Appendix 4
Geologic Hazard Mitigation Plan

Geologic Hazard Mitigation Plan Pennsylvania

October 10, 2019

PennEast Pipeline Project

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Contents

1 Introduction

Mott MacDonald has prepared this Geologic Hazard Mitigation Plan (GHMP) at the request of PennEast Pipeline Company, LLC (PennEast), for the PennEast Pipeline Project. The proposed Project consists of 115 miles of 36-inch diameter (NPS 36) high pressure, natural gas pipeline from Luzerne County, Pennsylvania to Mercer County, New Jersey.

PennEast has routed the alignment to avoid known areas of geological hazards to the extent practicable. Also, elements of pipeline design have been incorporated to improve system resiliency. However, the Project continues to cross areas where geohazards, such as steep slopes, karst areas and mines potentially exist. This GHMP presents potential mitigations options for implementation when a geohazard is encountered during construction. This GHMP should be used continuously to help evaluate and mitigate conditions as they are observed in the field.

This plan is intended to provide general guidance for field construction and inspection personnel to evaluate and mitigate potential residual geohazards encountered in the field during various stages of construction activities.

Field construction personnel are expected to use this document to help identify potentially hazardous conditions and allow for appropriate decision-making to occur. Making field observations and discussing encountered conditions with a geotechnical engineer and/or geologist is essential to implementing mitigation measures to provide safe construction work practices and long-term integrity of the proposed pipeline system. Geotechnical engineers and/or geologists should be consulted with where observed geological hazards are encountered.

2 Slope Hazards

2.1 Slope Hazard Classifications

Slope hazards were evaluated using GIS software to identify areas of potential hazard based principally on slope angles/percent grade. This evaluation was combined with review of aerial photography from various sources as well as geological mapping. This process resulted in a list of slopes identified as warranting site-specific field reconnaissance. Site-specific field reconnaissance was performed which resulted in a confirmed list of steep slopes that may present a hazard to the pipeline Project.

2.1.1 Landslide Susceptibility

"Landslide" is a general term for downslope mass movement of soil, rock, or a combination of materials on an unstable slope. Landslides can vary greatly in their rate of movement, area affected, and volume of material.

According to the United States Geological Survey (USGS) landslide susceptibility map, portions of the Project area in Luzerne, Carbon, Monroe and Northampton Counties, Pennsylvania are susceptible to landslides. The Project area between Mile Posts (MPs) 5.3 and 15.2 in Luzerne County and between MPs 40.7R2 in Carbon County and 53.2R3 in Northampton County have a relatively high susceptibility to landsliding with moderate incidence. The Project area between MP 20.9 in Luzerne County and MP 23.6 in Carbon County and between MPs 33.6R3 and 35.0 and 38.0 and 40.7R2 in Carbon County have a moderate landslide incidence. Following the field review, the majority of locations were evaluated to be of low risk and not requiring any specific design changes above the standard Erosion and Sedimentation Control (E&S) measures for work on slopes. The locations are presented on the E&S alignment sheets.

2.1.2 Seismic Hazard Evaluation

PennEast conducted a seismic hazard evaluation, including a screening-level ground failure evaluation, to evaluate potential seismic hazards such as landslides.

In addition, as part of the seismic hazard evaluation, PennEast conducted a preliminary evaluation of seismically induced landslides using the USGS landslide susceptibility maps and induced seismic demand. This procedure provides negligible Permanent Ground Disturbance (PGD) for MPs with low and moderate susceptibility and PGD displacements less than 0.1 m for MPs located in high susceptibility zone including segments from MP 5.3 to MP 15.2 and MP 40.7R2 to MP 53.2R3.

Pipeline Research Council International (PRCI) Guidelines indicate that vertical movements due to buoyancy will only be hazard for large diameter pipelines within soils with unusually low residual shear strength. Based on qualitative assessment of liquefaction susceptibility and relatively low seismic demand, the risk due to buoyancy hazard seems low to unlikely for the Project.

The surface fault displacement hazard along the Project pipeline is considered to be negligible and no mitigation measures are required.

2.2 Slope Hazard Mitigation Measures

Slopes can present a potential hazard for surface erosion and sedimentation if disturbed and unattended. This hazard will be addressed by implementing the Project-specific Erosion and Sediment Control Plan. The Erosion and Sediment Control (E&S) drawing sheets 000-03-09-01 through 000-03-09-09 contain 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. 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. Potentially hazardous slopes will be evaluated at key Project events, such as tree clearing and excavation activities. Evaluations will look for signs of historic, active or potential slope instability, including but not limited to looking for groundwater seeps, deformation of structures, tension cracking, and scarping.

Where hazardous conditions exist beyond the applicability of the standard construction details, additional slope restoration provisions will be developed and implemented. A geotechnical engineer and/or geologist will be consulted to develop location-specific mitigation measures in coordination with the contractor. The mitigation methods will focus on improving slope drainage and/or replacing unstable soils with stronger imported soils and/or adding engineered retaining items to the slope and/or modifying the slope geometry.

Examples of elevated slope hazard mitigation measures are provided in Appendix B to demonstrate a range of which will be considered, numbered Figure 12A, 13A and 135 through 142.

3 Karst Hazards

3.1 Karst Feature Classifications

Karst terrain is formed by the solution of carbonate rock (e.g., limestone, dolostone, and marble) and evaporate deposits by percolating surface water and groundwater along fractures, joints, and bedding planes. Karst is characterized by features such as cavern openings, sinkholes, closed depressions, and gaining and losing streams. Where present these conditions can create engineering and environmental issues due to subsidence, groundwater quality impacts, and stormwater flooding and control issues.

Sinkholes are naturally occurring phenomena in areas underlain by carbonate bedrock, such as the carbonate formations occurring in Pennsylvania. Most sinkholes are triggered by external factors such as significant or prolonged rainfall, periods of drought, heavy groundwater pumping, or stormwater management practices; however, activity at remnant or dormant sinkholes may be triggered by uncontrolled construction practices. Historically, installation of pipelines through this region has shown that the frequency of localized subsidence occurrences will be low, and the relative scale of related karst hazards would be small enough for standard mitigative measures.

3.2 Karst Hazards Identified

During the route selection process, aerial photograph, available data and resources produced by USGS and PADCNR were reviewed to report the existence or absence of karst hazards and sinkholes intersecting the Project alignment. In addition, geophysical and geotechnical investigations were conducted which provide Project-specific data for karst risks; however, each investigation method may not fully identify all areas of karst risk which may be present during construction of the Project. Should hazardous karst features be uncovered during the construction of the Project, the measures and mitigation strategies listed within the following sections of the GHMP may be implemented.

3.3 Karst Mitigation Measures

PennEast proposes to establish buffers around known hazardous karst features to generally maintain vegetation, structural integrity, or drainage of the existing hazardous karst feature within the buffer area where practicable. The prohibition of most land uses within the hazardous karst feature buffers, at least for sinkholes, also helps minimize exposure to sinkhole subsidence and sinkhole flooding. PennEast intends to implement the following considerations for buffers related to certain activities within hazardous karst areas.

3.3.1 Karst Mitigation During Construction

During conventional installation of the pipeline, the construction contractor will conduct earthmoving activities in a manner that will minimize altering the existing grade and hydrology of existing surficial hazardous karst features. Where a known and delineated hazardous karst feature exists, earthmoving including temporary filling within 100 feet of the feature will be avoided to the extent practicable or minimized. During routine trenching and pipe laying activities adjacent to hazardous karst features, spoils will be placed on the upgradient side of the excavation such that, if any erosion was to occur, the stockpiled soil would return into the excavation and not into the hazardous karst features.

Buffers of 100 feet around documented hazardous karst surface expressions and wells and springs recharging karst hydrology will be maintained between all work areas and the hazardous karst-related features. Surface water control measures including, but not limited to, diversion, detention, or collection and transportation will be considered to minimize construction-influenced surface water from entering into the hazardous karst-related features. At no time will the hazardous karst features be used for the disposal or extraction of construction water.

Following pipeline construction, hydrostatic testing will be performed prior to placing the pipeline into service. During this phase of construction, hydrostatic testing water will be prohibited from being returned into areas where known sinkholes, fissures, or other hazardous karst features or channels or surface features that flow towards those features exist. Hydrostatic testing water will be disposed of either downgradient of hazardous karst features (unless on-the-ground circumstances (e.g., manmade structures, terrain, other sensitive resources prevent such discharge),or in uplands greater than 300 feet from the hazardous karst features or, as far as practical from hazardous karst features with sediment and water flow control devices to minimize the increase of drainage recharge and discharge into the karst feature.

If a new sinkhole develops within the construction area while work is commencing/occurring, work in the area will be halted and the sinkhole area will be isolated and cordoned off to an area extending 100 feet radially from the feature. The sinkhole will be inspected by a geotechnical engineer and remedial measures such as filling of the sinkhole using inverted filter approach or adjustment of the pipeline alignment within the construction LOD may be implemented. The inverted filter approach is often used for sinkhole repair, especially when the sinkhole is not located near structures. The sinkhole area is excavated to expose either bedrock or the throat of the sinkhole. A course of rock large enough to bridge the throat of the sinkhole is placed at the bottom of the excavation. Courses of progressively finer rock and gravel are compacted above the base course. A geotextile fabric may be placed above the finest gravel course to prevent excessive loss of the uppermost course, which may consist of sand and/or soil. The inverted filter method provides filtration treatment of storm water and allows controlled storm water infiltration and groundwater recharge.

If an existing subsurface void is intersected within the work area, work will similarly be halted and cordoned off for further evaluation by a qualified geotechnical engineer. As indicated earlier, the principal approach to maintain rates of recharge and discharge at pre-development conditions, a filter fabric secured over the void may be implemented in addition to an inverted filter.

3.3.2 Blasting Near Karst Areas

Blasting in proximity to known and verified karst areas will be conducted in a manner so as not to comprise the structural integrity of pre-existing karst features or to alter subsurface hydrology through karst areas. If it is deemed that rock removal using blasting or hammering techniques is required in a karst-prone area, PennEast will inspect the area to be excavated for potential voids, openings, or other identifying features typical of karst. If the proposed rock removal is expected to intersect a karst feature such as sinkhole throat/void, cavern, or conduit, work in the area will be stopped until a location-specific assessment can be completed by a qualified geotechnical engineer familiar with the Project and with experience in karst terrain mitigation.

Following inspection of the area by the geotechnical engineer, blasting activities near any identified hazardous karst features may be allowed such that the use of all explosives will be limited to low-force charges to minimize propagation outside of blast area. PennEast may conduct subsurface explorations to determine if the voids have connectivity with a deeper structure. It is anticipated that such investigation may consist of additional percussive probes, electrical resistivity, or other techniques capable of resolving open voids in the underlying bedrock.

3.3.3 General Karst Mitigation During Construction

Methods to mitigate sinkhole collapses and similar subsurface voids are referenced in the Pennsylvania Department of Environmental Protection's (PADEP) Erosion and Sediment Pollution Control Manual dated March 2012. Typical details recommended by PADEP is included as Appendix A of this GHMP and may be implemented depending on the karst feature encountered. These are adapted from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) and include options for sinkhole repair with a Bentonite cap, pervious cover, impervious cover, and soil cover, respectively.

The mitigation methods detailed in the PADEP Manual would provide enhanced stability to the void and increase the long-term stability and integrity to the pipeline right of way. Final grading of contours and any necessary permanent erosion and sediment controls will be designed to prevent runoff from accumulating in the area of the void. In addition, during the discharge of any hydrostatic test water from the pipeline, a discharge location will be selected that will prevent the discharged water from encountering any unanticipated features discovered during trenching activities.

Typical sinkhole mitigation measures are presented in Appendix A. Location-specific information should be evaluated to determine the most appropriate methodology prior to implementation.

4 Mine Hazards

4.1 Mine Feature Classifications

It is not required to fully classify the origin of a void when encountered if the contractor can confidently remiediate the feature in the field. It is however useful to understand the various potential origins of a void, which may help in the selection of the most effective treatment method.

- Mine shafts

  The Project alignment has been located to avoid known mine shafts, however there is a potential to encounter unrecorded shafts. Should a mine shaft be discovered during construction, work should be stopped within the local area and a geotechnical engineer and/or geologist should be consulted. Coordination with the DEP Bureau of Abandoned Mine Reclamation may be required. Mitigation options will vary based on the type and orientation of the mine shaft encountered, and may require a specific consideration and design.

- Non-vertical mine entrances (tunnels, slopes, drifts)

  The Project area crosses the outcrop line of numerous worked anthracite coal seams. Near the anticipated outcrops and in other locations, historic entrance ways may be encountered. The stability of the historic workings is highly variable; openings may currently remain open but in a marginal state of stability.

- Crop lines

  The Project will cross crop lines of coal seams which were worked using underground mining methods. Crop lines of steeply dipping seams represent locations with a high potential for voiding and subsidence.

- Underground workings

  Where shallow workings exist, excavation operations may directly intersect the worked stratigraphy. The worked seams may have remained open or may have collapsed to form a thicker rubble zone. Upwards propagation of voids from collapsing worked seams can lead to the occurrence of mining subsidence holes (akin to sink holes). Stress fracturing from deep mining may extend far beyond the zone of potential void collapse. The extensive deep mining of the Wyoming Valley leads to a modification of the stress fields within the bedrock and additional fracturing.

- Strip mines

  Areas of historic strip mining may contain deep excavations with high walls. The areas may have been backfilled with uncontrolled filling methods, and spoil slopes may be marginally stable.

- Acid mine drainage

  Due to the exposure of minerals to atmospheric elements, the waters within mine networks can become enriched in acidity and other contaminants including iron and sulfur. Waters emanated from mine networks or within mine networks should be evaluated for contamination when encountered and where necessary.

4.2 Mine Hazard Areas Identified

Research of historic mining operations has been performed in consultation with PADEP Bureau of Abandoned Mine Reclamation for the Project area. A field investigation program was conducted to establish current-day condition at select locations. The primary location where mining related hazards exist is the Wyoming Valley (MP5.0- MP11.5). However, it should be noted that the localized conditions encountered during site preparation and construction will vary.

4.3 Mine Hazard Mitigation Measures

The objective of any mitigation method should be to create a safe right-of-way (ROW), reduce environmental impacts and to reduce the hazard posed to the pipeline during operation. The execution of mitigation methods utilized by the contractor should be pre-approved and overseen by a geotechnical engineer and/or geologist. An understanding of the hazard and adaptability will be key to an effective and safe mitigation of mining related hazards. Two generalized options for mitigation are presented in the following sections.

4.3.1 Backfilling Mine Hazards with Coarse Aggregate

Mine back fill aggregate may be imported or obtained from site sources. The aggregate backfill may contain a binder, such as cement, to stabilize the backfill within the mine working.

Small voids can be filled with an aggregate of approximately 1-inch diameter. Small voids are generally considered to be less than 100 cubic feet where the objective is to fill the void.

Where large voids are encountered, the objective should be to treat the void so that it no longer presents a hazard to the Project. Completely filling the void may be impractical and unnecessary where it extends outside the ROW or to great depth. The backfilling operations should aim to limit the flow of material beyond the relevant zone. When backfilling steeply dipping workings, a bridge may be required to choke off the hole allowing aggregate to be placed in the specified zone. Coarse aggregate of >6-inch diameter may be used to choke off holes.

4.3.2 Backfilling Mine Hazards with Grout

The injection of grout may be desirable to fill voids or to bind zones of collapsed rubble or gob. This mitigation technique can yield contact with the void roof and does not rely on arching to prevent any further damage. The grout specification should be agreed with the Project engineers prior to use. The use of fly ash may be permitted within the mixture.

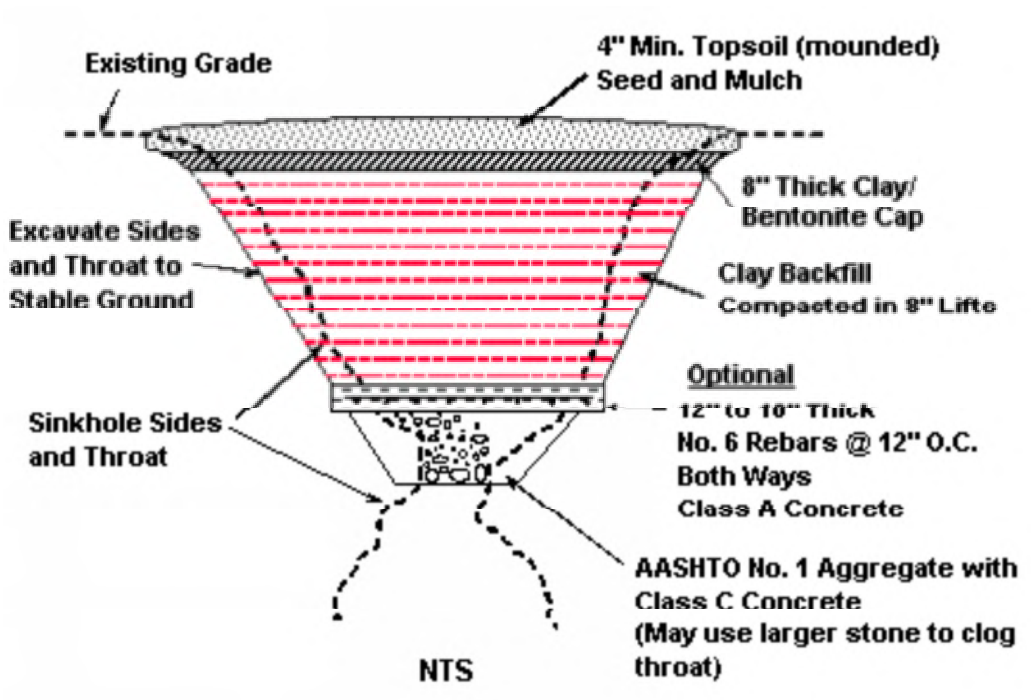
4.3.3 General Mine Hazard Mitigation During Construction

Typical sinkhole mitigation measures are presented in Appendix A. Location-specific information should be evaluated to determine the most appropriate methodology prior to implementation.

Appendices

A. USDA NRCS Mitigation Details

PADEP Sinkhole Repair with Bentonite Cap Detail



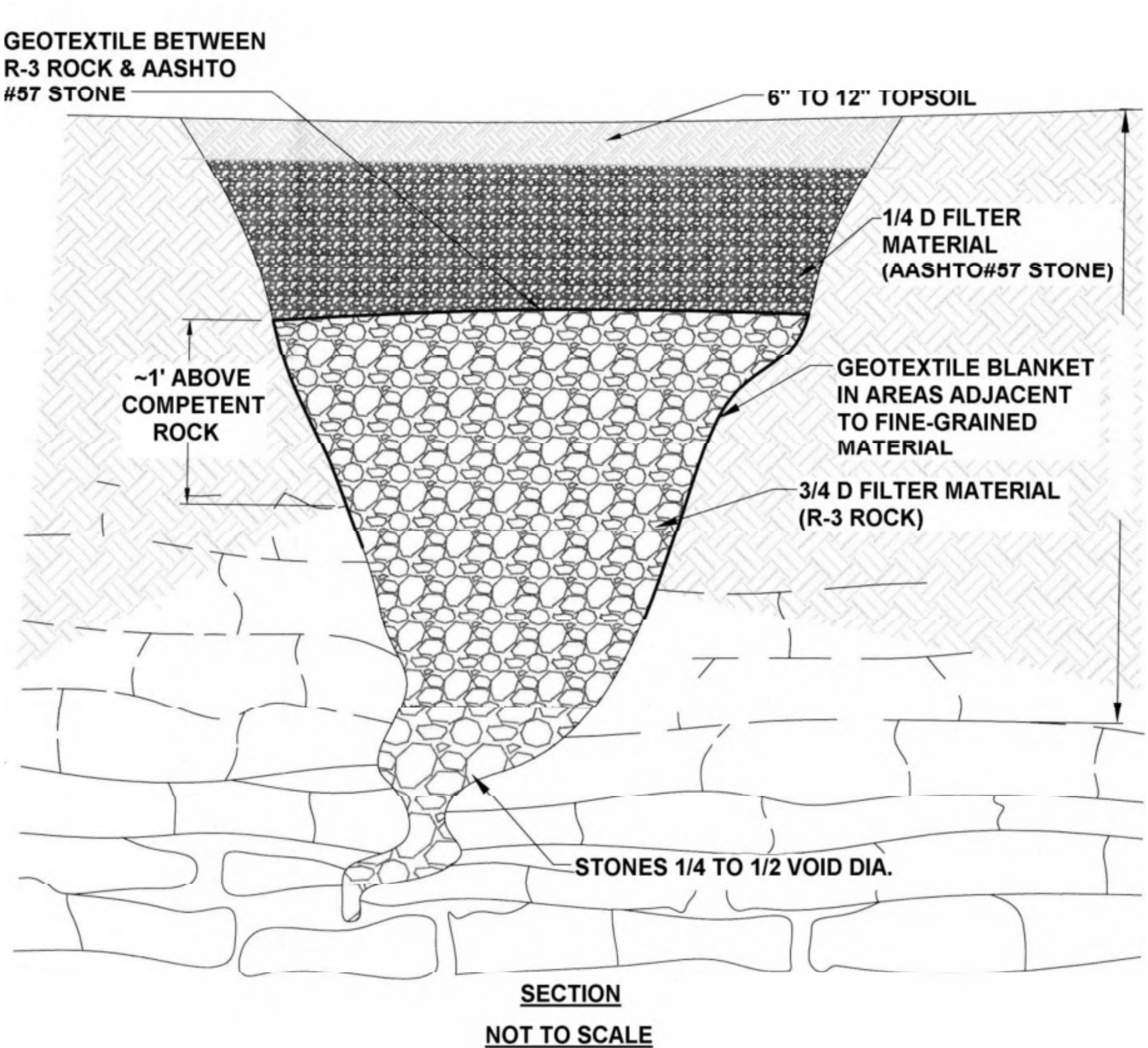
Source: Adapted from PADEP

Notes:

1. Loose material shall be excavated from the sinkhole and expose solution void(s) if possible. Enlarge sinkhole if necessary to allow for installation of filter materials. Occupational Safety and Health Administration (OSHA) regulations must be followed at all times during excavation.

2. Stones used for the “bridge” and filters shall have a moderately hard rock strength and be resistant to abrasion and degradation. Shale and similar soft and/or non-durable rock are not acceptable.

USDA NRCS Sinkhole Repair with Pervious Cover Detail



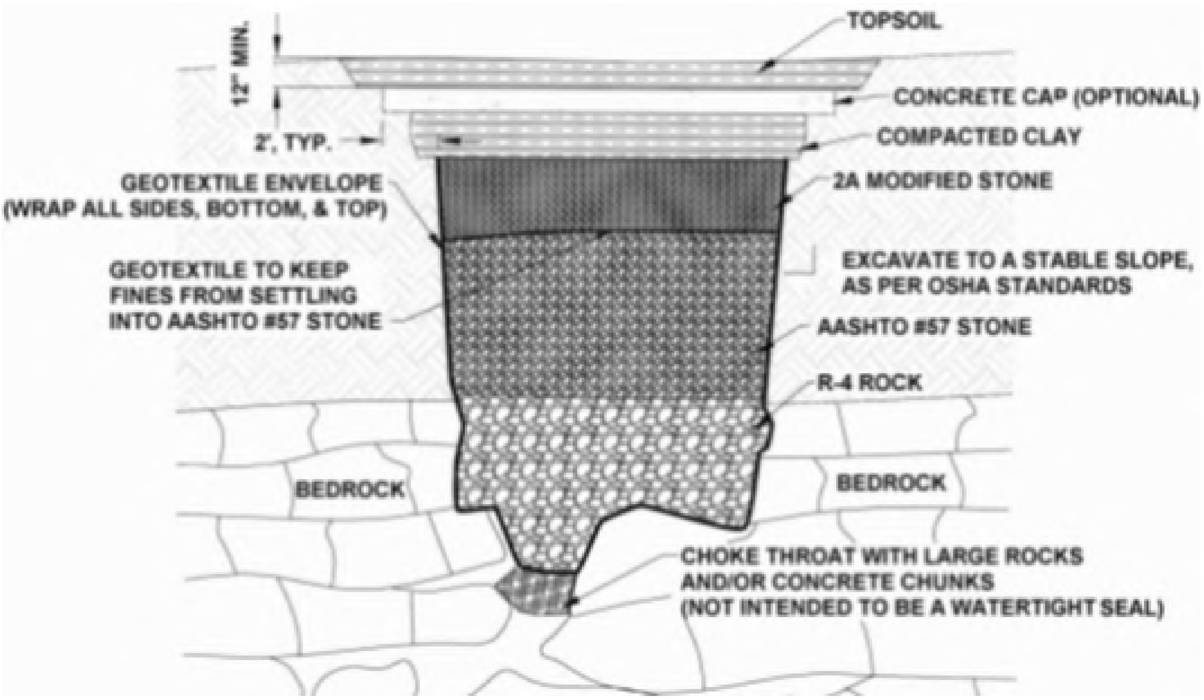
Source: Adapted from USDA NRCS

Notes

1. Loose material shall be excavated from the sinkhole and expose solution void(s) if possible. Enlarge sinkhole if necessary to allow for installation of filter materials. OSHA regulations must be followed at all times during excavation.

2. Stones used for the “bridge” and filters shall have a moderately hard rock strength and be resistant to abrasion and degradation. Shale and similar soft and/or non-durable rock are not acceptable.

USDA NRCS Sinkhole Repair with Impervious Cover Detail



Source: Adapted from USDA NRCS

Notes:

1. Loose material shall be excavated from the sinkhole and expose solution void(s) if possible. Enlarge sinkhole if necessary to allow for installation of filter materials. OSHA regulations must be followed at all times during excavation.

2. Geotextile shall be non-woven with a burst strength between 100 and 200 psi.

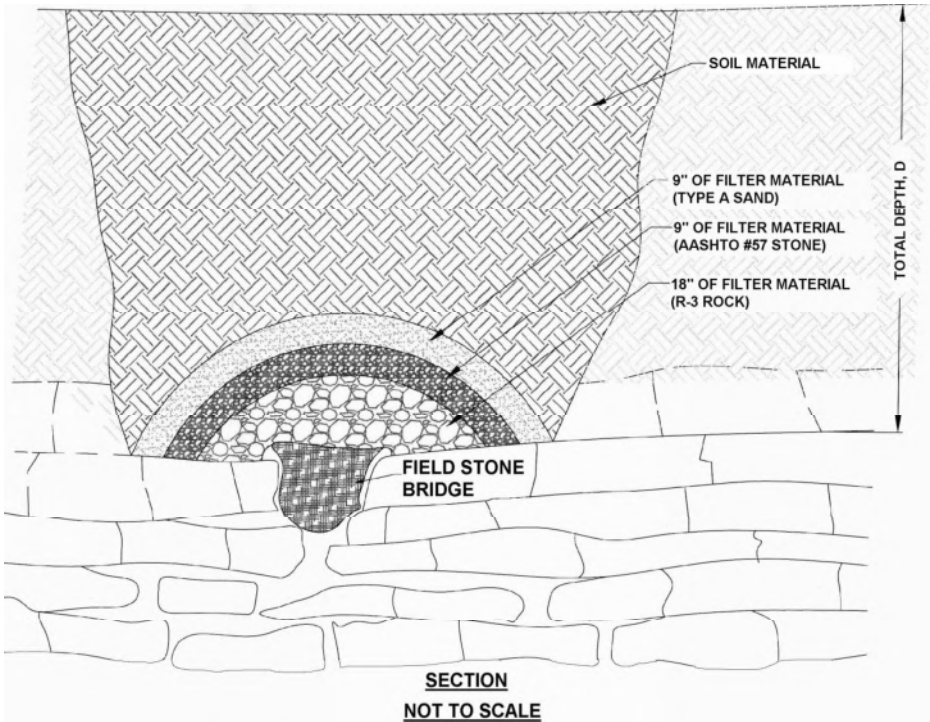
3. Select field stone(s) about 1.5 times larger than solution void(s) to form “bridge.” Place rock(s) so no large openings exist along the sides. Stones used for the “bridge” and filters shall have a moderately hard rock strength and be resistant to abrasion and degradation. Shale and similar soft and/or non-durable rock are not acceptable.

4. Minimum thickness of R-4 rock is 18.” AASHTO #57 stone thickness shall be ¼ to ½ that of the R-4 rock. Minimum thickness of 2A modified crushed stone shall be 9” AASHTO #57 stone and 2A modified crushed stone shall be compacted after each placement.

5. Compacted clay seal shall be a minimum of 12” thick. Clay shall be placed in 6” to 9” lifts and thoroughly compacted. Concrete cap, which is optional, shall be a minimum of 8” thick. Use 4,000 psi concrete with 6” X 6” - 6 gauge welded wire fabric, or # 3 rebar on 18” O.C. both ways.

6. Topsoil shall be a minimum of 12” thick. Grade for drainage away from sinkhole area.

USDA NRCS Sinkhole Repair with Soil Cover Detail



Source: Adapted from USDA NRCS

Notes:

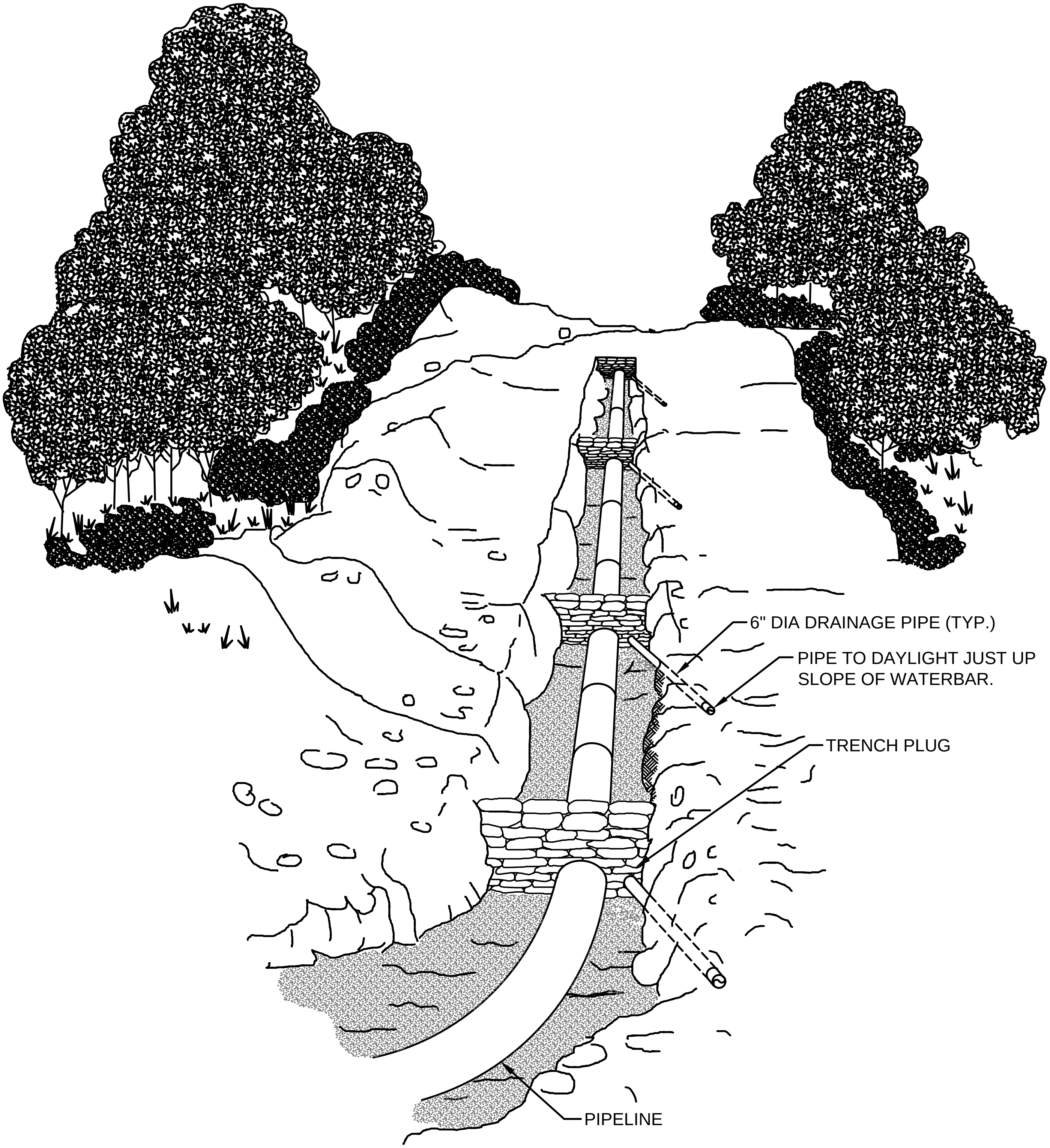
1. Loose material shall be excavated from the sinkhole and expose solution void(s) if possible. Enlarge sinkhole if necessary to allow for installation of filter materials. OSHA regulations must be followed at all times during excavation.

2. Select field stone(s) about 1.5 times larger than solution void(s) to form “bridge.” Place rock(s) so no large openings exist along the sides. Stones used for the “bridge” and filters shall have a moderately hard rock strength and be resistant to abrasion and degradation. Shale and similar soft and/or non-durable rock are not acceptable.

3. Minimum thickness of R-3 rock is 18” AASHTO #57 stone thickness shall be a minimum of 9” thick. Minimum thickness of type A sand shall be 9”. NOTE: A non-woven geotextile with a burst strength between 100 and 200 psi may be substituted for the AASHTO#57 stone and type A sand.

4. Soil shall be mineral soil with at least 12% fines and overfilled by 5% to allow for settlement. Suitable soil from the excavation may be used. Any available topsoil shall be placed on top surface.

B. Slope Restoration Typical Drawings



NOTE:

1. INSTALL TRENCH PLUG DRAINAGE PIPES 1 SAND BAG OFF BASE OF TRENCH.
2. RUN DRAINAGE PIPES DOWN SLOPE 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.

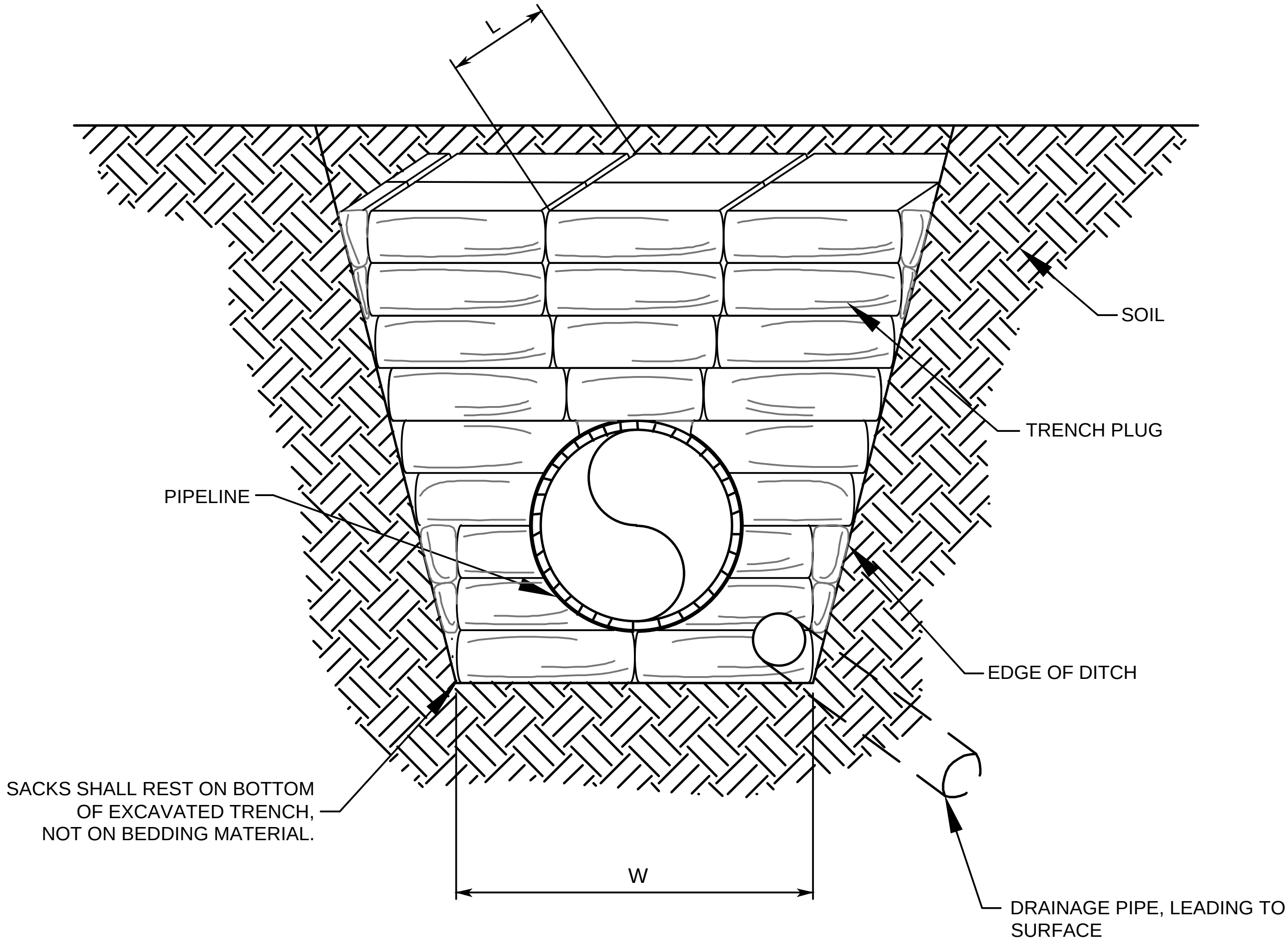
NOT TO SCALE

PennEast PIPELINE

PENNEAST PIPELINE PROJECT

DRAINED TRENCH PLUGS
FOLLOWING PIPELINE INSTALLATION

FIGURE 12A



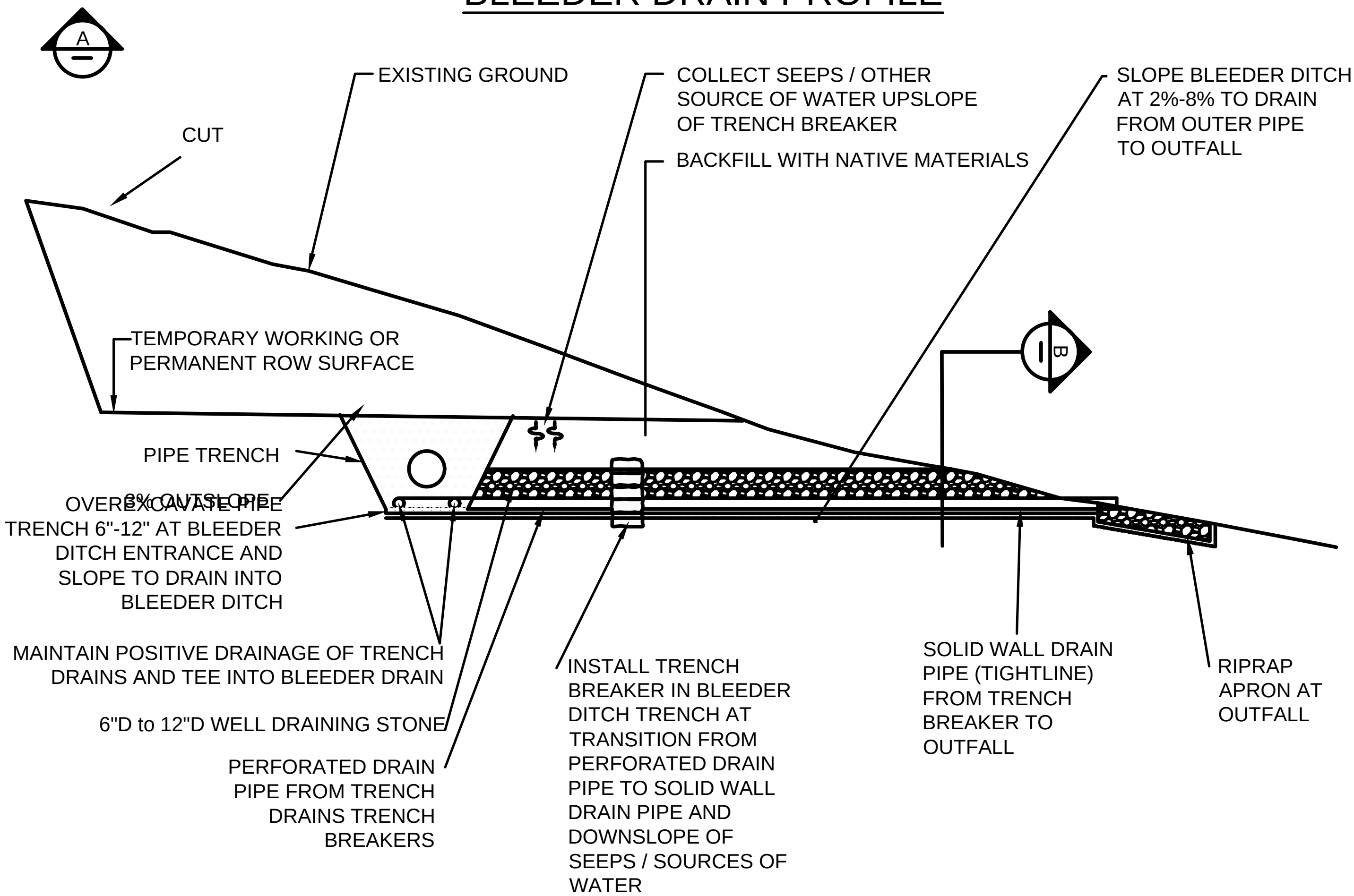
W = TRENCH WIDTH
L = 24" MINIMUM

PENNEAST PIPELINE PROJECT

DRAINED TRENCH PLUG DETAIL

FIGURE 13A

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.

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.

NOT TO SCALE

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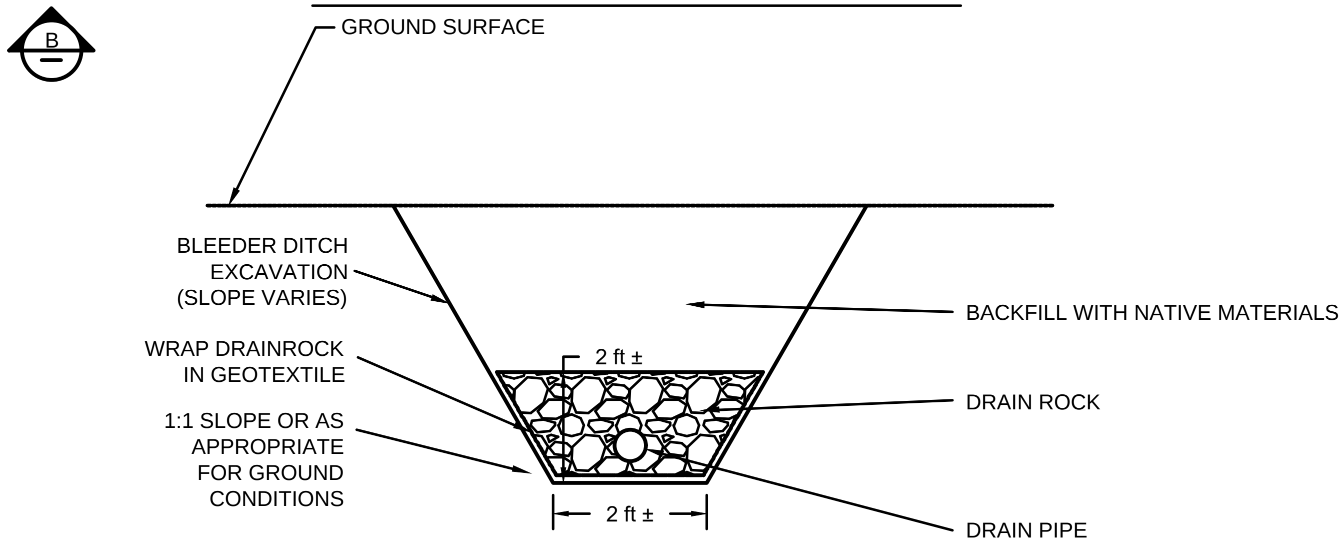
PennEast PIPELINE

PENNEAST PIPELINE PROJECT

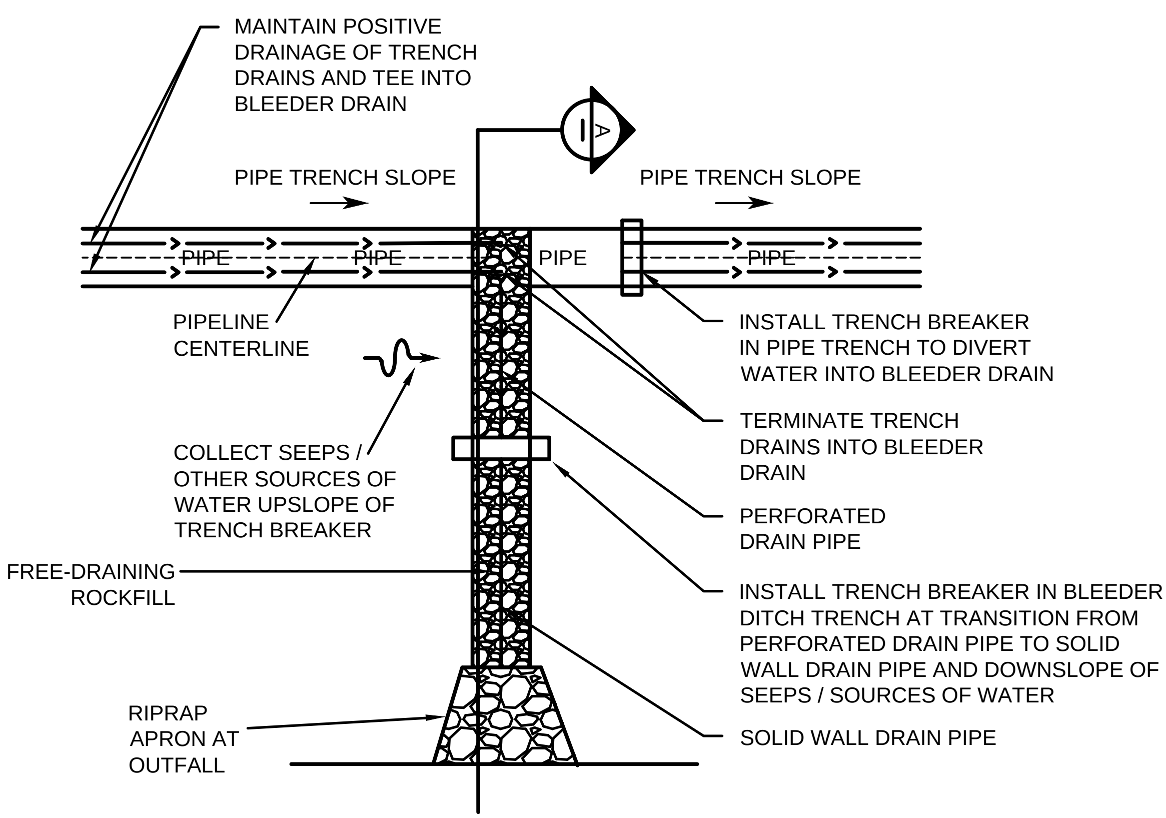
BLEEDER DRAIN PROFILE VIEW

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.

NOT TO SCALE

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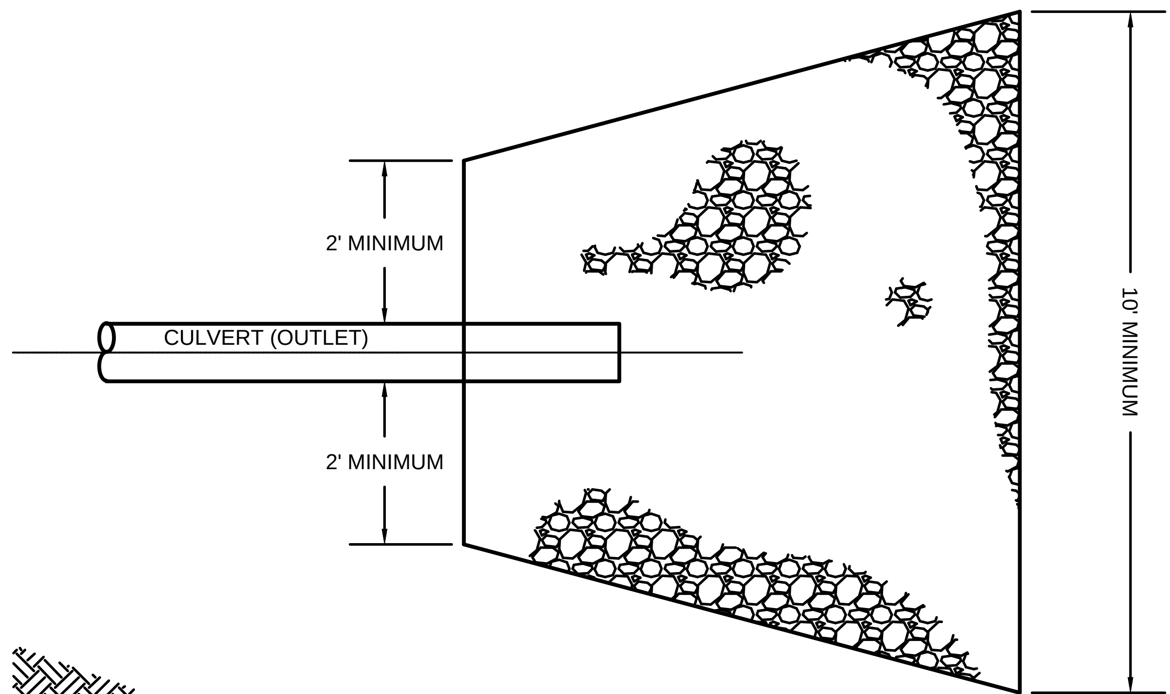
PENNEAST PIPELINE PROJECT

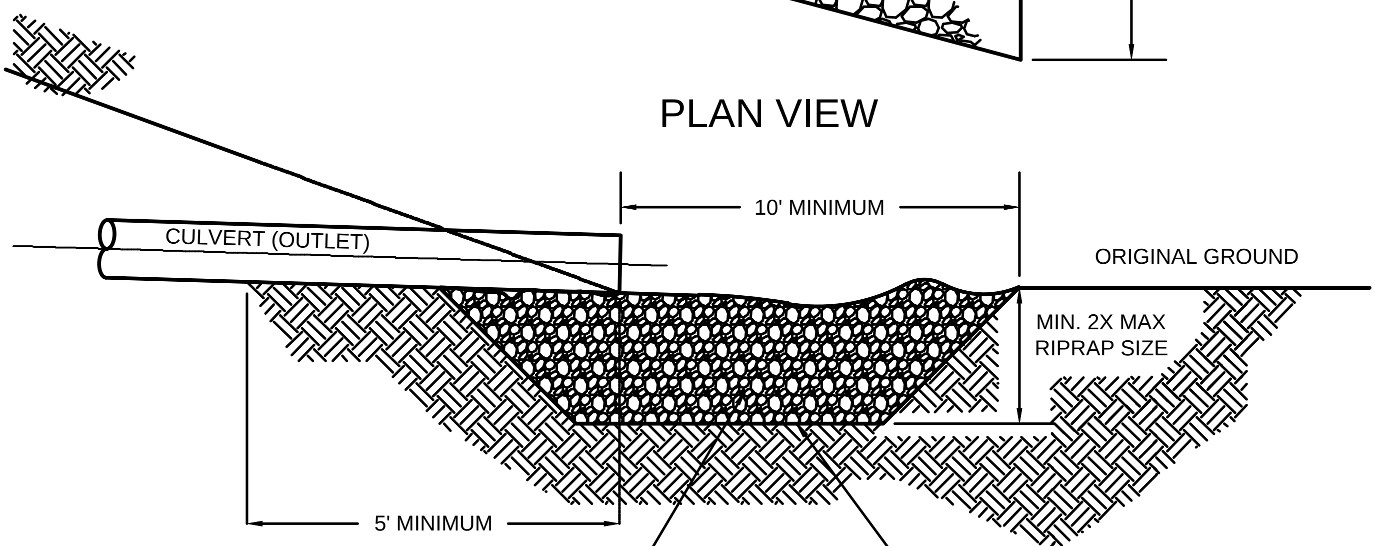
BLEEDER DRAIN DITCH
SECTION AND SLOPED
PIPE TRENCH

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.

NOT TO SCALE

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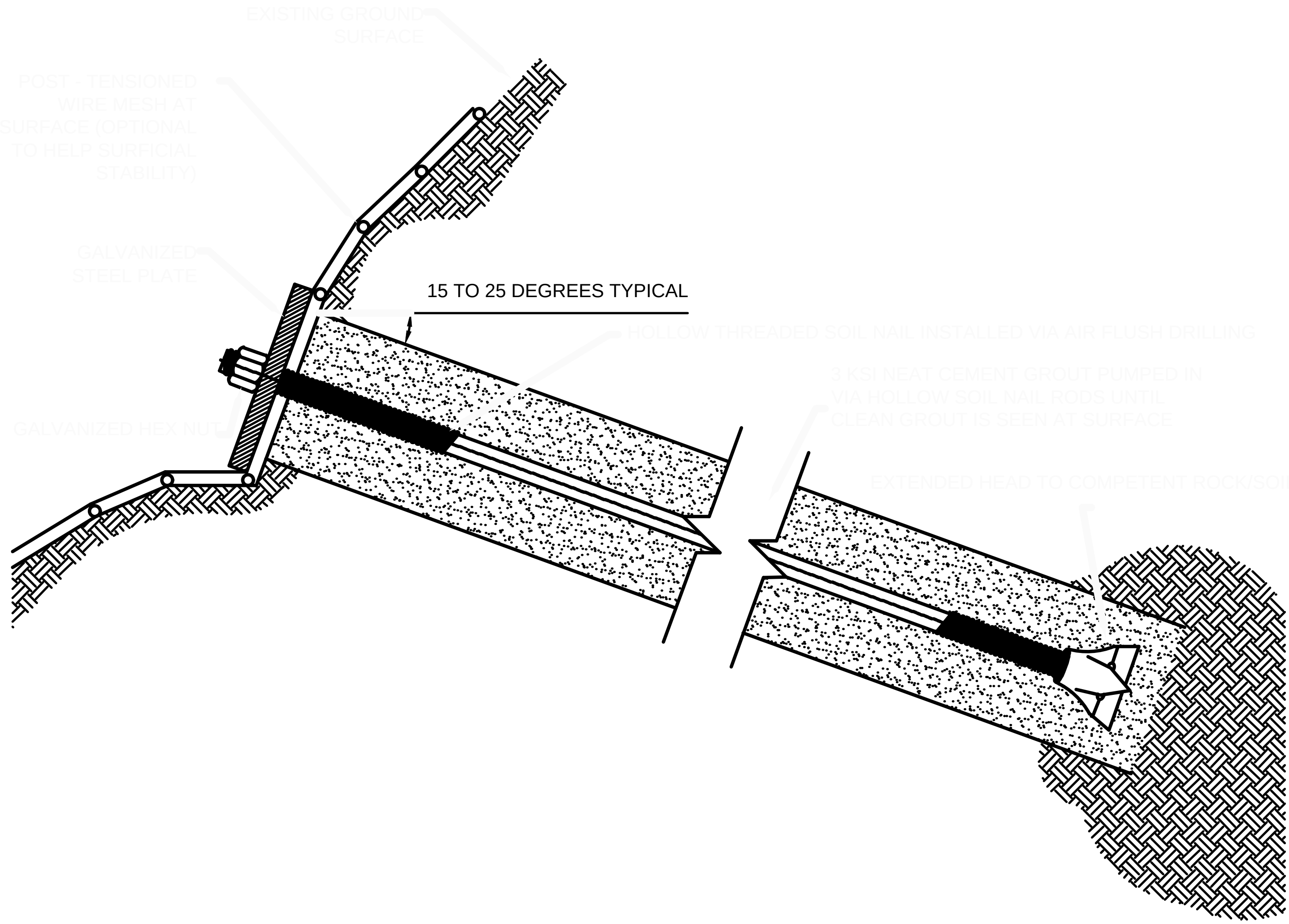
PENNEAST PIPELINE PROJECT

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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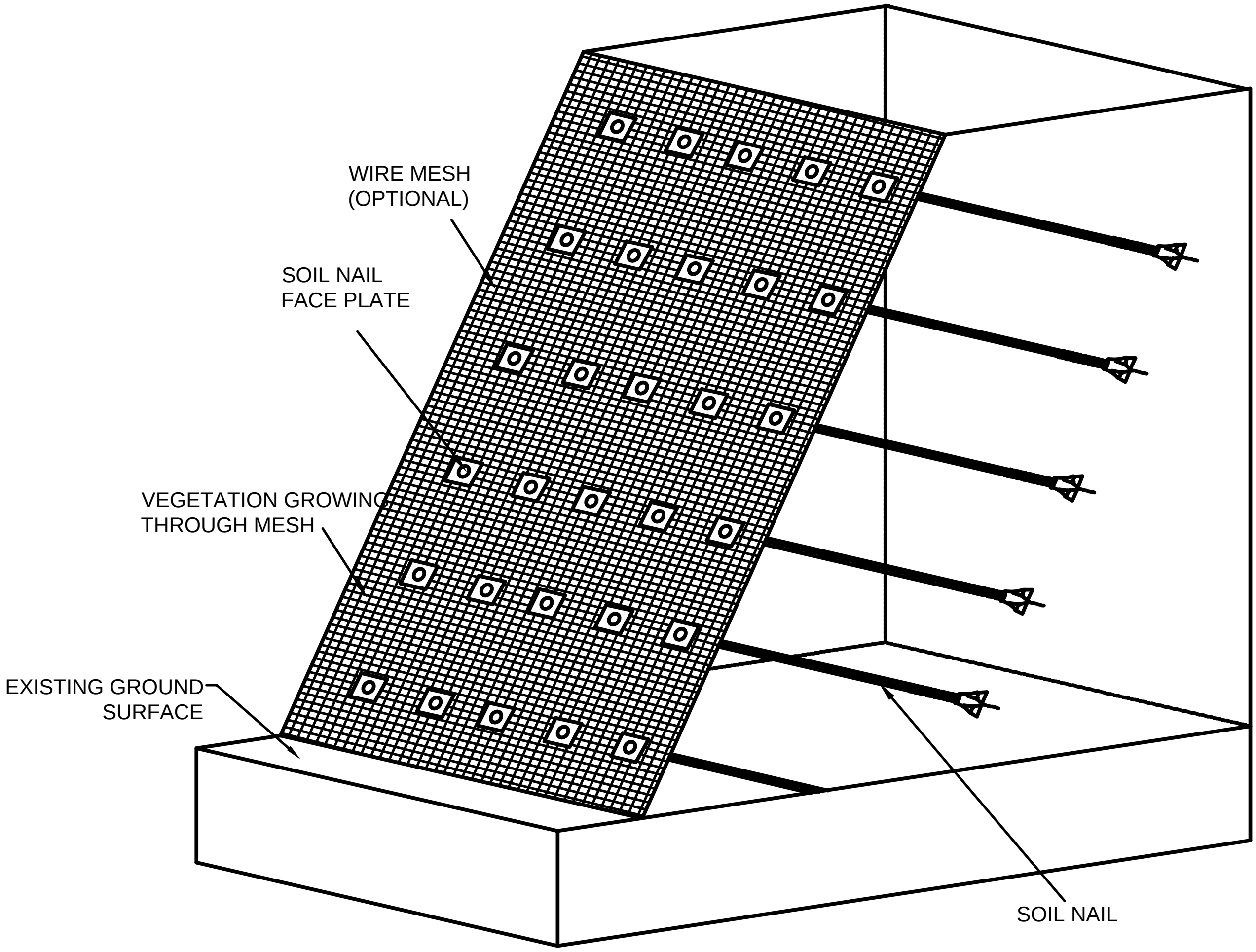
PENNEAST PIPELINE PROJECT

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

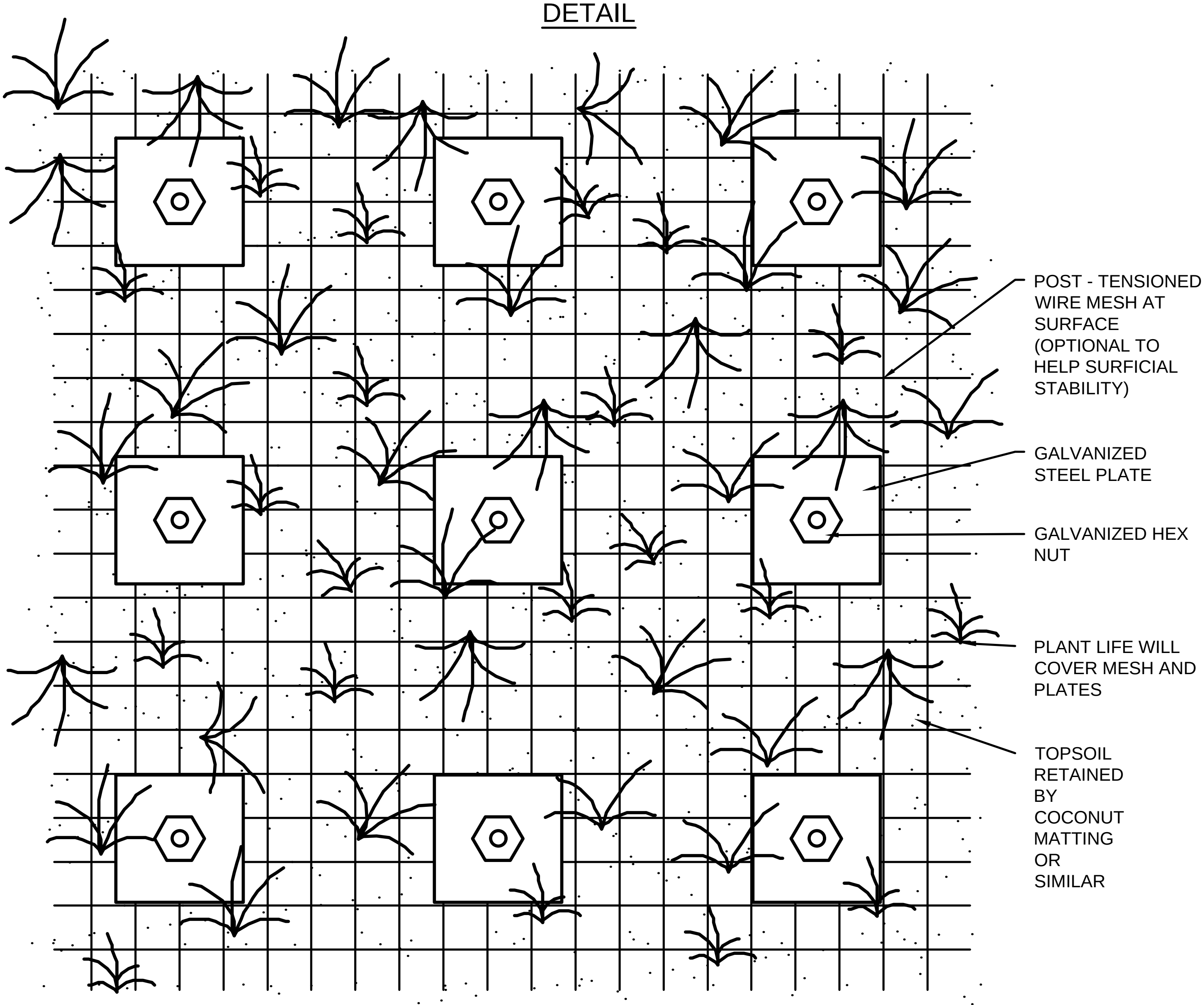
0	2019/07/24		DC	DH	

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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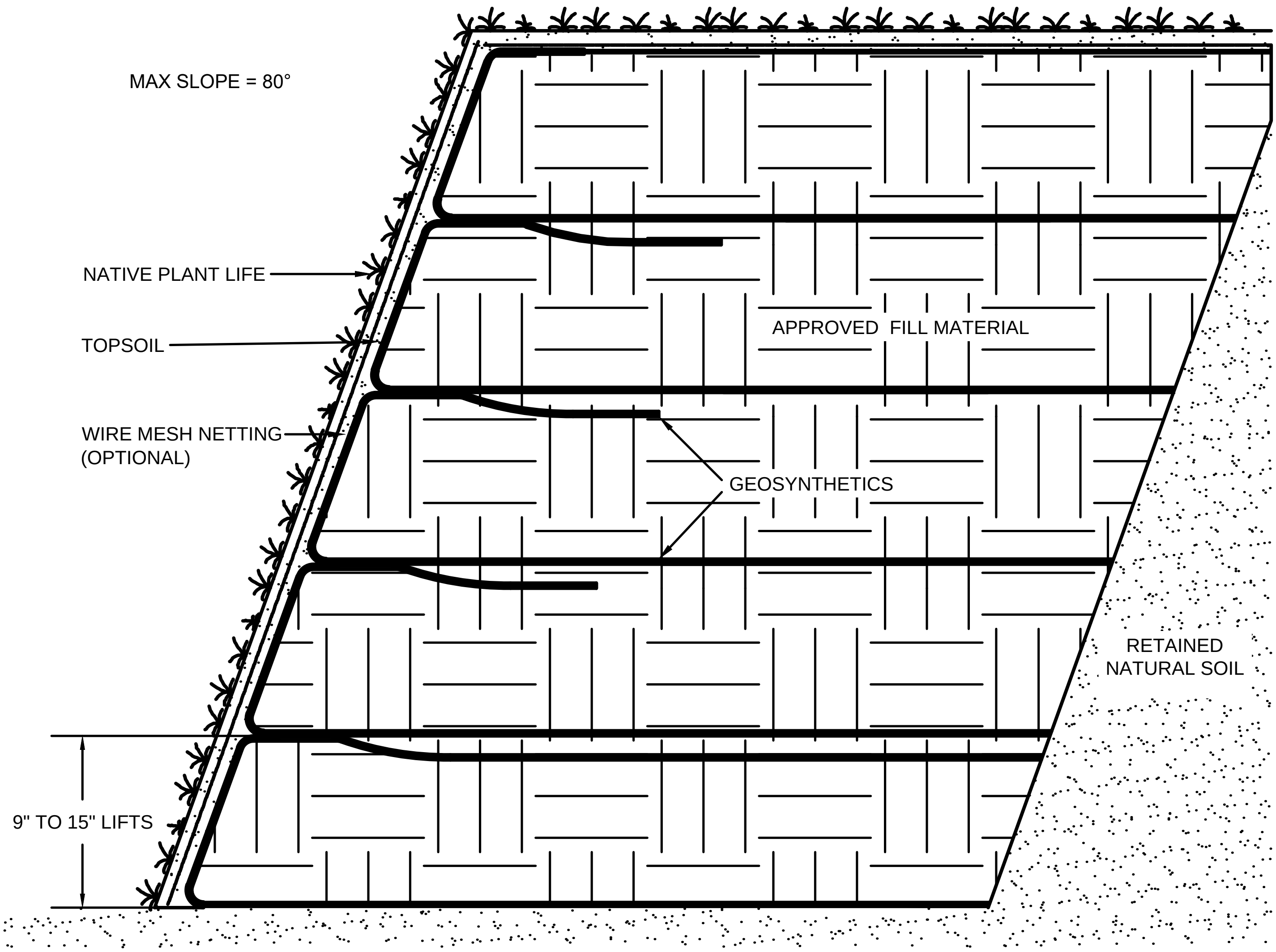
PENNEAST PIPELINE PROJECT

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 SPESIFIED FOR EACH APPLICATION AND FOLLOW GEOSYNTHETIC MANUFACTURE RECOMMENDATIONS.
2. BEARING CAPACITY OF UNDERLYING SOILS TO BE EVACUATED.

NOT TO SCALE

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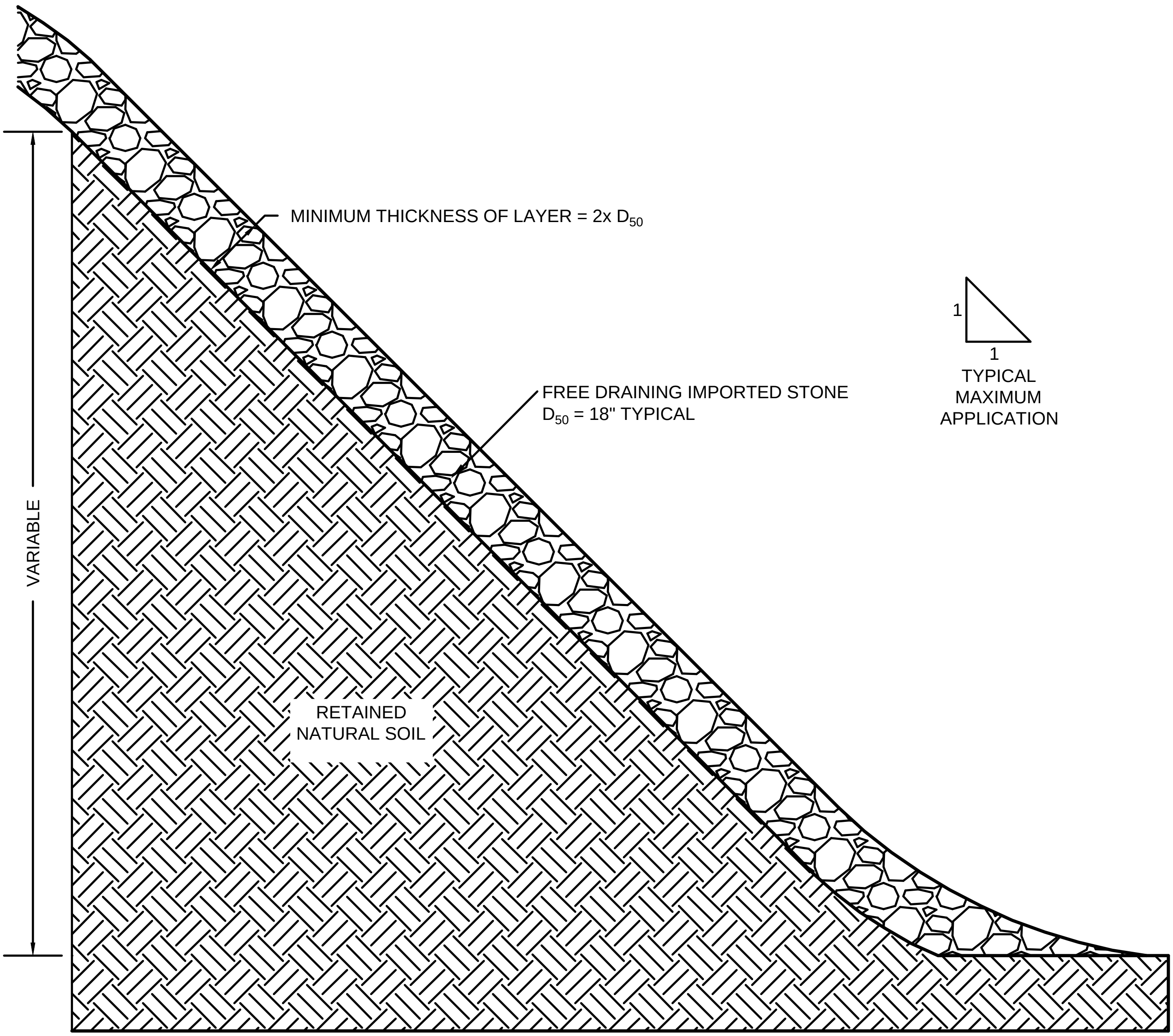
PennEast Pipeline

PENNEAST PIPELINE PROJECT

REINFORCED SOIL SLOPE
(LIVING WALL)

FIGURE 137

CLEAN CUT WITH IMPORTED STONE



TYPICAL APPLICATION

NOTES

NOT TO SCALE

REV	DATE	REVISION DESCRIPTION	BY	CKD	APP

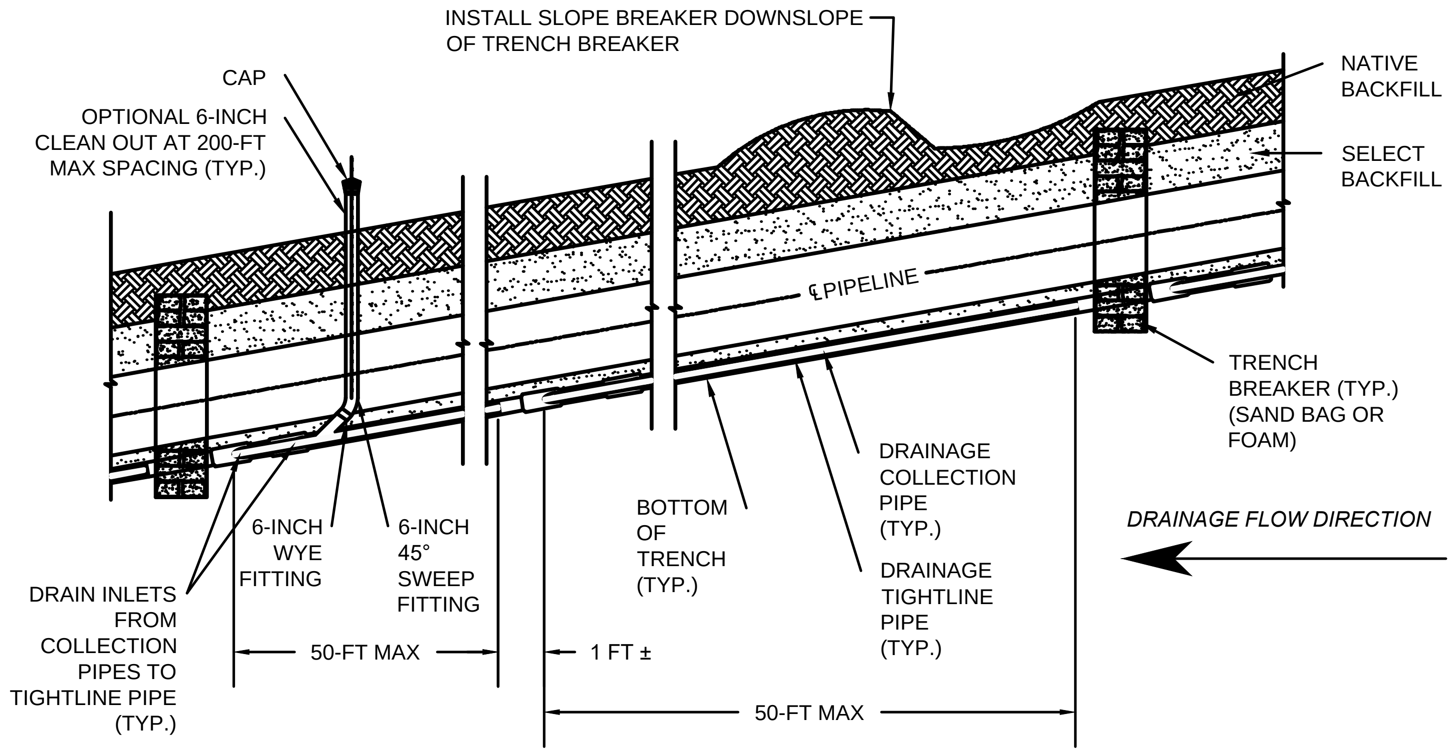
PennEast PIPELINE

PENNEAST PIPELINE PROJECT

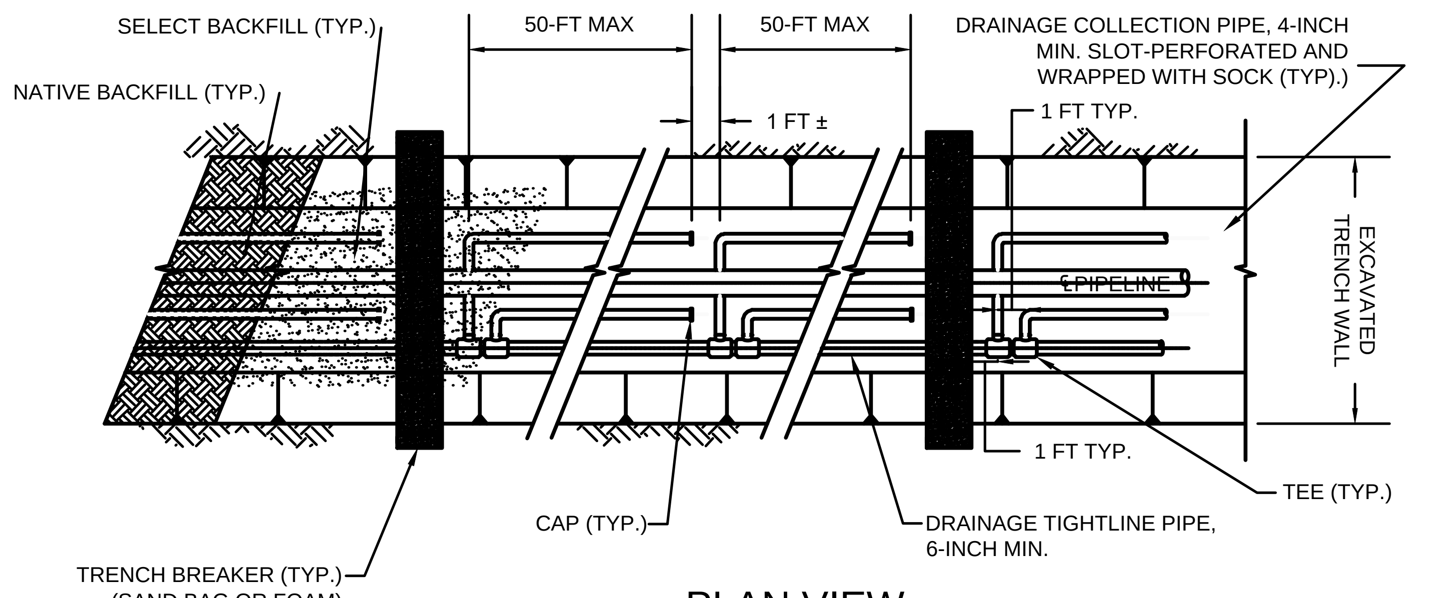
SLOPE PROTECTED WITH IMPORTED STONE

FIGURE 138

ENHANCED TRENCH DRAIN



PROFILE VIEW



PLAN VIEW

TYPICAL APPLICATION

1. PIPE CONSTRUCTION DOWN HEAVILY SATURATED GROUND WITH SLOPE STABILITY ISSUES OBSERVED BEFORE OR DURING CONSTRUCTION.
2. CONSTRUCTION WHERE ADDITIONAL DRAINAGE CAPACITY IS REQUIRED AND CLEAN OUT ACCESS COVERS ARE REQUIRED.

NOT TO SCALE

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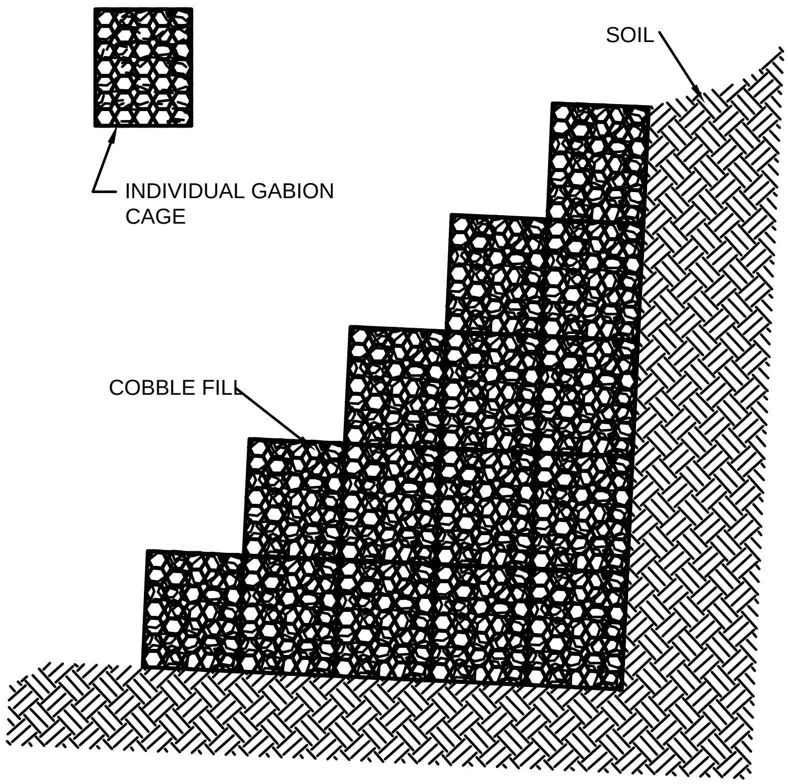
PENNEAST PIPELINE PROJECT

ENHANCED TRENCH DRAIN (GERMAN DRAIN)

FIGURE 139

GABION WALL



TYPICAL APPLICATION

1. FAILING SLOPE WHICH CANNOT BE GRADED BACK.
2. COMPETENT BASE SOILS REQUIRED TO SUPPORT WEIGHT OF WALL.
3. VEGETATION WILL GROW OVER WALL IN TIME.
4. WALL TO BE FILLED WITH LARGE FREE DRAINING ROCKS.

NOTES

1. TYPICAL DETAIL ONLY. ACTUAL CONSTRUCTION LAYOUT TO BE ADJUSTED AS APPROPRIATE FOR SITE CONDITIONS AND DESIGN.
2. WALL TO BE DESIGNED PRIOR TO CONSTRUCTION. MAY REQUIRE BOREHOLE DRILLING PRIOR TO DESIGN.
3. NOT TO BE USED MID SLOPE DUE TO ADDITIONAL WEIGHT LEADING TO HAZARD OF LARGER SLOPE FAILURE.
4. DESIGN TO FOLLOW MANUFACTURER GUIDELINES.

NOT TO SCALE

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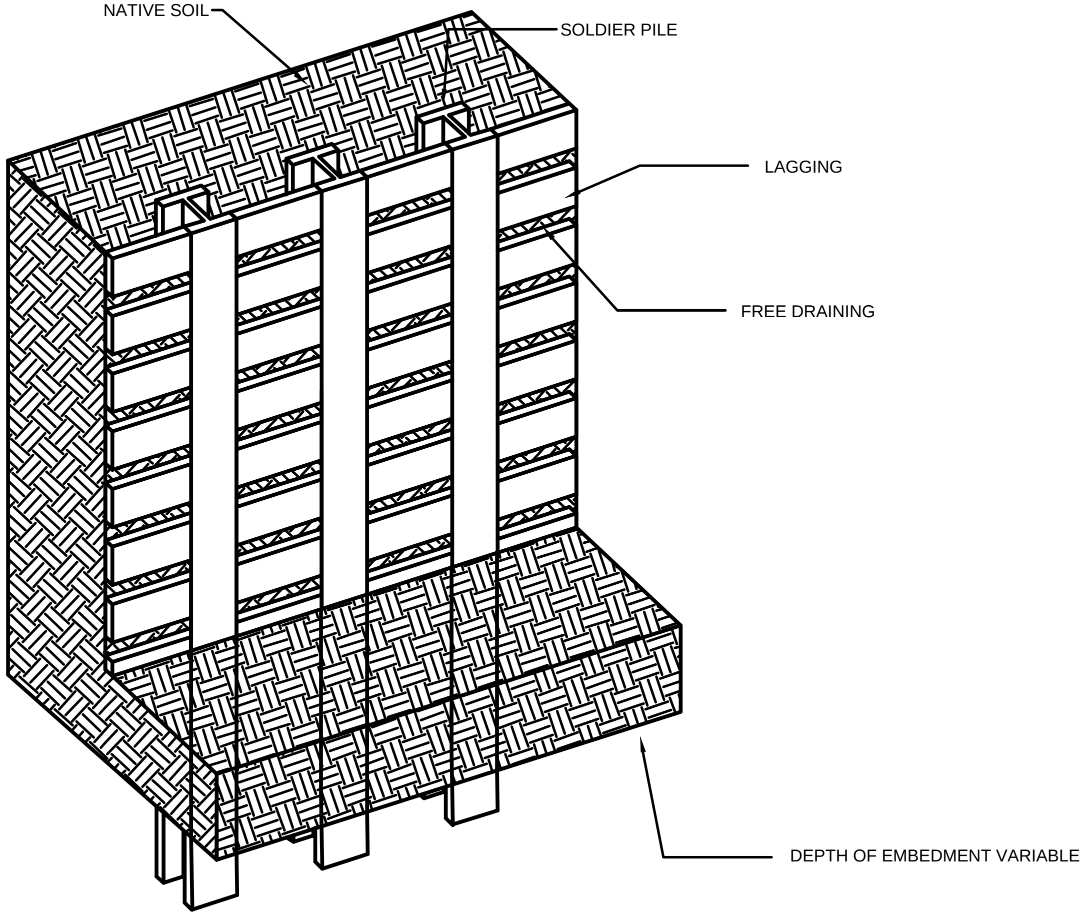
PENNEAST PIPELINE PROJECT

GABION WALL

FIGURE 140

SOLDIER PILE WALL



TYPICAL APPLICATION

1. FAILING SLOPE WHICH CANNOT BE GRADED BACK.
2. TIGHT ACCESS AND WORKING AREA RESTRICTIONS REQUIRE NEAR VERTICAL FINAL PROFILE.
3. SHALLOW SOILS ARE LOW STRENGTH.
4. PIPES DRIVEN TO STRONG MATERIALS.

NOTES

1. TYPICAL DETAIL ONLY. ACTUAL CONSTRUCTION LAYOUT TO BE ADJUSTED AS APPROPRIATE FOR SITE CONDITIONS AND DESIGN.
2. WALL TO BE DESIGNED PRIOR TO CONSTRUCTION. MAY REQUIRE BOREHOLE DRILLING PRIOR TO DESIGN.
3. DRAINAGE HOLES ARE REQUIRED IN WALL.
4. CANNOT BE INSTALLED WHERE LOW STRENGTH SOILS ARE PRESENT OVER SHALLOW BEDROCK.

NOT TO SCALE

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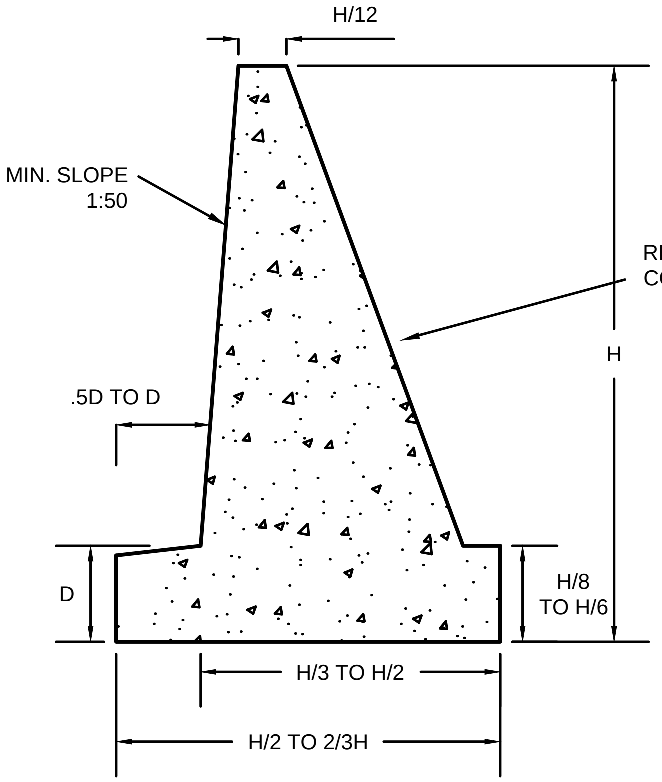
PENNEAST PIPELINE PROJECT

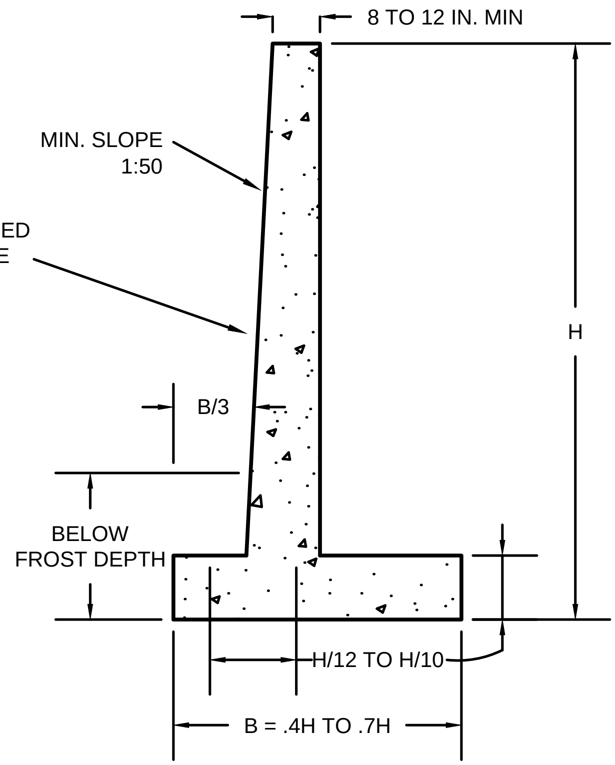
SOLDIER PILE WALL

FIGURE 141

MASS CONCRETE WALL



CANTILEVER WALL



TYPICAL APPLICATION

1. FAILING SLOPE WHICH CANNOT BE GRADED BACK.
2. TIGHT ACCESS AND WORKING AREA RESTRICTIONS REQUIRE NEAR VERTICAL FINAL PROFILE.
3. SHALLOW ROCK PREVENTS DRIVEN PILES.

NOTES

1. TYPICAL DETAIL ONLY. ACTUAL CONSTRUCTION LAYOUT TO BE ADJUSTED AS APPROPRIATE FOR SITE CONDITIONS AND DESIGN.
2. WALL TO BE DESIGNED PRIOR TO CONSTRUCTION. MAY REQUIRE BOREHOLE DRILLING PRIOR TO DESIGN.
3. NOT TO BE USED MID SLOPE DUE TO ADDITIONAL WEIGHT LEADING TO HAZARD OF LARGER SLOPE FAILURE.
4. COMPETENT BASE SOILS REQUIRED.
5. DRAINAGE HOLES ARE REQUIRED IN WALL.
6. COMPETENT BASE SOILS REQUIRED TO SUPPORT WEIGHT OF WALL.

NOT TO SCALE

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GRAVITY WALLS

FIGURE 142

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