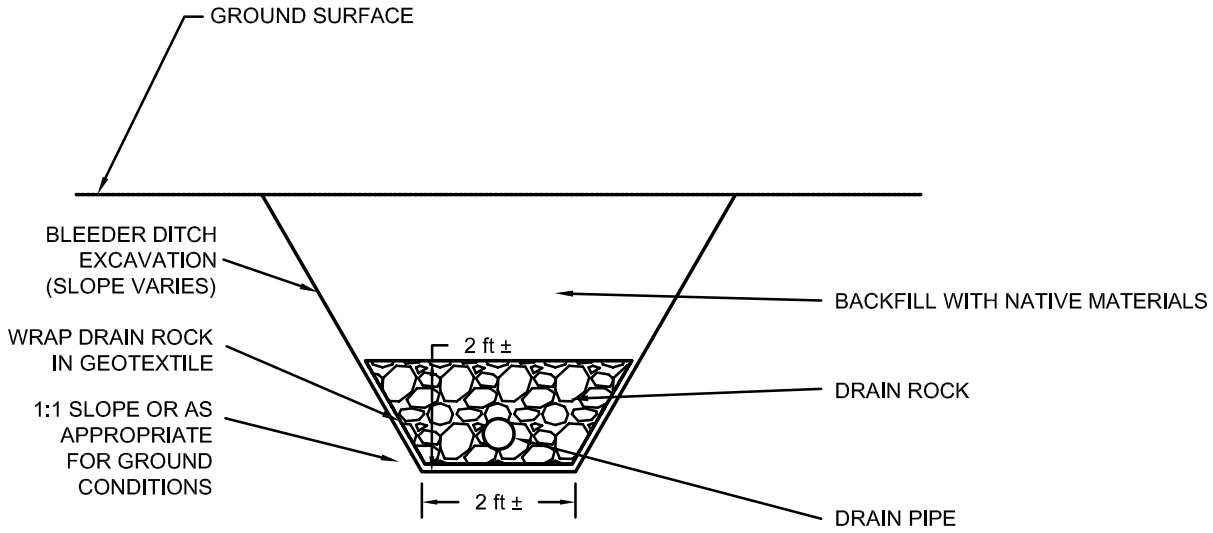
PennEast PIPELINE

PENNEAST PIPELINE PROJECT

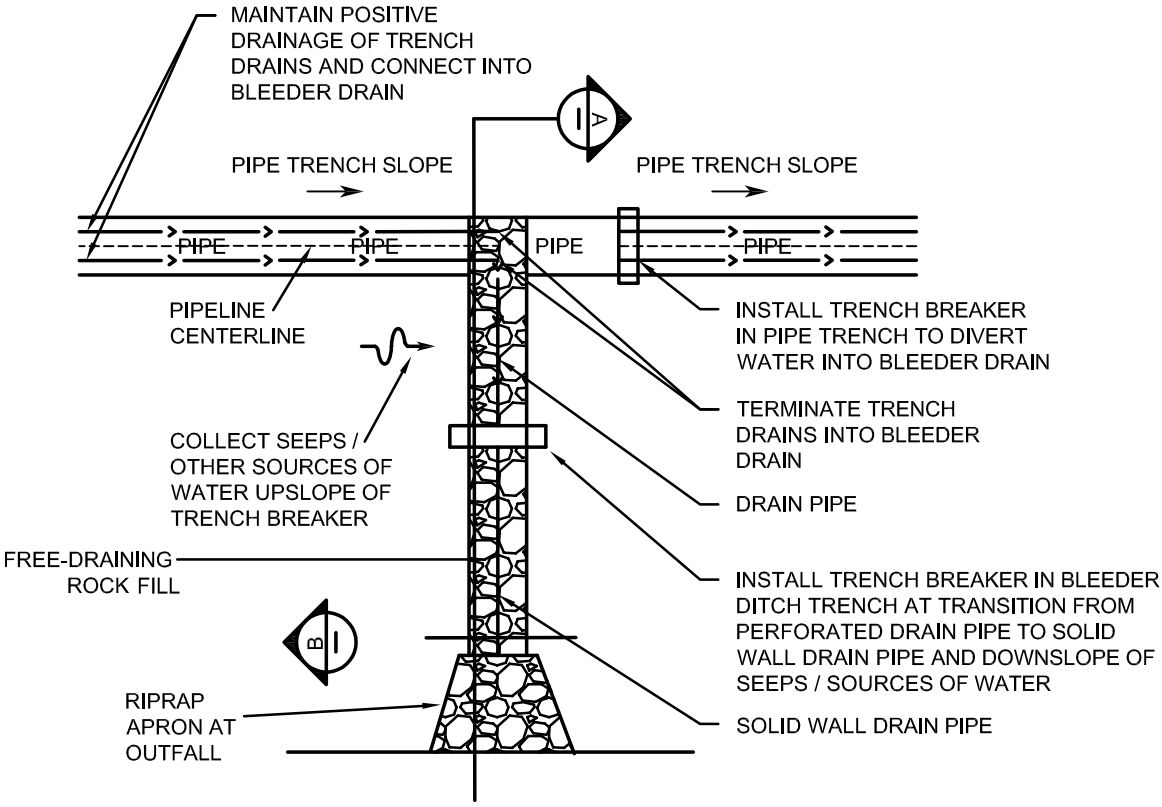
BLEEDER DRAIN PROFILE VIEW

FIGURE 135

BLEEDER DRAIN DITCH SECTION



BLEEDER DRAIN WITH SLOPED PIPE TRENCH



TYPICAL APPLICATION

1. PIPE CONSTRUCTION ACROSS HEAVILY SATURATED GROUND WITH SLOPE STABILITY ISSUES OBSERVED BEFORE OR DURING CONSTRUCTION. SIDE SLOPE CONSTRUCTION.

X CROSS SECTION ALIGNMENT

NOT TO SCALE

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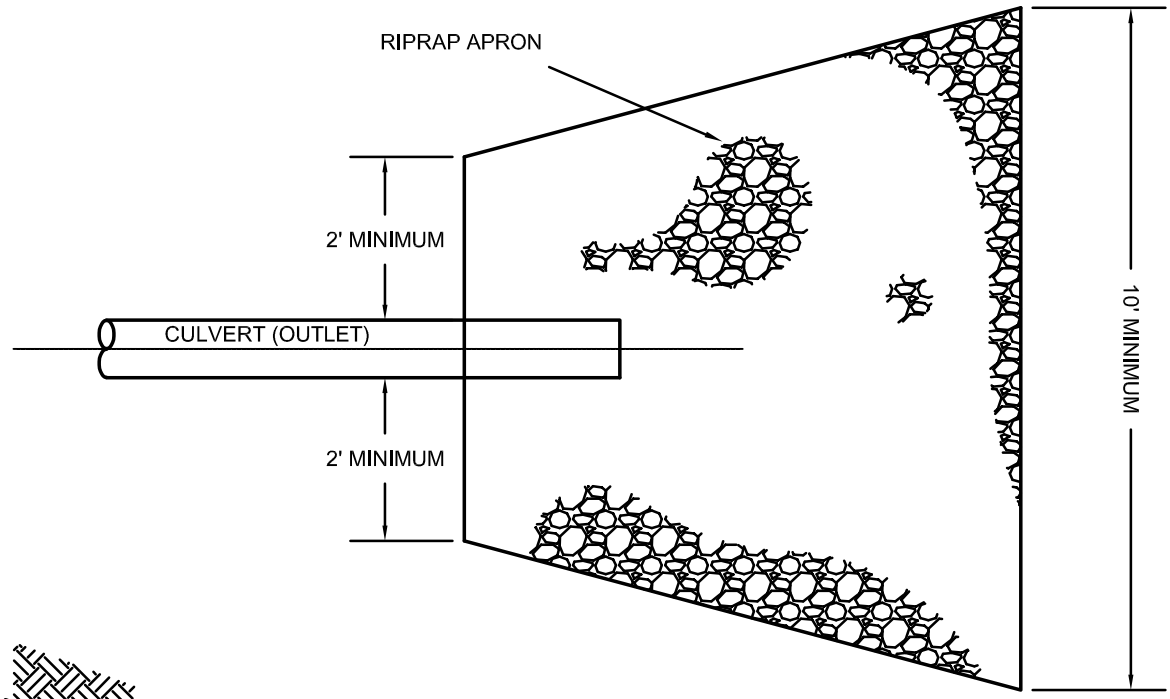
PennEast PIPELINE

PENNEAST PIPELINE PROJECT

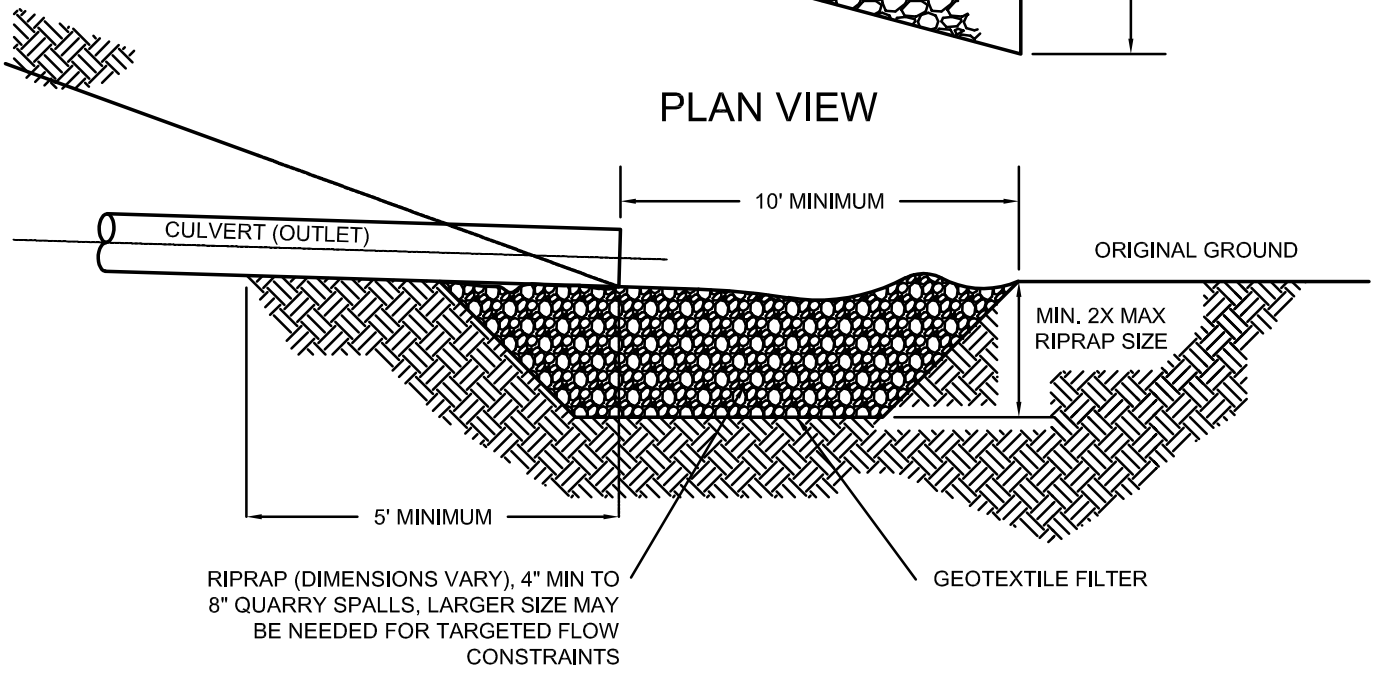
BLEEDER DRAIN DITCH SECTION AND SLOPED PIPE TRENCH

FIGURE 135A

DRAIN PIPE OUTFALL



PLAN VIEW



PROFILE VIEW

NOTES

1. TYPICAL DETAIL ONLY. ACTUAL CONSTRUCTION LAYOUT TO BE ADJUSTED AS APPROPRIATE AND APPROVED FOR SITE CONDITIONS AND DESIGN.
2. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.

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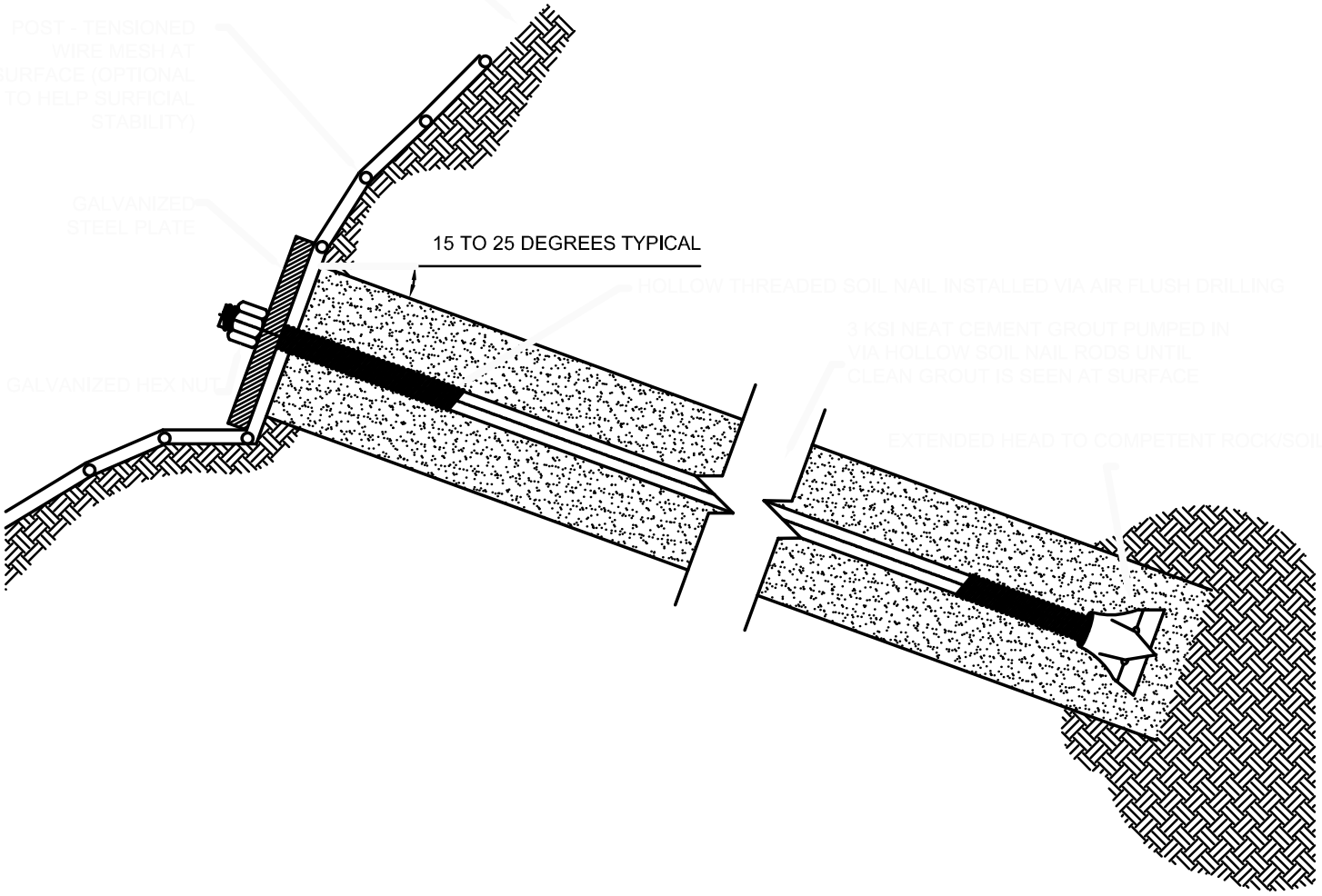
PennEast PIPELINE

PENNEAST PIPELINE PROJECT

DRAIN PIPE OUTFALL
RIPRAP APRON

FIGURE 135B

SOIL NAILS



TYPICAL APPLICATION

1. ROTATIONAL SLUMP.
2. SLOPE FAILURE WHICH CANNOT BE EXCAVATED DUE TO ASSETS ABOVE OR BELOW SLOPE.
3. TO SECURE UNSTABLE SOILS BY TYING INTO STABLE SOILS/ROCK DEEP WITHIN THE SLOPE.

NOTES

1. TYPICAL DETAIL ONLY. ACTUAL CONSTRUCTION LAYOUT TO BE ADJUSTED AS APPROPRIATE FOR SITE CONDITIONS AND DESIGN.
2. SOIL NAILS TO BE DESIGNED AND INSTALLED BY SPECIALIZED CONTRACTOR. MAY REQUIRE BOREHOLE DRILLING PRIOR TO DESIGN.
3. SOIL NAIL AND GROUT TO BE DESIGNED TO SUPPORT SLOPE. SURFICIAL NETTING TO PREVENT SHALLOW MOVEMENTS ONLY.
4. SEE FIGURE 136A, FIGURE 136B.

NOT TO SCALE

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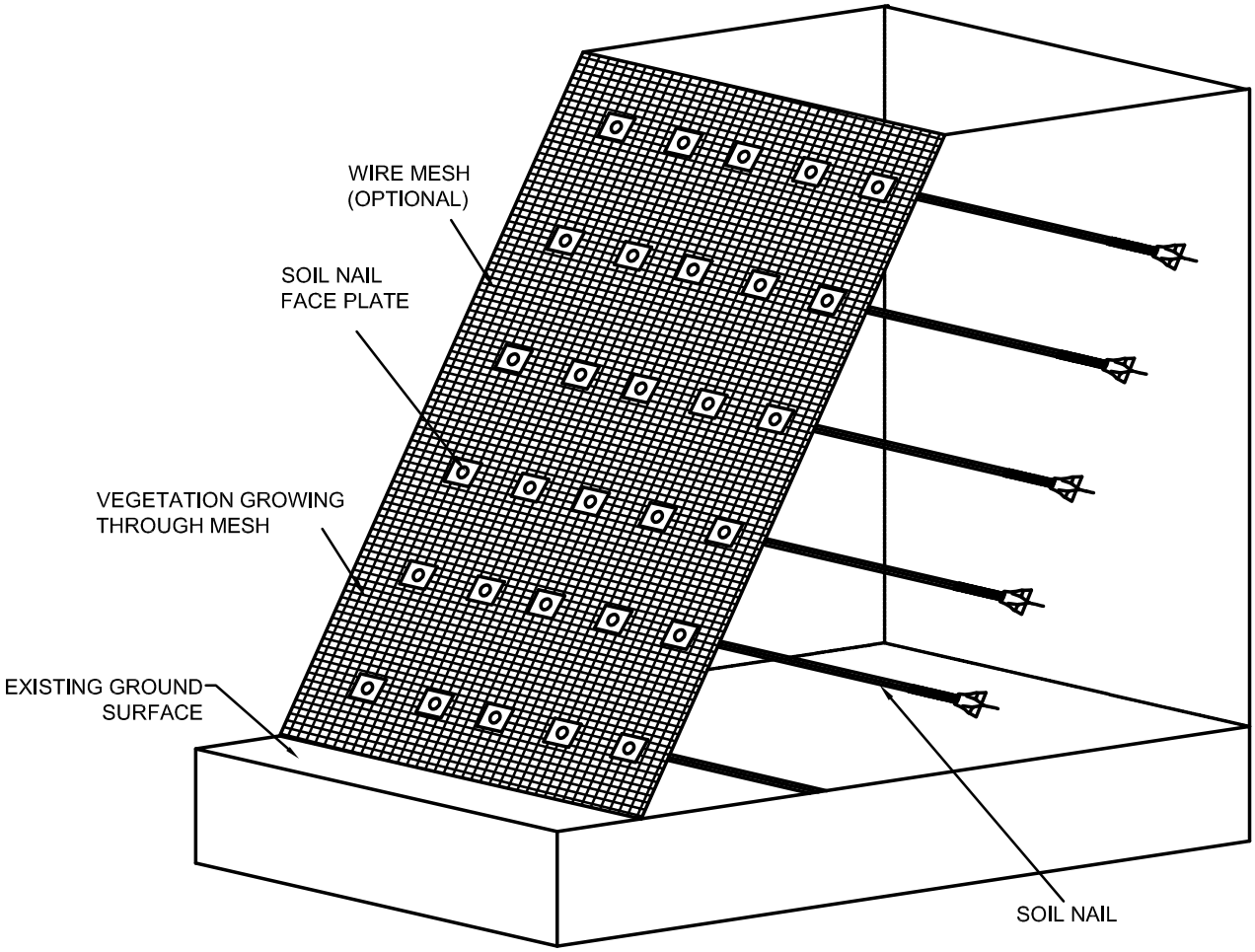
PennEast PIPELINE

PENNEAST PIPELINE PROJECT

SOIL NAILS DETAIL

FIGURE 136

SOIL NAIL SLOPE



TYPICAL APPLICATION

1. ROTATIONAL SLUMP.
2. SLOPE FAILURE WHICH CANNOT BE EXCAVATED DUE TO ASSETS ABOVE OR BELOW SLOPE.
3. INTENT IS TO SECURE UNSTABLE SOILS BACK INTO STABLE SOILS/ROCK DEEP WITHIN THE SLOPE.

NOTES

1. TYPICAL DETAIL ONLY. ACTUAL CONSTRUCTION LAYOUT TO BE ADJUSTED AS APPROPRIATE FOR SITE CONDITIONS AND DESIGN.
2. SOIL NAILS TO BE DESIGNED AND INSTALLED BY SPECIALIZED CONTRACTOR. MAY REQUIRE BOREHOLE DRILLING PRIOR TO DESIGN.
3. SOIL NAIL AND GROUT TO BE DESIGNED TO SUPPORT SLOPE. SURFICIAL NETTING TO PREVENT SHALLOW MOVEMENTS ONLY.

NOT TO SCALE

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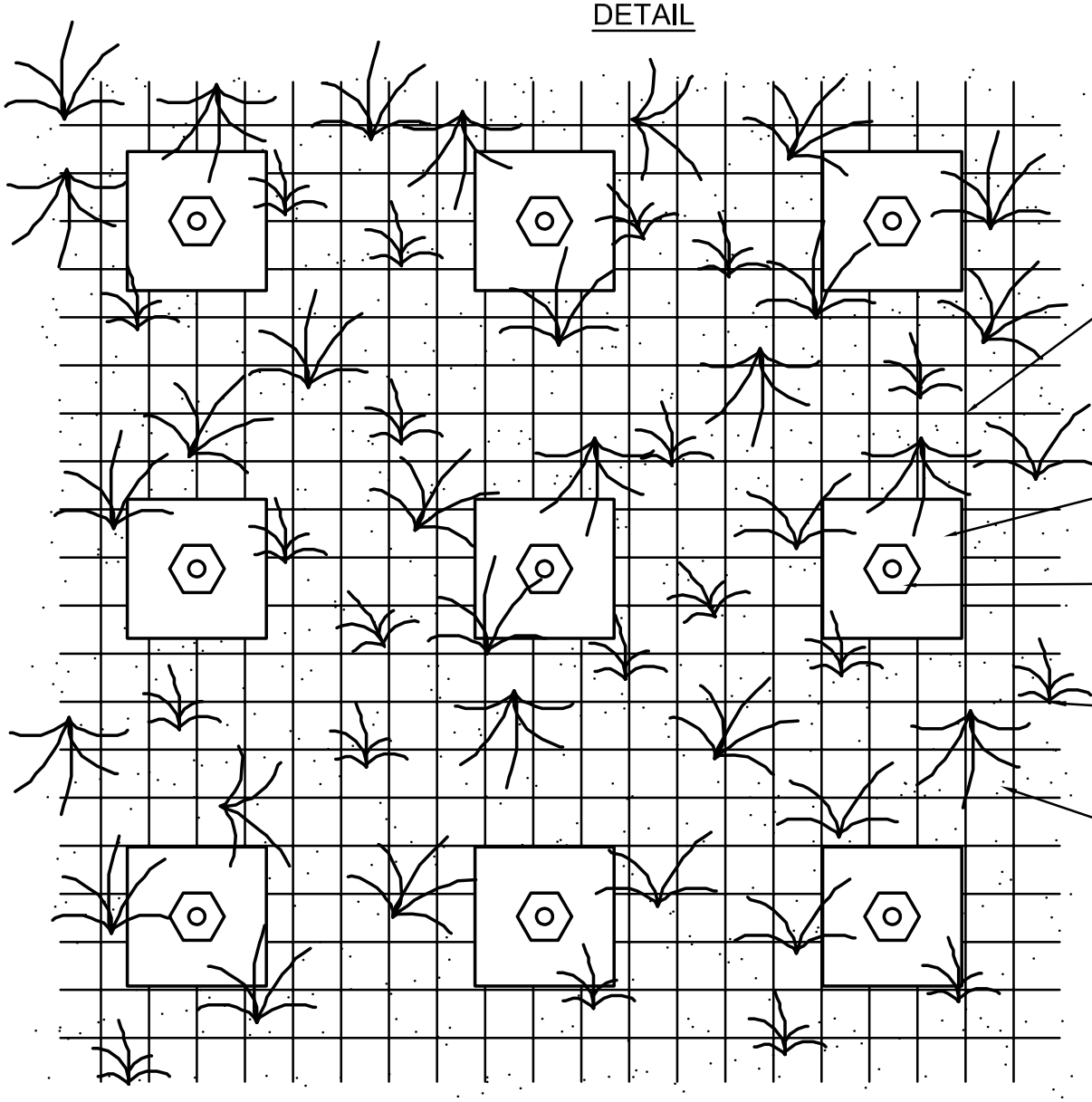
PennEast PIPELINE

PENNEAST PIPELINE PROJECT

SOIL NAIL CONFIGURATION

FIGURE 136A

SOIL NAIL - WIRE MESH DETAIL



TYPICAL APPLICATION

1. ROTATIONAL SLUMP.
2. SLOPE FAILURE WHICH CANNOT BE EXCAVATED DUE TO ASSETS ABOVE OR BELOW SLOPE.
3. INTENT IS TO SECURE UNSTABLE SOILS BACK INTO STABLE SOILS/ROCK DEEP WITHIN THE SLOPE.

NOTES

1. TYPICAL DETAIL ONLY. ACTUAL CONSTRUCTION LAYOUT TO BE ADJUSTED AS APPROPRIATE FOR SITE CONDITIONS AND DESIGN.
2. SOIL NAILS TO BE DESIGNED AND INSTALLED BY SPECIALIZED CONTRACTOR. MAY REQUIRE BOREHOLE DRILLING PRIOR TO DESIGN.
3. SOIL NAIL AND GROUT TO BE DESIGNED TO SUPPORT SLOPE. SURFICIAL NETTING TO PREVENT SHALLOW MOVEMENTS ONLY.

NOT TO SCALE

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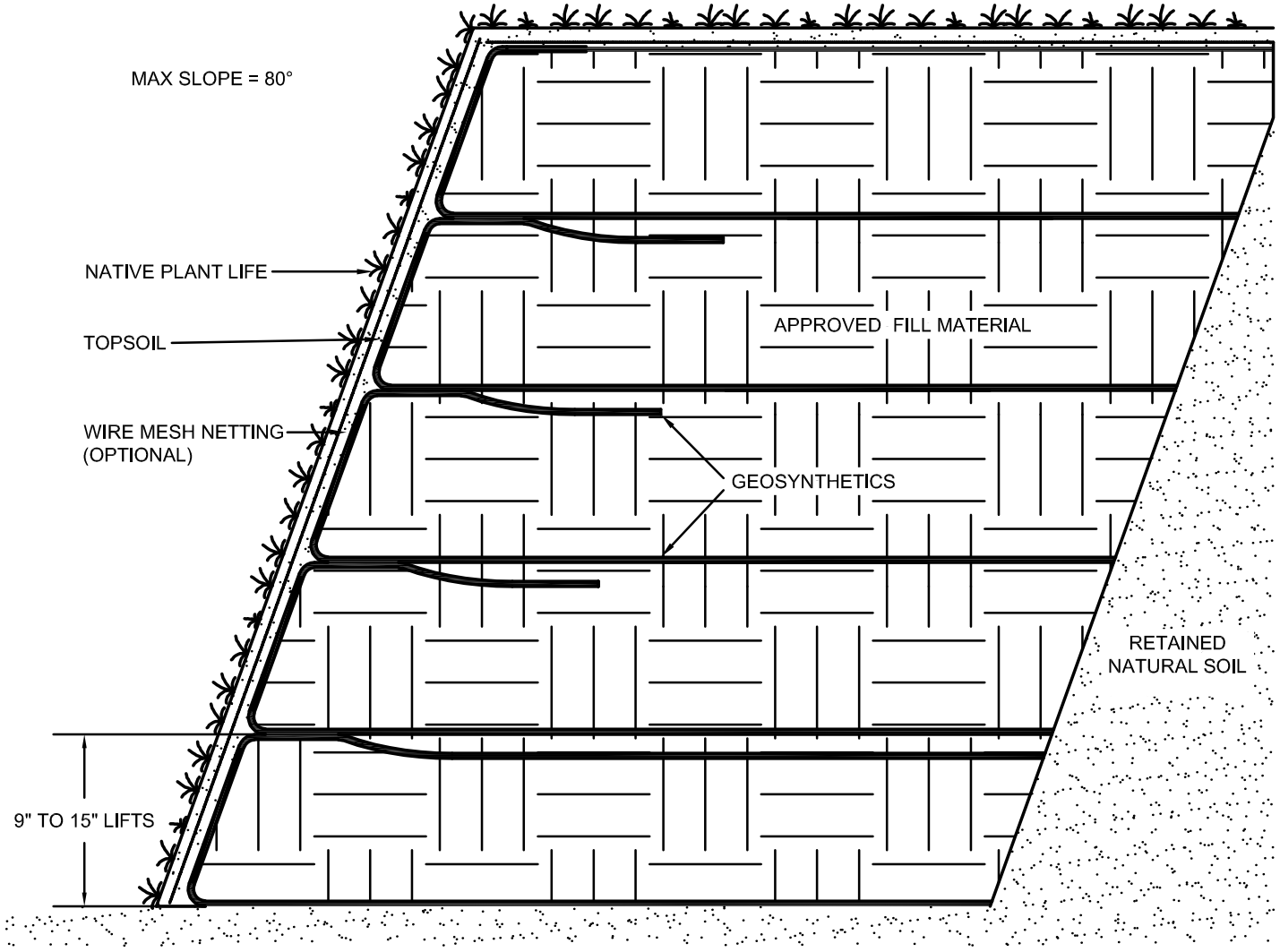
PennEast PIPELINE

PENNEAST PIPELINE PROJECT

SOIL NAIL - WIRE MESH DETAIL

FIGURE 136B

REINFORCED SLOPE - LIVING WALL



TYPICAL APPLICATION

1. RESTORATION OF SLOPE WHICH HAD SIGNIFICANT THICKNESS OF WEEK MATERIAL STRIPPED OFF.
2. SLOPES WHICH WILL BE EXPOSED TO IMPOSED LOADING AT THE CREST (E.G. TRAFFIC LOAD)
3. ADJACENT TO SMALL WATER BODIES

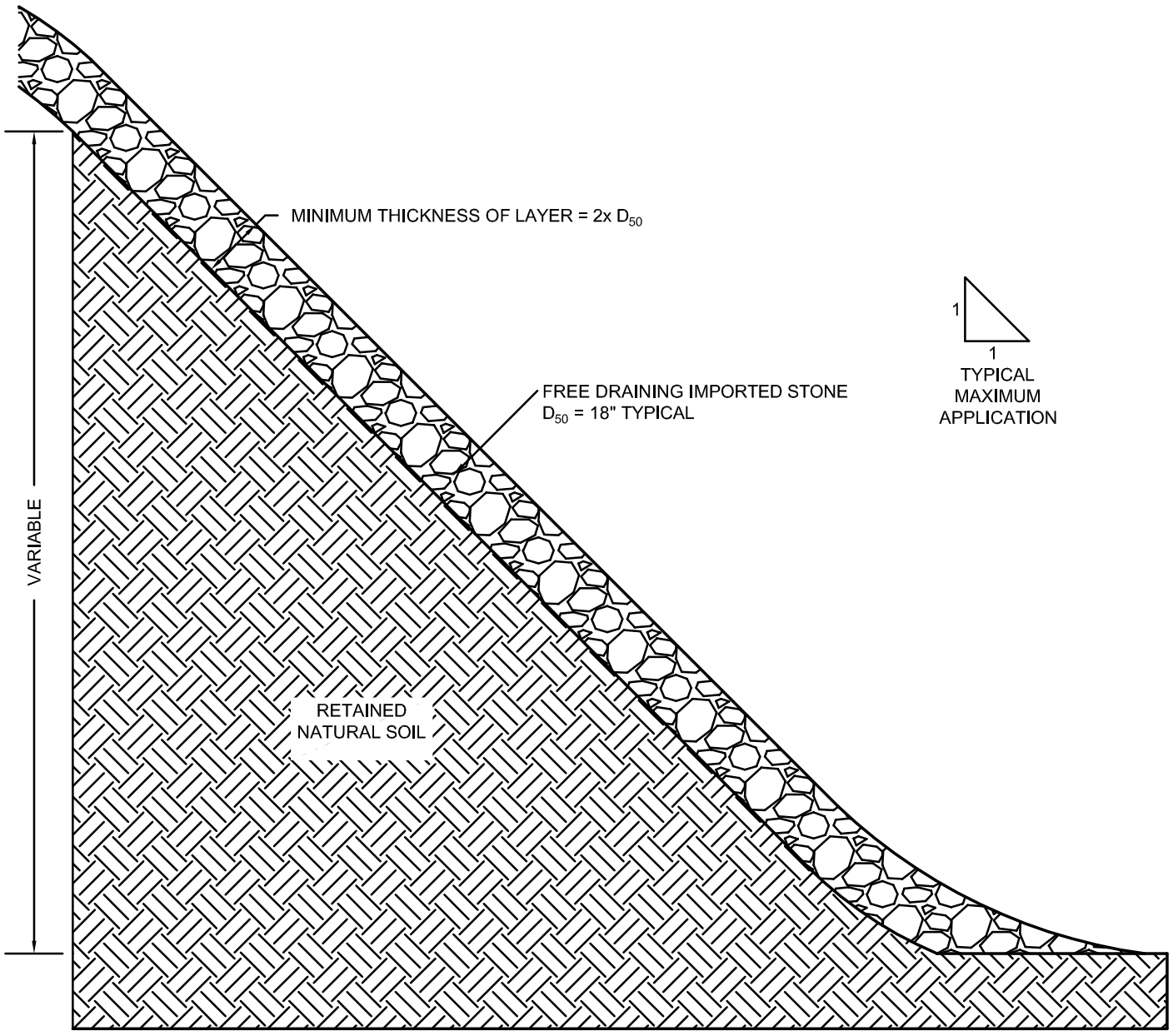
NOTES

1. REINFORCED SOIL SLOPE TO BE DESIGNED AND SPECIFIED FOR EACH APPLICATION AND FOLLOW GEOSYNTHETIC MANUFACTURER RECOMMENDATIONS.
2. BEARING CAPACITY OF UNDERLYING SOILS TO BE EVACUATED.

NOT TO SCALE

0	2019/08/07		DC	DH		PennEast PIPELINE	PENNEAST PIPELINE PROJECT
							REINFORCED SOIL SLOPE (LIVING WALL)
							FIGURE 137
NO.	DATE	REVISION DESCRIPTION	BY	CHK	APP		

CLEAN CUT WITH IMPORTED STONE



TYPICAL APPLICATION

NOTES

NOT TO SCALE

PENNEAST PIPELINE PROJECT	
SLOPE PROTECTED WITH IMPORTED STONE	
FIGURE 138	