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Subject: Landslide and slip prevention and mitigation
Date: Tuesday, October 18, 2016 10:15:50 AM

Please find attached links to information you may find useful regarding landslide and slip prevention and mitigation procedures.

http://www.dep.wv.gov/WWE/Programs/stormwater/csw/Documents/E%20and%20S_BMP_2006.pdf
Chapter 8

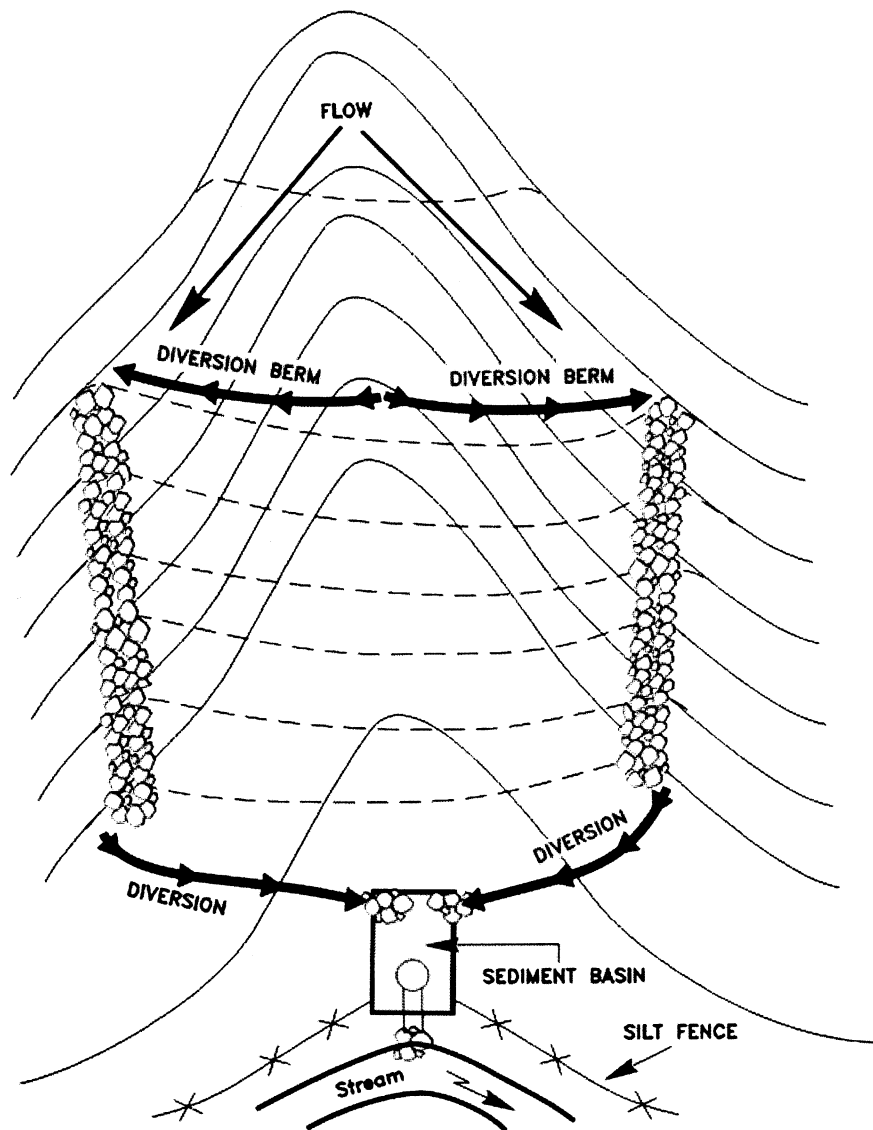
<http://www.ingaa.org/Foundation/Foundation-Reports/28623.aspx>

C

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FIGURE 3.20.6

FILL WITH ROCK CHANNELS



3.21 - INSTREAM BMPs

Introduction

Many times construction activities have to take place within the streambed. Utility construction in particular, by virtue of its linear nature, frequently crosses and negatively impacts streams. Large amounts of sediment can be generated when equipment is working in a stream. The only way that sediment be reduced during instream construction is by isolating the work or “working in the dry”. By isolating the work area from the stream flow much of this sediment can be eliminated. There are several techniques that can be used to dewater and isolate the work area.

While this practice emphasizes utility construction each of these techniques can be used for any type of instream construction activity.

When the project will last more than 72 hours and the work area has to be completely dewatered such as when culverts are being installed, the temporary stream diversion can be used.

Runoff from the shore and approaches can also produce sediment, as can improperly stabilized streambanks.

Conditions Where Practice Applies

These practices are applicable to all instream construction activities such as utility lines, bridge piers and abutments, retaining walls and/or bank stabilization, culverts, water intakes and pipe outfalls. Temporary isolation techniques are used when construction within a full flowing stream will create severe environmental impacts due the resulting sedimentation.

Under most circumstances the pump around technique will be sufficient to dewater the work site. However, a full stream diversion is required when the construction of an instream structure will take place across the entire channel width and the pump around or flume would not be sufficient to handle the anticipated stream flows. It is also applicable when the construction timeframe is longer than 72 hours and there is sufficient lead-time to construct the new channel and stabilize it.

The stream diversion technique only works if there is sufficient room to install the diversion and construct the structure.

These practices are not permanent. A full engineering design is required if a stream channel has to be relocated into new permanent channel. There are numerous requirements, including natural stream design, in the Army Corps of Engineers’ Section 404 Permit, WV DEP Section 401 Certification and the Public Lands Corporation Right-to-Enter.

Planning Considerations

The production of significant amounts of sediment is inevitable when conducting construction activities in a stream. There is also a potential

for excessive sediment loss into a stream by runoff from the adjoining streamside and approach areas.

It is often a difficult task to decide what type of control to use when working in a stream. The ONLY way to limit sediment is to work “in the dry”. Any attempt to trap sediment in the stream below the construction site is pointless. There are several very effective methods that can be used to work in the dry and prevent the creation of sediment. One, “boring and jacking” or horizontal directional drilling of pipe under the streambed, which prevents any disturbance within the watercourse, is the least destructive and preferred method. However, boring is expensive and sometimes impractical. But when working in very high quality streams such as Tier 2.5 or 3 it may be the only method allowed. In others it may be convenient as a continuation of an ongoing project, such as extending a Division of Highways’ road bore underneath an adjacent stream.

However, when instream work is unavoidable, consideration must be given to providing adequate mitigation of sediment loss while minimizing the amount of encroachment and time spent working in the channel. There are several methods available that completely isolate the work area from the stream flow. These “dry ditch” measures include pumping around, flume pipes, cofferdams and stream diversions. Each of these techniques work in smaller streams and during periods of low flows.

In larger streams where isolation techniques become difficult or impossible to install, there can be some “give and take”. Sometimes there can be less damage to the environment if minimal instream sediment control takes place. When using these “wet ditch” methods it is necessary to minimize the amount of time spent working in the stream, quickly stabilize the work area and provide substantial controls on the approach areas. However, when the construction within streambed and banks will take an extended period of time, consideration should be given to substantial in-stream controls or to construct a stream diversion.

As a result of the difficulty in choosing the right method for a utility stream crossing, designers should always make a site visit of proposed crossing to ensure that the most appropriate method is chosen. The designer should also be aware that most instream construction projects are subject to federal section 404 Army Corps of Engineers, NPDES Construction Permit and Public Lands Corporation’s Right of Entry.

Included in this BMP are several methods (with varying construction time and stream size scenarios) which allow for “work in the dry” to prevent excessive sedimentation damage. By no means are these methods all-inclusive. As with other control measures, site-specific design and innovative variations are encouraged.

All planning should begin with an onsite evaluation. The following items should be considered when designing a stream crossing..

Site Conditions

Channel Cross Section

Channel Bed (Solid Rock, Cobbles, Soil)

Bank Slopes

Bank Stability

Flow Characteristics of Stream

Season

Suitable Location

Avoid bends of the streams

Avoid Wetlands or other environmental sensitive areas

Other Considerations

Applicability of other permitting regulations (See Permitting section of this manual)

Endangered Species

Floodplain encroachment

Determine the appropriate construction method

General Design Criteria

1. The drainage area should be no greater than one square mile (640 acres).
2. All filter cloth used in the construction of the utility crossing must conform to physical requirements noted in GEOTEXTILE.
3. Water diverting structures should be used at all trenching and/or construction road approaches (50 feet on either side of the crossing).
4. Design criteria more specific to each particular crossing can be found in the following drawings.
5. All construction activities must meet the applicable Minimum Standard for Instream Construction.
6. Bank stabilization should be based on soil erodibility and bank-full velocity. Restabilization shall consist of the installation of ungrouted riprap on all disturbed streambank areas (or on the area 6 feet on both sides of the centerline of its utility trench, whichever is greater) with slopes of 3:1 or greater. Refer to RIPRAP and the drawings in this section for installation requirements. For slopes of 3:1 or less, vegetative stabilization may be used, pending approval by the Division of Water and Waste Management. Stabilization of its streambed and banks and the approach areas should occur immediately following the attainment of final grade.
7. Provide sediment control such as SILT FENCE, SUPER SILT FENCE or DIVERSIONS and SEDIMENT TRAP on either side of the stream

Construction Criteria

The following specifications are for stream crossings such as would be needed for a utility line crossing. Each can be used for other instream activities with little or no modification. The stream diversion will typically be used for larger projects.

The least damaging and preferred method is “boring and jacking” or horizontal directional drilling..

Open cut dry ditch methods - In these methods the work area is isolated by diverting the stream around the pipeline crossing. The trench is then excavated, the pipe installed and backfilled and the stream and streambank stabilized, all “in the dry”.

The three main methods of dry ditch crossings are the pump around, cofferdam and the flume pipe methods. In the pump around, the stream is dammed and water is moved around the construction site with a pump. In the cofferdam method, impervious barriers are used to isolate part of the work area. Typically half the stream is dammed and the pipe is laid before moving to the other half. In the flume method, the stream is dammed and the stream is bypassed in a culvert that spans across the work area.

One negative to using these methods is the installation and removal of the dam can create a good bit of sediment. Other problems include: leakage around/underneath dam, dam and flume failures, insufficient pump capacity, flooding, and inadequate maintenance.

Pump-Around

The pump around method is the preferred technique to dewater a work site. It is the simplest method if the necessary equipment is available. This method requires damming the stream with a non-erodible material covered with an impervious membrane to create a pool upstream of the work area where a pump intake can be placed. Depending on the gradient of the stream another dam below the work area may be needed. In between the dams a dry work area is created. A pump moves the water around the construction area where the installation of the pipe can be done in the dry. It can be labor intensive when placing the sand or gravel bags. Obtaining sand bags in West Virginia can also be problematic.

Key issues:

1. Provide adequate sediment and erosion control on the approaches.
2. Construction should be preformed in low flow periods.
3. Use a pump or pumps sufficiently large to pump the entire stream flow around the site
4. Construct a dam impervious to water.
5. The inlet of the pump is to be suspended above the streambed in order to prevent sucking mud and sediment.
6. The discharge point must be stabilized with rock to disperse the energy and prevent erosion.

Cofferdam

Cofferdams have long been used to provide dry work areas. Their use is declining as other methods gain ground. However in the right circumstance they can still provide adequate performance. Cofferdams are labor intensive and costly and can be difficult to seal to prevent infiltration of water. To be used when stream diversion is not practical and stream is wide enough (10 feet or wider) to make cofferdam installation practical.

If the stream needs to be diverted more than 75% of its width, then Diversion Channel criteria should be followed.

- a) Construction should be performed in low flow periods
- b) Crossing shall be accomplished in a manner that will not inhibit the flow of the stream.
- c) Dewatering to be accomplished in accordance with section for DEWATERING.
- d) Cofferdams should not extend beyond $\frac{2}{3}$ the width of the streambed to allow for stream flows.
- e) As with all utility line crossings, approach areas should be controlled with perimeter measures (silt fence, diversions, etc.)
- f) Remove large rocks, woody vegetation, or other material from the streambed and banks that may get in the way of placing the stone, sandbags, sheet metal, or wood planks or installing the utility pipe or line.
- g) Form a cofferdam by placing stone or sandbags, jersey barriers (or other non-erodible materials), covered by an impervious material in a semicircle along the side of the stream in which the utility installation will begin. It must be surrounded and underlain with filter cloth as shown in the drawing. The height of and area within the dam will depend upon the size of the work area and the amount of stream flow. Stack materials as high as will be necessary to keep water from overtopping the dam and flooding the work area.
- h) Cofferdams should be no more than one half the height of the stream bank plus one-foot.
- i) When the stream flow is successfully diverted by the cofferdam, dewater the work area into a dewatering structure.
- j) Stabilization of the crossing, streambanks, and approaches should occur immediately following completion of the crossing.

There are commercially available cofferdams now on the market. These water filled bladders or standing steel supports can be installed quickly and can provide cost savings over traditional hardened cofferdams. Their installation and removal can lessen the creation of sediment. Some of the products available are Portadam, Dam-it Dams, and Aqua-Barrier

Flume Pipe

A flume pipe crossing consists of two impervious dams across a stream with one or more culverts installed to pass the stream flow across the work area. A flume pipe crossing can be used when in-stream construction will last less than 72 hours and stream is narrow (less than 15 feet wide) or wider in low water conditions. Ideal for gas pipeline, sewerline and waterline construction especially when used in conjunction with and as an extension of a Vehicular Stream Crossing.

- a) The flume pipe crossing must be made operational prior to the start of the instream construction.
- b) A large flume pipe(s) or culvert(s) of an adequate size to support normal water channel flow (see Table 3.21.1) shall be installed in the streambed across the proposed pipeline trench centerline. Riprap, jersey barrier or sandbags shall be placed close to each end of the flume pipe so as to dam off the creek forcing the water to flow through the flume pipe (see drawing). Sandbags are the preferred method for diverting water into the flumes. The commercial cofferdams can be used if a tight seal can be created.
- c) The entrapped water in the work area can then be pumped into an approved Dewatering Device. The trench can then be dug under the flume pipe. The pipe sections will then be installed to the proper depth under the flume pipe. After the pipe is installed, the ditch will be backfilled and restabilization shall be carried out.
- d) Reclamation of the stream banks will occur the same day as the installation of the pipe is completed. Restabilization shall consist of the installation of ungrouted riprap on all disturbed streambank areas (or on the area 6 feet on both sides of the centerline of the utility trench, whichever is greater) with slopes of 3:1 or greater. Refer to the specification for Riprap, for installation requirements. For slopes of 3:1 or less, vegetative stabilization with or without Rolled Erosion Control Product may be used, pending approval by the Division of Water and Waste Management. Stabilization of its streambed and banks and the approach areas should occur immediately following the attainment of final grade.
- e) After completion of backfilling operation and restoration of stream banks and leveling of streambed, the flume pipe can then be removed. The stone can be removed or spread as stabilization of the streambed depending on permit requirements. Sediment control in approach areas shall not be removed until all construction is completed in the stream crossing area and the contributing drainage area to the device is stabilized. All ground contours shall be returned to their original condition.

Drainage Area (Acres)	Table 3.21.1 Average Slope of Watershed			
	1%	4%	8%	16%
	Culvert Size			
1 – 25	24	24	30	30
26 - 50	24	30	36	36
51 – 100	30	36	42	48
101- 150	30	42	48	48
151 - 200	36	42	48	54
200 - 250	42	48	60	60
251 - 300	42	48	60	60
301 - 350	42	48	60	60
351 - 400	42	54	60	60
401 - 450	42	54	60	72
451 - 500	42	54	60	72
501 - 550	48	60	60	72
551 - 600	48	60	60	72
601 - 640	48	60	72	72

Note: Table is based on USDA-SCS Graphical Peak Discharge Method for 2-year frequency storm event, CN = 65; Rainfall depth = 3.5 inches (average for Virginia). Source: Va. DSWC

Open cut wet ditch

This technique does not use any method to divert the stream around the work area. The utility line is installed and backfilled while the river/stream continues to run through the site. The benefits are low cost and a quick completion time. However, this type of crossing produces some very negative impacts. These include severe pollution from greatly increased total suspended sediment (TSS) concentrations, changes in channel morphology, and localized destruction of aquatic ecosystems. These impacts can be somewhat mitigated by a quick completion time.

DEP does not recommend this type of crossing unless a creating a dry ditch is impossible. There shouldn't be any significant rain forecast during the entire construction timeframe. This method may be used with prior approval when other preferred methods are proven to be unfeasible.

Stabilization of the crossing, streambanks, and approaches should occur immediately following completion of the crossing.

The wet ditch method may be used when the following conditions are met:

- a.) When the distance across the flume pipes become too wide for a backhoe to dig from both sides and connect the trench underneath the pipes. This measurement would vary according to the number of flume pipes, the height of the stream banks, the

size and digging angle of the backhoe, the depth to bed rock and ease of digging.

- b.) When the crossing can be accomplished within 72 hours. However, the contractor should make every effort to complete the crossing in one working day. All disturbed streambanks must be stabilized the same day the construction is finished
- c.) When the crossing is at right angles ($\pm 5^\circ$) to the stream channel.
- d.) If water is pumped during the installation of the pipe it must be treated as per the DEWATERING specification.

This method is also applicable to small intermittent and ephemeral streams that are completely dry and no rain is forecast for the entire installation timeframe.

Stream Diversion Bypass

Temporary stream diversions are used when construction within a full flowing stream will create severe environmental impacts due the resulting sedimentation. This technique also provides a safe and dry work area. Typically a stream diversion is required when the construction of an instream structure will take place in the entire channel and the pump around or flume dewatering techniques would not be sufficient to handle the anticipated stream flows. It is also applicable when there is a significant construction timeframe. A stream diversion is most commonly used when a large fill is placed across a valley and a culvert is installed to carry the stream such as when building a road or dam.

Once started, any work to relocate the stream and install the permanent structure shall not be discontinued until it is completed. The connection to the natural channel should be performed under dry conditions

Diversion channels only work if there is sufficient room to both install the diversion and construct the structure.

Construction Specifications

- a) The diversion channel crossing must be operational before the construction activity starts so that construction can occur “in the dry”).
- b) Minimum width of bottom shall be four feet or equal to average width of existing streambed, whichever is greater.
- c) Maximum steepness of side slopes shall be 2:1. Depth and grade may be variable, dependent on site conditions, but shall be sufficient to ensure continuous flow of water in the diversion.
- d) There are three types of diversion channel linings that can be used, based upon expected velocity of bankfull flow. Refer to the drawing and the accompanying table.

- e) The seed mix for the grass liner is to be in accordance with the Temporary Seeding” section. An average growth of two inches in height shall be achieved throughout the diversion with 70% cover before water is turned into it.
- f) Stream diversion liners shall be entrenched at the upstream end as shown in the stream channel drawing for ROLLED EROSION CONTROL PRODUCTS. Fabric liners must be stapled every three feet. Polyethylene liners shall be weighted with rock along the base of the side slope.

Table 3.21.2 STREAM DIVERSION LININGS		
Acceptable Lining Material	Classification	Maximum Velocity
Grass and Matting	TYPE A	5.0 f.p.s.
Geotextile Filter Cloth	TYPE B	8.0 f.p.s.
Class I Riprap and Filter Cloth	TYPE C	13.0 f.p.s.

- g) Start installing stream diversion liners at the downstream end. Stream diversion liners should be overlapped 18 inches (upstream over downstream) when a continuous liner is not available or is impractical. Overlaps along the sides should be made such that a liner is placed in the stream diversion bottom first and additional pieces of liner on the slopes overlap the bottom piece by a minimum of 18 inches. See ROLLED EROSION CONTROL PRODUCTS for drawings.
- h) Stream diversion liners shall be entrenched at the top of the diversion slopes (slopes breaks) along with a line of silt fence. Silt fence may be excluded if the diversion liner is extended to such a point that siltation of the stream will not occur. If silt fence is excluded, the diversion liner must be secured. Liners shall extend from slope break to slope break as shown in the drawing.
- i) Non-erodible materials such as riprap, jersey barriers, sandbags, or sheet piling, shall be used as flow barriers to divert the stream away from its original channel and to prevent or reduce backup into the lower end of the construction area.
- j) The downstream and upstream connection to the natural channel should be performed under dry conditions and may be so accomplished by use of sandbag cofferdams. The downstream

flow barrier is to be removed prior to the upstream barrier when preparing a stream diversion for the transport of water.

- k) The diversion should be sealed off at the down stream end and then backfilled once water is put back in its original channel.
- l) Stream should be re-diverted only after restabilization of original streambed and banks is completed or the inlet and outlet of the culvert pipe is finished. Stabilization of the streambed and banks and the approach areas should occur immediately following the attainment of final grade.
- m) Temporary bypass channels should be backfilled and properly stabilized by riprap or RECPs to prevent the stream from reestablishing the path.
- n) Any water pumped from this operation shall be directed into an approved Dewatering Structure.

Alternative Technique

Designers need to know that another way of installing culverts is possible. Traditionally a new culvert was installed as close to the original alignment of the existing stream as possible. This entails the construction of a significant stream diversion. If the conditions are right there is another way.

An alternative to building a stream diversion is to design and install the new culvert outside the existing stream channel and use the existing natural channel as the bypass. With this method there is much less likelihood of erosion and sedimentation of a temporary channel. Time can also be saved by not having to construct a whole new channel. The only “instream” work will be the tying in the old channel into the inlet and outlet channels of the new culvert or spillway.

It is sometimes likely that a combination of existing and new channel will be needed.

Other Considerations

Stream crossings must be approached as a separate project. All materials necessary to construct the crossing must be on site and ready to use. If possible, pipe should be coupled on shore and then pulled across and placed in the trench in one operation.

During reclamation it is not necessary to create a perfectly smooth stream bottom. Elevated spots should be removed but in most cases the bed load and scour from next high water event will eliminate all signs of the crossing. On smaller crossings the bed load from one flood event can fill the entire trench. In these cases, anchoring the pipe with river weights or critically placed buckets of gravel may be all that is required to reclaim the creek bottom.

It is important to use machinery that is in good mechanical shape. Use newer pieces of equipment that are less likely to have fluid leaks. Maintain spill containment kits inside each piece of equipment working in moving water. Maintain hydraulic hoses on equipment that is used for work in or around streams.

Refuel and maintain vehicles a minimum of 100 feet from of the stream. A comprehensive spill containment and cleanup kit should be readily available on site.

Maintenance

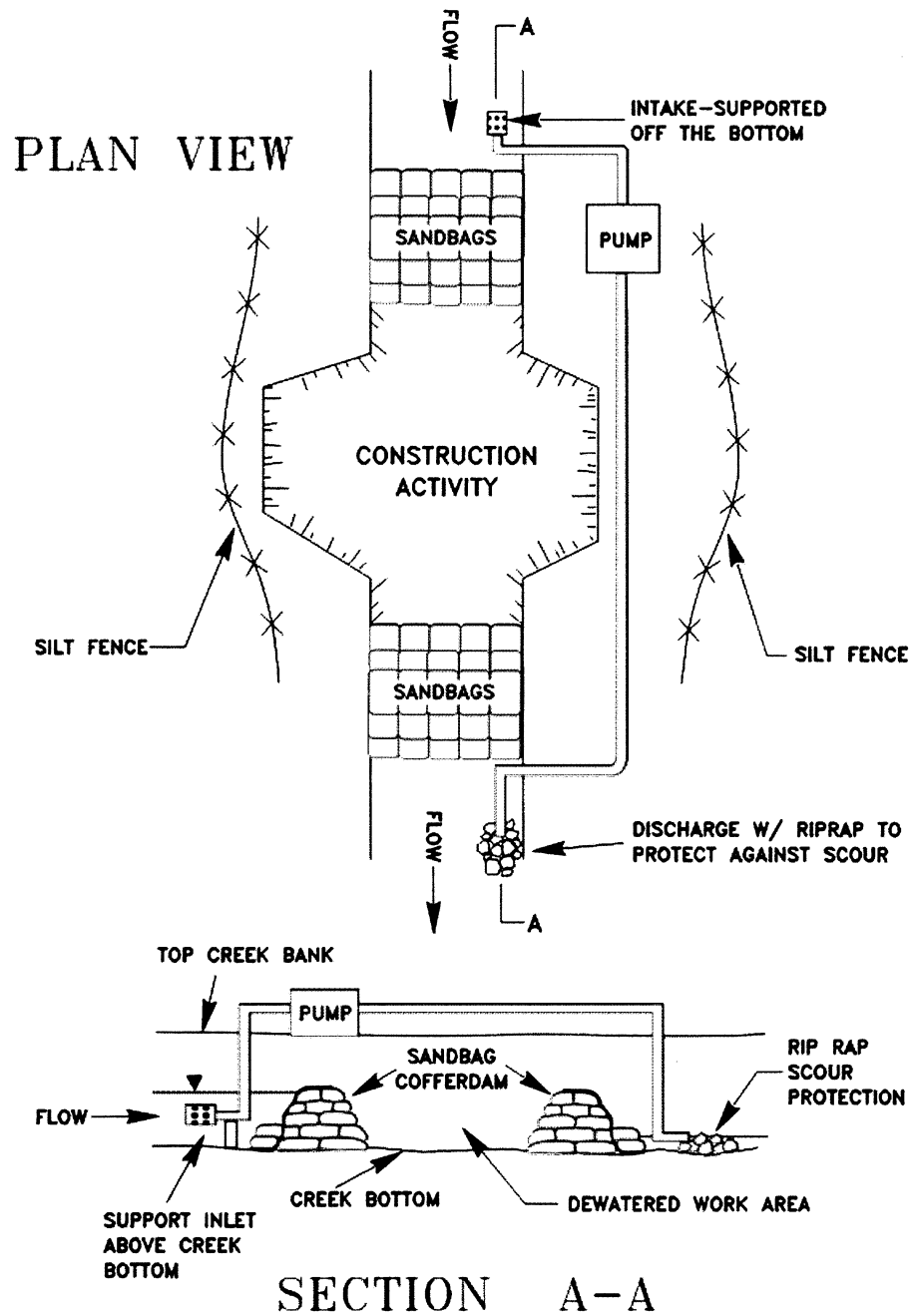
Structures and erosion and sediment controls should be inspected after every rainfall of 0.5 inches or more and at least once a week and repair all damages immediately. Check for debris especially flotsam clogging the inlet to the culverts. All deposited materials and obstructions must be removed immediately.

In general inspect all active stream crossings at the end of each day to make sure that the construction materials are positioned securely. This will ensure that the work area stays dry and that no construction materials float downstream. The contractor should carefully watch the weather forecast and coordinate the installation based on the proper conditions.

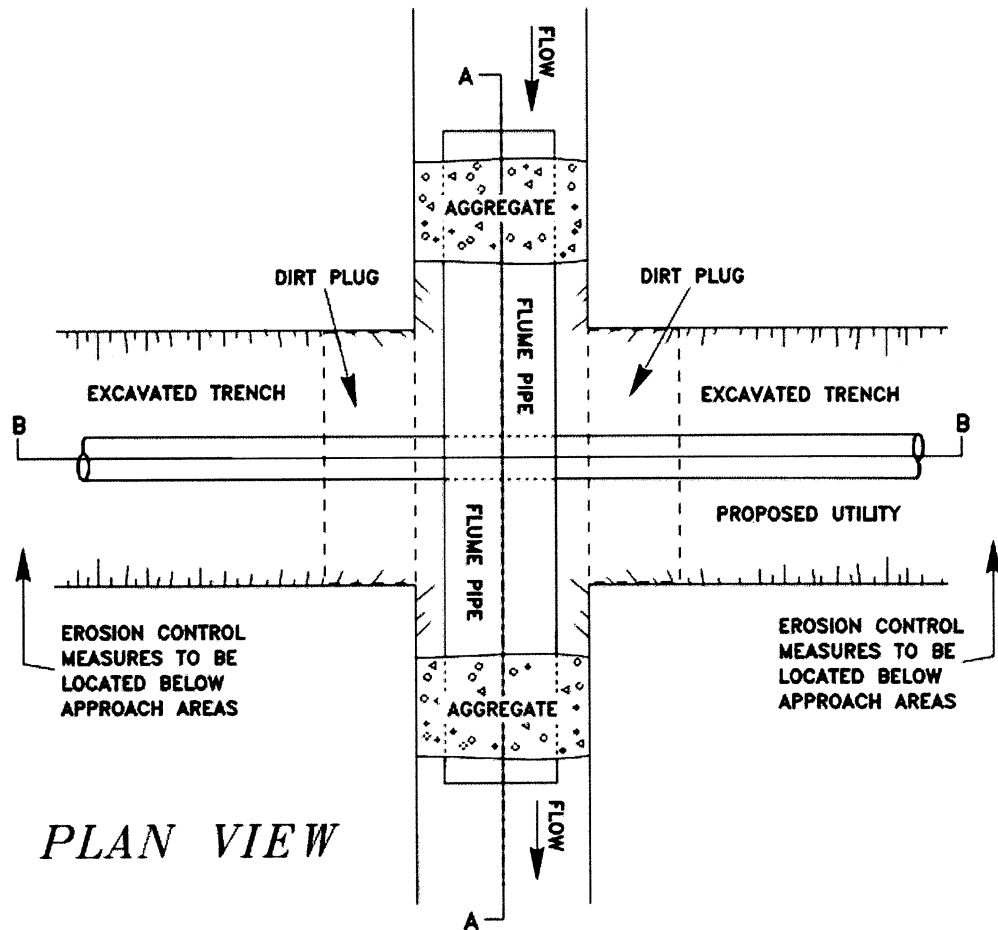
Cleanup and stabilize the entire stream crossing site immediately upon completion of the installation of the pipe. One exception would be on a natural gas transmission lines where the attached vehicle crossing will be used for an extended time. Stabilize all other areas immediately.

FIGURE

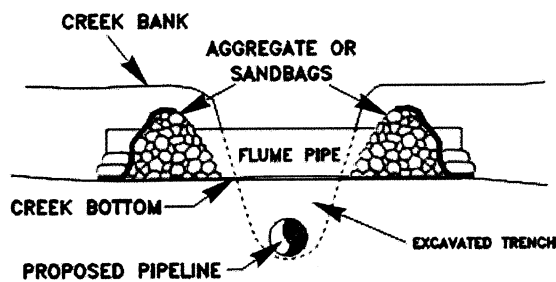
PUMP AROUND



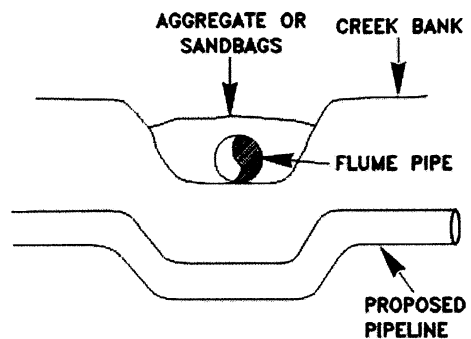
FLUME PIPE CROSSING



PLAN VIEW



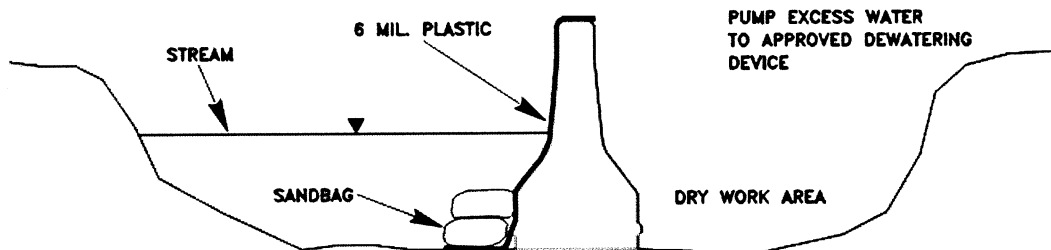
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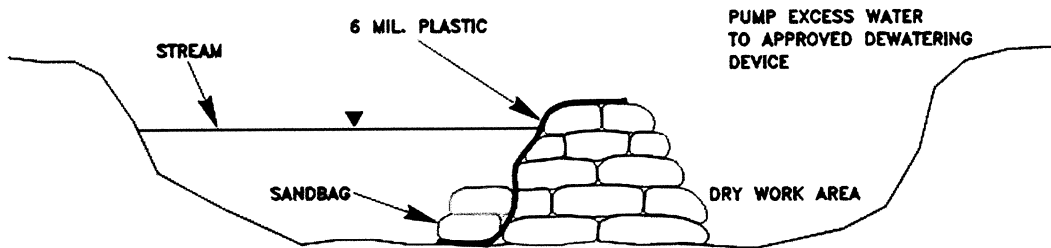
SECTION "B-B"

SOURCE: Va. DSWC

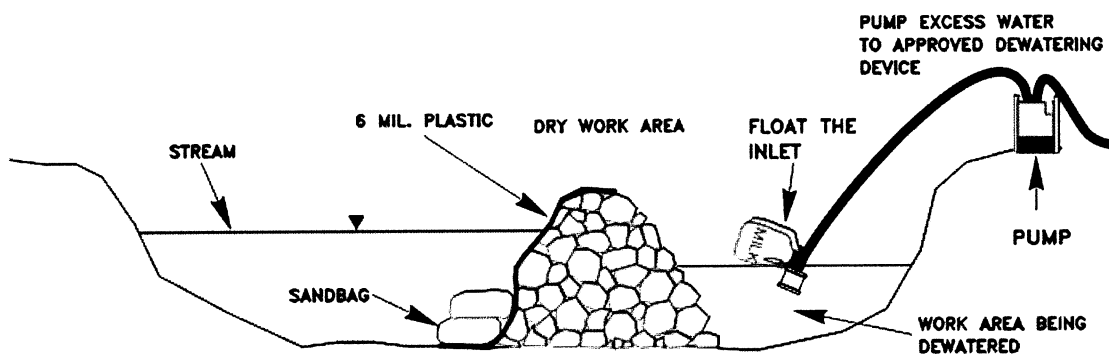
COFFERDAMS



JERSEY BARRIER COFFERDAM



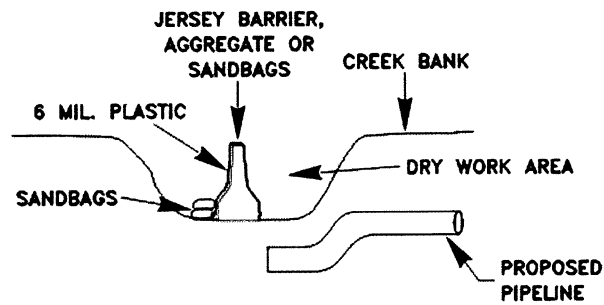
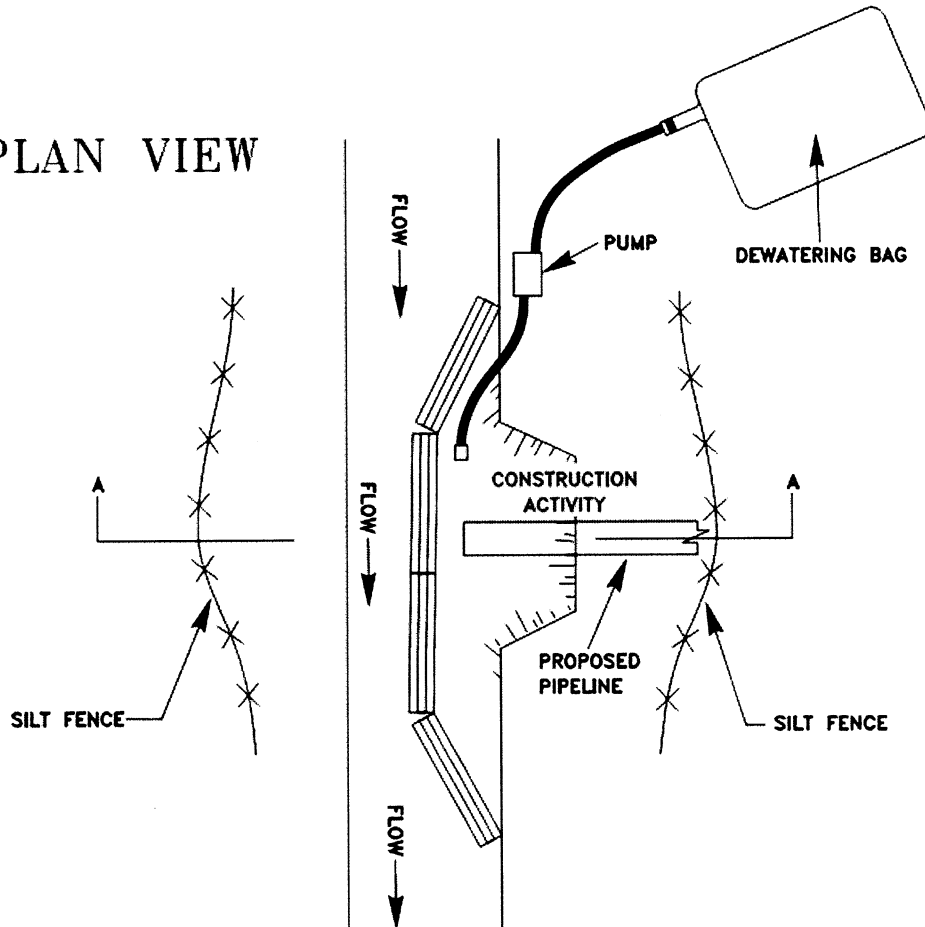
SAND or GRAVEL BAG COFFERDAM



ROCK COFFERDAM

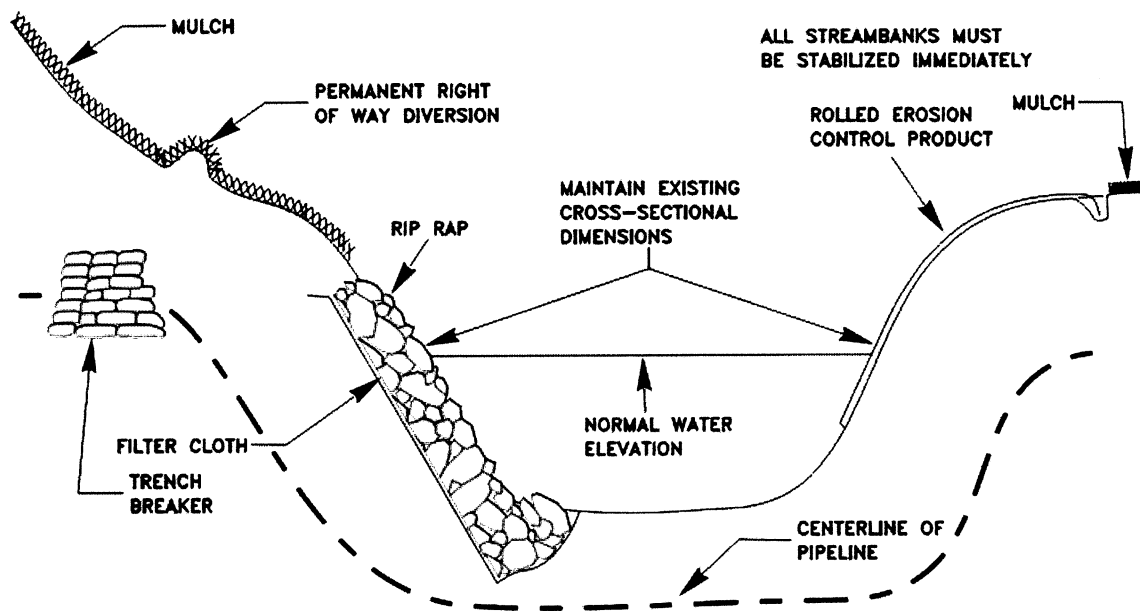
COFFERDAM CROSSING

PLAN VIEW



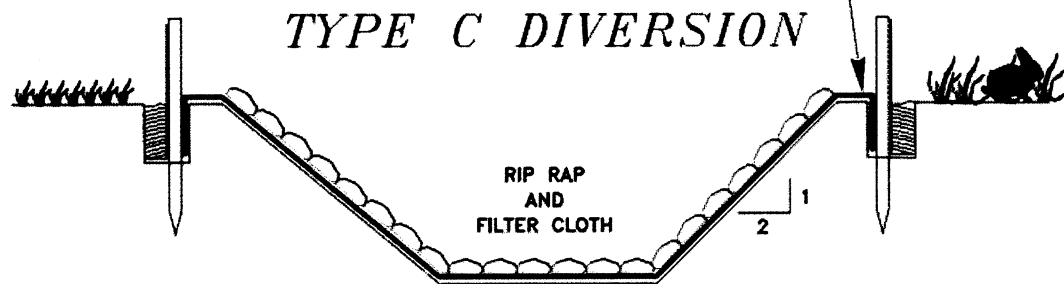
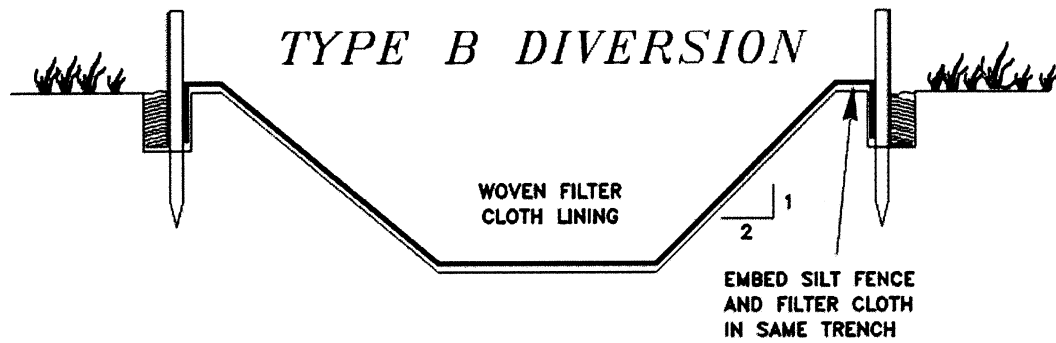
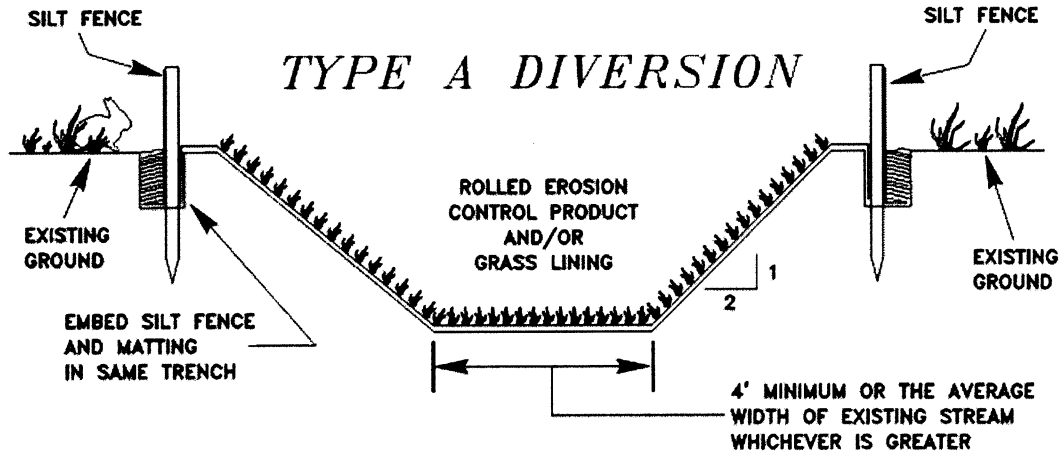
SECTION "A - A"

STREAM BANK STABILIZATION SHOWING VARIETY OF E/S CONTROLS



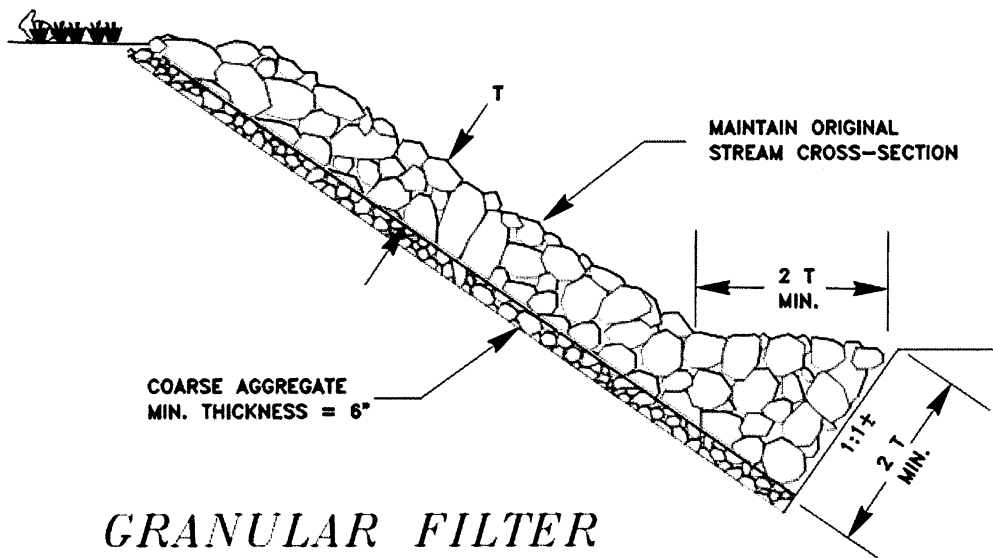
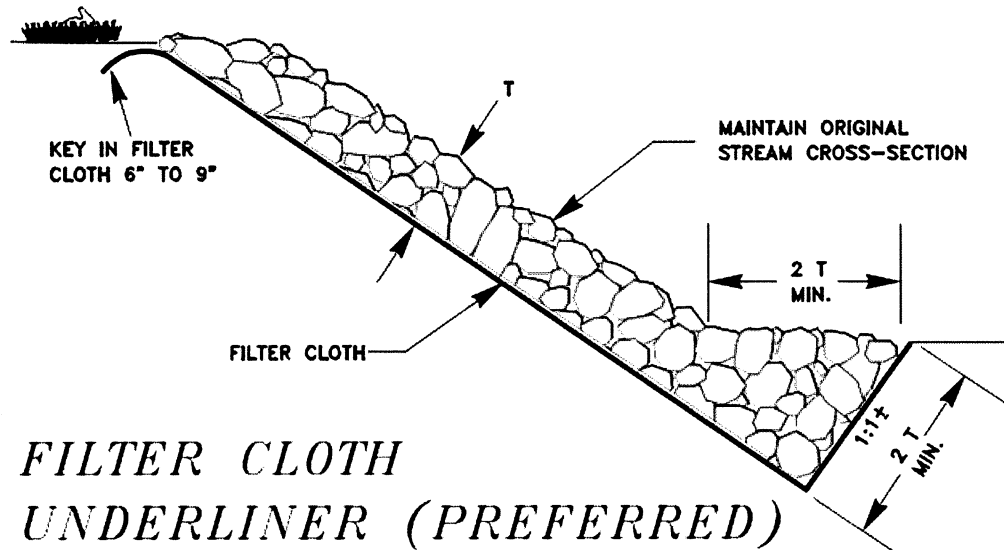
ADAPTED FROM DOMINION RESOURCES

DIVERSION CHANNEL CROSSING



SOURCE: ADAPTED FROM VA DSWC

TOE AND UNDERLAYMENT REQUIREMENTS FOR BANK STABILIZATION



SOURCE: Adapted from VDOT Drainage Manual

Temporary Vehicular Stream Crossing

A temporary structural span (includes bridges, round pipes, pipe arches, or oval pipes) installed across a watercourse for use by construction traffic. These structures are used to provide a means for construction traffic to cross a stream without damaging the channel or banks and to keep sediment generated by construction traffic out of the stream.

A rule of thumb is that if there are more than two crossings a stabilized stream crossing must be installed. As an example, if during the clearing and grubbing a bulldozer has to cross a stream going out and coming back just once a culverted stream crossing is not necessary. However if the route the bulldozer takes becomes the access to the site and more than one other vehicle has to cross the stream then a crossing as specified here needs to be installed.

Generally applicable to streams with drainage areas less than 1 square mile (660 acres).

For streams larger than 1 square mile the structure should be designed by a registered professional engineer, using professionally recognized methods that will more accurately define the actual hydrologic and hydraulic parameters that will affect the functioning of the structure.

Design Criteria

Temporary Bridge Crossing

- a. Bridges may be designed in various configurations. However, the materials used to construct the bridge must be able to withstand the anticipated loading of the construction traffic.
- b. Crossing Alignment - The temporary waterway crossing shall be at right angles to the stream. Where the approach conditions dictate, the crossing may vary 15° from a line drawn perpendicular to the centerline of the stream at the intended crossing location.
- c. The centerline of both roadway approaches shall coincide with the crossing alignment centerline for a minimum distance of 50 feet from each bank of the waterway being crossed. If physical or right-of-way restraints preclude the 50 feet minimum, a shorter distance may be provided. All fill materials associated with the roadway approach shall be limited to a maximum height of 2 feet above the existing flood plain elevation.
- d. A water diverting structure such as a dike or swale shall be constructed (across the roadway on both roadway approaches) 50 feet (maximum) on either side of the waterway crossing. This will prevent roadway surface runoff from directly entering the waterway. The 50 feet is measured from the top of the waterway bank. If the roadway approach

is constructed with a reverse grade away from the waterway, a separate diverting structure is not required.

e. Appropriate perimeter controls such as SILT FENCE, SUPER SILT FENCE and/or DIVERSION and SEDIMENT TRAP must be employed when necessary along banks of stream parallel to the same.

f. Clearing and excavation of the streambed and banks shall be kept to a minimum.

g. The temporary bridge structure shall be constructed at or above bank elevation to prevent the entrapment of floating materials and debris.

h. Any abutments shall be placed parallel to and on stable banks.

i. Bridges shall be constructed to span the entire channel. Instream piers should be kept to a minimum. Any work within the normal high water mark will require a Public Lands Corporation Right-of-Entry, a Army Corps of Engineers 404 Permit and WV DEP 401 Certification..

j. Stringers shall either be logs, sawn timber, pre-stressed concrete beams, metal beams, or other engineer-approved materials.

k. Curbs or fenders may be installed along the outer sides of the deck. Curbs or fenders are an option that will provide additional safety and keep mud from flowing over the edge into the stream.

l. Bridges should be securely anchored at only one end using steel cable or chain. Anchoring at only one end will prevent channel obstruction in the event that floodwaters float the bridge. Acceptable anchors are large trees, large boulders, or driven steel anchors. Anchoring shall be sufficient to prevent the bridge from floating downstream and possibly causing an obstruction to the flow.

m. All areas disturbed during installation shall be stabilized immediately.

n. When the temporary bridge is no longer needed, all structures including abutments and other bridging materials should be removed immediately.

o. Final clean up shall consist of removal of the temporary bridge from the waterway, protection of banks from erosion, and removal of all construction materials. All removed materials shall be stored outside flood plain of the stream. Removal of the bridge and clean up of the area shall be accomplished without construction equipment working in the waterway channel.

Temporary Culvert Crossing

a. 2" to 4" Coarse Aggregate or larger will be used to form the crossing. DO NOT USE ERODIBLE MATERIAL FOR CONSTRUCTION OF THE CROSSING. The depth of stone cover over the culvert shall be equal to one-half the diameter of the culvert or 12 inches, whichever is greater. If multiple culverts are used, they shall be separated by at least 12 inches of compacted aggregate fill. To protect the sides of the stone from erosion, riprap shall be used.

b. If the structure will remain in place for up to 6 months, the culvert shall be large enough to convey the bankfull flow without appreciably altering the stream flow characteristics. To insure the proper capacity the culvert(s) should have cross sectional area equal to the cross sectional area of the stream at bankfull.

Should the structure will remain in place 6 months or longer, the culvert shall be large enough to convey the flow from a 10-year frequency storm. In this case, the hydrologic calculations and subsequent culvert size must be done for the specific watershed characteristics. If the structure must remain in place over 1 year, a qualified registered Professional Engineer must design it as a permanent measure.

c. Multiple culverts may be used in place of one large culvert if they have the equivalent capacity of the larger one. The minimum sized culvert that may be used is 18 inches. Two 18-inch culverts do not replace a 36-inch culvert.

d. All culverts shall be strong enough to support their cross-sectioned area under maximum expected loads.

e. The culvert(s) shall extend a minimum of five foot beyond the upstream and downstream toe of the aggregate placed around the culvert.

f. The slope of the culvert shall be at least 0.25 inch per foot.

g. Crossing Alignment - The temporary waterway crossing shall be at right angles to the stream. Where approach conditions dictate, the crossing may vary 15 from a line drawn perpendicular to the centerline of the stream at the intended crossing location.

h. The centerline of both roadway approaches shall coincide with the crossing alignment centerline for a minimum distance of 50 feet from each bank of the waterway being crossed. If physical or right-of-way restraints preclude the 50 feet minimum, a shorter distance may be provided. All fill materials associated with the roadway approach shall be limited to a maximum height of 2 feet above the existing flood plain elevation.

i. The roadway approaches to the structure shall consist of stone pads meeting the following specifications:

- 1) Stone: 2"- 4"
- 2) Minimum thickness: 6 inches
- 3) Minimum width: equal to the width of the structure
- 4) Minimum length: 50 feet on either side of the crossing.

j. A water diverting structure such as a swale shall be constructed (across the roadway on both roadway approaches) 50 feet (maximum) on either side of the waterway crossing. This will prevent roadway surface runoff from directly entering the waterway. The 50 feet is measured from the top of the waterway bank. If the roadway approach is constructed with a reverse grade away from the waterway, a separate diverting structure is not required.

k. Appropriate perimeter controls such as SILT FENCE, SUPER SILT FENCE and/or DIVERSION and SEDIMENT TRAP must be employed when necessary along banks of stream parallel to the same.

l. Clearing and excavation of the streambed and banks shall be kept to a minimum.

m. The invert elevation of the culvert shall be installed on the natural streambed grade to minimize interference with fish migration.

n. Filter cloth shall be placed on the streambed and streambanks prior to placement of the pipe culvert(s) and aggregate. The filter cloth shall cover the streambed and extend a minimum of six inches and a maximum of one foot beyond the end of the culvert and bedding material. Filter cloth reduces settlement and improves crossing stability. The required physical qualities of the filter cloth should be sufficient for the anticipated loads.

o. When the crossing has served its purpose, all structures including culverts, bedding and filter cloth materials shall be removed. Removal of the structure and clean up of the area should be accomplished without construction equipment working in the waterway channel.

p. Upon removal of the structure, the stream bank shall immediately be stabilized.

q. During routine road maintenance do not grade mud and debris over the sides of the crossing into the stream.

When the temporary structure has served its purpose, including bridge abutments or culverts and other bridging materials shall be removed and the disturbed area stabilized within 7 days. Care should be taken so that any aggregate left does not create an impediment to the flow or restrict fish passage.

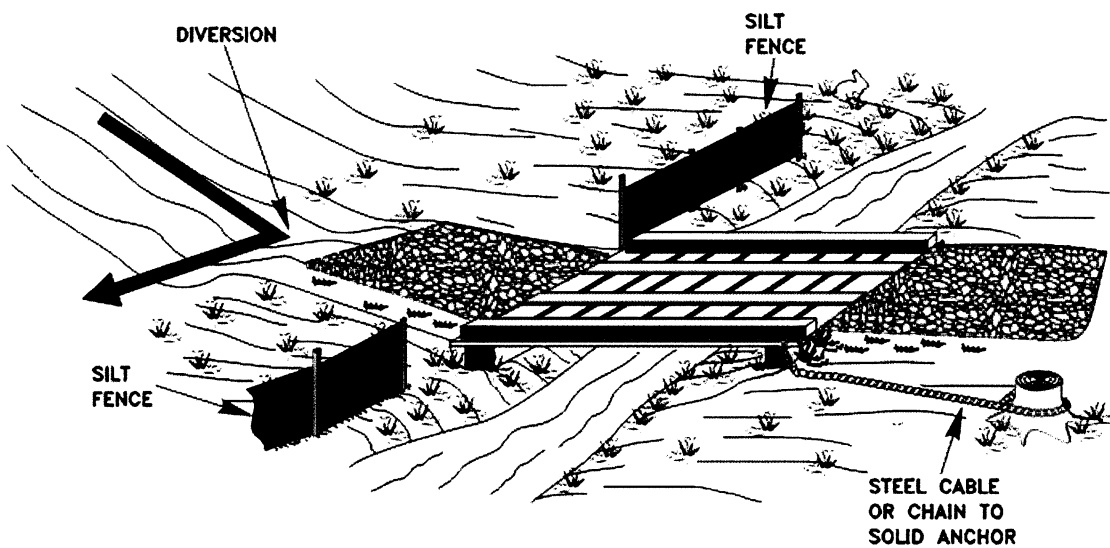
All construction materials shall be stored outside the waterway flood plain. Clean up shall be accomplished without construction equipment working in the stream channel.

Maintenance

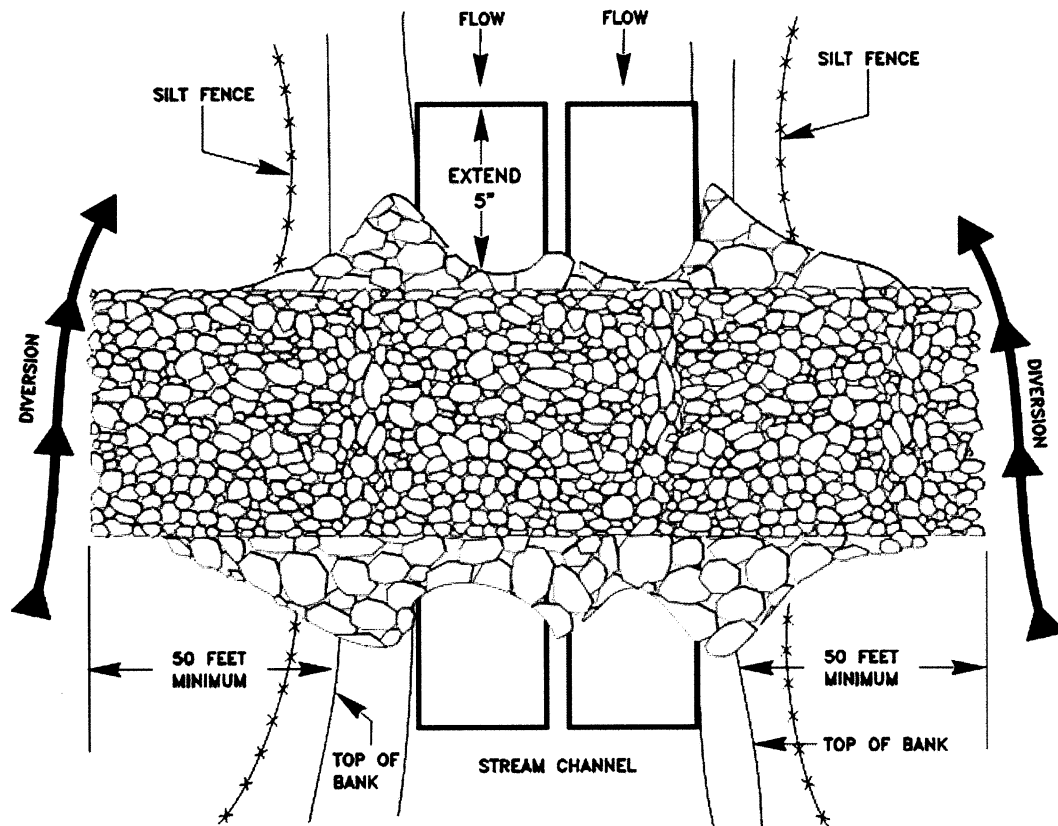
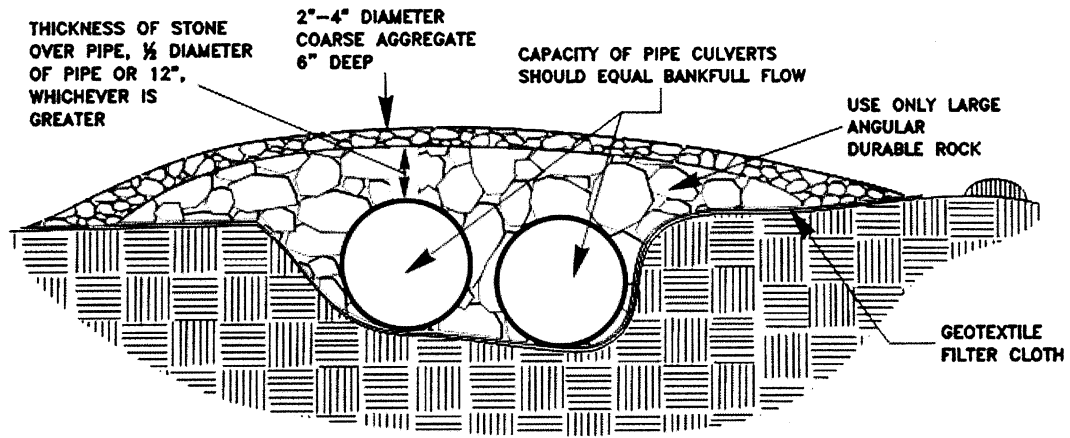
Periodic inspection must be performed to ensure that the bridge, culverts, streambed and stream banks are maintained and not damaged, that sediment is not entering the stream. At a minimum each crossing must be inspected after every rain event of 0.5 inches or more and once a week. Never allow the culverts to become clogged with debris. Remove any obstructions immediately.

Sediment and debris removed shall be disposed of outside of the flood plain and stabilized.

TEMPORARY BRIDGE CROSSING



CULVERT STREAM CROSSING



FROM: VA DSWC

MINIMUM STANDARDS FOR INSTREAM CONSTRUCTION ACTIVITIES

General Requirements for all instream activities

1. All appropriate permits should be obtained prior to beginning instream construction activities such as construction activities such as creating a restriction or impediment of flow. See the Regulatory Requirements section of this manual.
6. Isolating the work area and "working in the dry" is the only effective way of controlling sediment.
7. All instream construction should be scheduled to occur during low flow periods, typically during the summer and fall months. If construction must be accomplished during higher flows, the work area must be isolated from the stream by a structural measure such as a non-erodible cofferdam or sheet piling. Emergency repairs of public utilities or public roads are exempted.
8. All streambanks are to be stabilized with an appropriate protective material such as riprap, revegetation, geotextiles, revetments, etc. immediately upon completion of the final grading.
9. The choice of stabilization materials (vegetative or structural) should be based on sound engineering practices and will include investigations of the soil's erodibility and the anticipated velocities of the stream.
10. Inlet and outlet protection is required for all culverts (both temporary and permanent). Outlet protection can consist of riprap, gabion baskets, or other approved materials. See Outlet Protection section of this manual.
11. Every effort, in both planning and construction, should be made to limit the amount of instream work. Utility lines should not be installed within the stream, with the exception of stream crossing, without irrefutable proof that alternate avenues of alignment are not available. Convenience is not a justifiable reason to install a utility line down a stream.
12. Utility lines and roadways should cross the stream at right angles ($\pm 15^\circ$) to the flow of the water.
13. Each stream crossing should be treated as a separate project and work should progress until the approaches and stream banks are completely stabilized. In no case should stabilization of the stream bank exceed 24 hours from completion of the backfill.
14. Streamside vegetation should be left intact to the greatest extent possible. Riparian buffer zones are to be enhanced whenever possible.
15. The sequence of construction events for the each instream activity should be included in the sediment control plan.

16. When a stream crossing is being constructed for vehicles, the crossing should be constructed as detailed in vehicle stream crossing section of this manual.
17. When work is performed in a flowing stream, precautions should be taken to minimize encroachment, control sediment transport and stabilize the work area to the greatest extent possible during construction. Use only non-erodible material for the construction of causeways, stream diversions and berms and cofferdams. Earthen fill may be used for cofferdams if armored by non-erodible cover materials such as filter fabric and appropriately sized stone.
18. All water pumped from a work area along, in or near a stream must be treated in an approved settling structure located outside the waterway before being discharged into a waterway. See DEWATERING section of this manual.
19. Green concrete is toxic to aquatic life and must not be placed in contact with flowing water.
20. Streambed excavation should be undertaken from the top of stream banks whenever possible.
21. When instream work is required, the use of rubber-tired vehicles and excavators is recommended.
22. Excavated material to be reused for trench backfill should be stockpiled outside the stream channel. Surround the storage area by silt fence or similar barrier to prevent sediment and mud from running back into the stream. Material not used for backfill should be removed to an appropriate soil disposal area located outside the floodplain and properly stabilized.
23. Temporary access roads in close proximity to a stream should be stabilized using the same requirements for a Stabilized Construction Entrance.
24. Do not use the stream as a vehicular right-of-way. Do not use the stream to deliver materials or to move construction equipment from one section to another.
25. Spill containment kits should be readily available onsite.

3.22 - DEWATERING

Definition

Dewatering refers to the act of removing and discharging water from excavated areas on construction sites, utility line construction or from sediment traps or basins on construction sites.

Given the unique conditions at any particular construction site, any or all of the practices may apply. In all cases, every effort shall be made to eliminate sediment pollution associated with dewatering.

Practices for Dewatering

Excavated Areas

1. Pumping of water to an existing sediment basin or trap in which the entire volume of water from the area to be dewatered can be contained without discharge to receiving waters.
2. Pumping of water to an existing sediment basin or trap such that the entire volume of water from the area to be dewatered can be managed without exceeding the design outflow from the sediment control structure.
3. Use of a straw bale/silt fence pit or trap as shown in the drawings.
4. Pumping water through a geotextile bag made specifically for this purpose.
5. A well-vegetative Filter Strip, capable of withstanding the velocity of discharged water without eroding. Install some sort of energy dissipation (haybales, riprap or sheet of plywood) at the pump discharge.
6. Use a sump pit as shown on drawings to reduce the pumping mud.

Dewatering of Sediment Traps and Basins

Designers shall specify on plans, in the sequences of events and in the the practices for dewatering of traps and basins. In all cases, water removed from traps and basins shall be discharged so that it passes through a sediment control device prior to entering receiving waters.

Practices for Dewatering of Traps and Basins

1. Use of a straw bale/silt fence pit or trap as shown in the drawings.
2. Pumping water through a geotextile bag made specifically for this purpose.
3. A well-vegetative Filter Strip, capable of withstanding the velocity of discharged water without eroding. Install some sort of energy dissipation (haybales, riprap or sheet of plywood) at the pump discharge.
4. Regardless of the type of treatment always use a floating suction hose to pump the cleaner water from the top of the pond. As the cleaner water is pumped, the suction hose will lower and

eventually encounter sediment-laden water. At this point cease pumping operations and remove the remainder of the trapped sediment with machinery. Even when pumping from the top of the water column, provisions must still be made to filter water as required in this section prior to discharging to a stream. During the dewatering, personnel should be assigned to monitor pumping operations at all times to ensure that sediment pollution is abated. Pumping sediment-laden water into the waters of the State without filtration is prohibited.

Design Criteria

1. The dewatering device must be sized (and operated) to allow pumped water to flow through the filtering apparatus without exceeding the capacity of the structure. The following formula can be used to determine the storage volume for dewatering structures:

Pump discharge (g.p.m.) x 16 = cubic feet of storage required
2. Material from any required excavation shall be stored in an area and protected in a manner that will prevent sediments from eroding and moving off-site.
3. An excavated basin (applicable to "Straw Bale/Silt Fence Pit") may be lined with filter fabric to help reduce scour and to prevent erosion of soil from within the structure. It may also be helpful to direct the discharge onto a hay or straw bale or riprap.
4. Design criteria more specific to each particular dewatering device can be found in the drawings.

Construction Methods

Straw Bale/Silt Fence Pit

- a. Measure shall consist of straw bales, silt fence, a stone outlet consisting of a combination of 4-8 inch riprap and ½ to 2 inch aggregate and a wet storage pit oriented as shown in drawing.
- b. The excavated area should be a minimum of 3 feet below the base of the perimeter measures (straw bales or silt fence).
- c. Once the water level nears the crest of the stone weir (emergency overflow), the pump must be shut off while the structure drains down to the elevation of the wet storage.
- d. The wet storage pit may be dewatered only after a minimum of 6 hours of sediment settling time. This effluent should be pumped across a well-vegetated area or through a silt fence prior to entering a watercourse.
- e. Once the device has been removed, ground contours will be returned to original condition.

Geotextile Filter Bag

- a. The bag shall be installed on a very slight slope so incoming water flows downhill through the bag without creating more erosion.
- b. The neck of the Filter Bag shall be tightly strapped (minimum two straps) to the discharge hose.
- c. The bag should be placed on an aggregate or hay bale bed to maximize water flow through the entire surface area of the bag.
- d. The Filter Bag is full when it no longer can efficiently filter sediment or pass water at a reasonable rate.
- e. Flow rates vary depending on the size of the Dewatering Device, amount of sediment discharged into the Dewatering Device, the type of ground, rock, or other substance under the bag and the degree of the slope on which the bag lies. The Filter Bag should be sized to accommodate the anticipated flow rates from the type of pump used. Typically Filter Bags can handle flow rates of up to 1000 gallons per minute, but in all cases follow the manufacturers recommendations for flow rates.
- f. Use of excessive flow rates or overfilling the Dewatering Device with sediment will cause ruptures of the bag or failure of the hose attachment straps.
- g. The Filter Bag can be left in place after cutting the top off and seeding and mulching the accumulated sediment or removed and disposed of offsite in an approved landfill.
- h. Each standard Dewatering Device shall have a fill spout large enough to accommodate the discharge hose. Use two stainless steel straps to secure the hose and prevent pumped water from escaping without being filtered.
- i. The Dewatering Device shall be a nonwoven bag, which is sewn with a double needle stitching using a high strength thread.
- j. The Dewatering Device seams shall have an average wide width strength per ASTM D 4884 of 100 LB/IN (1.15 kg/meter).
- k. The geotextile fabric shall be a nonwoven fabric with the following properties:

Table 3.22.1 GEOTEXTILE FABRIC PROPERTIES

Properties	Test Method	English	Metric
Grab Tensile	ASTM D-4632	250 Lbs.	113 kg
Puncture	ASTM D-4833	165 Lbs.	75 kg
Flow Rate	ASTM D-4491	70 Gal/Min/ Square Foot	25 liters/Min/ Square Meter
Permittivity	ASTM D-4491	1.3 Sec.-1	1.3 Sec.-1
Mullen Burst	ASTM D-3786	550 Lbs./ Square inch	3.79 MPa
UV Resistant	ASTM D-4355	70%	70%
AOS % Retained	ASTM D-4751	100%	100%

*All properties are minimum average roll value.

Maintenance

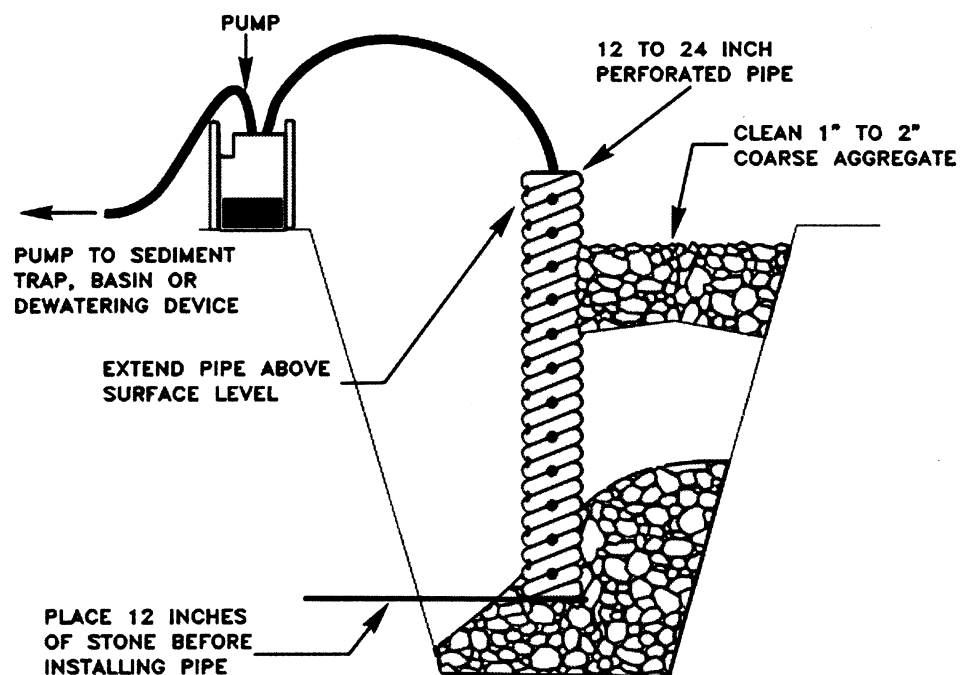
The filtering devices must be inspected frequently during pumping operations and repaired or replaced once the sediment build-up prevents the structure from functioning as designed.

Once the wet storage area becomes filled with sediment to one-half of the excavated depth, accumulated sediment shall be removed and disposed of properly.

The accumulated sediment that is removed from a dewatering device must be spread on-site and stabilized or disposed of at an approved disposal site as per approved plan.

FIGURE 3.22-1

SUMP PIT

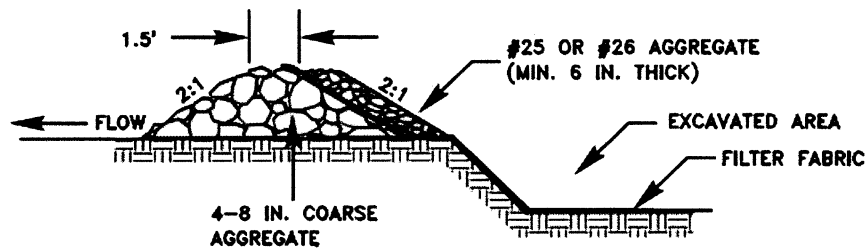
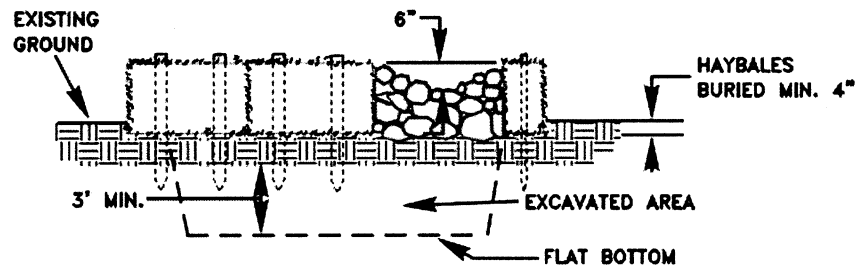
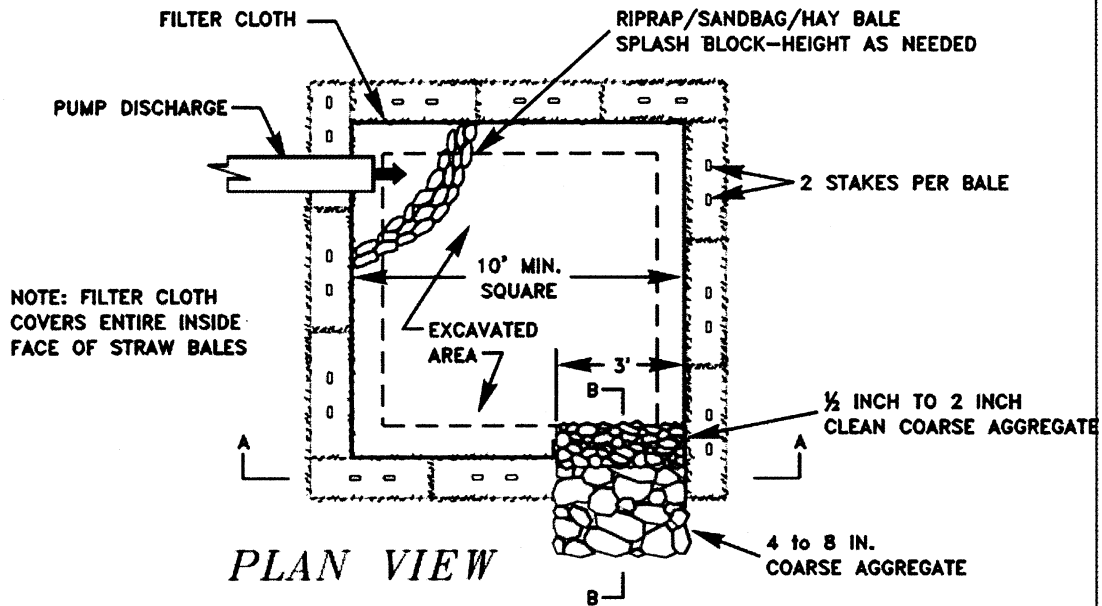


FROM NEW YORK DEC

3.22-5

FIGURE 3.22-2

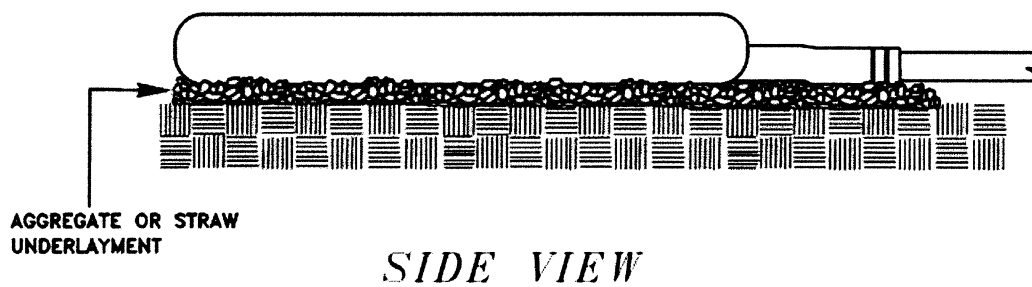
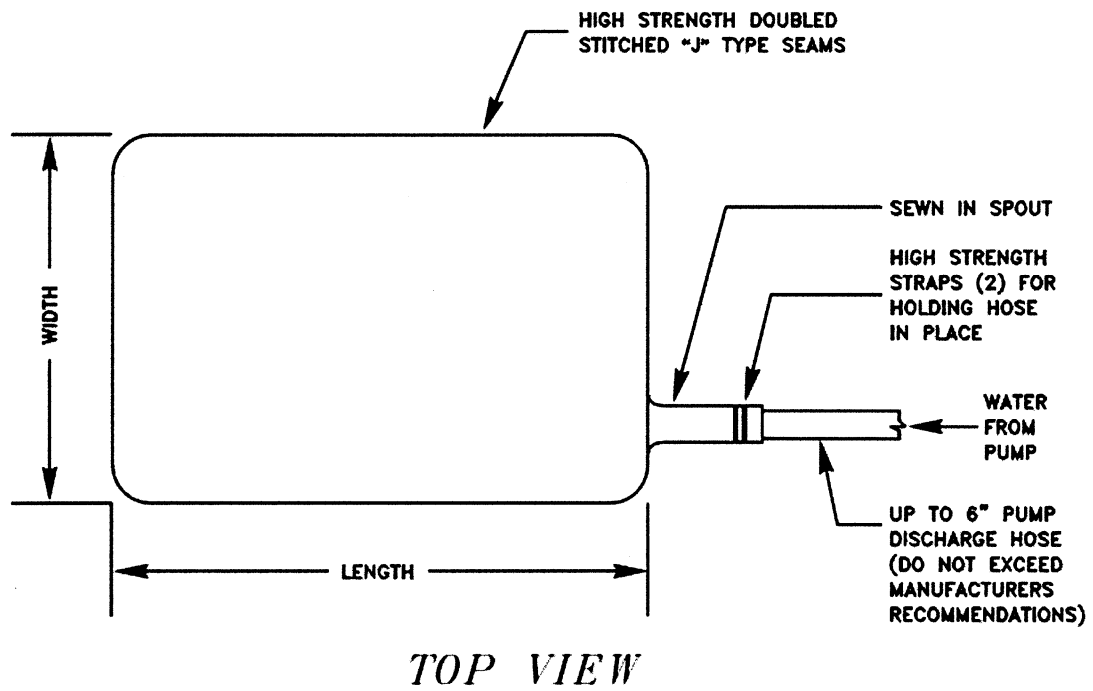
STRAW BALE/SILT FENCE PIT



SOURCE: Va. DSWC

FIGURE 3.22-3

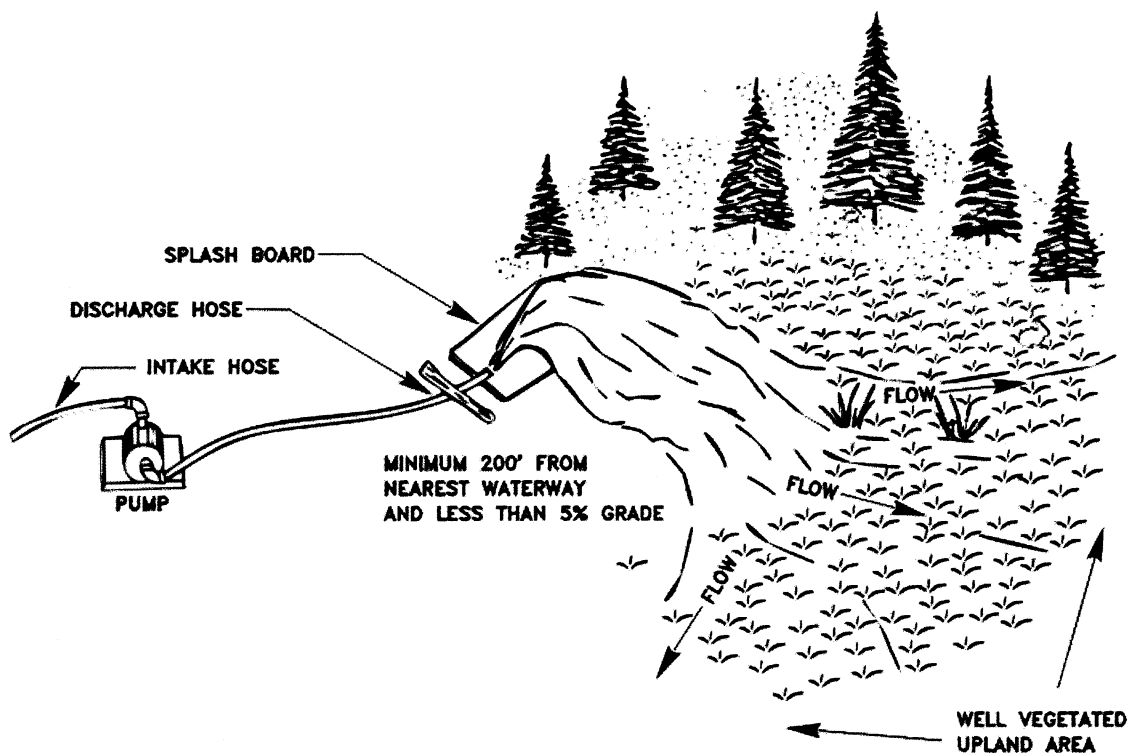
DEWATERING BAG



3.22-7

FIGURE 3.22-4

DEWATERING DISCHARGE IN UPLAND AREA WITH ADEQUATE VEGETATION



FROM: CNG TRANSMISSION CORP.

3.23 - RIPRAP

Introduction

A permanent, erosion-resistant ground cover of large, loose, angular stone with filter fabric or granular underlining used to protect the soil from:

1. The erosive forces of concentrated runoff.
2. To slow the velocity of concentrated runoff while enhancing the potential for infiltration.
- 3, To stabilize slopes with seepage problems and/or non-cohesive soils.

Conditions Where Practice Applies

Wherever soil and water interface and the soil conditions, water turbulence and velocity, expected vegetative cover, etc., are such that the soil may erode under the design flow conditions. Riprap may be used, as appropriate, at storm drain outlets, on channel banks and/or bottoms, roadside ditches, drop structures, at the toe of slopes, as transition from concrete channels to vegetated channels, etc.

Planning.

Riprap is classified as either graded or uniform. A sample of graded riprap would contain a mixture of stones that vary in size from small to large. A sample of uniform riprap would contain stones which are all fairly close in size. For most applications, graded riprap is preferred to uniform riprap. Graded riprap forms a flexible self-healing cover, while uniform riprap is more rigid and cannot withstand movement of the stones. Graded riprap is cheaper to install, requiring only that the stones be dumped so that they remain in a well-graded mass. Hand or mechanical placement of individual stones is limited to that necessary to achieve the proper thickness, line and grade. Uniform riprap requires placement in a more or less uniform pattern, requiring more hand or mechanical labor.

Riprap sizes can be designed by either the diameter or the weight of the stones. The weight of the stone is the more significant design parameter but it is simpler to specify the diameter of the stone. The correlation between stone size and weight is typically based upon an assumed specific weight of 165 lbs./ft³.

Since graded riprap consists of a variety of stone sizes, a method is needed to specify the size range of the mixture of stone. This is done by specifying a diameter of stone in the mixture for which some percentage, will be smaller. For example, d85 refers to a mixture of stones in which 85% of the stone would be smaller than the diameter specified. Most designs are based on d50. In other words, the design is based on the median size of stone in the mixture, where 50% will be larger than the

d50 and 50% will be smaller. It is also necessary to give the upper and lower limits for the stone size too.

To ensure that stone of substantial weight is used when constructing riprap structures, specified weight and diameter ranges for individual stones and composition requirements should be followed. Such guidelines will help to prevent inadequate stone from being used in construction of the measures and will promote more consistent stone classification statewide. Table 3.23.1 notes these requirements.

Table 3.23.1 AASHTO RIPRAP GRADATION CLASSES

Riprap Class	Rock Size ¹ feet (mm)		Rock Size ² pounds (kg)		Percent of Riprap Smaller Than
A	1.30	(400)	200	(90)	100
	0.95	(290)	75	(35)	50
	0.40	(120)	5	(2)	10
B	1.80	(550)	500	(225)	100
	1.30	(400)	200	(90)	50
	0.40	(120)	5	(2)	10
C	2.25	(690)	1000	(455)	100
	1.80	(550)	500	(225)	50
	0.95	(290)	75	(35)	10
D	2.85	(870)	2000	(910)	100
	2.25	(690)	1000	(455)	50
	1.80	(550)	500	(225)	5
E	3.60	(1100)	4000	(1815)	100
	2.85	(870)	2000	(910)	50
	2.25	(690)	1000	(455)	5
F	4.50	(1370)	8000	(3630)	100
	3.60	(1100)	4000	(1815)	50
	2.85	(870)	2000	(910)	5

1 Assuming a specific gravity of 2.65.

2 Based on AASHTO gradations.

In practice though it is hard to acquire stones of the desired size. Quarries normally sell a narrower range of riprap sizes and in ranges incompatible with the above chart. The typical range of riprap available in West Virginia will be 4"-8" (gabion stone per DOH specifications), 6"-12", 10"-24", and 12"-36". Many times the contractor will crush their own stone on site.

If stone is crushed on site great care must be taken to produce stone sizes that mirror the requirements created by the designer and this specification. The most common problem is generating stone that is much too large and in a range of sizes that does not meet the gradation requirements.

Oversize stones, even in isolated spots, may cause riprap failure by precluding mutual support between individual stones, providing large

voids that expose filter and bedding materials, and creating excessive local turbulence that removes smaller stones. Small amounts of oversize stone should be removed individually and replaced with proper size stones.

When excessively large stone is used for channel lining there is an increased chance of erosion underneath the rock, which can cause a total failure of the channel. During higher flows the runoff must travel across the top of the riprap, not underneath. This point cannot be stressed enough. Bigger is not better when it comes to rock for channel lining.

Sequence of Construction

Since riprap is used where erosion potential is high, construction must be sequenced so that the riprap is put in place as quickly as possible.

Disturbance of areas where riprap is to be placed should be undertaken only when final preparation and placement of the riprap can follow immediately behind the initial disturbance. Where riprap is used for outlet protection, the riprap should be installed before the construction of the pipe or channel is completed

Design Criteria

Gradation-The riprap shall be composed of a well-graded mixture down to the 1-inch size particle such that 50% of the mixture by weight shall be larger than the d50 size as determined from the design procedure. A well-graded mixture as used herein is defined as a mixture composed primarily of the larger stone sizes but with a sufficient mixture of other sizes to fill the progressively smaller voids between the stones. The diameter of the largest stone size in such a mixture shall be 1.5 times the d50 size.

The designer, after determining the riprap size that will be stable under the flow conditions, should consider that size to be a minimum size and then, based on riprap gradations actually available in the area, select the size or sizes that equal or exceed the minimum size. The possibility of damage by children shall be considered in selecting a riprap size, especially if there is nearby water or a gully in which to toss the stones.

Thickness-The minimum thickness of the riprap layer shall be 2 times the maximum stone diameter, but not less than 6 inches.

Quality of Stone-Stone for riprap shall consist of fieldstone or rough unhewn quarry stone of approximately rectangular shape. The stone shall be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering and it shall be suitable in all respects for

the purpose intended. The specific gravity of the individual stones shall be at least 2.5.

Rubble concrete may be used provided it has a density of at least 165 pounds per cubic foot, and other wise meets the requirements of this BMP. All rebar shall be removed flush with the surface of the concrete.

Filter Fabric Underlining--A lining of engineering filter fabric (geotextile) shall be placed between the riprap and the underlying soil surface to prevent soil movement into or through the riprap. GEOTEXTILE has the minimum physical properties of the filter fabric.

Filter fabric shall not be used on slopes greater than 1.5:1 as slippage may occur and should be used in conjunction with a layer of coarse aggregate (granular filter blanket is described below) when the riprap to be placed is Class C or larger.

Granular Filter--Although the filter cloth underlining or bedding is the preferred method of installation, a granular (stone) bedding is a viable option when the following relationship exists:

$$\frac{d_{15} \text{ filter}}{d_{85} \text{ base}} < 5 < \frac{d_{15} \text{ filter}}{d_{15} \text{ base}} < 40$$

and

$$\frac{d_{50} \text{ filter}}{d_{50} \text{ base}} < 40$$

In these relationships, filter refers to the overlying material and base refers to the underlying material. The relationships must hold between the filter material and the base material and between the riprap and the filter material. In some cases, more than one layer of filter material may be needed. Each layer of filter material should be approximately 6-inches thick.

Riprap at Outlets-

Design criteria for sizing the stone and determining the dimensions of riprap pads used at the outlet of drainage structure are contained in OUTLET PROTECTION. A filter fabric underlining is required for riprap used as outlet protection.

Riprap for Channel Stabilization

Riprap for channel stabilization shall be designed to be stable for the condition of bankfull flow in the reach of channel being stabilized. This method establishes the stability of the rock material relative to the forces exerted upon it. (see Figure 3.21.7)

Riprap shall extend up the banks of the channel to a height equal to the maximum depth of flow or to a point where vegetation can be established to adequately protect the channel.

The riprap size to be used in a channel bend shall extend upstream from the point of curvature and downstream from the bottom of the channel to a minimum depth equal to the thickness of the blanket and shall extend across the bottom of the channel the same distance.

Freeboard and Height of Bank

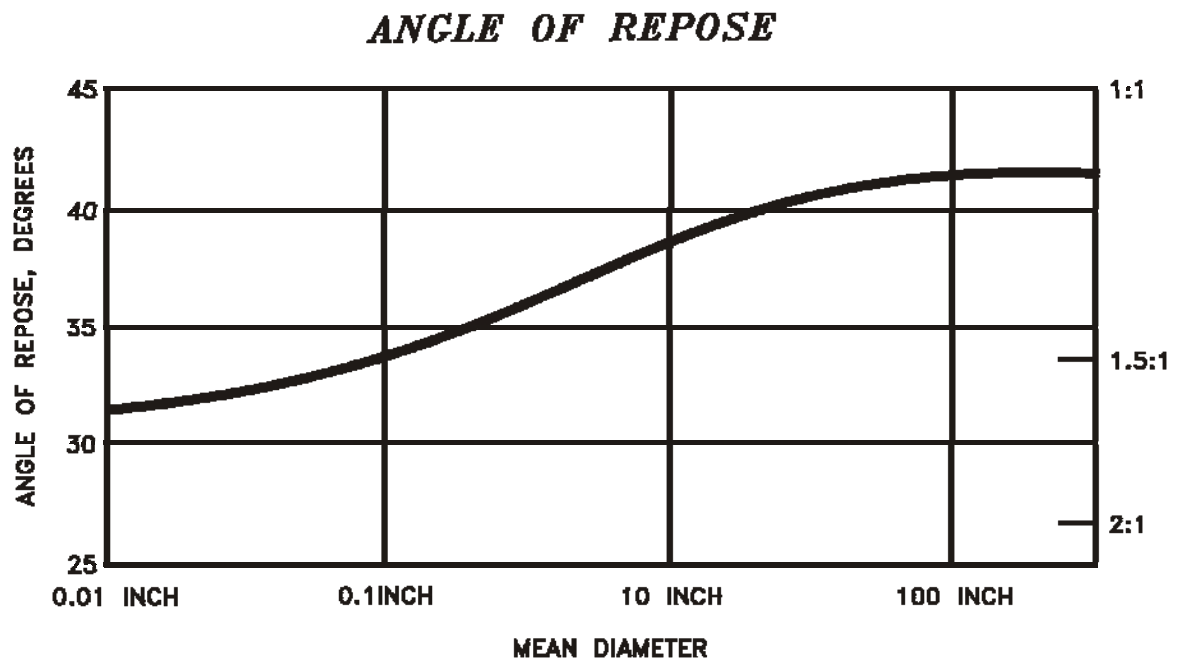
For riprapped and other lined channels, the height of channel lining above the water surface should be based on the size of the channel, the flow velocity, the curvature, inflows, wind action, flow regulation, etc. This manual does not provide the design for riprap revetment. The Federal Highway Administration in HEC-11 provides the necessary information to design riprap streambank protection.

The height of the bank above the water surface varies in a similar manner, depending on the above factors plus the type of soil.

Riprap for Slope Stabilization

Riprap for slope stabilization shall be designed so that the natural angle of repose of the stone mixture is greater than the gradient of the slope being stabilized (see Figure 3.23.1).

Figure 3.23.1 ANGLE OF REPOSE



Construction Specifications

Subgrade Preparation: The subgrade for the riprap or filter shall be prepared to the required lines and grades. Any fill required in the subgrade shall be compacted to a density approximately that of the surrounding undisturbed material. Brush, trees, stumps and other objectionable material shall be removed.

Filter Fabric or Granular Filter: Placement of the filter fabric should be done immediately after slope preparation. For granular filters, the stone should be spread in a uniform layer to the specified depth, normally 6 inches. Where more than one- layer of filter material is used, the layer should be spread so that there is minimal mixing of the layers.

When installing geotextile filter cloths, the cloth should be placed directly on the prepared slope. The edges of the sheets should overlap by at least 12 inches. Anchor pins, 15 inches long, should be spaced every 3 feet along the overlap. The upper and lower ends of the cloth should be buried at least 12 inches. Care should be taken not to damage the cloth when placing the riprap. If damage occurs, that sheet should be removed and replaced. For large stone (Class C or greater), a 6-inch layer of granular filter will be necessary to prevent damage to the cloth.

Stone Placement: Placement of riprap should follow immediately after placement of the filter. The riprap should be placed so that it produces a dense well-graded mass of stone with a minimum of voids. The desired distribution of stones throughout the mass may be obtained by selective loading at the quarry, controlled dumping of successive loads during final placing, or by a combination of these methods.

The riprap should be placed to its full thickness in one operation. The riprap should not be placed in layers. The riprap should not be placed by dumping into chutes or similar methods that are likely to cause segregation of the various stone sizes.

Blend the stone surface smoothly with the surrounding area, allowing no protrusions, overfall or in the case of channels so the stone does not form a dam to incoming runoff.

Care should also be taken not to dislodge the underlying material when placing the stones.

The finished slope must be free of pockets of small stone or clusters of large stones.

Hand placing may be necessary to achieve the required grades and a good distribution of stone sizes. Final thickness of the riprap blanket should be within plus or minus 1/4 of the specified thickness.

Common Installation Problems

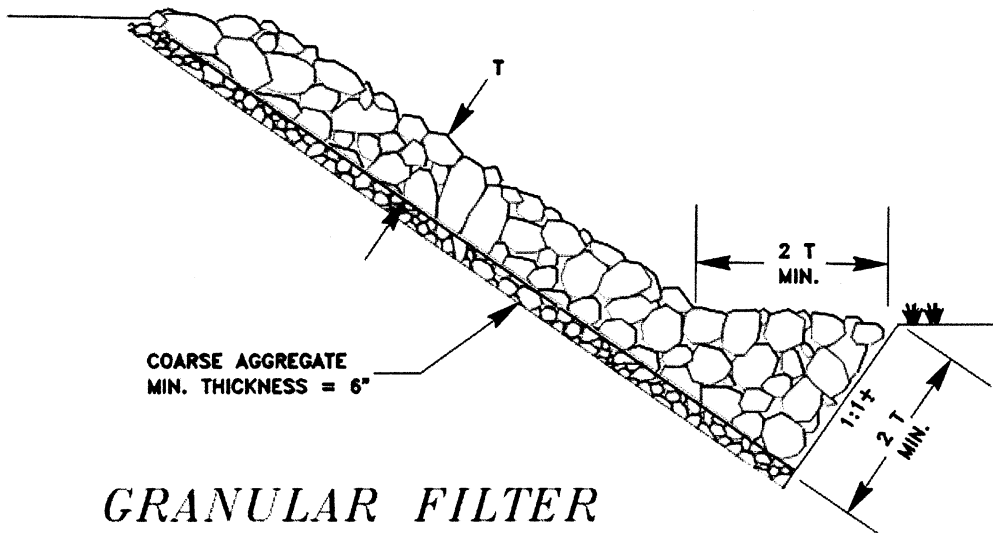
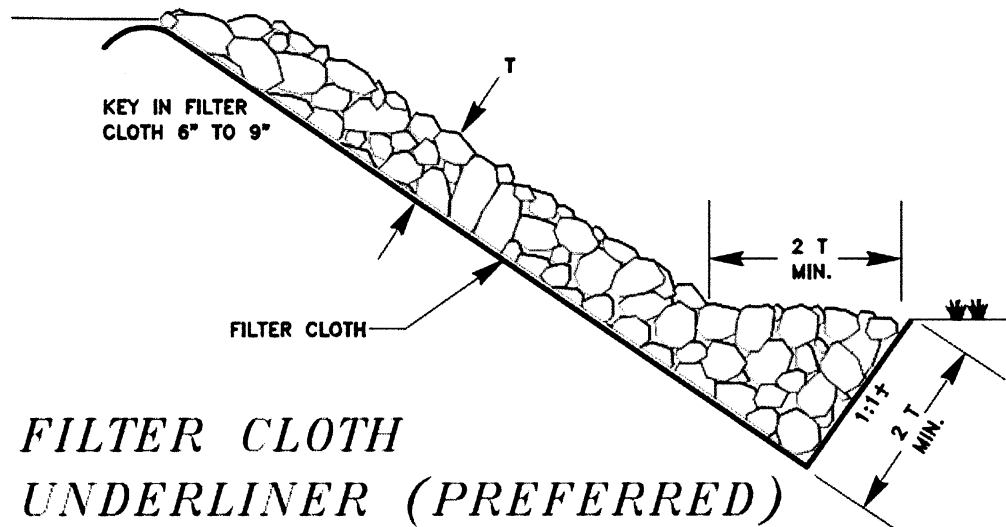
- Channel not excavated deep enough to accept the design thickness of the stone. Riprap blocks channel, resulting in erosion along edges.
- Stone too large resulting in water eroding underneath and undermining the stone.
- Slope too steep: Results in stone displacement. Do not use riprap as a retaining wall.
- Foundation not properly smoothed for filter placement: Results in damage to filter.
- Filter omitted or damaged: Results in piping or slumping.
- Riprap not properly graded: Results in stone movement and undermining and erosion of foundation.
- Foundation toe not properly reinforced: Results in undercut riprap slope or slumping.
- Fill slopes not properly compacted before placing riprap: Results in stone displacement.

Maintenance

Once a riprap installation has been completed, it should require very little maintenance. It should, however, be inspected periodically to determine if high flows have caused scour beneath the riprap or filter fabric or dislodged any of the stone. Care must be taken to properly control sediment-laden construction runoff that may drain to the point of the new installation. If repairs are needed, they should be accomplished immediately.

FIGURE 3.23.2

TOE REQUIREMENTS FOR BANK STABILIZATION



SOURCE: Adapted from VDOT Drainage Manual

3.24 - GEOTEXTILES

Introduction

Geotextiles are any permeable textile fabric used to increase soil stability, provide erosion control or aid in drainage. Geotextiles are usually made from a synthetic polymer such as polypropylene, polyester, polyethylenes and polyamides. Geotextiles can be woven, knitted or non-woven.

Conditions Where Practice Applies

Geotextiles come in a tremendous variety and are used in many situations on a construction site. Geotextiles usage falls into four broad categories, three of which are important to sediment and erosion control. These three categories are separation, reinforcement and filtration. The fourth type is as an impervious barrier. Each subcategory of geotextile is designed to perform a specific function. To select the right product, it is important to understand the product's functions and the physical characteristics needed to meet those functions.

Separation- It is sometimes necessary to maintain a physical separation between two dissimilar materials to maximize the physical attributes of each of those materials. For example, in drainage systems, it is necessary to prevent fine soils from filling the voids in a rock base; otherwise, the drainage system becomes clogged and ineffective over time. Yet, it is important to allow water to pass between the soil and the drainage system.

In other applications, it is desirable to prevent any water from coming into contact with the soil, so an impervious separation surface is required. The selection of an appropriate product to achieve a physical separation is determined, therefore, by the desired outcome.

Reinforcement- The physical characteristics of soils, especially on slopes resulting from cuts and fill activities, can create unstable conditions. Geotextiles can help strengthen the soil face and increase the soil's ability to remain in place. Slopes can be stabilized either temporarily or permanently, slowing or preventing creep or slips. Also, geotextiles can be used either to prevent water from permeating a slope or to control the amount of infiltration that occurs during rainfall.

Geotextiles are especially useful in reinforcing inadequate subsoil when building roads, parking areas and paths. When soil conditions are weak, adding an appropriate geotextile can create a three-dimensional surface that will withstand heavier vehicles.

Filtration- The filtration aspect of geotextiles was understood early on by the originator of silt fence as a sediment control device. Where the flows are minimal, a geotextile can be placed across the contour to create a dam and settle out the suspended solids contained in the runoff. While not technically a filter, the geotextile's openings serve as the outlet

necessary to pass water through the dam and filter out soil particles that are in suspension. Finer particles can pass through the fabric, so the size of the particles, the flow rate of the water and the physical location of the filter will determine the type of fabric that is appropriate.

For most geotextile applications relating to the construction industry, the American Association of State Highway and Transportation Officials (AASHTO) has developed guidelines. These guidelines provide classifications that are primarily based on the mechanical stresses the geotextile would be subjected to during installation. Typically, the stresses borne by geotextiles are highest during the installation of the fabric and placement of the cover material. The charts in this section are based on these AASHTO guidelines but come from the city of Seattle.

Geotextiles are either woven or non-woven.

Woven- Typically, woven fabric provides higher strengths. Weaving two or more strands of synthetic yarn at right angles produces woven fabrics. The yarn typically comes in two shapes: round and flat. Flat, also called slit film, is used where high strength is required but filtration is not. Round, or monofilament fabric, provides both high strength and filtration.

Woven stabilization fabrics provide the strength and separation needed for paved or unpaved road applications. High tensile strength and low elongation reduces rutting in both paved and unpaved surfaces. The fabrics separate the base course while reinforcing the adjacent soft soil.

Woven fabric is also used for silt fence and super silt fence. Geotextiles used for these practices must have the porosity and strength to withstand and pass through water as well as ultraviolet light inhibitors to protect it from the sun.

Non-woven- Non-woven fabric resembles felt and can provide planar water flow when used in subsurface drains, asphalt pavement overlays and erosion control. Higher weight non-woven fabric can be also used for separation under aggregate.

Non-woven fabric, slit films and combination fabrics have little open area, and often trap soil particles with the thickness of the fabric, clogging the geotextile.

Care must be taken to choose the appropriate fabric for the existing conditions, and, as with all commercial products, follow the manufacturer's recommendations.

Other design considerations are the porosity of the fabric, permittivity, tensile strength, elongation, Mullen burst, puncture strength, AOS (average opening size), seam strength and resistance to ultraviolet radiation. Each use will have a unique set of requirements that need to be taken into consideration.

ASSHTO M288 Classifications

M288-96 is based on geotextile survivability from installation stresses. Selection of the geotextile is based on knowledge of the anticipated exposure to installation stresses. M288-96 covers six geotextile applications: subsurface drainage, separation, stabilization, permanent erosion control, temporary silt fences and paving fabrics.

In M288-92, geotextile survivability was divided into classes A and B. Class A was used where installation stresses determined by aggregate shape, trench depth, and the size and height of an armor stone drop were more severe than in Class B installations. There are no definitive measurements set for differentiating between severe and less severe installation stresses.

In M288-96, the general strength requirements for the subsurface drainage, separation, stabilization and permanent erosion control applications are broken into three classes of geotextiles. Class 1 represents the most robust and Class 3 the least. Within each survivability class, the strength requirements are established based on elongation at break in the grab strength test. The highest strength requirement is for materials that break at less than 50 percent elongation (typically woven) and the least for those that break at greater than 50 percent elongation (typically unwoven). The requirements for the silt-fence applications are based on supported or unsupported fences. Paving fabrics are limited to fabrics with elongation at break of greater than 50 percent.

AASHTO Specification M288-96 for geotextiles is published in the two volume Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 18th Ed.

Design Considerations

In order to choose the appropriate geotextile, a proper evaluation of the proposed use, material specification and installation procedure is required. Since using geotextiles for stabilization of soils involves four basic functions, reinforcement, separation, filtration and drainage, it is important to be familiar with both the site conditions where the fabric will be installed and the various properties of geotextiles. The local soil characteristics and groundwater are two of the more important considerations to be considered. And since fabric strength calculations are based primarily on installation stresses, the type and size of the aggregate to be used is also important. Therefore there are a number of factors that will need to be considered when specifying fabrics.

Geotextile and thread for sewing

The material shall be a geotextile consisting 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. The geotextile shall conform to the properties as indicated in Tables 3.24.2 through 3.24.7 for each use specified.

Thread used for sewing shall consist of high strength polypropylene, polyester or polyamide. Nylon threads will not be allowed. The thread used to sew permanent erosion control geotextiles shall be resistant to ultraviolet radiation. The thread shall be of contrasting color to that of the geotextile itself.

The geotextile uses included in this section and their associated tables of properties are as follows:

Table 3.24.1 List of geotextile tables

Geotextile application	Applicable property tables
Underground drainage, low survivability, Classes A, B, and C	Tables 3.24.2 and 3.24.3
Underground drainage, moderate survivability, Classes A, B, and C	Tables 3.24.2 and 3.24.3
Separation	Table 3.24.4
Soil stabilization	Table 3.24.4
Permanent erosion control, moderate survivability, Classes A, B, and C	Tables 3.24.5 and 3.24.6
Permanent erosion control, high survivability, Classes A, B, and C	Tables 3.24.5 and 3.24.6
Ditch lining	Table 3.24.5
Temporary silt fence	Table 3.24.7

Table 3.24.2 Geotextile for underground drainage strength properties for survivability

		Geotextile property requirements¹	
Geotextile property	Test method²	Low survivability woven/non-woven	Moderate survivability woven / non-woven
Grab tensile strength, min. in machine and x-machine direction	ASTM D 4632	180 lbs. / 115 lbs. min.,	250 lbs. / 160 lbs. min.
Grab failure strain, in machine and x-machine direction	ASTM D 4632	<50% / / 50%	<50% / /50%
Seam breaking strength	ASTM D 4632 ³	160 lbs. / 100 lbs. min.	220 lbs. / 140 lbs. min.
Puncture resistance	ASTM D 4833	67 lbs. / 40 lbs. min.	80 lbs. / 50 lbs. min.
Tear strength, min. in machine and x-machine direction	ASTM D 4533	67 lbs. / 40 lbs. min.	80 lbs. / 50 lbs. min.
Ultraviolet (UV) radiation stability	ASTM D 4355	50% strength retained min., after 500 hrs. in weatherometer	50% strength retained min., after 500 hrs. in weatherometer

See notes after Table 3.24.7, this specification.

Table 3.24.3 Geotextile for underground drainage filtration properties

		Geotextile property requirements¹		
Geotextile property	Test method²	Class A	Class B	Class C
AOS	ASTM D 4751	.43 mm max. (No. 40 sieve)	.25 mm max. (No. 60 sieve)	.18 mm max. (No. 80 sieve)
Water permittivity	ASTM D 4491	.5 sec ⁻¹ min.	.4 sec ⁻¹ min.	.3 sec ⁻¹ min.

See notes after Table 3.24.7, this specification.

Table 3.24.4 Geotextile for separation or soil stabilization

		Geotextile property requirements¹	
Geotextile property	Test method²	Separation woven/non-woven	Soil stabilization woven/non-woven
AOS	ASTM D 4751	.60 mm max. (No. 30 sieve)	.43 mm max. (No. 40 sieve)
Water permittivity	ASTM D 4491	.02 sec-1 min.	.10 sec-1 min.
Grab tensile strength, min. in machine and x-machine direction	ASTM D 4632	250 lbs. / 160 lbs. min.	315 lbs./200 lbs. min.
Grab failure strain, in machine and x-machine direction	ASTM D 4632	<50% / /50%	<50% / /50%
Seam breaking strength	ASTM D 4632 ³	220 lbs. / 140 lbs. min.	270 lbs./180 lbs. min.
Puncture resistance	ASTM D 4833	80 lbs. / 50 lbs. min.	112 lbs./79 lbs. min.
Tear strength, min. in machine and x-machine direction	ASTM D 4533	80 lbs. / 50 lbs. min.	112 lbs./79 lbs. min.
Ultraviolet (UV) radiation stability	ASTM D 4355	50% strength retained min., after 500 hrs. in weatherometer	50% strength retained min., after 500 hrs. in weatherometer

See notes after Table 3.24.7, this specification.

Table 3.24.5 Geotextile for permanent erosion and ditch lining

		Geotextile property requirements¹		
		Permanent erosion control		Ditch lining
Geotextile property	Test method²	Moderate survivability woven / non-woven	High survivability woven / non-woven	Woven / non-woven
AOS	ASTM D 4751	See Table 3.24.6	See Table 3.24.6	.60 mm max(No. 30 sieve)
Water permittivity	ASTM D 4491	See Table 3.24.6	See Table 3.24.6	.02 sec ⁻¹ min.
Grab tensile strength, min. in machine and x-machine direction	ASTM D 4632	250 lbs. / 160 lbs. min.	315 lbs. / 200 lbs. min.	250 lbs. / 160 lbs. min.
Grab failure strain, in machine and x-machine direction	ASTM D 4632	15%- 50% / > 50%	15%- 50% / > 50%	<50% / ³ 50%
Seam breaking strength	ASTM D 4632 ³	220 lbs./ 140 lbs. min.	270 lbs. / 180 lbs. min.	220 lbs. / 140 lbs. min.
Burst strength	ASTM D 3786	400 psi/ 190 psi min.	500 psi / 320 psi min.	-----
Puncture resistance	ASTM D 4833	80 lbs./ 50 lbs. min.	112 lbs. / 79 lbs. min.	80 lbs. / 50 lbs. min.
Tear strength, min. in machine and x-machine direction	ASTM D4533	80 lbs./ 50 lbs. min.	112 lbs. / 79 lbs. min.	80 lbs. / 50 lbs. min.
Ultraviolet (UV) radiation stability	ASTM D 4355	70% strength retained min., after 500 hrs. in weatherometer	70% strength retained min., after 500 hrs. in weatherometer	70% strength retained min., after 500 hrs. in weatherometer

See notes after Table 3.24.7, this specification.

Table 3.24.6 Filtration properties for geotextile for permanent erosion control

		Geotextile property requirements¹		
Geotextile property	Test method²	Class A	Class B	Class C
AOS	ASTM D4751	0.43 mm max. (No.40 sieve)	0.25 mm max. (No.60 sieve)	0.22 mm max. (No. 70 sieve)
Water permittivity	ASTM D4491	0.7 sec ⁻¹ min.	0.4 sec ⁻¹ min.	0.2 sec ⁻¹ min.

See notes after Table 3.24.7, this specification.

Table 3.24.7 Geotextile for temporary silt fence

		Geotextile property requirements¹	
Geotextile property	Test method²	Unsupported between posts	Supported between posts with wire or polymeric mesh
AOS	ASTM D 4751	.60 mm max. for slit film wovens (No. 30 sieve) .30 mm max. for all other geotextile types (No. 50 sieve).15 mm min.(No. 100 sieve)	.60 mm max. for slit film wovens (No. 30 sieve).30 mm max. for all other geotextile types (No. 50 sieve).15 mm min. (No. 100 sieve)
Water permittivity	ASTM D 4491	.02 sec ⁻¹ min.	.02 sec ⁻¹ min.
Grab tensile strength, min. in machine and x-machine direction	ASTM D 4632	180 lbs. min. in machine direction, 100 lbs. min. in x-machine direction	100 lbs. min.
Grab failure strain, min. in machine direction only	ASTM D 4632	30% max. at 180 lbs. or more	-----
Ultraviolet (UV) radiation stability	ASTM D 4355	70% strength retained min., after 500 hrs. in weatherometer	70% strength retained min., after 500 hrs. in weatherometer

Notes

¹All geotextile properties in Tables 1 through 6 are minimum average roll values (i.e., the test result for any sampled roll in a lot shall meet or exceed the values shown in the table).

²The test procedures used are essentially in conformance with the most recently approved ASTM geotextile test procedures, except for geotextile sampling and specimen conditioning, which are in accordance with WSDOT Test Methods 914 and 915, respectively.

³With seam located in the center of 8-inch long specimen oriented parallel to grip faces.

Source for tables: <http://www2.ci.seattle.wa.us/util/engineering/ArticleView.asp?ArticleID=9-05.22#9-05.22>

**Construction
Specifications**

Since the greatest stresses occur during installation of the geotextile and overlying material, the following conditions should be met:

1. Ensure the ground surface is clear of stones, roots, and debris.
2. Provide a surface to lay the fabric on that is as smooth as possible and free of humps or holes.
3. Ensure that the geotextile is in intimate contact with the soil.
4. Carefully place the stone on top of the fabric to prevent damage to the geotextile.

When the geotextile is used between two layers of aggregate, there is a greater chance of stress and damage, so it is recommended to use a higher strength fabric.

Maintenance

Once the installation of the filter fabric system has been completed, it should require very little maintenance. It should, however, be inspected periodically to determine if high flows have caused scour beneath the fabric or dislodged any of the stone. If repairs are needed, they should be completed immediately.

References

City of Seattle

L. David Suits and Gregory N. Richardson on www.geosynthetics.com,
FNW Geosynthetics Division

“Basic Geosynthetics: A Guide to Best Practices” Jonathan Fannin
Ph.D., P. Eng., Forest Resources Management and Civil Engineering,
University of British Columbia, Canada.

3.25 - VEGETATIVE BUFFER STRIP

Introduction

A vegetative buffer strip is the maintenance of existing or planted vegetation adjacent to streams, wetlands, or other areas of significant natural resource value for the purpose of stormwater pollutant removal. The term vegetative buffer is typically used to describe the preservation of existing vegetation without specific regard to pollutant removal efficiency, whereas the term filter strip is generally used when vegetation (usually grass) is specifically designed to achieve pollutant removal goals.

However, since the terms are often used interchangeably and provide essentially the same sediment removal function, both will be considered as one practice. However, developers should not destroy native vegetation to plant a grass strip for this practice. The protection of vegetation along streams also stabilizes stream banks, moderates water temperatures, and provides food sources and habitat for fish and wildlife.

Conditions Where Practice Applies

This practice may be utilized on construction sites with good existing vegetative cover or where good vegetative cover can be established prior to site disturbance. Vegetative buffers are most useful adjacent to streams, wetlands or other water bodies, although they may also be used as a non-structural practice on upland sites. To function effectively, runoff to and flow across the buffer area must not be concentrated or channelized. The use of level spreaders or other energy-dissipating devices may be utilized in some circumstances to promote overland (sheet) flow across the buffer. Buffers are probably more effective as filters during the growing season, when the density of vegetation is generally higher.

Approved Practices

1. Retaining existing native vegetation adjacent to the area to be protected. The width needed is dependent on site conditions (see design criteria).
2. Establishing vegetation by planting or natural regeneration adjacent to the area to be protected. The width and vegetation type is dependent on site conditions (see design criteria). Planting and/or natural regeneration can be used in conjunction with preserving existing vegetation if needed to achieve desired buffer width. All vegetation must be established prior to site disturbance.
3. Stormwater runoff to the buffer area must be in the form of overland (sheet) flow. If treatment occurs outside of the buffer, stabilized outlets may be located within the buffer area. The use of energy-dissipating devices may be used in some circumstances to promote overland flow within the buffer.
4. No disturbance is permitted within a vegetative buffer, except for necessary infrastructure improvements (utility lines, road crossings, etc.), or unless planting is required.

Design Criteria

It is recommended that designers use site-specific criteria to determine the

appropriate buffer width, if possible. Factors to consider include soil type, slope, size distribution of the sediment, contributing drainage area, vegetation present and other natural resource considerations, such as fish and wildlife habitat value. Because vegetative buffers along streams provide many environmental benefits, designers are encouraged to provide as large a buffer area as practicable for the project. If there is insufficient buffer width, the buffer available may be used in conjunction with other BMPs such as silt fence or super silt fence.

1. The minimum vegetative buffer width shall be 100 feet, unless specific design information can be provided to justify a smaller buffer width. For slopes greater than 10 percent, the minimum distance is 250 feet. Smaller buffers may be used in conjunction with other BMPs.
2. The width of the contributing area to the vegetative buffer should not exceed 300 feet, unless energy-dissipating devices are provided. Buffers may be used as a supplement to other BMPs for larger drainage areas.
3. Good (minimum of 80 percent) vegetative cover must be present in the proposed buffer area.

**Construction
Specifications**

1. The buffer boundary shall be clearly marked onsite prior to site clearing or grading.
2. No soil disturbances, equipment storage or construction traffic shall occur within the buffer area.

Maintenance

Inspect at a minimum once every seven calendar days and within 24 hours after any storm event greater than 0.5 inches per 24 hour period. Heavy deposits of sediment should be removed (with minimal disturbance to the buffer vegetation). If erosion gullies form, the use of an energy- dissipating device or an alternative BMP is needed.

3.27 - SILT FENCE

Introduction

A temporary sediment barrier consisting of a synthetic filter fabric stretched across and attached to supporting posts and entrenched. Used to intercept and detain small amounts of sediment from disturbed areas during construction operations in order to prevent sediment from leaving the site.

No sediment control device is misused more than silt fence (with the possible exception of hay bales). Much of the silt fence used in West Virginia is not installed properly. The device does not work if:

1. not entrenched a minimum of 4 inches.
2. not placed on the contour-perpendicular to the flow of the water.
3. installed in areas of concentrated flows.
4. installed to contain sediment from too large of an area.
5. little or no maintenance is performed on it.

Silt fence does not actually filter sediment from muddy water. In field conditions silt fence acts as a barrier to the flow of water, like a dam, reducing the energy of the water, which causes the suspended material to settle out. It is because of the low permeability of the fabric that silt fence is limited to small drainage areas

Installing silt fence is very labor intensive. It is usually installed by hand and accumulated sediment must be removed and disposed of by hand. In many scenarios, installing a diversion and sediment trap would be more effective and less expensive than using silt fence. In addition, the NPDES permit requires that a sediment trap or basin be installed whenever possible.

Conditions Where Practice Applies

1. Below disturbed areas where erosion would occur in the form of sheet and small rill erosion.
2. Where the size of the drainage area is no more than one-quarter acre per 100 feet of silt fence length; the maximum gradient above the barrier should be less than 2:1.
3. Silt fence will not be used in areas where rock or some other hard surface prevents the full and uniform anchoring of the barrier.
4. Silt fence should NEVER be installed in streams or swales or in any area where there is a reasonable chance of concentrated flow. In areas where concentrated flows can be expected, use diversions and sediment traps and /or sediment basins. In ditches or swales rock check dams should be used in place of silt fence.

Design Criteria

1. No formal design is required. An effort should be made to locate silt fence at least 5 feet to 10 feet beyond the toe of slope.

2. Silt fence should be limited to situations in which only sheet is expected.
3. Silt fence should be installed prior to major soil disturbance.
4. Silt fence should be placed across the bottom of a slope along a line of uniform elevation (ALWAYS perpendicular to the direction of flow).
5. Any time a section of silt fence is knocked down by concentrated flows the silt fence will be replaced with a diversion and sediment trap or super silt fence.

Construction Specifications

Materials

1. Synthetic filter fabric shall be a pervious sheet of propylene, nylon, polyester or ethylene yarn and shall be certified by the manufacturer or supplier as conforming to the requirements noted in WV DOT DOH Specifications or the GEOTEXTILE section.
2. Synthetic filter fabric shall contain ultraviolet ray inhibitors and stabilizers to provide a minimum of 6 months expected usable construction life at a temperature range of 0 to 120 degrees Fahrenheit.
3. If wooden stakes are utilized for silt fence construction, they must be a minimum of 2" x 2" when oak is used and 2" x 4" when pine is used. Wooden stakes should have a minimum length of 5 feet.
4. If steel posts (standard "U" or "T" section) are utilized for silt fence construction, they must have a minimum weight of 1.33 pounds per linear foot and should have a minimum length of 5 feet.

Installation

1. The height of a silt fence shall be a minimum of 16 inches above the original ground surface and shall not exceed 34 inches above ground elevation.
2. The filter fabric shall be purchased in a continuous roll cut to the length of the barrier to avoid the use of joints. When joints are unavoidable, the silt fence shall be spliced together only at a support post, by twisting the last post of each run around the other, and securely sealed. (see drawing)
3. A trench shall be excavated approximately 4 inches wide and 4 inches deep on the upslope side of the proposed location of the measure.
4. The filter fabric shall be fastened securely to the upslope side of the posts using one inch long (minimum) heavy-duty wire staples or tie wires and eight inches of the fabric shall be extended into the trench. The fabric shall not be stapled to existing trees. The most common type of silt fence has the stakes attached to the fabric at the factory.
5. The 4-inch by 4-inch trench shall be backfilled and the soil compacted over the filter fabric.

6. Silt fence shall be removed when it has served its useful purpose, but not before the upslope area has been permanently stabilized.
7. Turn the end of a run of Silt Fence slightly uphill to prevent runoff from going around the end.

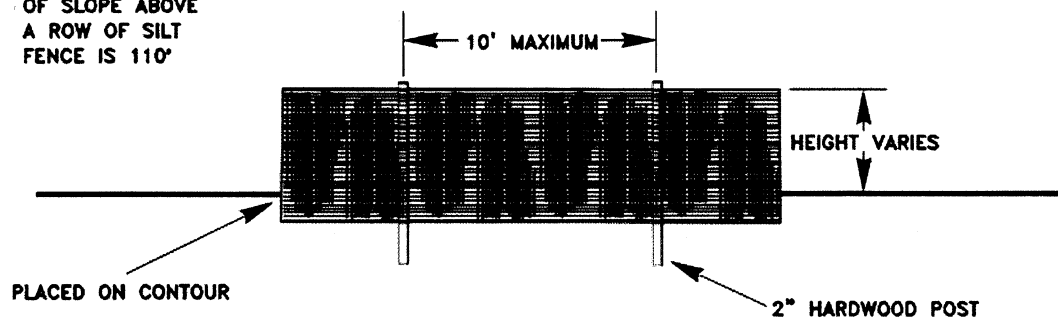
Maintenance

1. Silt fences shall be inspected immediately after each rainfall of 0.5 inch or greater and at least daily during prolonged rainfall or once a week. Any required repairs or maintenance shall be made immediately.
2. Close attention shall be paid to the repair of damaged silt fence resulting from end runs and undercutting. If the fence is not installed on the contour (perpendicular to the flow of the water) both of these conditions can occur.
3. Should the fabric on a silt fence decompose or become ineffective prior to the end of the expected usable life and the barrier still is necessary, the fabric shall be replaced promptly.
4. Sediment deposits should be removed after each storm event. They must be removed when deposits reach approximately one-half the height of the barrier.
5. If any section of silt fence is knocked down during a rain event (because it was installed in an area of concentrated flow) then other measures such as a sediment trap and diversion or super silt fence must be installed.

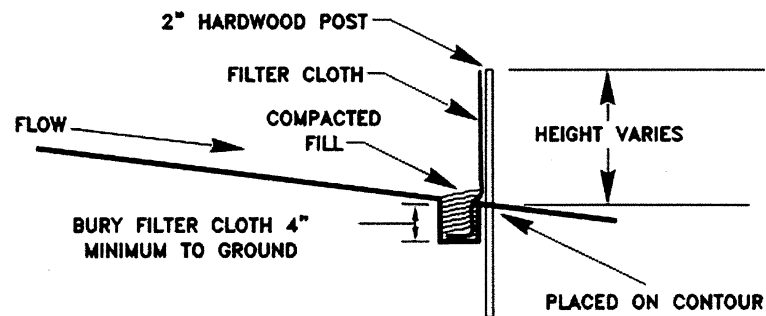
FIGURE 3.27.2

SILT FENCE

NOTE:
THE MAXIMUM LENGTH
OF SLOPE ABOVE
A ROW OF SILT
FENCE IS 110'



FRONT ELEVATION



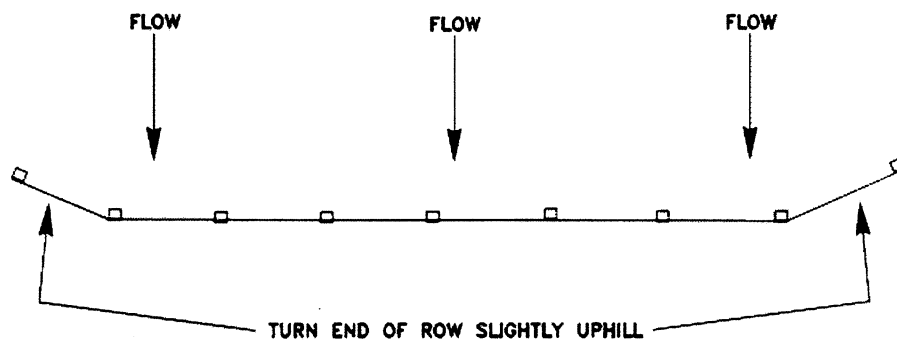
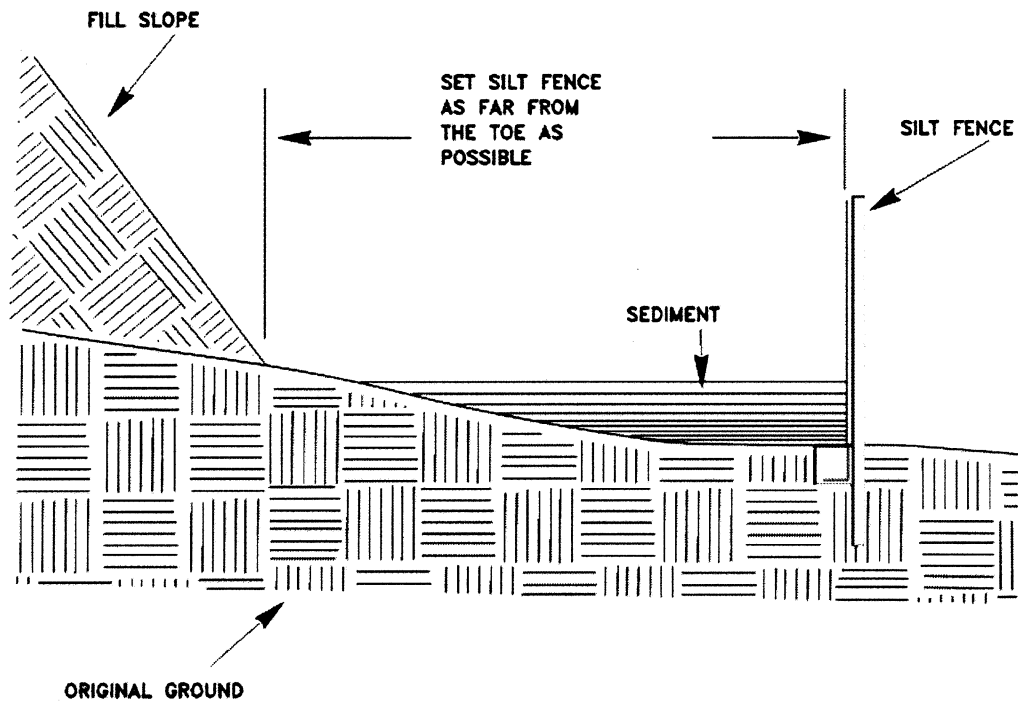
SIDE ELEVATION



TOP VIEW

FIGURE 3.27.1

PLACEMENT OF SILT FENCE



3.28 - SUPER SILT FENCE

Definition

A super silt fence is a temporary barrier of geotextile fabric over chain link fence. It is used to intercept sediment-laden runoff from areas that are too large for regular silt fence. Super silt fence can be a replacement for sediment traps in certain instances.

Conditions Where Practice Applies

To reduce runoff velocity and allow sediment to become trapped behind or up slope of the super silt fence. Limits imposed by ultraviolet light stability of the fabric will dictate the maximum period that the silt fence may be used.

Super silt fence provides a barrier that can collect and hold debris and soil, preventing the material from entering critical areas, streams, streets, etc.

Super silt fence can be used where the installation of a DIVERSION and/or SEDIMENT TRAP would destroy sensitive areas, woods, wetlands, riparian zones, etc. This practice is very useful below bridge piers and abutments along streams and rivers.

Design Criteria

Design computations are not needed.

- Slope length above the fence should not exceed 400 ft in steep terrain. In flatter terrain the slope length can be extended with consultation with DWW.
- Where ends of the geotextile fabric come together, the ends shall be overlapped, folded, and stapled to prevent sediment bypass.
- The backfilled trench shall be compacted.
- Only woven geotextile fabric will be used.
- Super silt fence should be placed as close to the contour as possible. No section of silt fence should exceed a grade of 5% for more than a distance of 20 feet.

Construction Specifications

Fencing shall be 48 inches in height and constructed in accordance with the WV DOT, Division of Highways specification for Chain Link Fencing. The DOT specification for a 6-foot fence shall be used, substituting 48-inch fabric and 6 foot length posts. The filter fabric shall meet the requirements of 715.11.5/AASHTO M 288, Section 7, Class 1.

1. The poles do not need to set in concrete.
2. Chain link fence shall be fastened securely to the fence posts with wire ties or staples.
3. Geotextile fabric shall be fastened securely to the chain link fence with ties spaced every 24" at the top and mid section.

4. Geotextile fabric shall be embedded a minimum of 12" into the ground.
5. When two sections of geotextile fabric adjoin each other, they shall be overlapped by 6" and folded.
6. Metal posts as specified by DOH can be replaced by pressure-treated 4" x 4" posts.

Maintenance

Silt fences shall be inspected immediately after each rainfall, daily during prolonged rainfall and once a week during dry periods. Any required repairs shall be made immediately.

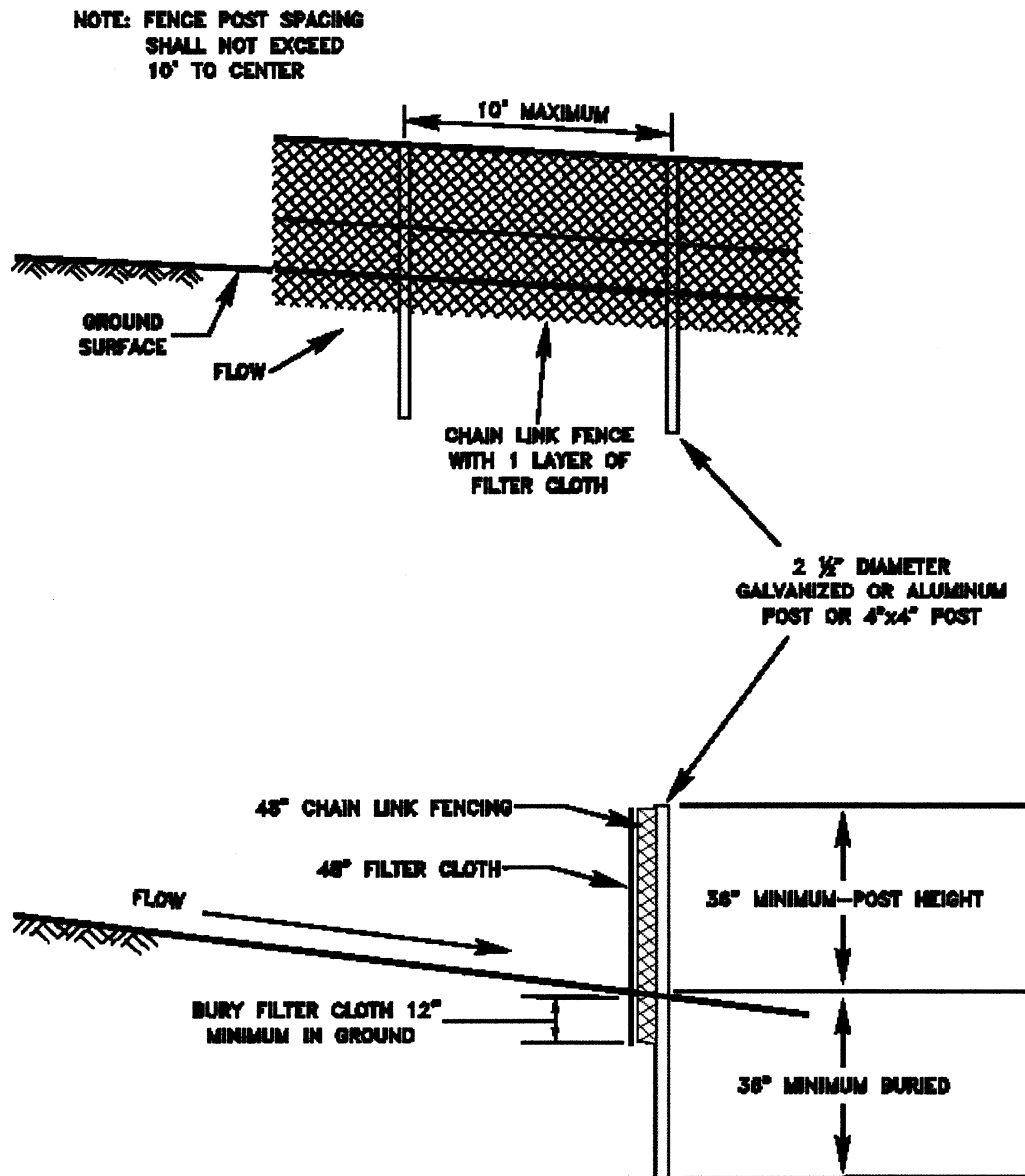
Close attention shall be paid to the repair of damaged silt fence resulting from end runs and undercutting. If the fence is not installed perpendicular to the flow of the water, these conditions will occur.

Should the fabric on a silt fence decompose or become ineffective, the fabric shall be promptly replaced.

Sediment deposits shall be removed when deposits reach approximately one-half the height of the barrier.

FIGURE 3.28.1

SUPER SILT FENCE



3.29 - SEDIMENT TRAP

Introduction

A temporary ponding area formed by constructing an embankment or excavation and embankment that will trap the flow of sediment-laden runoff. Sediment traps have a properly stabilized outlet/weir or riser and pipe to detain sediment-laden runoff from small disturbed areas of five acres or less. Outlets must be designed to extend the detention time and allow the majority of the sediment to settle out.

This practice is one of the most efficient and cost effective methods of sediment control. When possible, sediment traps should be constructed as a first step in any land-disturbing activity. As with any sediment control device the sediment trap should not be removed until the contributing drainage area is stabilized.

Sediment traps can be highly variable in design and configuration. Almost every site has someplace to install one or more sediment traps. However it may not be evident during the design stages exactly where a trap would fit best. Once clearing, grubbing and site excavation begins, logical locations usually appear. It may be necessary to state in the plan that a particular trap will be field located to fit the site conditions.

Conditions Where Practice Applies

1. Sediment traps are appropriate for drainage areas of 5 acre or less. For drainage areas greater than 5 acres use a Sediment Basin (See SEDIMENT BASIN)
2. At the outlet of ditches and other perimeter controls installed during the first stage of construction.
3. At the outlet of any structure which concentrates sediment-laden runoff i.e. at the discharge point of diversions, channels, slope drains, or other runoff conveyances.
4. At the inlet to culverts underneath roads
5. Above a storm water inlet that may receive sediment-laden runoff.

Design Considerations

The following items should be addressed where applicable when planning and designing a sediment trap.

1. The sediment trap should have a storage volume of 3600 cubic feet per acre of drainage area. Half of the volume must be in the form of a permanent pool or wet storage to provide a stable-settling medium. The remaining half must be in the form of a drawdown or dry storage, which provides extended settling time. The volume of the wet storage should be measured from the low point of the excavated area to the base of the outlet structure or the invert of the first perforation in the riser. The volume of the dry storage should be measured from the base of the outlet to the crest of the outlet (overflow mechanism) or from the lowest perforation in the riser to the top of riser.

2. The embankment should not exceed 5 feet in height. The recommended minimum width at the top of the embankment should be equal to the height of the embankment.
3. The recommended inside embankment should be a 2:1 slope or flatter. The recommended outside embankment should be a 3:1 slope or flatter.
4. The width of the outlet channel weir must not be less than 4 ft. wide or, 2 feet plus 2 feet for each acre of drainage i.e. 12 ft wide for 5 acres. The top of the outlet channel must be at least 1 ft. below the top of embankment to provide a minimum of 1 ft. of free board.
5. The trap should be accessible for ease of maintenance.
6. Sediment must be removed from the trap when the trap's wet storage volume is reduced by one-half. Designers should designate a clean-out elevation.
7. The trap should provide a storage area which is at least twice as long as it is wide; with the outlet position at the furthest possible point from the inlet (measured from point of maximum runoff introduction to the outlet). Baffling can be used if this 2 to 1 ratio cannot be met.
8. All earthen side slopes should be a minimum of 2:1.
9. Seed and mulch all disturbed areas associated with the installation of the sediment trap immediately.
10. The sediment trap must have a stabilized outlet, either a weir or pipe and riser. Outlet protection must be provided.
11. Fill material around the pipe spillway where it goes through the embankment shall be hand compacted in 4" to 6" layers. A minimum of 2' of hand compacted backfill should be placed over the barrel before construction traffic is allowed to cross.
12. The riser shall be anchored with either a concrete base or steel plate bases sufficient to prevent flotation. For concrete bases, the depth shall be 12" with the riser buried 9". A 1/4" minimum thickness steel plate shall be attached to the riser by a continuous weld around the bottom to form a watertight connection and then place 2" of stone, gravel or tamped earth on the plate.
13. Anti-seep collars are required. Install based on manufacturers' instructions.
14. It is recommended that a concentric trash rack and anti-vortex device be installed on all risers.
15. If a stone outlet is used for the sediment trap, it should consist of a stone section of the embankment located at the low point in the basin. The stone outlet should be a combination of coarse aggregate and rock riprap. The stone section of the embankment should be separated from the earthen embankment by a geotextile. Riprap should consist of well-graded stone 2 inches to 8 inches in diameter. Coarse aggregate is washed gravel 1/2 to 1 1/2 inches in diameter. The coarse aggregate is placed 1 ft thick on the upstream face of the stone outlet. The crest of the stone outlet must be at least 1.0 foot below the top of the embankment to ensure that the flow will travel over the stone and not the embankment. The outlet should be configured as noted in the drawing.
16. The outlet pipe and riser should be sized as noted in the table below. The riser pipe should be weighted to prevent flotation. An anti-seep collar is

recommended around the outlet pipe as well as a concentric trash rack and anti-vortex device.

17. If there is any chance that a failure of the structure could damage any downstream property, the designer should look into creating a spillway or combination of spillways commensurate with the level risk should the structure fail.
18. The inlet to the sediment trap should be excavated to provide for a gentle transition from the diversion ditch to the bottom of the trap to protect from head cutting and scour.
19. The maximum depth of excavation within the wet storage area should be 4 feet to facilitate clean-out and for site safety considerations

Table 3.29.1 PIPE OUTLET DIAMETER SELECTION

Maximum Drainage Area (Acres)	Minimum Size Outlet Diameter (inches)	Minimum Size Riser Diameter (inches)
1	12	15
2	15	18
3	18	21
4	21	24
5	21	27

Volume calculation

For an embankment sediment trap, the **wet storage volume** may be approximated as follows:

$$V_1 = 0.85 \times A_1 \times D_1$$

where,

V_1 = the wet storage volume in cubic feet

A_1 = the surface area of the flooded area at the base of the stone outlet, in square feet

D_1 = the maximum depth in feet, measured from the low point in the trap to the base of the stone outlet

The **dry storage volume** may be approximated as follows:

$$V_2 = \frac{A_1 \times D_2}{2} \times D_2$$

where,

V_2 = the dry storage area of the flooded area at the base of the stone outlet in square feet

A_1 = the surface area of the flooded area at the base of the stone outlet, in square feet

A_2 = the surface area of the flooded area at the crest of the stone outlet (overflow mechanism), in square feet

D_2 = the depth in feet, measured from the base of the stone outlet to the crest of the stone outlet

Plan

Preparation

During the preparation of the sediment control plan for the Construction Storm Water General Permit prepare a table detailing the key design aspects of each sediment trap planned and designed.

Table 3.29.2 SEDIMENT TRAP KEY DESIGN ASPECTS

TRAP NUMBER	1	2	3	4	5	6
TYPE (stone weir/pipe)						
DRAINAGE AREA						
WET STORAGE REQ						
WET STORAGE PROV						
DRY STORAGE REQ						
DRY STORAGE PROV						
WEIR WIDTH						
PIPE DIAMETER						
WEIR/PIPE ELEVATIONS						
STORAGE DEPTH						
CLEANOUT ELE						
EMBANKMENT ELE						
TRAP BOTTOM ELE						

Construction

Specifications

1. The area under the embankment should be cleared, grubbed, and stripped of any vegetation and root mat.
2. Fill material for the embankment should be free of roots or other woody vegetation, organic material, large stones, and other objectionable material. The embankment should be compacted in 6-inch layers by traversing with construction equipment.
3. The earthen embankment should be seeded and mulched to provide temporary or permanent vegetation immediately after installation.
4. Construction operations should be carried out in such a manner that erosion and water pollution are minimized.
5. Sediment Traps should not be removed until the contributing disturbed area has been stabilized.
6. Material removed from the excavated section of the sediment trap should be placed in an area and stored in a manner that will not create an erosion problem.

7. The outlet pipe and riser connections should be watertight.
8. Above the wet storage elevation, the riser should be perforated with 1-inch diameter holes spaced 8 inches vertically and 10 inches to 12 inches horizontally.

Maintenance

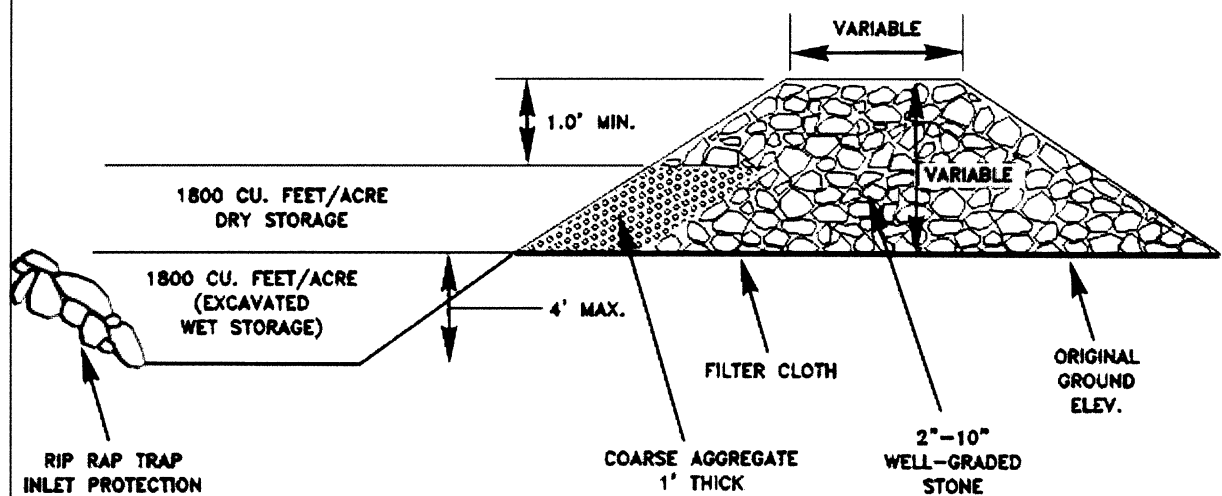
Sediment should be removed from the trap before the traps wet storage volume is reduced by one-half. Sediment removed from the trap should be stored or disposed in a manner in which will not create an erosion or sediment problem.

Filter stone should be regularly checked to ensure that filtration performance is maintained. Stone choked with sediment should be removed and cleaned or replaced

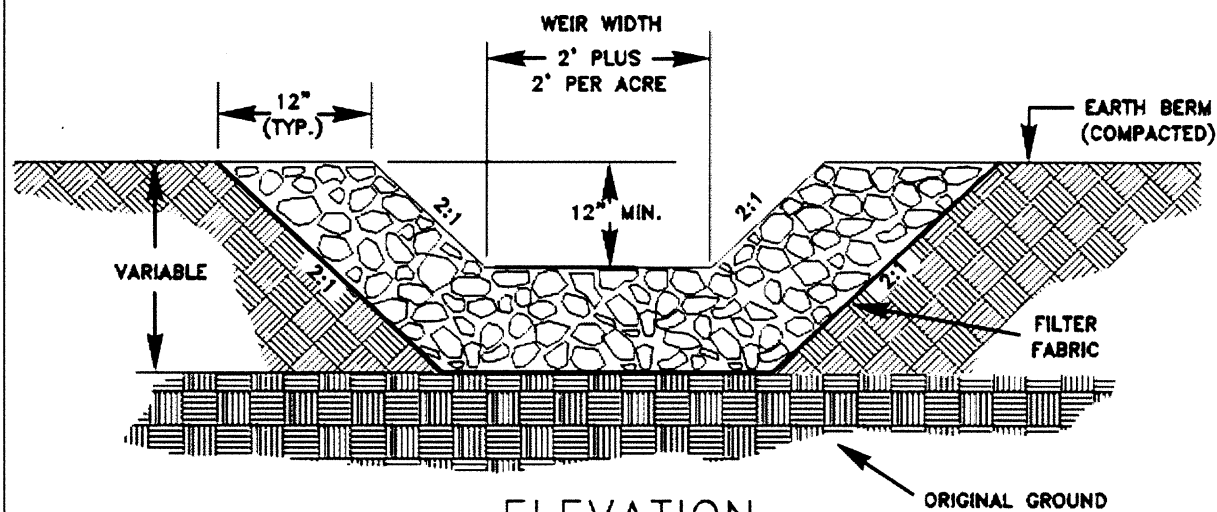
The structure shall be checked every 7 days and /or after 0.5 inch of rain to ensure that it is structurally sound and has not been damaged.

FIGURE 3.29.1

ROCK OUTLET SEDIMENT TRAP



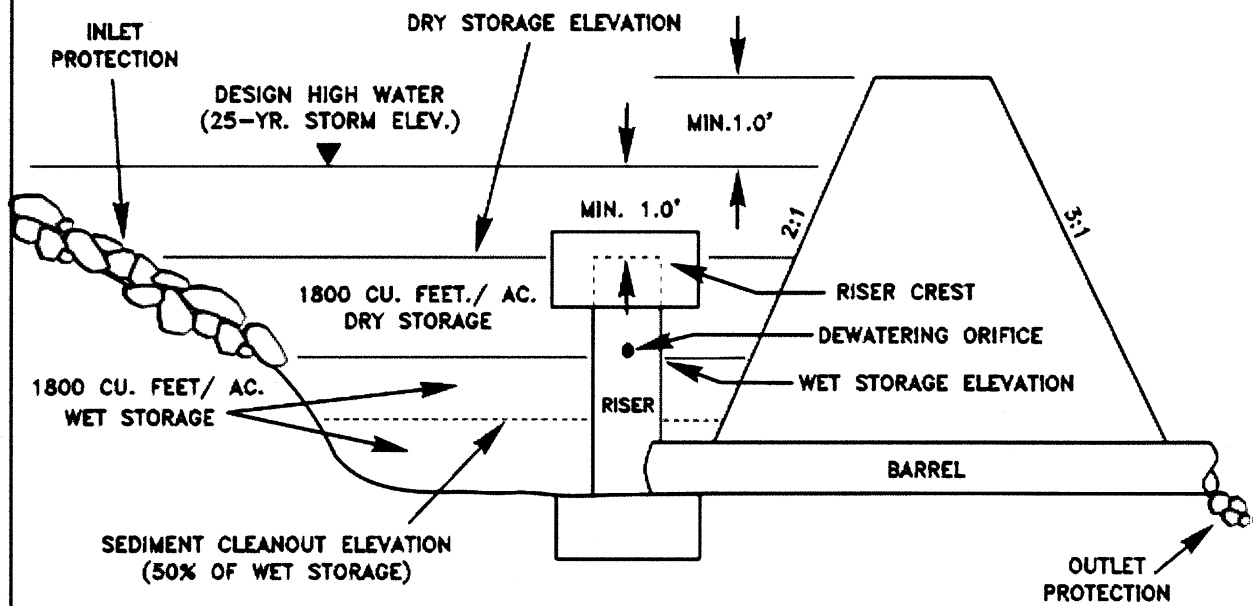
CROSS SECTION



ELEVATION

FIGURE 3.29.2

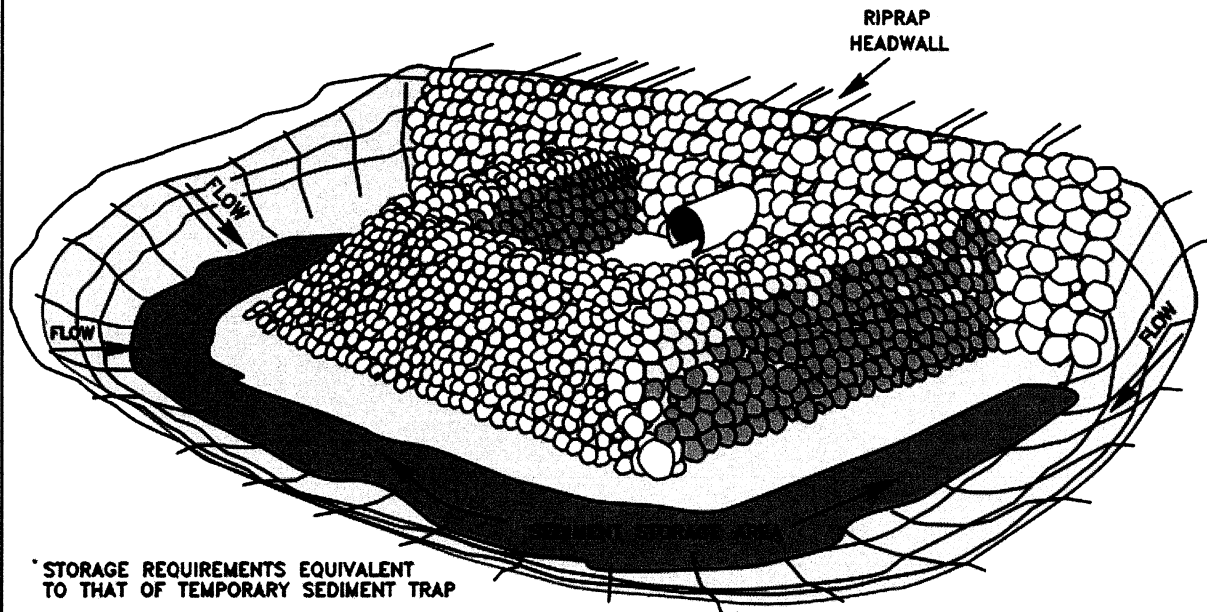
PIPE RISER SEDIMENT TRAP



ADAPTED FROM: VA. DSWC

FIGURE 3.29.3

CULVERT INLET SEDIMENT TRAP

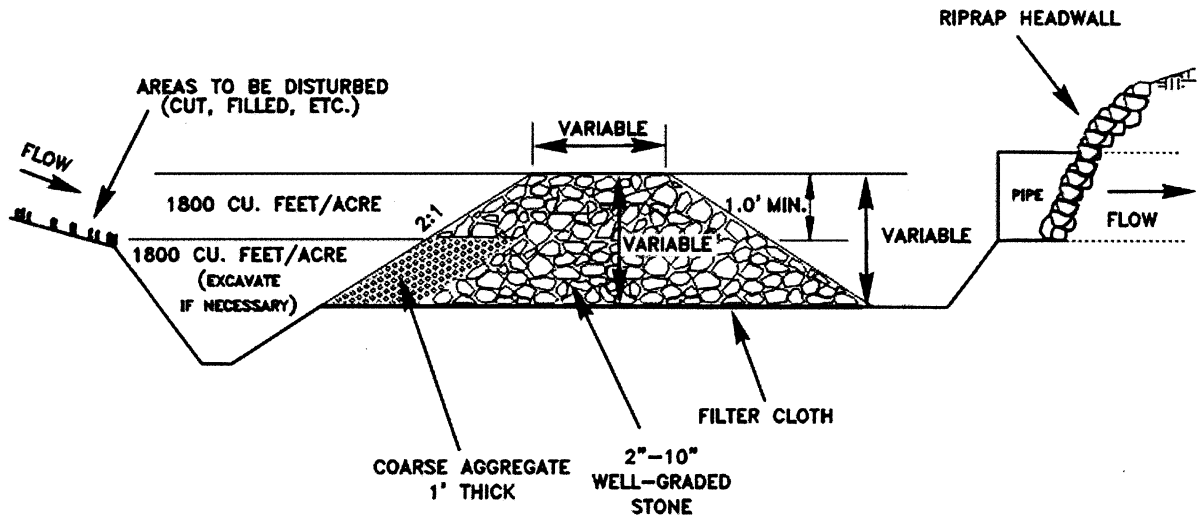


*STORAGE REQUIREMENTS EQUIVALENT
TO THAT OF TEMPORARY SEDIMENT TRAP

1800 CU FEET/ACRE WET STORAGE
(BELOW INVERT OF PIPE)

1800 CU FEET/ACRE DRY STORAGE
(INVERT OF PIPE TO TOP
OF STONE BERM)

PERSPECTIVE VIEW



CROSS SECTION

From VA DSWC

3.30 - SEDIMENT BASIN

Introduction

A temporary structure consisting of an earthen embankment, or embankment and excavated area, located in a suitable area to capture sediment laden runoff from a construction site. A sediment basin reduces the energy of the water through extended detention (48 to 72 hours) to settle out the majority of the suspended solids and sediment and prevent sedimentation in waterways, culverts, streams and rivers. Sediment basins have both wet and dry storage space to enhance the trapping efficiency and are appropriate in drainage areas of 5 acres and greater. For drainage areas of less than 5 acres see the standard for SEDIMENT TRAP.

Basins are dewatered through a riser and drainage hole(s) or a skimmer system. Because sediment basins are located in larger drainage areas and the failure of a structure could cause significant damage or death they need to be designed to safely pass the peak discharge from a 25-year/24-hour storm with one foot of freeboard.

They are temporary structures but are often modified to function as a permanent structure after construction is completed.

Properly designed and maintained sediment basins can be very effective in preventing sedimentation of downstream areas. Coarse and medium size particles and associated pollutants will settle out in the basin. Suspended solids and attached nutrients may break down before proceeding downstream.

The effectiveness of sediment trapping structures is greatly improved by use of aggressive erosion control (especially in diversions leading to the basin) in the contributing drainage.

Conditions Where Practice Applies

Sediment basins are needed where drainage areas exceed the design criteria of other measures. Sediment traps are allowed in watersheds of 5 acres and less. General criteria for installation of a sediment basin are as follows:

1. Keep the drainage area less than 100 acres;
2. Ensure that basin location provides a convenient concentration point for sediment-laden flows from the area served;
3. Ensure that basin location allows access for sediment removal and proper disposal under all weather conditions;
4. Keep the basin life limited to 1 year, unless it is designed as a permanent structure;
5. Should not locate sediment basins in intermittent or perennial streams;
6. Sediment basins must dewater in 2 to 3 days;

7. Skimmers can be used to enhance trapping efficiency, however perforated risers are also acceptable;
8. Install basins where they will not interfere with construction activities.

**Planning
Considerations**

Select key locations for sediment basins during initial site evaluation. Install basins before any site grading takes place within the drainage area. Select basin sites to capture sediment from all areas that are not treated adequately by other sediment trapping devices. Always consider access for cleanout and disposal of the trapped sediment. Locations where a pond can be formed by constructing a low dam across a natural swale are generally preferred to sites that require excavation. If practical, divert sediment-free runoff away from the basin. This will help reduce the size of the structure and decrease the amount of erosion on the construction site.

Sediment trapping efficiency is primarily a function of sediment particle size, the ratio of basin surface area to inflow rate and the ability of the basin to reduce the energy of the water. Therefore, design the basin to have a large surface area for its volume and the maximum amount of detention time.

The performance of sediment trapping structure depends on several factors:

1. The size and shape of the basin
2. The soil properties
3. Runoff volume and flow rates
4. Water chemistry
5. Outlet type
6. Temperature

Structures larger than 25 feet in height from the downstream toe to highest point along the crest of the dam and have a maximum storage capacity of 15 acre-feet of water or more are subject to the West Virginia Dam Safety Act.

By virtue of their potential to impound and release large volumes of water, the design of sediment basins is required to be completed by professionals trained in the design of impounding structures, and in accordance with good engineering practices. Sediment basins with an expected life greater than 1 year should be designed as permanent structures. Permanent ponds must be designed and certified by a Professional Engineer. Permanent pond design is beyond the scope of this manual. For further information the USDA Soil Conservation Service Practice Standard Ponds Code No. 378 is an excellent source of information and provides criteria for design of permanent ponds.

In larger drainages or when the discharge is to a Tier 2.5 or 3 Stream, an alternative design procedure that more accurately defines the specific

hydrology, sediment loading, hydraulics of the site, and the control measures in use be utilized to perform design calculations. The design criterion in this manual does not generate hydrographs, estimate erosion and delivery rates, provide hydraulic routing or predict sediment capture efficiency. More rigorous and accurate design considerations that are more site specific than those in this manual, are acceptable and encouraged with any size basin.

The design and construction of sediment basins shall comply with all state and local laws, ordinances, permit requirements, rules and regulations. Basins shall be constructed according to the approved Storm Water Pollution Prevention Plan (SWPPP) unless modified a engineering design professional.

Sediment basins must dewater in 2 to 3 days. Skimmers are the preferred dewatering device, however perforated risers are also acceptable.

Sediment basins should be provided with an emergency spillway constructed in original ground with a minimum bottom width of 8'. Energy dissipaters must be included at all inlet and outfalls to prevent scouring.

Sediment basins are attractive to children and can be very dangerous. Local ordinances regarding health and safety must be adhered to. If fencing of the basin is required, the type of fence and its location should be shown in the SWPPP and in the construction specifications.

Limit the contributing area to the sediment basin to only the runoff from the disturbed soil areas. Use temporary water controls to divert runoff from undisturbed areas away from the sediment basin.

The basin should be located: (1) by excavating a suitable area or where a low embankment can be constructed across a swale, (2) where post-construction (permanent) detention basins will be constructed, and (3) where the basins can be maintained during construction to provide access for maintenance, including sediment removal and sediment stockpiling in a protected area, and to maintain the basin to provide the required capacity.

As with all sediment control device it must be maintained until the drainage area is permanently stabilized.

Provide construction details for each proposed sediment basin on the erosion and sediment control plans. Show all significant features and elevations on those plans.

Design Criteria

Drainage areas—Limit drainage areas to 100 acres.

Design basin life—Ensure a design life of 1 year or more.

Dam height—Limit dam height to 15 feet if possible. Height of a dam is measured from the highest point of the dam to the lowest point at the downstream toe. According to the Dam Control Act the volume is measured to the highest point on the top of the dam.

Basin locations—Select areas that:

Provide capacity for storage from as much of the planned disturbed area as practical;

Exclude runoff from undisturbed areas, where practical;

Provide access for sediment removal throughout the life of the project and;

Interfere minimally with construction activities.

Basin shape—It is important that the designer of the sediment basin incorporate features to maximize detention time and reduce the energy of the inflow before water is discharged. Some of the methods to improve basin geometry:

1. Length to width ratio of at least 2:1, with 4:1 optimal. Try not to exceed 6:1 as basin velocities can increase and the basin starts to behave as a channel. Length is measured at the elevation of the principal spillway.
2. Wedge shape with the inlet at the narrow end. Line up the inlet, riser and center of the dam.
3. Installation of baffles
4. Maximize surface area to provide efficient settling.

Storage volume—Ensure that the sediment storage volume of the basin, measured at the elevation of the crest of the principal spillway, is at least 3,600 cubic feet per acre of the total area draining into the basin.

Unless using a skimming device, half of the volume shall be in wet storage and half of the storage shall be in dry storage. Use the maximum drainage area found at any point during construction. Since watersheds often change during grading operations, the largest drainage area is not necessarily the pre- or post-construction drainage area. The maximum watershed area used to size the basin should be delineated on the drawings.

Remove sediment from the basin when approximately one-half of the wet storage volume has been filled. Show this elevation in the plans and provide a method of determining it in the field.

When the construction of a single basin with storage volume of 3600 cubic feet per acre is not feasible due to site constraints it can be advantageous to install several smaller structures in series with a

combined storage volume of 3600 cubic feet. Creating a fore bay can also improve the trapping efficiency.

The volume requirements of the General Permit and this standard should be regarded as the minimum necessary to protect water quality. The design professional is encouraged to increase these storage requirements to protect a critical aquatic resource such as Tier 2.5 or 3 streams or the safety/health of the public. The following conditions could require additional storage or increased spillways capacity:

1. Highly erodible soils
2. Steep upslope topography
3. Space limiting basin geometry (depth or shape)
4. Degree to which off-and/or on-site runoff is diverted from the contributing undisturbed areas
5. Sediment cleanout schedule
6. Ease of access to clean out basin
7. Flocculant use
8. Extent of upslope erosion and sediment control
9. Critical downstream conditions

Minimum depth The sediment basin should be at least two feet deep.

Spillway capacity—The combined spillway system must carry the peak runoff from the 25-year/24 hour storm with a minimum 1-foot of freeboard.

Base peak flow runoff computations on the largest disturbed area expected and the worst soil cover conditions during the effective life of the structure.

Sediment basin spillways must be able to discharge 2 cfs/acre from the entire contributing watershed. However, if this rule of thumb is used, a minimum of 24 inches of freeboard will be required above the elevation of the 2 cfs/acre. If the emergency spillway is being used to provide part of the 2 cfs/acre discharge, the freeboard must be provided above the design flow elevation in the emergency spillway.

Principal spillway—Construct the principal spillway with a vertical riser connected to a horizontal barrel that extends through the embankment and outlets beyond the downstream toe of the dam, or an equivalent design.

- **Capacity**—The primary spillway system should carry the peak runoff from the 2-year storm, with the water surface at the emergency spillway crest elevation.

Basin dewatering A sediment basin must be able to dewater the dry storage volume in 48 to 72 hours. There are two traditional ways to accomplish this

The basin should be provided either with a perforated riser with a hole or series of holes at the wet storage elevation or to enhance the trapping efficiency a surface skimmer.

Dewatering orifice---In order to dewater the sediment basin in 48 to 72 a hole or several holes that add up to A_o should be cut into the riser.

$$A_o = A_s \times (2h)^{0.5} / (T \times C_d \times 20,428)$$

where

A_o = total area of dewatering holes, ft²;

A_s = surface area of the basin, ft²;

h = head of water above the hole, ft;

C_d = coefficient of contraction for an orifice, approximately 0.6;

T = detention time or time needed to dewater the basin, hours

• **Skimmer**—A floating skimmer may be attached to the base of the riser. The orifice in the skimmer will control the rate of dewatering. The skimmer should be sized to dewater the basin in 48-72 hours.

Use the manufacturers Installation Manual to size the skimmer orifice. See SKIMMER BASIN for details on the installation of skimmers.

Sediment cleanout elevation—The clean out elevation is 50 percent of the wet storage elevation. Indicate on the drawings this elevation and mark in the field with a permanent stake.

Crest elevation—Keep the crest elevation of the riser a minimum of 1 foot below the crest elevation of the emergency spillway.

Riser and Barrel—Keep the minimum barrel size at 15 inches for corrugated metal pipe or 12 inches for smooth wall pipe to facilitate installation and reduce potential for failure from blockage. Ensure that the pipe is capable of withstanding the maximum external loading without yielding, buckling or cracking. To improve the efficiency of the principal spillway system, make the cross-sectional area of the riser at least 1.5 times that of the barrel. The riser should be sized to minimize the range of stages when orifice flow will occur.

Pipe Connections—Ensure that all conduit connections are watertight.

Rod and lug type connector bands with gaskets are preferred for corrugated metal pipe to assure water tightness under maximum loading and internal pressure. Do not use dimple (universal) connectors under any circumstances.

It is important that a suitable trash guard be installed to prevent the dewatering holes from becoming clogged.

Trash rack—Install a trash rack on the top of the riser to prevent trash and other debris from clogging the conduit. A combination anti-vortex device and trash rack improves the efficiency of the principal spillway and protects against trash intake.

Protection against piping—Install at least one watertight anti-seep collar with a minimum projection of 1.5 feet around the barrel of principal spillway conduits, 8 inches or larger in diameter. Locate the anti-seep collar slightly downstream from the dam centerline. A properly designed drainage diaphragm installed around the barrel may be used instead of an anti-seep collar when it is appropriate.

Protection against flotation—Secure the riser by an anchor with buoyant weight at least 1.25 times greater than the water displaced by the riser.

Outlet—Protect the outlet for the barrel against erosion. Discharge velocities must be within allowable limits for the receiving stream. (See OUTLET PROTECTION)

Emergency spillway—Construct the entire flow area of the emergency spillway in undisturbed soil (not fill). Make the cross section trapezoidal at least 8 feet wide and with side slopes of 3:1 or flatter. Make the control section of the spillway straight and at least 20 feet long. The inlet portion of the spillway may be curved to improve alignment, but ensure that the outlet section is straight due to supercritical flow in this portion. The channel should be located so as to avoid sharp bends. The outlet of the spillway channel should be to a defined natural channel downstream of the toe of the embankment.

Capacity—The minimum design capacity of the emergency spillway must be the peak rate of runoff from the 25-year/24 hour storm, less any reduction due to flow in the principal spillway. In no case should freeboard of the emergency spillway be less than 1 foot above the design depth of flow.

Outlet Velocity—Ensure that the velocity of flow discharged from the basin is non-erosive for the existing conditions. When velocities exceed that allowable for the receiving areas, provide outlet protection (See OUTLET PROTECTION).

Embankment Design Standards

Cut-off trench Excavate a minimum of 2 feet wide trench with 1:1 side slopes at the centerline of the embankment. Ensure that the trench is in undisturbed soil and extends through the length of the embankment to the elevation of the riser crest at each end. A minimum of 2 feet depth is recommended.

Top width The minimum top width of the dam is as follows.

Acceptable Dimensions for Basin Embankment

<u>Fill Height</u>	<u>minimum top Width</u>
less than 10 ft	8.0 ft
10 ft to 15 ft	10.0 ft
16 ft to 25 ft	15.0 ft

Freeboard Ensure that the minimum difference between the design water elevation in the emergency spillway and the top of the settled embankment is 1 foot.

Side slopes Make the side slopes of the impoundment structure so that the total slope of both sides equals 5:1 or flatter. IE. If the upstream slope is 2:1 the downstream must be 3:1 but at no time shall an embankment slope exceed 2:1.

Allowance for settlement Increase the constructed height of the fill at least 10 percent above the design height to allow for settlement.

Erosion protection Stabilize all areas disturbed by construction (except the lower 1/2 of the wet storage pool) by suitable means immediately after completing the basin.

Trap efficiency Sediment basin trapping efficiency can be improved by using the following considerations in the basin design:

Surface area In the design of the settling pond, allow the largest surface area possible. Studies indicate that surface area (in acres) should be larger than 0.01 times the peak inflow rate in cfs.

$$A = 0.01q$$

where A is the basin surface area in acres and q is the peak inflow rate in cubic feet per second

Length The length to width ratio should be between 2:1 to 6:1.

Baffles Provides a minimum of two baffles to evenly distribute flow across the basin and reduces turbulence. See specification on BAFFLES.

Inlets Locate the sediment inlets to the basin the greatest distance from the principal spillway. Protect the inlet from scour and erosion with appropriate riprap protection. If there is room, provide a forebay to help slow the speed of the water down.

Inflow rate Reduce the inflow velocity and divert all sediment-free runoff away from the basin's watershed.

A summary table showing all critical dimensions and elevations for each basin should be prepared for the construction drawings and the NPDES application.

Construction Specifications

Site preparation—Install appropriate sediment and provide erosion controls as required. Clear, grub, and strip topsoil from areas under the embankment to remove trees, vegetation, roots, and other objectionable material. Delay clearing the pool area until the dam is complete and then remove brush, trees, and other objectionable materials to facilitate sediment cleanout and prevent floatables that can clog the outlets. Stockpile all topsoil or soil containing organic matter for use on the outer shell of the embankment to facilitate vegetative establishment.

Cut-off trench—Excavate a cut-off trench along the centerline of the earth fill embankment. Cut the trench to stable soil material, but in no case make it less than 2 feet deep. The cut-off trench must extend into both abutments to at least the elevation of the riser crest. Make the minimum bottom width wide enough to permit operation of excavation and compaction equipment, but in no case less than 2 feet. Make side slopes of the trench no steeper than 1:1. Compaction requirements are the same as those for the embankment. Keep the trench dry during backfilling and compaction operations.

Embankment Core - The core shall be parallel to the centerline of the embankment as shown on the plans. The top width of the core shall be a minimum of four feet. The height shall extend up to at least to the top of the riser or as shown on the plans. The side slopes shall be 1 to 1 or flatter. The core shall be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum permeability. In addition, the core shall be placed concurrently with the outer shell of the embankment.

Embankment—Take fill material from the approved areas shown on the plans. It should be clean mineral soil, free of roots, woody vegetation, rocks, organic topsoil and other objectionable material. Scarify areas on which fill is to be placed before placing fill. Fill material for the center of the embankment, and cut off trench shall conform to Unified Soil Classification GC, SC, CH, or CL and must have at least 30% passing the #200 sieve. The fill material must contain sufficient moisture so it can be formed by hand into a ball without crumbling. If water can be squeezed out of the ball, it is too wet for proper compaction.

Place fill material in 8 inch continuous layers over the entire length of the fill area and compact it. Hand compact areas around the anti-seep collars. Compaction may be obtained by routing the construction hauling equipment over the fill so that the entire surface of each layer is traversed by at least one wheel or tread track of heavy equipment, or a compactor may be used. Construct the embankment to an elevation 10 percent higher than the design height to allow for settling.

As an alternate, the following can be used to specify embankment placement. The minimum required density shall not be less than 95% of

maximum dry density with a moisture content within 2% of the optimum. Each layer of fill shall be compacted as necessary to obtain that density, and is to be certified by the Engineer at the time of construction. All compaction is to be determined by AASHTO Method T-99 (Standard Proctor).

Conduit spillways—Securely attach the riser to the barrel or barrel stub to make a watertight structural connection. Secure all connections between barrel sections by approved watertight assemblies. The backfill adjacent to pipes or structures shall be of the type and quality conforming to that specified for the adjoining fill material. Place the barrel and riser on a firm, smooth foundation of impervious soil. Do not use pervious material such as sand, gravel, or crushed stone as backfill around the pipe or antiseep collars. Place the fill material around the pipe spillway in 4-inch layers, and compact by hand tampers or other manually directed compaction equipment under and around the pipe to at least the same density as the adjacent embankment. The material needs to fill completely all spaces under and adjacent to the pipe. The pipe shall be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material shall be removed and replaced with suitable earth compacted to provide adequate support. Care must be taken not to raise the pipe from firm contact with its foundation when compacting under the pipe haunches. At no time during the backfilling operation shall driven equipment be allowed to operate closer than four feet, measured horizontally, to any part of a structure. Place a minimum depth of 2 feet of compacted backfill over the pipe spillway before crossing it with construction equipment.

Anchor the riser in place by concrete or other satisfactory means to prevent flotation.

In no case should the pipe conduit be installed by cutting a trench through the dam after the embankment is complete.

Emergency spillway—Install the emergency spillway in undisturbed original ground. The achievement of planned elevations, grade, design width, and entrance and exit channel slopes are critical to the successful operation of the emergency spillway.

Inlets—Discharge water into the basin in a manner to prevent erosion. Use diversions with outlet protection to divert sediment-laden water to the upper end of the pool area to improve basin trap efficiency (See DIVERSIONS and OUTLET PROTECTION).

Erosion control— The installation of a sediment basin can in some instances be a significant construction project in its own right. The designer must create a comprehensive sediment control plan for each sediment basin installation.

Install appropriate sediment control prior to starting constructing. Minimize the disturbed area. Divert surface water away from bare areas and around the embankment footprint. Complete the embankment before the remaining construction site is cleared. Stabilize the emergency spillway embankment and all other disturbed areas above the wet storage elevation immediately after construction. Install Riprap channel protection in the emergency spillway if needed and at the outlet of the pipe.

Care of Water during Construction --All work on permanent structures shall be carried out in areas free from water. The contractor shall construct and maintain all temporary dikes, levees, cofferdams, drainage channels, and stream diversions necessary to protect the areas to be occupied by the permanent works. The contractor shall also furnish, install, operate, and maintain all necessary pumping and other equipment required for removal of water from various parts of the work and for maintaining the excavations, foundation, and other parts of the work free from water as required or directed by the engineer for constructing each part of the work.

After having served their purpose, all temporary protective works shall be removed or leveled and graded to the extent required to prevent obstruction in any degree whatsoever of the flow of water to the spillway or outlet works and so as not to interfere in any way with the operation or maintenance of the structure. Stream diversions shall be maintained until the full flow can be passed through the permanent works.

The removal of water from the required excavation and the foundation shall be accomplished in a manner and to the extent that will maintain stability of the excavated slopes and bottom required excavations and will allow satisfactory performance of all construction operations. During the placing and compacting of material in required excavations, the water level at the locations being refilled shall be maintained below the bottom of the excavation at such locations which may require draining the water sumps from which the water shall be pumped.

Baffles Install baffles as specified in Baffles section.

Safety—Sediment basins may attract children and can be dangerous. Avoid steep side slopes, and fence and mark basins with warning signs if trespassing is likely. Follow all state and local requirements.

Sediment Basin Removal and Cleanup

Final cleanup and disposition : The designer shall prepare a Sediment Control Plan for the removal of all sediment-trapping structures. Include in the Plan the method for dewatering the wet storage and removal of the trapped sediments.

Once the site is stabilized and the basin is no longer needed the structure shall be removed and the original contours reestablished. Sediment shall be removed so it cannot reenter a waterway.

Dewatering must not cause water quality violations. See the Basin or Sediment Trap Sediment Storage Dewatering Facility drawing for approved procedures to dewater a basin or trap.

All disturbed areas will be seeded and mulched immediately according to the specifications in this manual.

Maintenance

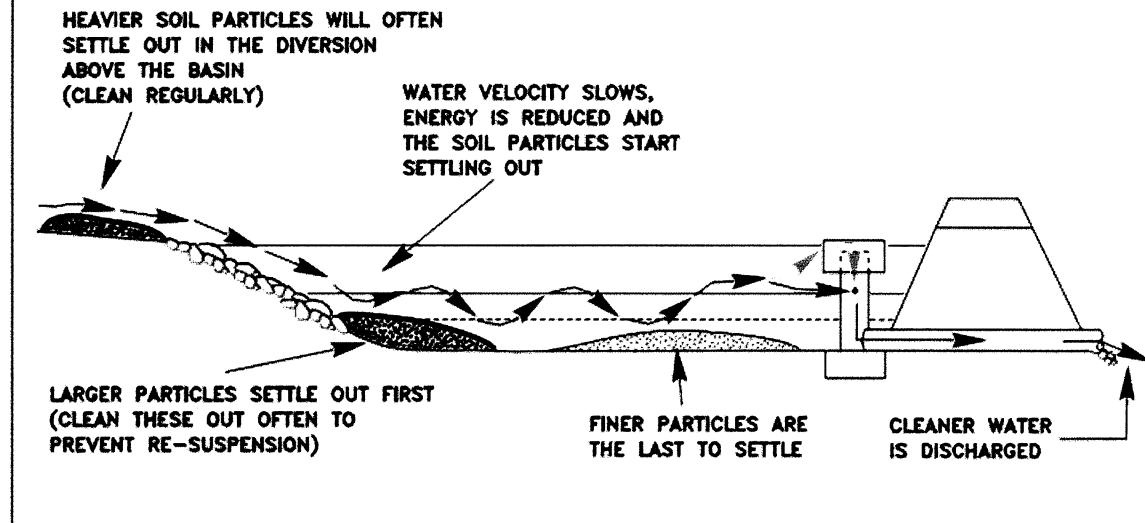
Inspect temporary sediment basins weekly and after each rainfall event 0.5 inch or greater and repair immediately.

Provide access for sediment removal and other required maintenance activities. Remove sediment and restore the basin to its original dimensions when it accumulates to one-half the wet storage depth. Place removed sediment where there is no possibility of its reentry into a waterway.

Check the embankment, spillways, and outlet for erosion damage, and inspect the embankment for piping and settlement. Make all necessary repairs immediately. Remove all trash and other debris from the riser and pool area.

FIGURE 3.30.1

HOW A SEDIMENT BASIN WORKS



HOW A SEDIMENT BASIN DOES NOT WORK

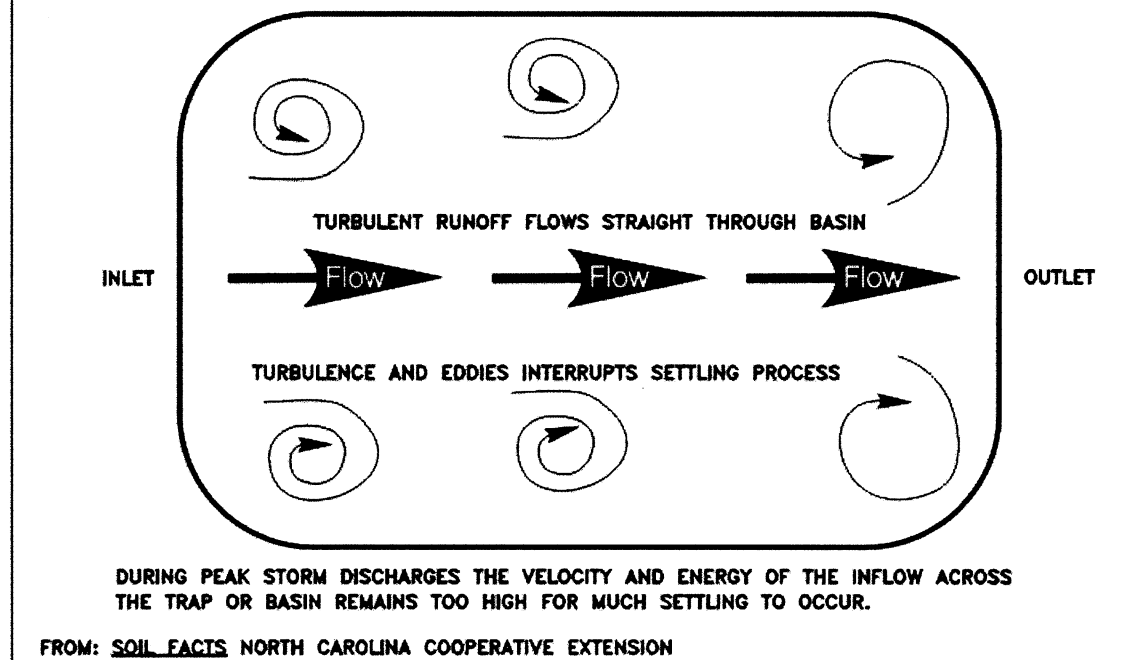
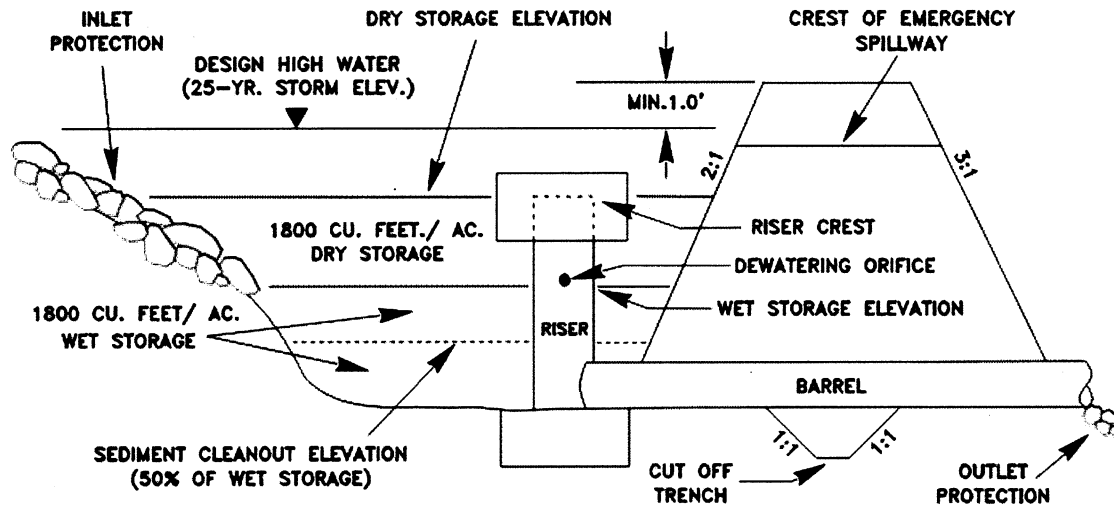
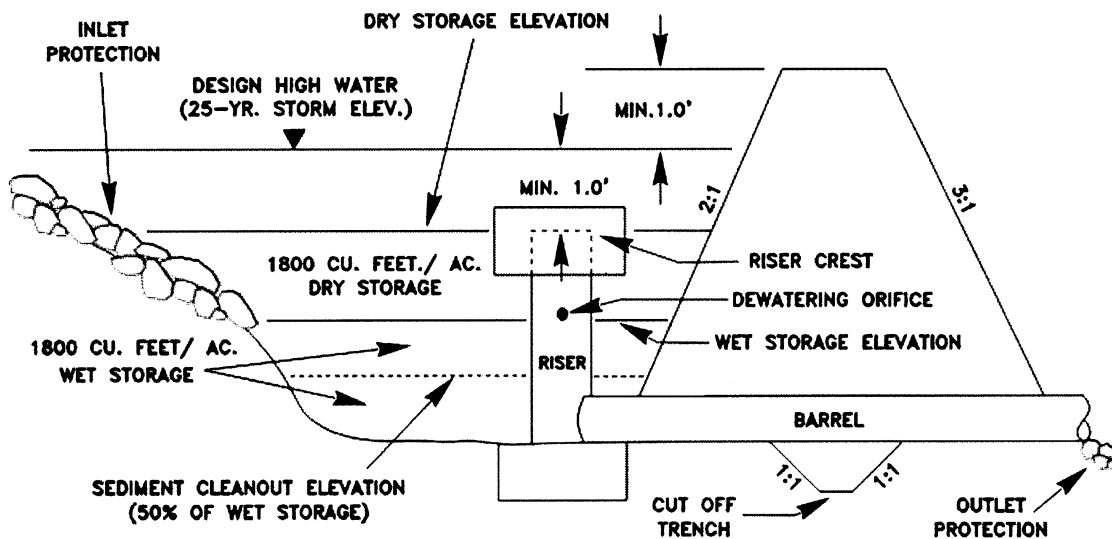


FIGURE 3.30.2

SEDIMENT BASIN



DESIGN ELEVATIONS WITH EMERGENCY SPILLWAY



DESIGN ELEVATIONS NO EMERGENCY SPILLWAY

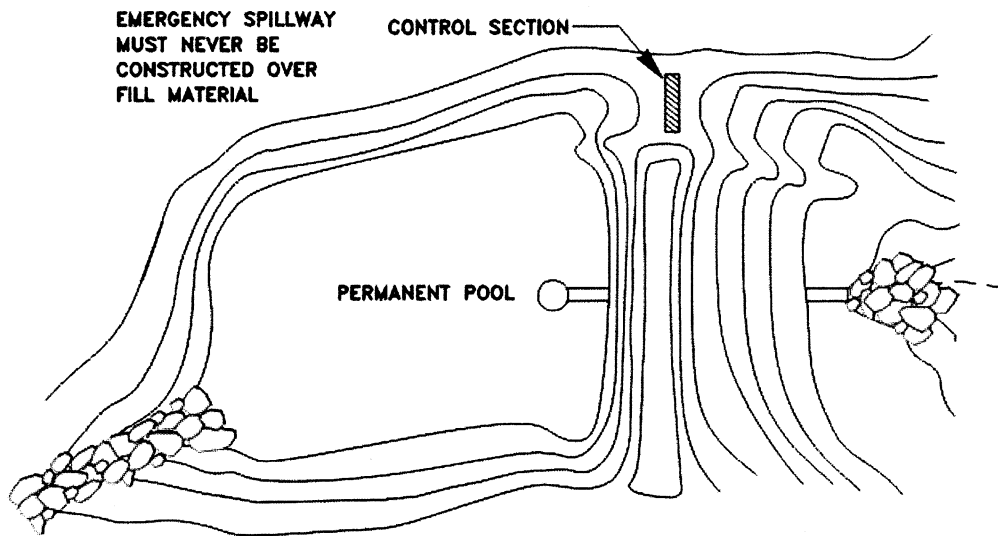
(NTS)

ADAPTED FROM: VA. DSWC

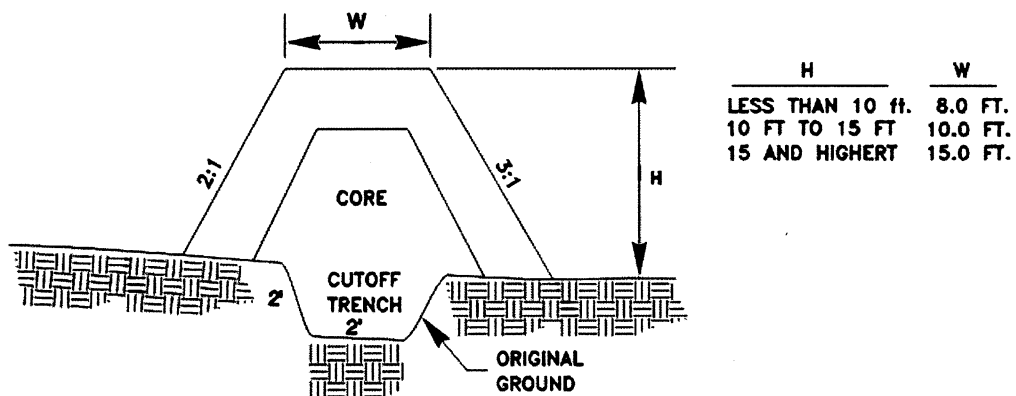
FIGURE 3.30.3

BASIN SCHEMATIC

EMERGENCY SPILLWAY



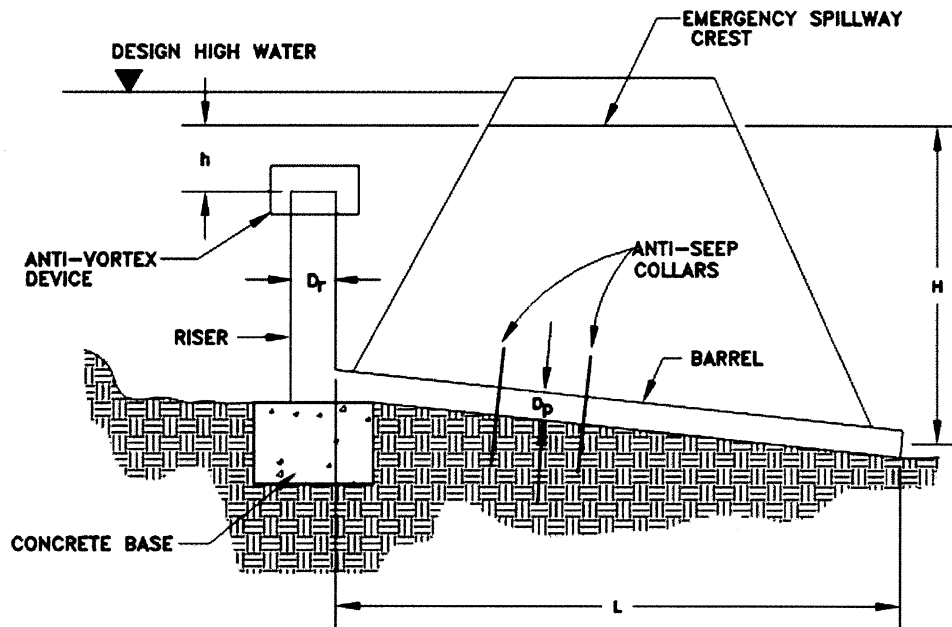
MINIMUM DIMENSIONS FOR SEDIMENT BASIN EMBANKMENTS



SOURCE: VA. DSWC

FIGURE 3.30.4

PRINCIPAL SPILLWAY DESIGN

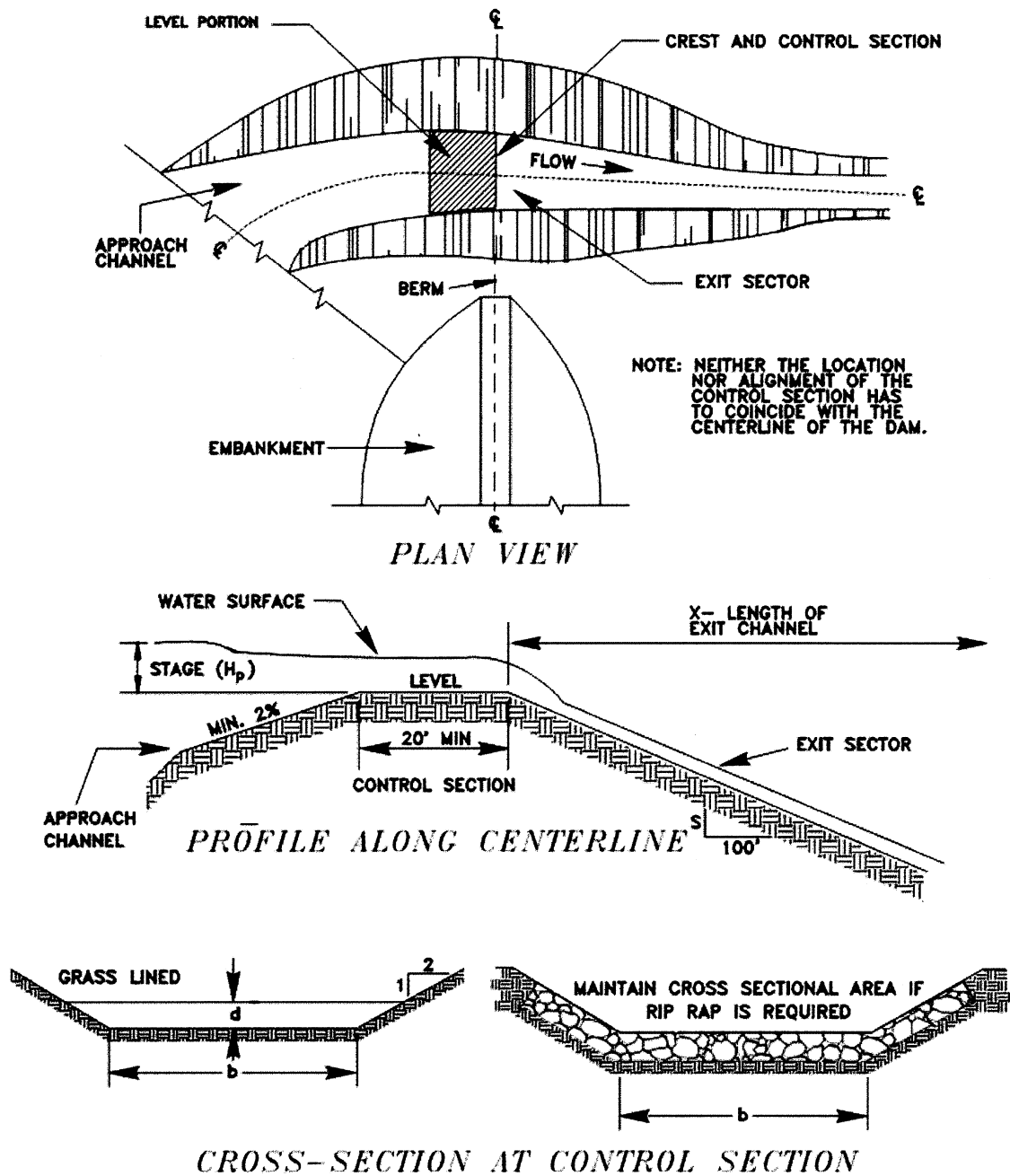


- H = HEAD ON PIPE THROUGH EMBANKMENT
 h = HEAD OVER RISER CREST
 L = LENGTH OF PIPE THROUGH EMBANKMENT
 D_p = DIAMETER OF PIPE THROUGH EMBANKMENT
 D_r = DIAMETER OF RISER

SOURCE: VA. DSWC

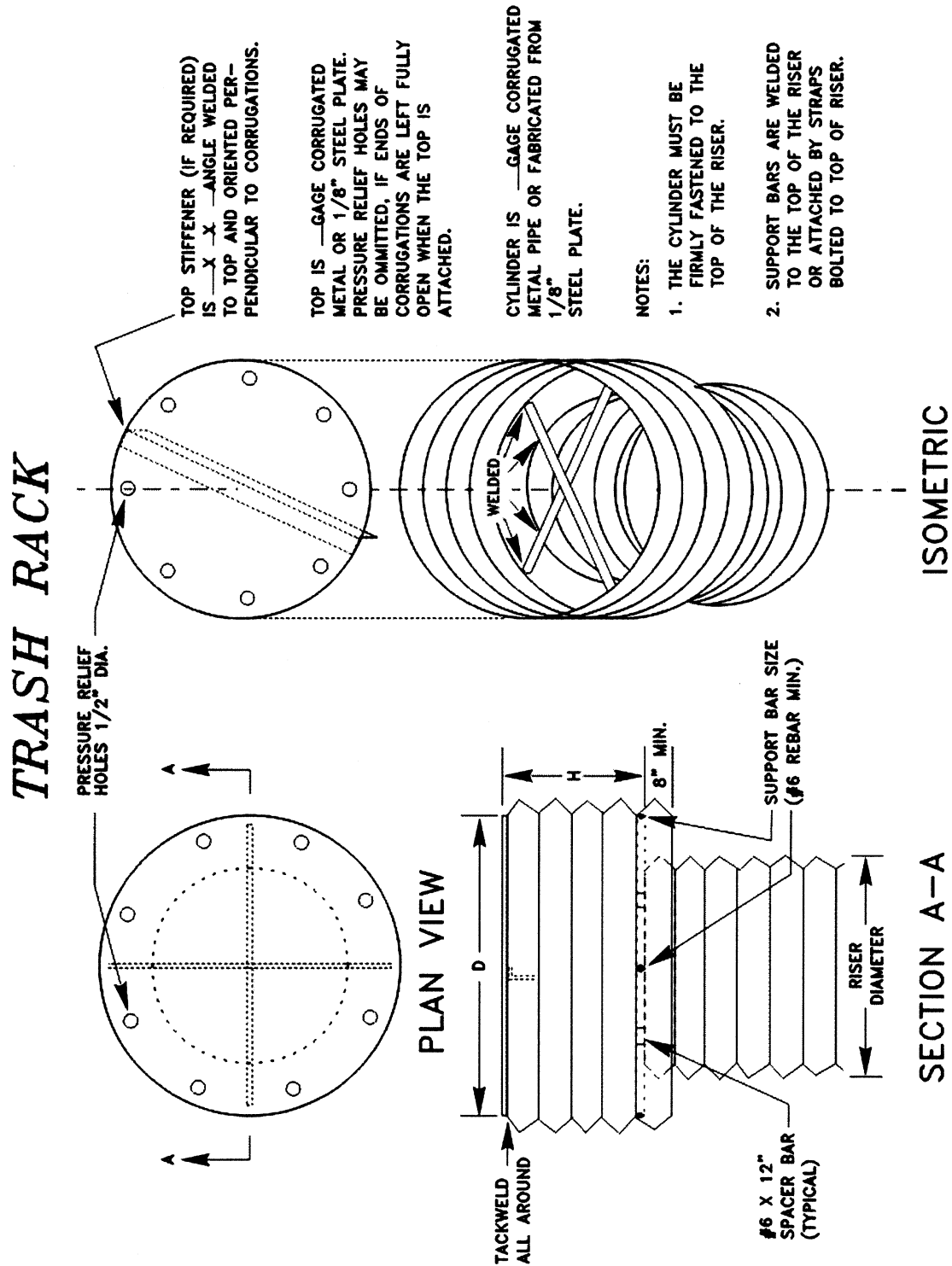
FIGURE 3.30.5

EXCAVATED EARTH SPILLWAY



SOURCES: USDA-NRCS AND VA DNRC

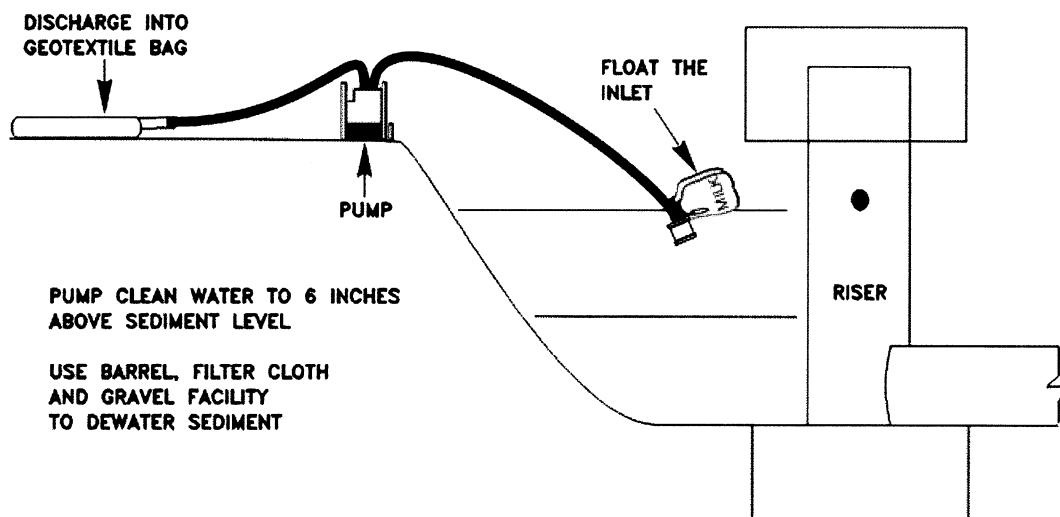
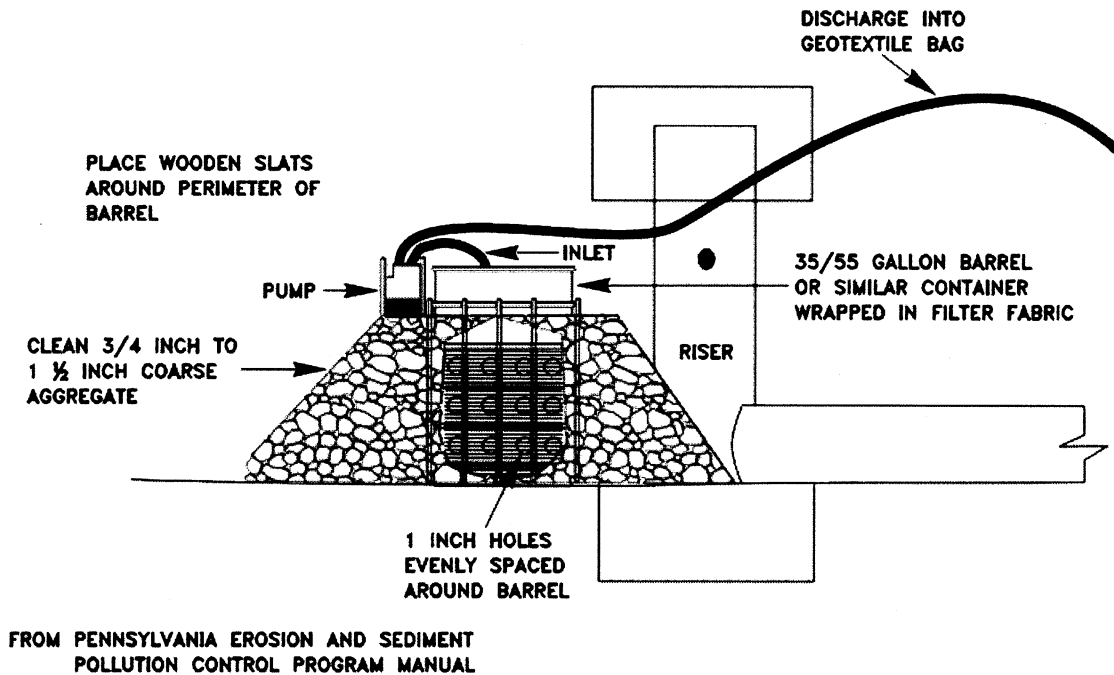
FIGURE 3.30.6



SOURCE: USDA-SCS AND VA DNRC

FIGURE 3.30.7

SEDIMENT BASIN OR TRAP DEWATERING DEVICE



3.33 - DROP INLET PROTECTION

Introduction

A sediment barrier and/or an excavated impounding area around a storm drain drop inlet or curb inlet used to trap sediment before contaminated runoff enters a storm drainage system.

Conditions Where Practice Applies

Where storm drain inlets are to be made operational before permanent stabilization of the corresponding disturbed drainage area.

Storm sewers that are made operational prior to stabilization of the associated drainage areas can convey large amounts of sediment to natural drainageways. In case of severe sediment loading, the storm sewer itself may clog and lose a major portion of its capacity. To avoid these problems, it is necessary to prevent sediment from entering the system at the inlets.

>>Storm sewers are installed to handle the runoff from their contributing drainage area and are sized to handle the flows from a particular size storm event. Installing any of these drop inlet protection practices reduces opening size of the inlet or severely restricts the hydraulic conditions entering the inlet, thereby reducing the capacity of the inlet to handle the excess flows from storm events. Design and install each of these practices with great care. It is highly recommended to use the 6" freeboard requirement whenever possible. Care must be taken not to create conditions where flooding will occur either when the inlet becomes clogged with sediment or debris and/or the top of the drop inlet protection is higher than the nearest low spot and storm flows bypass the inlet. This could lead to a cascading series of failures of other inlet protection, ending up with severe flooding to adjacent properties or severe erosion of fill slopes.

This practice contains several types of inlet barriers and traps that have different applications dependent upon site conditions and type of inlet. Plan developers are encouraged to investigate some of the commercially available products now on the market.

General Design Criteria

1. The drainage area should be no greater than 1 acre per inlet. The drainage area should be fairly flat with slopes of 5% or less and the area immediately around the inlet should not exceed a slope of 1%.
2. The inlet protection device shall be constructed in a manner that will facilitate clean out and disposal of trapped sediment and minimize interference with construction activities.
3. The inlet protection devices shall be constructed in such a manner that any resultant ponding of stormwater will not cause excessive inconvenience or damage to adjacent areas or structures.
4. For the inlet protection devices that utilize stone as the chief ponding/filtering medium, a range of stone sizes is offered. The designer should attempt to get the greatest amount of "filtering" action possible.

(by using smaller-sized stone), while not creating significant ponding problems.

5. In all designs that utilize stone with a wire-mesh support as a filtering mechanism, the stone can be completely wrapped with the wire mesh to improve stability and provide easier cleaning.
6. Filter Fabric may be added to any of the devices that utilize stone to significantly enhance sediment removal, but with a reduced flow capacity. The fabric, which must meet the physical requirements noted for “extra strength”, should be secured between the stone and the inlet (on wire-mesh if it is present). As a result of the significant increase in filter efficiency provided by the fabric, a larger range of stone sizes (up to gabion size) may be utilized with such a configuration.
Note: Significant ponding will occur at the inlet if filter cloth is utilized in this manner.
7. If there is a possibility that ponding will occur, the top of the inlet protection must be at least six inches below the nearest low spot to insure sufficient freeboard. See Figure 3.33.2.
8. Remove any obstructions to excavating and grading. Excavate any sump area, grade slopes and properly dispose of soil.
9. The inlet grate should be secured to prevent seepage of sediment-laden water.
10. Ensure that weep holes in the inlet structure are protected by filter fabric and gravel.
11. Hardware cloth or wire mesh with ½-inch inch openings.
12. Filter fabric
13. Washed gravel 3/4 inches to 4 inches in diameter. All cut slopes shall be 2:1 or flatter.

Construction Specifications

Silt Fence Drop Inlet Protection

- a. Silt Fence shall conform to the specifications for “extra strength” and shall be cut from a continuous roll to avoid joints.
- b. For stakes, use 2 x 4-inch wood (preferred) or equivalent metal with a minimum length of 3 feet.
- c. Space stakes evenly around the perimeter of the inlet a maximum of 3-feet apart, and securely drive them into the ground, approximately 18 inches deep.
- d. To provide needed stability to the installation, frame with 2 x 4-inch wood strips around the crest of the overflow area at a maximum of 1 foot above the drop inlet crest.
- e. Place the bottom 12 inches of the fabric in a trench and backfill the trench with 12 inches of compacted soil. This limits this practice to unpaved areas.
- f. Fasten fabric securely by staples or wire to the stakes and frame. Joints must be overlapped to the next stake.
- g. It may be necessary to build a temporary dike on the downslope side of the structure to prevent bypass flow.
- h. It is recommended that a sediment trapping sump of 1 to 2 feet in depth with side slopes of 2:1 be provided.
- i. If the filter fabric becomes clogged it should be replaced immediately.

- j. Make sure that the stakes are firmly in the ground and that the filter fabric continues to be securely anchored.

Gravel and Wire Mesh Drop Inlet Protection

- a. Wire mesh shall be laid over the drop inlet so that the wire extends a minimum of 1 foot beyond each side of the inlet structure. Wire mesh with ½-inch openings shall be used. If more than one strip of mesh is necessary, the strips shall be overlapped.
- b. Coarse aggregate shall be placed over the wire mesh as indicated in the drawing. The depth of stone shall be at least 12 inches over the entire inlet opening. The stone shall extend beyond the inlet opening at least 18 inches on all sides.
- c. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stones must be pulled away from the inlet, cleaned and/or replaced.

Note: This filtering device has no overflow mechanism; therefore, ponding is likely especially if sediment is not removed regularly. This type of device must never be used where overflow may endanger an exposed fill slope or flooding of adjacent properties. Consideration should also be given to the possible effects of ponding on traffic movement, nearby structures, working areas, adjacent property, etc.

Block and Gravel Drop Inlet Protection

- a. Place concrete blocks lengthwise on their sides in a single row around the perimeter of the inlet, with the ends of adjacent blocks abutting. The height of the barrier can be varied, depending on design needs, by stacking combinations of 4-inch, 8-inch and 12-inch wide blocks. The barrier of blocks shall be at least 7½-inches high but no greater than 24-inches high.
- b. Wire mesh shall be placed over the outside vertical face (webbing) of the concrete blocks to prevent stone from being washed through the holes in the blocks. Wire mesh with ½-inch openings shall be used.
- c. Stone shall be piled against the wire to the top of the block barrier, as shown in the drawing.
- d. If the stone filter becomes clogged with sediment so that it not longer adequately performs its function, the stone must be pulled away from the blocks, cleaned and replaced.

Pipe Riser Drop Inlet Protection

- a. Each pipe riser must be constructed from steel plate that is cut to the dimensions of the drop inlet grate with an inch over lap on each side and a length of 12 inch corrugated metal pipe. Use a minimum of 10 gauge steel plate with a 12 inch hole cut in the center. The corrugated pipe is welded to the plate.
- b. Cut a series of one-inch holes in the corrugated pipe as shown on the drawings. Wire mesh with ½ inch openings can be wrapped around the outside of the pipe to prevent stone from being washed through the holes.

- c. Place a square piece of geotextile filter fabric at least one foot larger than the inlet dimensions around the riser and over the metal plate.
- d. Stone shall be piled to the top of the pipe, as shown in the drawing.
- e. If the stone filter becomes clogged with sediment so that it not longer adequately performs its function, the stone must be pulled away from the blocks, cleaned and replaced.
- f. This practice can be combined with the Excavated Drop Inlet Sediment Trap to increase the available storage.

***Excavated Drop Inlet
Sediment Trap***

- a. The excavated trap shall be sized to provide a minimum storage capacity calculated at the rate of 3600 cubic feet per acre of drainage area. (if attainable). The trap should be not less than 1-foot nor more than 2-feet deep measured from the top of the inlet structure. Side slopes shall not be steeper than 2:1.
- b. The slope of the basin may vary to fit the drainage area and terrain. Observations must be made to check trap efficiency and modifications shall be made as necessary to ensure satisfactory trapping of sediment. Where an inlet is located so as to receive concentrated flows, such as in a highway median, it is recommended that the basin have a rectangular shape in a 2:1 (length/width) ratio, with the length oriented in the direction of the flow.
- c. Sediment shall be removed and the trap restored to its original dimensions when the sediment has accumulated to one-half the design depth of the trap. Removed sediment shall be deposited in a suitable area and in a manner such that it will not erode.
- d. If there is sufficient freeboard available this practice can be combined with other drop inlet protection devices such as Silt Fence or Pipe Riser.

***Gravel Curb Inlet
Protection***

- a. Wire mesh with ½-inch openings shall be placed over the curb inlet opening so that at least 12 inches of wire extends across the inlet cover and at least 12 inches of wire extends across the concrete gutter from the inlet opening, as depicted in drawing.
- b. Stone shall be piled against the wire so as to anchor it against the gutter and inlet cover and to cover the inlet opening completely.
- c. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stone must be pulled away from the block, cleaned and replaced.

***Curb Inlet Protection
with 2-inch x 4-inch
Wooden Weir***

- a. Attach a continuous piece of wire mesh (30-inch minimum width x inlet throat length plus 4 feet) to the 2-inch x 4-inch wooden weir (with a total length of throat length plus 2 feet) as shown in the drawing. Wood should be “construction grade” lumber.
- b. Place a piece of approved “extra-strength” filter cloth of the same dimensions as the wire mesh over the wire mesh and securely attach to the 2-inch x 4-inch weir.

- c. Securely nail the 2-inch x 4-inch weir to the 9-inch long vertical spacers which are to be located between the weir and inlet face at a maximum 6-foot spacing.
- d. Place the assembly against the inlet throat and nail 2-foot (minimum) lengths of 2-inch x 4-inch board to the top of the weir at spacer locations. These 2-inch x 4-inch anchors shall extend across the inlet tops and be held in place by sandbags or alternate weight.
- e. The assembly shall be placed so that the end spacers are a minimum 1 foot beyond both ends of the throat opening.
- f. Form the wire mesh and filter cloth to the concrete gutter and against the face of curb on both sides of the inlet. Place coarse aggregate over the wire mesh and filter fabric in such a manner as to prevent water from entering the inlet under or around the filter cloth.
- g. This type of protection must be inspected frequently and the filter cloth and stone replaced when clogged with sediment.
- h. Assure that storm flow does not bypass inlet by installing temporary earth or asphalt dikes directing flow into inlet.

***Block and Gravel
Curb Inlet
Protection***

- a. Two concrete blocks shall be placed on their sides abutting the curb at either side of the inlet opening.
- b. A 2-inch x 4-inch stud shall be cut and placed through the outer holes of each spacer block to help keep the front blocks in place.
- c. Concrete blocks shall be placed on their sides across the front of the inlet and abutting the spacer blocks as depicted in the drawing.
- d. Wire mesh with ½-inch opening shall be placed over the outside vertical face (webbing) of the concrete blocks to prevent stone from being washed through the holes in the blocks.
- e. Coarse aggregate shall be piled against the wire to the top of the barrier as shown in the drawing.
- f. If the stone filter becomes clogged with sediment so that it not longer adequately performs its function, the stone must be pulled away from the blocks, cleaned and/or replaced.

***Gravel Bag
Curb Inlet
Protection***

- a. In general, gravel bags are used to create a small sediment trap upstream of inlets and are appropriate for gently sloping streets where ponded water will not endanger the public or cause property damage
- b. Flow from a severe storm should not overtop the curb.
- c. In areas of high clay and silts, use filter fabric and gravel as additional filter media.
- d. Use sandbags made of geotextile fabric (not burlap) and fill with uniform coarse aggregate material such as ½" rock or ¼" pea gravel. Do not use sand, as the bag must be porous.
- e. Place one or two layers of overlapping gravel bags, and pack them tightly together. A gap of one sandbag on the top row on either side of the inlet can serve as an overflow spillway for larger storms.
- f. Leave room upstream of barrier for water to pond and sediment to settle.

- g. Drape geotextile filter fabric over the barrier and place the aggregate to “filter” sediment from storm water. Small pipes (2” diameter or smaller) for additional safety can be placed through the gravel bag barrier if also covered by filter fabric.
- h. If the stone filter becomes clogged with sediment so that it not longer adequately performs its function, the stone must be pulled away from the blocks, cleaned and/or replaced

***Manufactured Drop
Inlet Protection***

There are a number of new commercially available products on the market now. Some show great promise in providing excellent sediment control. However, great care must be taken when choosing a product as some have significant problems with their design.

Do not install any practice that completely blocks the entrance of a drop inlet without some type of excess freeboard or adequate overflow. There are several curb inlet protections that block the inlet while providing several small holes for overflow. These holes are not large enough to pass larger storm events and can cause localized flooding. Some drop inlet protections cover the entire top of the inlet or are installed under the grate. These too have little overflow capacity and must be used judiciously. Practices that are placed inside inlets and out of sight are particularly easy to forget and become clogged and fail. In all cases the freeboard requirement must be met. While some of the products can work, great care must be taken to install correctly and to insure the design capacity of the inlet is not compromised.

Maintenance

- 1. The structure shall be inspected after each .5" of rain and at least once a week and repairs made as needed. Construction traffic has a tendency to destroy these practices so frequent inspections are necessary.
- 2. Sediment shall be removed and the trap restored to its original dimensions when the sediment has accumulated to one half the design depth of the trap. Removed sediment shall be deposited in a suitable area and in such a manner that it will not erode.
- 3. Inlet protection should remain in place and operational until the drainage area is completely stabilized. Immediately stabilize the area disturbed by the installation and removal of the practice.
- 4. It is essential that maintenance be done to insure that structures do not fail, especially to prevent clogging. Failure of one practice can create a domino effect of failures, with the potential of severe flooding of adjacent properties.

SILT FENCE DROP INLET PROTECTION

The diagram illustrates the construction and use of a silt fence drop inlet protection. It includes two perspective views and a specific application detail.

PERSPECTIVE VIEWS

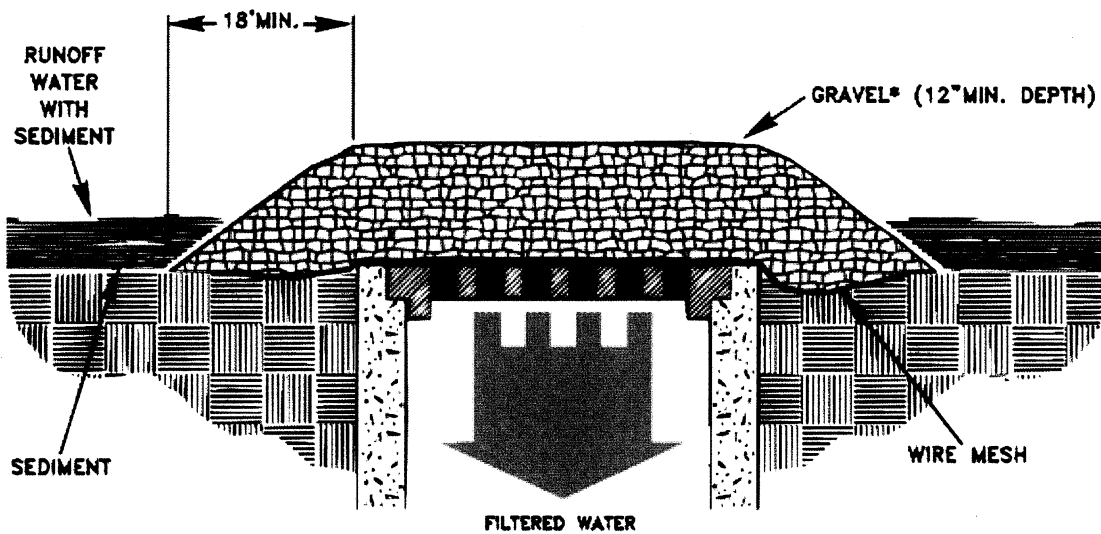
- Left View:** Shows a 2' x 4' wood frame structure. The height is labeled as 1.5' MAX. The text "See Text" is also present.
- Right View:** Shows the drop inlet with a grate. The frame is labeled, and the text "GATHER EXCESS AT CORNERS" is shown.

SPECIFIC APPLICATION

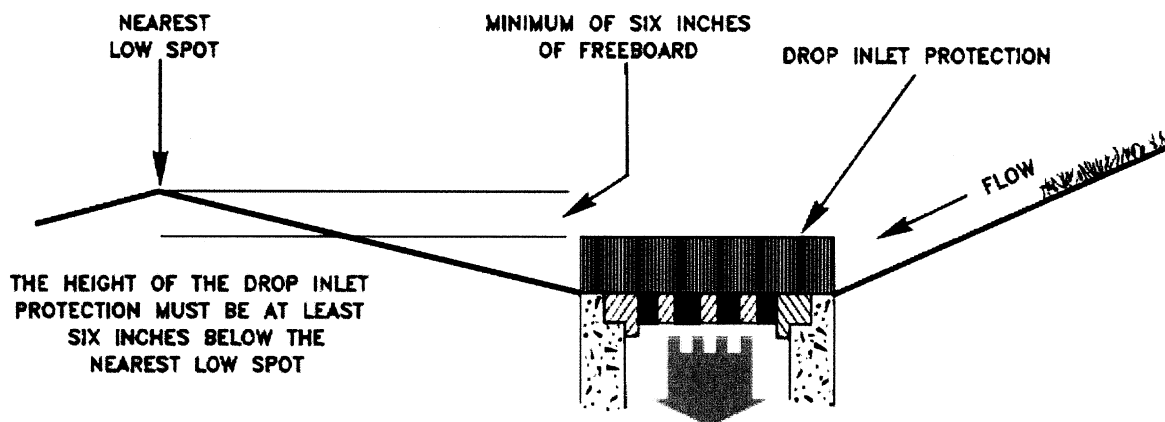
- Left Detail:** Shows a stake driven into the ground, with fabric attached to it. The text "STAKE" and "FABRIC" are labeled.
- Right Detail:** A circular detail labeled "DETAIL A" showing a close-up of the fabric and stake connection.

FIGURE 3.33.2

GRAVEL AND WIRE DROP INLET PROTECTION



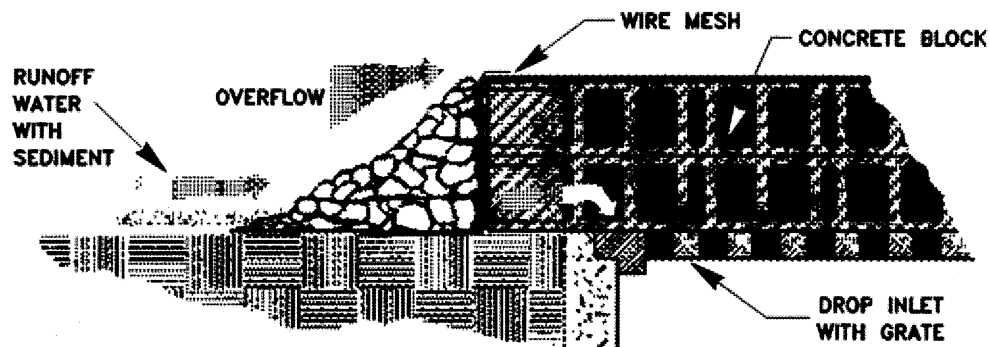
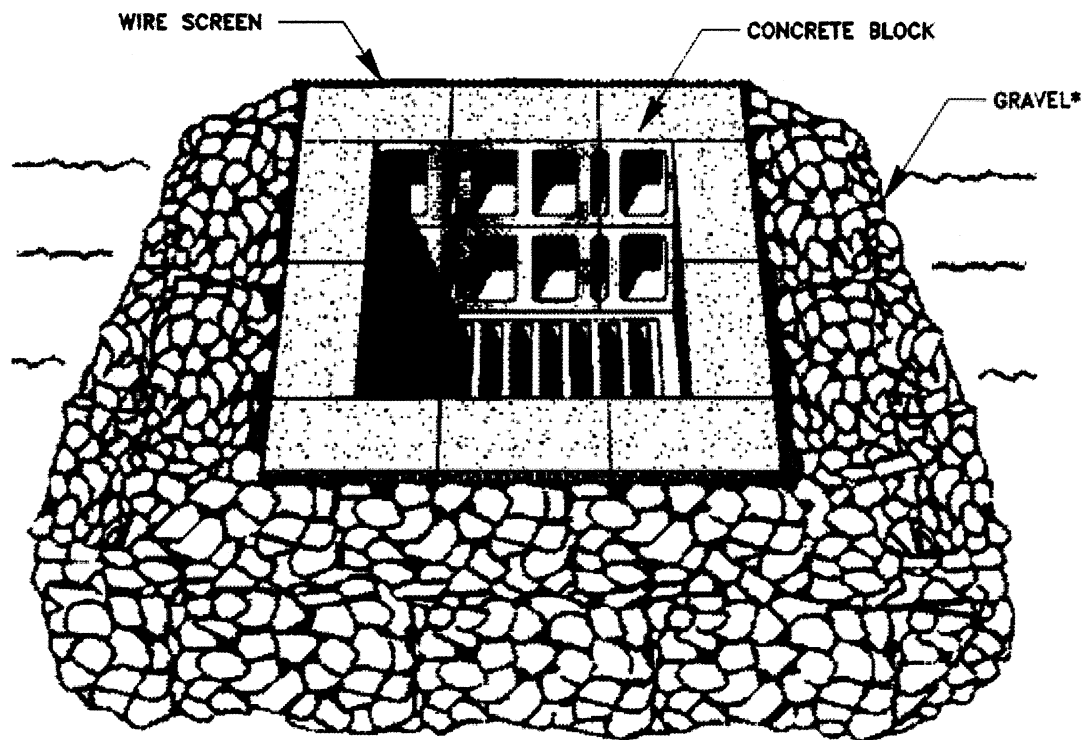
FREEBOARD REQUIREMENTS FOR ALL DROP INLET PROTECTION



* GRAVEL SHALL BE CLEAN 3/4" TO 2" COARSE AGGREGATE

FIGURE 3.33.3

BLOCK AND GRAVEL DROP INLET SEDIMENT FILTER

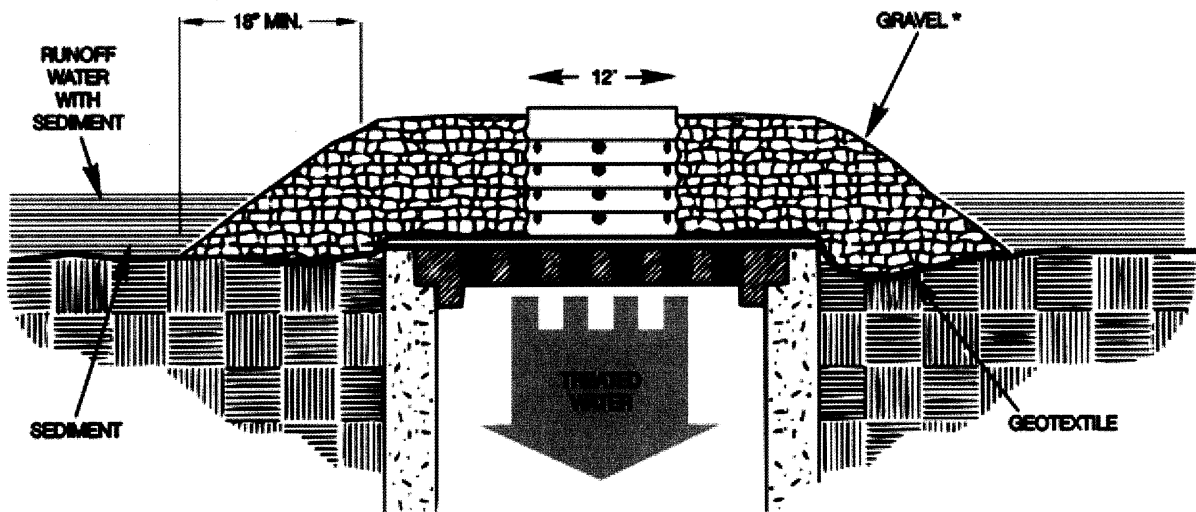


*SIDE
ELEVATION*

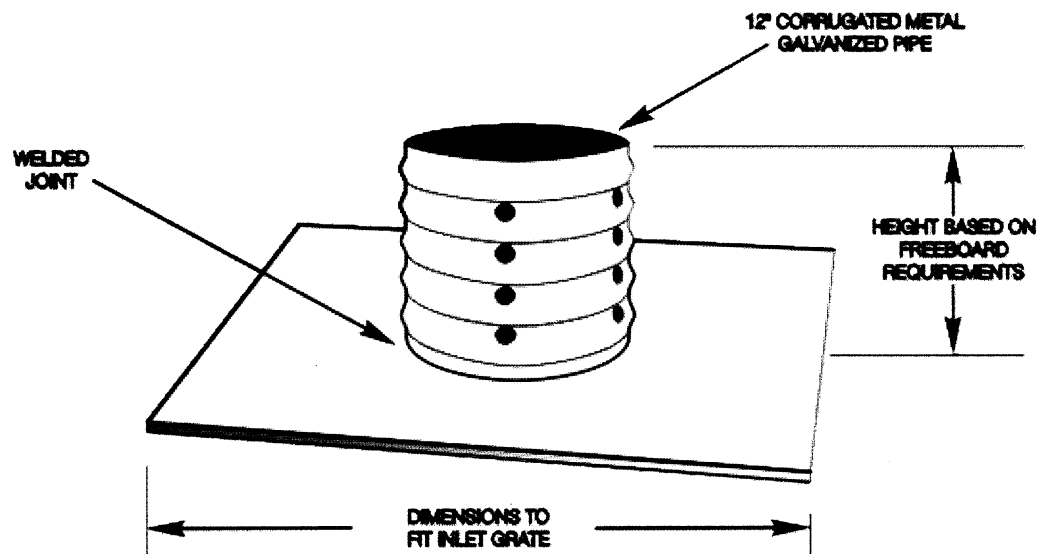
* GRAVEL SHALL BE CLEAN 3/4" TO 2" COARSE AGGREGATE

FIGURE 3.33.4

PIPE RISER AND GRAVEL DROP INLET PROTECTION



SIDE ELEVATION



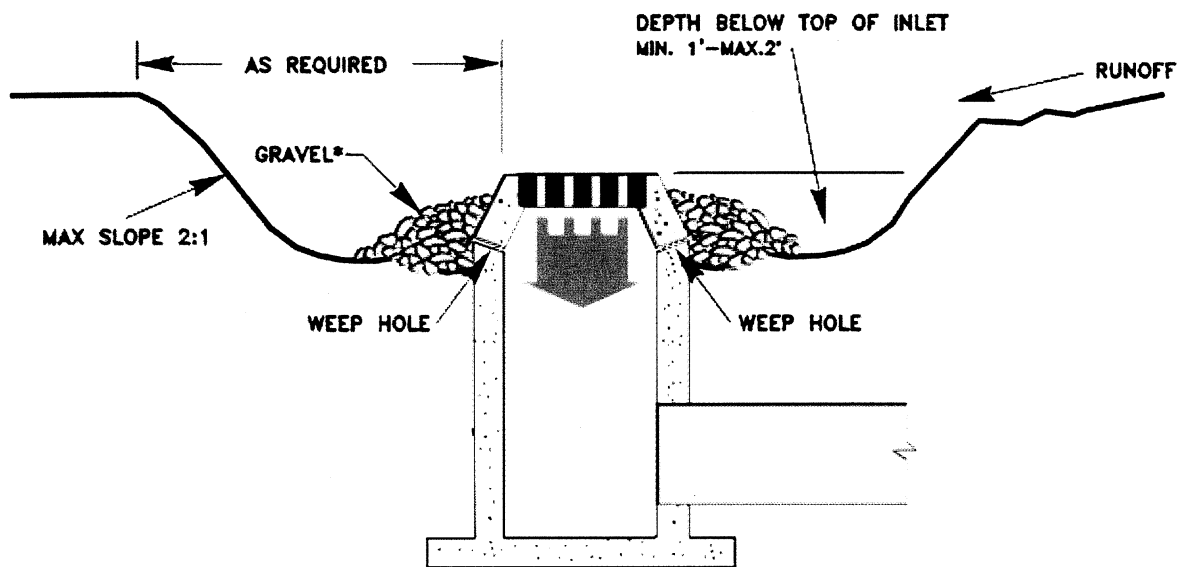
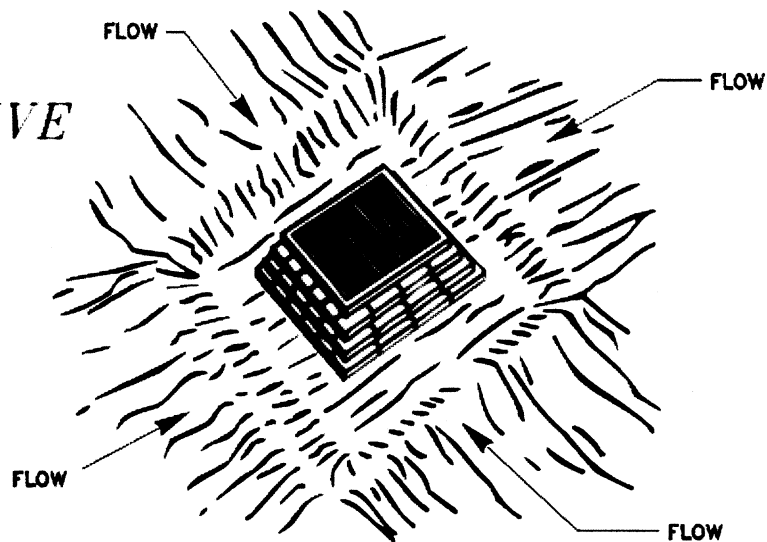
PERSPECTIVE VIEW

* GRAVEL SHALL BE CLEAN 3/4" TO 2" COARSE AGGREGATE

FIGURE 3.33.5

EXCAVATED DROP INLET PROTECTION

PERSPECTIVE
VIEW

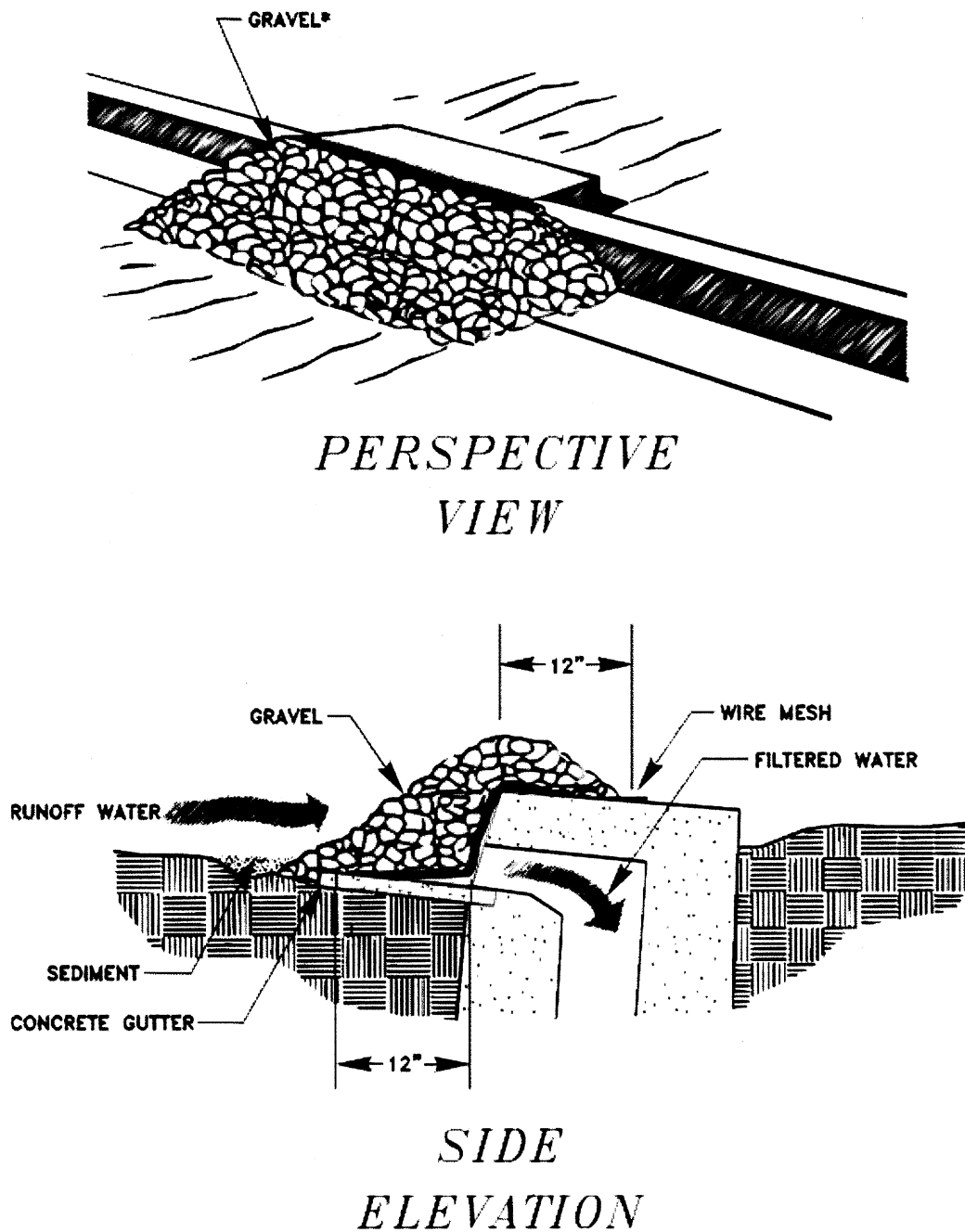


SIDE
ELEVATION

* GRAVEL SHALL BE CLEAN
3/4" TO 2" COARSE AGGREGATE

FIGURE 3.33.6

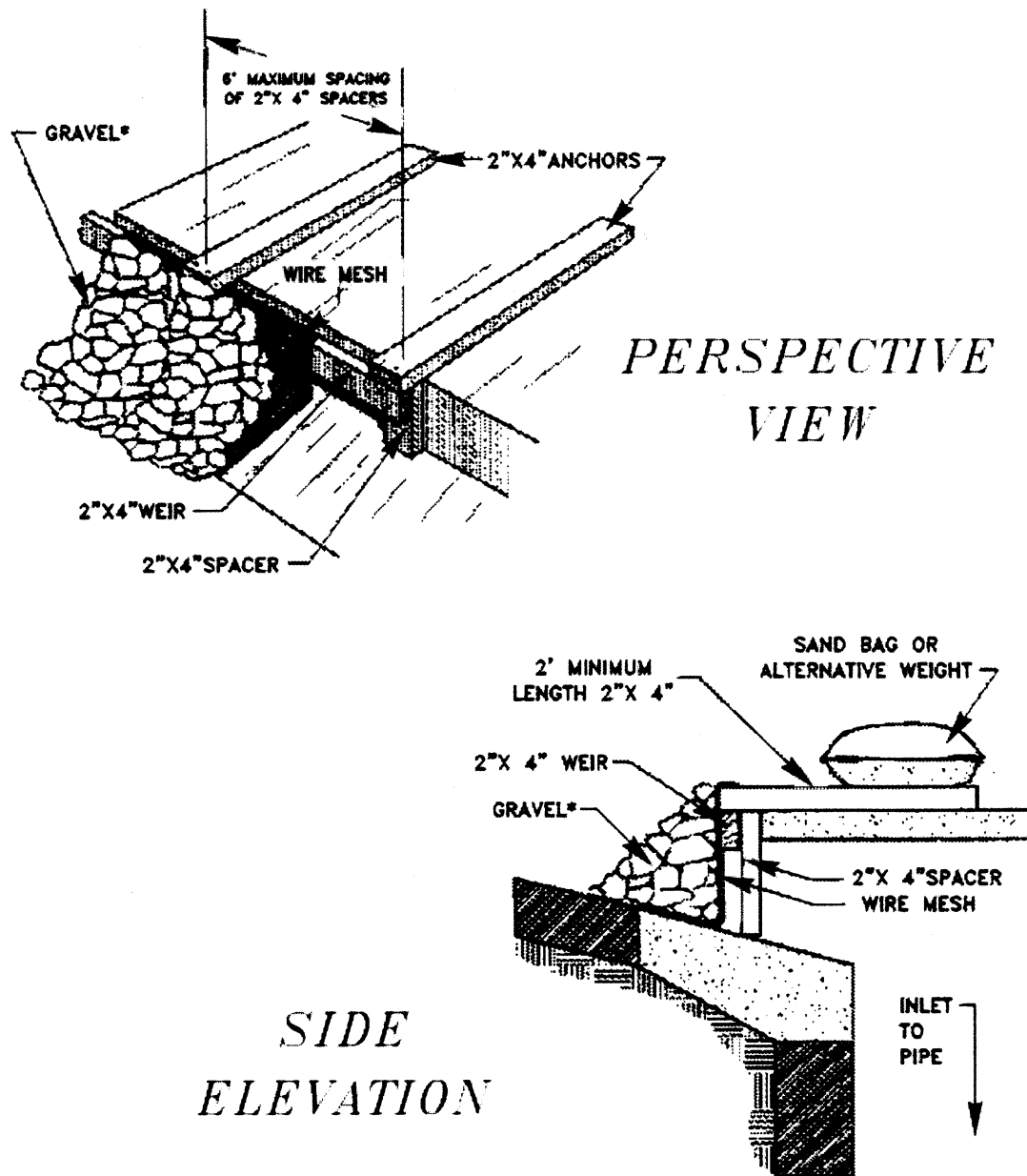
GRAVEL AND WIRE CURB INLET PROTECTION



* GRAVEL SHALL BE CLEAN 3/4" TO 2" COARSE AGGREGATE

FIGURE 3.33.7

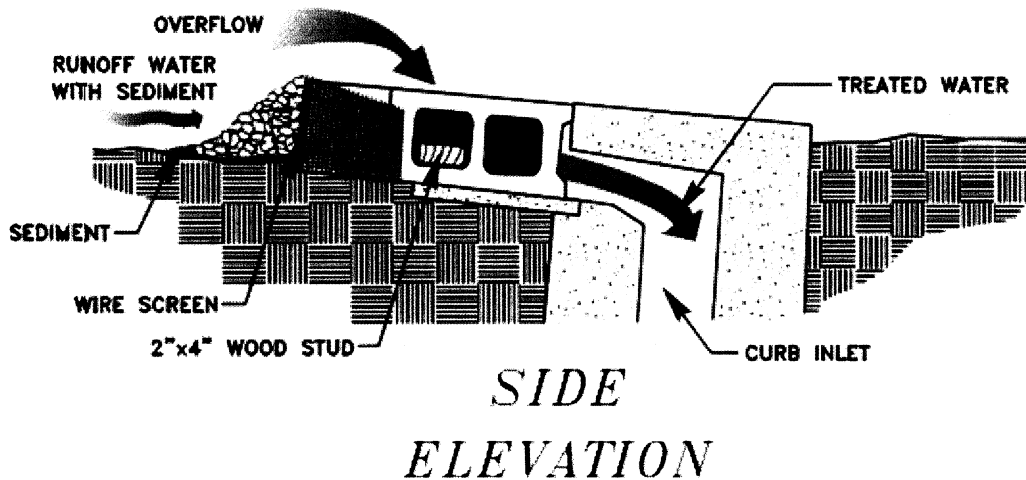
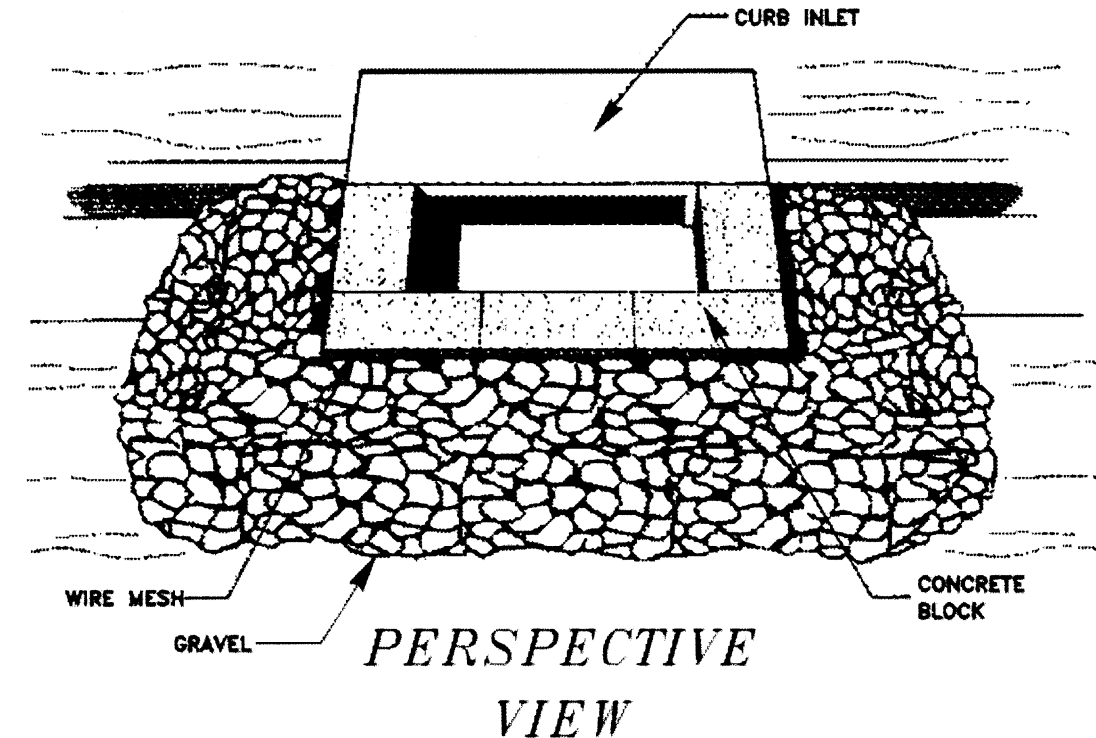
CURB INLET PROTECTION WITH 2" x 4" WOODEN WEIR



* GRAVEL SHALL BE CLEAN 3/4" TO 2" COARSE AGGREGATE

FIGURE 3.33.8

BLOCK & GRAVEL CURB INLET PROTECTION



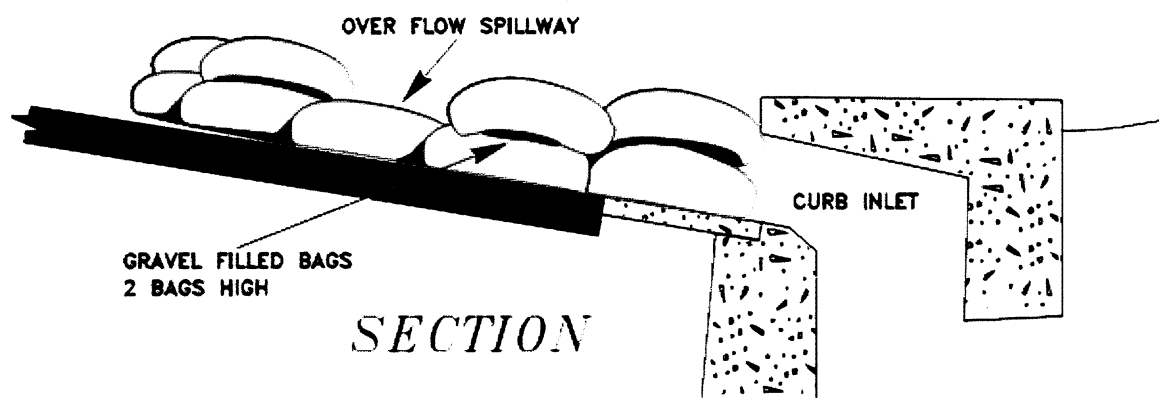
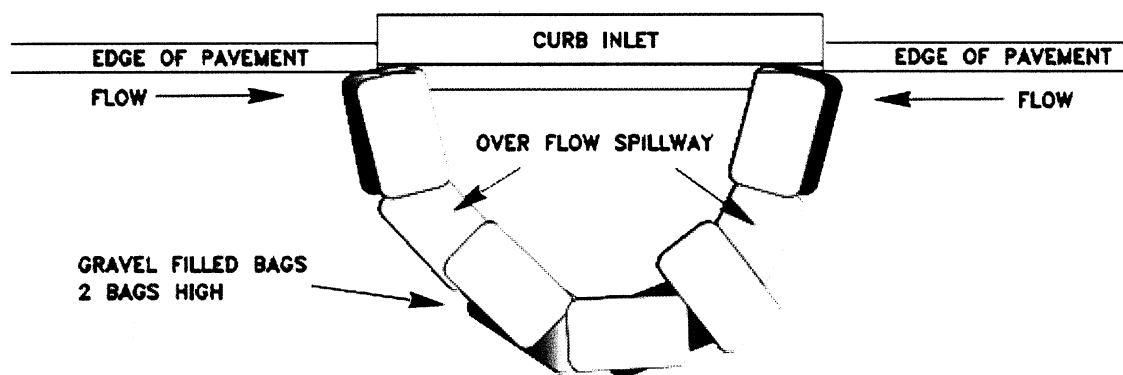
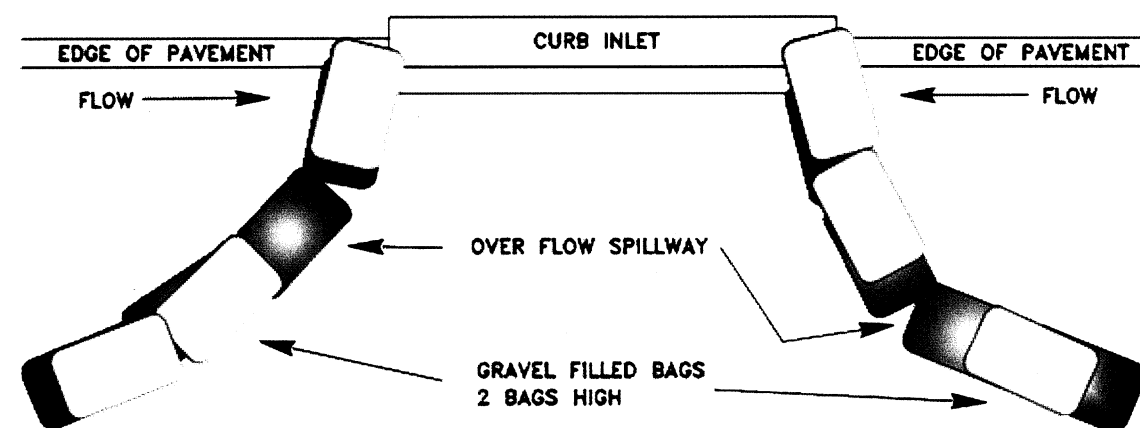
SPECIFIC APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE AT CURB INLETS WHERE AN OVERFLOW CAPABILITY IS NECESSARY TO PREVENT EXCESSIVE PONDING OR FLOODING.

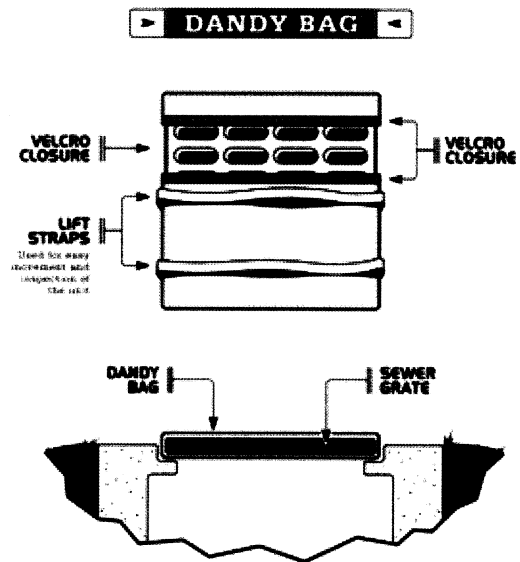
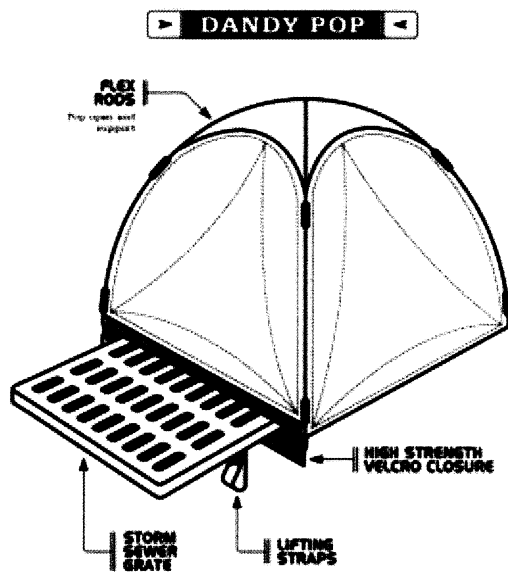
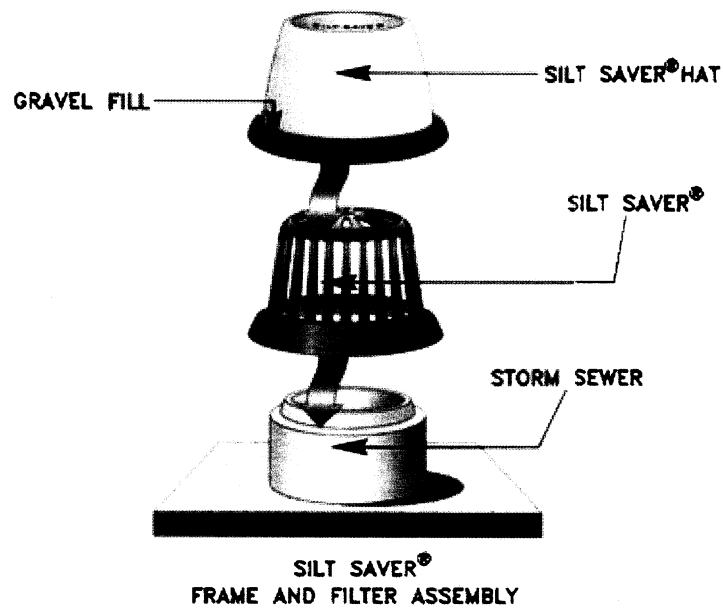
• GRAVEL SHALL BE CLEAN 3/4" TO 2" COARSE AGGREGATE

FIGURE 3.33.9

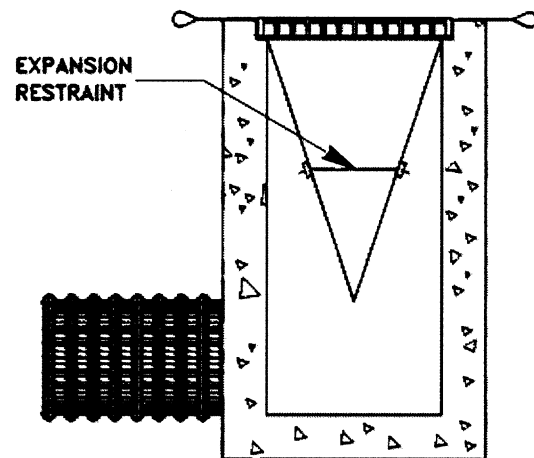
GRAVEL BAG CURB INLET PROTECTION



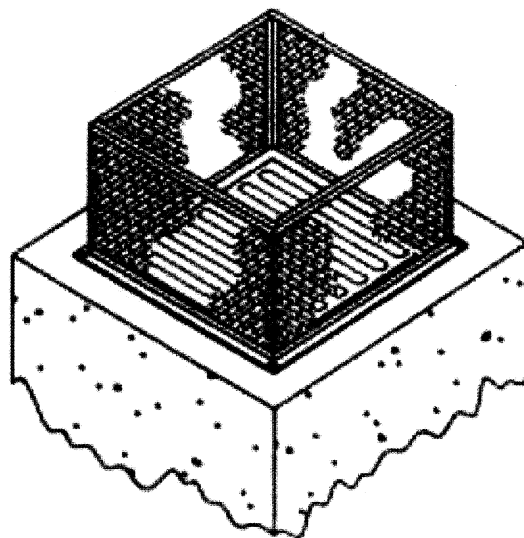
COMMERCIAL INLET PROTECTION



COMMERCIAL INLET PROTECTION



SILT SACK™



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3.35 - ACCESS ROAD/ LOW VOLUME ROAD/DRIVEWAY

Introduction

Access roads and driveways are a major source of sediment in the State of West Virginia. Roads can dramatically change the hydrologic conditions of the immediate watershed. Roads that are improperly designed, constructed and stabilized can cause significant erosion and produce vast quantities of sediment. Common problems with roads are:

1. Inadequate number and size of culverts.
2. Road grade too steep.
3. Road surface not stabilized.
4. Poor soil conditions.
5. Poor drainage.
6. Poor stream crossings.
7. Cuts and fills too steep causing slips.

Since roads are typically long-term features, cutting costs during the construction phase almost always costs more in the long run as maintenance costs will be significantly higher on improperly designed and constructed roads.

To control sediment from roads it is necessary to practice aggressive erosion control. The single most important thing to do when designing and building a road is to control the water. Running water more than a few hundred feet down a road will cause long-term erosion and increase maintenance costs.

It is important that concentrated upslope water from streams or drainageways is directed immediately across the road with a culvert. Adequately sized and stabilized ditches to catch minor hillside runoff must also be constructed. The goal is to maintain the existing hydrologic conditions as much as possible by installing adequate numbers of cross culverts.

Conditions Where Practice Applies

Wherever low volume access roads are built. This practice can apply to any type of dirt or gravel road outside the Department of Transportation's road system.

Planning.

Planning and location are two of the more important aspects of road development and takes considerable time and effort. Good planning upfront can forestall problems later on.

1. You will need topographic maps, soil surveys and soil maps, and a device to determine grade. Roads should not be built on some soils. Check with the Natural Resources Conservation Service for information on soils. Review available information and

consult with professionals as necessary to help identify erodible soils and unstable areas, and to locate appropriate road surface materials.

2. Fit the road to the topography by locating roads on natural benches and following natural contours. Avoid long, steep road grades and narrow valleys.
3. If possible use switchbacks where it is impossible to construct a road below the maximum grade.
4. If it is necessary to construct in steep terrain break the road grade as much as possible by alternating steep section with flatter sections. Sometimes the road grade can be reversed which will shorten slope length and reduce the number of culverts, water bars and broad-based dips.
5. Locate roads on stable geology, including well-drained soils and rock formations that tend to dip into the slope. Avoid slumps and slide prone areas characterized by steep slopes, highly weathered bedrock, clay beds, concave slopes, hummocky topography, and rock layers that dip parallel to the slope.
6. Avoid wet areas, including moisture laden or unstable toe slopes, seeps, wetlands, and natural drainage channels. Ridge tops can be good places for a road as long as proper drainage can be constructed. Be aware that conditions may change when constructing in the dryer times of the year. Be prepared to add culverts after construction when hidden springs and streams start back up in the winter and spring.
7. Avoid crossing streams, if practical. If unavoidable, look for the best places to cross, considering the following.
 - Always cross at right angles.
 - Cross at points where the stream is narrow and the stream banks are stable.
 - Minimize the number of crossings.
 - Leave a buffer zone of undisturbed ground between the road and streambed, where the road runs parallel to the stream.
 - Divert water from road with a diversion or water bar to prevent water running directly into the stream.
8. If possible build roads on the drier south or west facing slopes. Clear trees to allow the sun to hit the road as much as possible.
9. Stabilization of all disturbed soil must take place as quickly as possible. Seed and mulch all cut and fill slopes and shoulders within seven days of reaching final grade. Stabilize the ditches as the line and grade is finalized.
10. Stabilization should occur as the road is constructed. Build the road in sections. Initiate stabilization on a finished section prior to moving to the next section. Finish road crossings and section nearest the creek immediately. Do not rough grade the entire road and then come back to the beginning to start restoration and stabilization. Quick stabilization of the disturbed area will greatly enhance any sediment control.

Mapping

Using the above information, locate control points (areas where you can and can't build a road) such as rock outcrops, extreme slopes, slip prone areas, poor soils, streams, ridges, saddles, hillside benches, property lines, access points and end point on a topo map. Lay the road out on a contour map with a pencil hitting or missing these control points. Calculate the grade of the road, attempting to keep it below 10 percent. This will show where sections are too steep and the road needs to be moved. Grades over 12 percent for more than a few hundred feet should be avoided if possible. Change the location of the road or break the grade to maintain the optimum grade. After all the changes are made it is time to go to the field to verify the site conditions.

Next mark on the map the tentative locations of the culverts using this formula:

$$400/\% \text{ grade} + 75' = \text{culvert spacing}$$

Do not space culverts more than 300' apart.

In field walk the centerline. Locate the control points and flag the centerline by tying plastic ribbon at eye level. Using an Abney Level or Clinometer, check the actual grades from ribbon to ribbon, back checking each run. Adjust the grade where the road exceeds 12 percent

Look for wet spots, springs and water features missed because of the topo map's scale. Move the centerline to miss any unmapped features or add culverts where needed. It may be necessary to move most of the culverts to make it easier to install them and to correctly locate where concentrated flows cross the road. If bedrock is found, the culvert can be moved down hill even if it exceeds the spacing requirement. Sometimes it is advantageous to add a culvert immediately above a steep section to keep upslope drainage from entering a high velocity section.

Approaches to public roads need an Entrance Permit from the Division of Highways. Do not allow water to run onto public roads, divert with berm or water bar. The BMP for STABILIZED CONSTRUCTION ENTRANCE can be used for permanent access roads.

Design and Construction Criteria

There are several critical design criteria that must be met if the long-term stability of an access road is to be maintained.

The key criteria are:

1. Cross-section
2. Road Grade
3. Ditch line protection
4. Water Control

5. Stream Crossing
6. Stabilization
7. Sediment Control

One of the most important design parameters is to keep the road grade as flat as possible. Any road grade over 10 percent can cause difficulties with surface stability, washing off of the gravel surface, and gully formation. If steeper sections (such as to get over a rocky section) are necessary install more culverts or break the grade, or add water bars.

Road Cross-Sections Five road cross-sections typically are used in road construction: crowned fill, crowned turnpike, outslope, inslope with ditch, and crowned and ditched (Figure 3.35.1).

The choice of which cross-section to use depends on the drainage needed, soil stability, slope, and the expected volume of traffic on the road. You can use these cross-sections in combination as the terrain changes or as drainage problems are encountered.

- Crowned fill section is for use on flat ground where water standing on a road surface may be a problem.
- Outslope section is for use on moderate slopes for low volume roads and stable soils. Outsloping can be more dangerous in wet and snowy weather. Broad-based dips and water bars can be used on this cross-section rather than culverts.
- Inslope with ditch section is for use on steep hills, areas with fine textured soils, winter logging, and areas where drainage is necessary.
- Crowned and ditched section is for high volume roads on steep side hills.

Road Grade: Road grade is the single most important factor in planning a low volume road. Road grades must be kept to a minimum. If possible do not exceed 10 percent. The maximum for short distances can be 12 percent but it will be harder to keep gravel in place, ditch lines are harder to stabilize and culverts, water bars and broad-based dips are harder to install. Ruts form easier and the higher runoff velocities will erode them faster.

Grade is expressed as a percent and can be determined as follows.

percent slope = rise in vertical feet divided by the horizontal run in feet.

Ditch line Protection: Recommended ditch line protection can be based on the grade as follows:

1. Less than 3 percent - grassed
2. 3 – 8 percent - grass with rolled erosion control products

3. Greater than 9 percent - riprap or equivalent geotextile (must submit manufacturers specifications and calculated velocities).

If the flows are significant the protection should be based on an engineering study of the particular characteristics of the waterway and soils.

For more information see DIVERSIONS.

Water Control Structures: The construction of roads can radically alter the hydrologic regime of the local watershed. By installing structures, devices and measures to reestablish or approximate the original flow paths, erosion and road maintenance can be almost eliminated. Conversely, failure to provide adequate flow management can create very serious erosion. In most situations, providing appropriate measures is straightforward and simple. Proper planning and the flexibility to address onsite problems are necessary to control storm flows and will make it easier to protect the investment of building the road and improve water quality.

The single most common problem on low volume roads is the lack of culverts. Culverts allow the upslope water to cross the road at right angles and without coming into contact with the road surface. Maintaining the natural flow path is critical to reducing erosion on roads. Streams of any size should NEVER be allowed to run down a road. The road surface can wash away and ditch lines can be destroyed.

Culverts: There are two types of culverts on roads. One is used to pass upslope perennial and intermittent streams across the road. The other is sometimes called a cross-drainage culvert and is used to move lesser amounts of water from springs, seeps and upslope runoff across the road.

Culverts must be installed at each stream/waterway crossing and periodically along the roadway. Cross-drainage culverts are spaced apart at least 125' and no more than 300'.

$$400/\text{percent grade} + 75' = \text{culvert spacing}$$

Install OUTLET PROTECTION at each culvert. Install a headwall or similar device at each culvert.

The minimum size should be 12 inches. The culvert chart (Table 3.35.1) can be used to size culverts with a drainage area up to 600 acres.

The minimum grade should be 1 percent and culverts should be installed from 25 to 45 degrees to the centerline of the ditch to minimize turbulence at the inlet.

Culverts must extend at least one foot beyond the toe of the fill. Do not discharge onto the side of a road fill. If not possible, design OUTLET PROTECTION using grouted riprap .

Firmly backfill the trench and around culvert with fine-grained material, taking care to create good contact underneath the pipe. Cover the top of the culvert with at least 12 inches of fill, more if heavy loads are anticipated on the road.

Drainage Area (Acres)	Table 3.35.1 Average Slope of Watershed			
	1%	4%	8%	16%
	Culvert Size			
1 – 25	24	24	30	30
26 - 50	24	30	36	36
51 – 100	30	36	42	48
101- 150	30	42	48	48
151 - 200	36	42	48	54
200 - 250	42	48	60	60
251 - 300	42	48	60	60
301 - 350	42	48	60	60
351 - 400	42	54	60	60
401 - 450	42	54	60	72
451 - 500	42	54	60	72
501 - 550	48	60	60	72
551 - 600	48	60	60	72
601 - 640	48	60	72	72

Broad-based Dips: Broad-based dips (Figure 3.35.3) were developed at the Fernow Experimental Forest in West Virginia to control surface water on Forest Service roads. Under the right conditions and correctly constructed they are an excellent method of controlling runoff.

Regular traffic can easily traverse them and once installed require little maintenance. However, they are almost impossible to install on steep roads and difficult to maintain in poor soil conditions. They are easily installed on roads with less than 10 percent grade and where the subgrade material is suitable:

Broad-based dips cannot be used to pass continuous flowing water across the road or under extended damp conditions such as where springs are located. Culverts are required in these situations.

Spacing for Broad-based Dips is the same as culverts.

$$400/\text{percent grade} + 75 \text{ feet} = \text{dip spacing}$$

Do not space broad-based dips more than 300 feet apart.

Water Bars: Water bars (Figure 3.35.4) are a small berm and swale construction across a road to direct surface water off the road and into a stabilized vegetated area. Water bars are useful on infrequently used or abandoned roads.

Water bars are installed similarly to TEMPORARY RIGHT-OF-WAY DIVERSIONS. They should be installed at an angle (30 to 45 degrees) across the road. The water bar must extend across the entire width of the road. They should never dam the water but should intercept and divert the water off the road. The discharge point should be fully open and protected from erosion and discharge to a stable vegetated area or undisturbed forest flow.

As with the broad-based dip it should not be used where there is a continuous flow of water such as a stream or spring or seep. It is very important the water bar not create erosion over the road fill. To prevent erosion use RIP RAP or a RECP.

The spacing for water bars is the same as for broad based dip.

Turnouts: Turnouts are extensions of the ditch line into a vegetated area or natural waterway. Sometimes the ground drops off either side of the road and a culvert can't be installed. A turnout can be constructed to transfer water away from the roadway into a natural water way or onto a flat well-vegetated area. Turnouts are similar to LEVEL LIP SPREADERS but for smaller quantities of flow. It is important that a dam isn't formed at the end that can erode and the turnout is PERMANENT SEEDED immediately upon completion.

It is possible to install a SEDIMENT TRAP at the end of many turnouts.

Stream Crossings: See the specification under INSTREAM CONSTRUCTION BMPS for more information. Bridges are always preferable to culverts when crossing a perennial stream.

Culverts installed for permanent applications must be designed at a minimum to pass the peak discharge from a ten-year/24-hour storm with out causing upstream backup and downstream scour.

Sediment Control: During construction sediment control will consist of installing appropriate sediment control devices such as BRUSH BARRIERS, SILT FENCE, SUPER SILT FENCE and SEDIMENT TRAPS. (Figure 3.35.2)

On extreme slopes it may be impossible to install anything other than a BRUSH BARRIER or SILT FENCE. Sediment control can be accomplished by following the recommendations in this BMP and by rapid restoration and stabilization according to the PERMANENT SEEDING specification. Recognizing these difficulties, DEP will allow lesser sediment control if offset by an aggressive stabilization schedule shown in the SWPPP.

Critical areas such as stream crossings will still require appropriate sediment control while in other areas smaller traps/sumps may be used. Alternative sediment controls can be pursued or modifying existing one

may be necessary. One place is at the head of most of the side ditch culverts. A small sediment trap/sump can be installed here.

This BMP does not cover specifications for earth moving nor sets out standards other than the basics covered above.

For more information on construction see the following drawings.

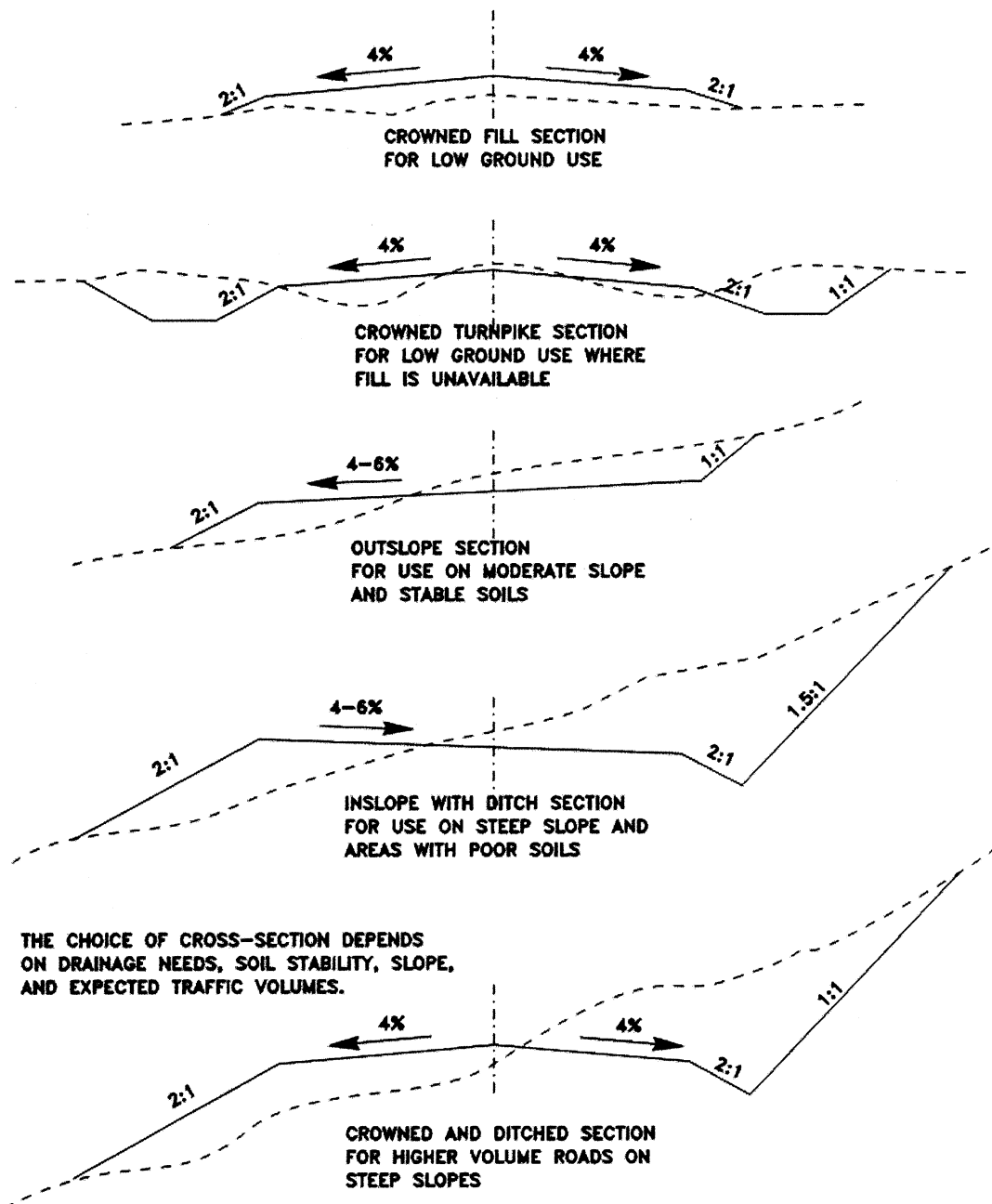
Maintenance

Initially inspect the road after each rainfall of 0.5 inch or more. Initially it would be better to inspect during the first few rainstorms. Look for water running down the road and for scour in the ditch lines. Look for water coming out of cut slopes and for upslope concentrated flows not going to culverts. If water bars or broad based dips are used see if they are deep enough to capture road surface runoff. If runoff goes past either practice, repair immediately.

If ruts are found immediately regrade and direct runoff into ditch line or to outslope as necessary.

FIGURE 3.35.1

TYPES OF ROAD CROSS-SECTIONS



FROM: US FOREST SERVICE AND MICHIGAN DNR

FIGURE 3.35.2

SEDIMENT AND EROSION CONTROL FOR ACCESS ROADS AND DRIVEWAYS

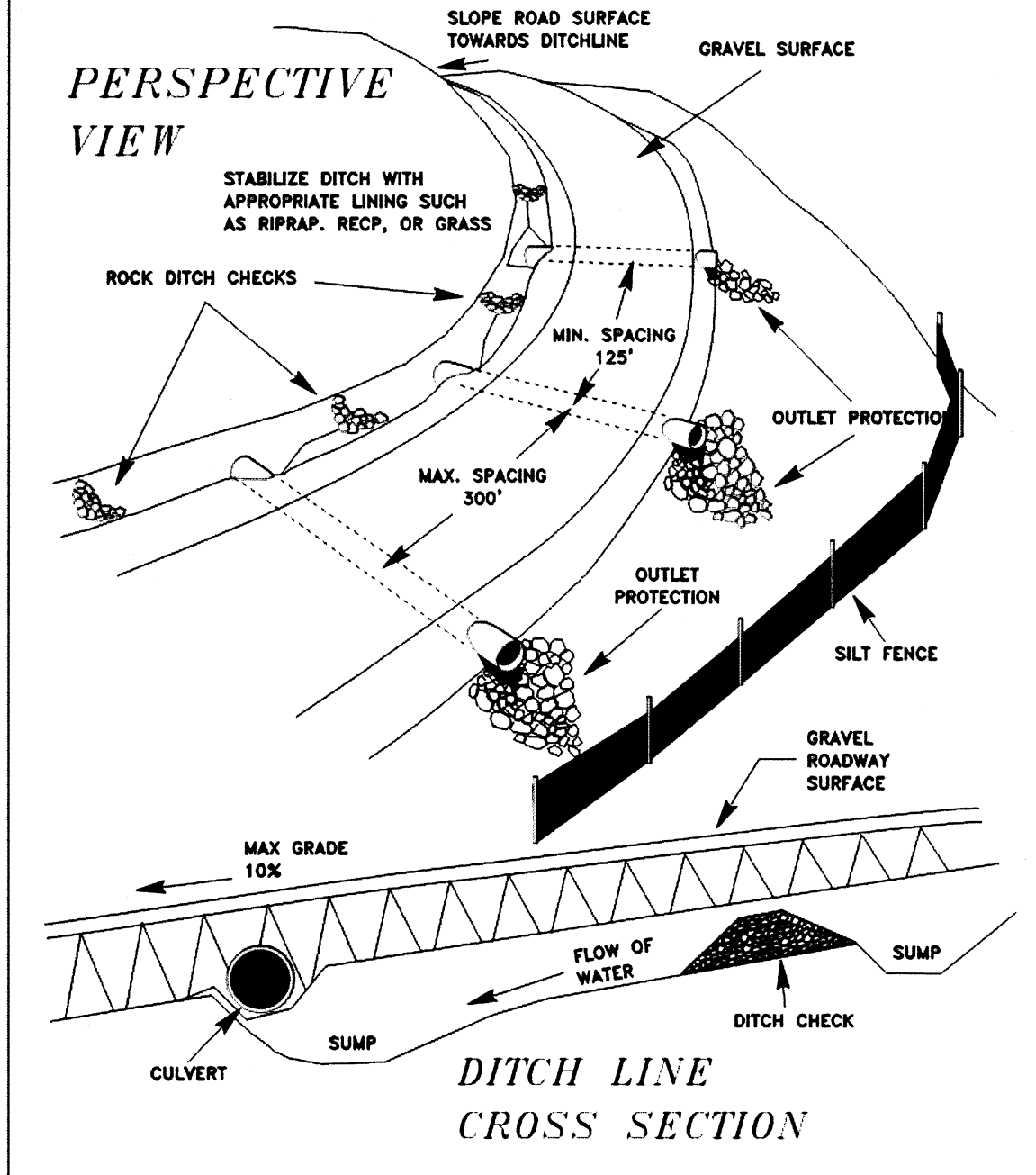
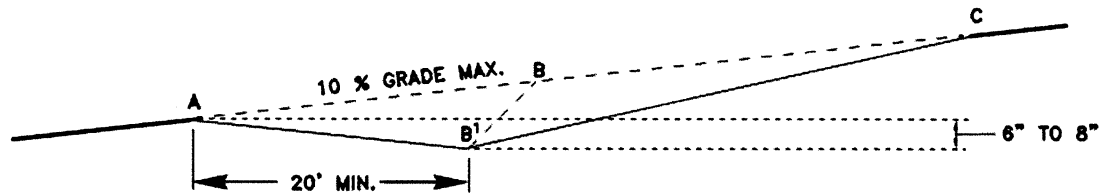
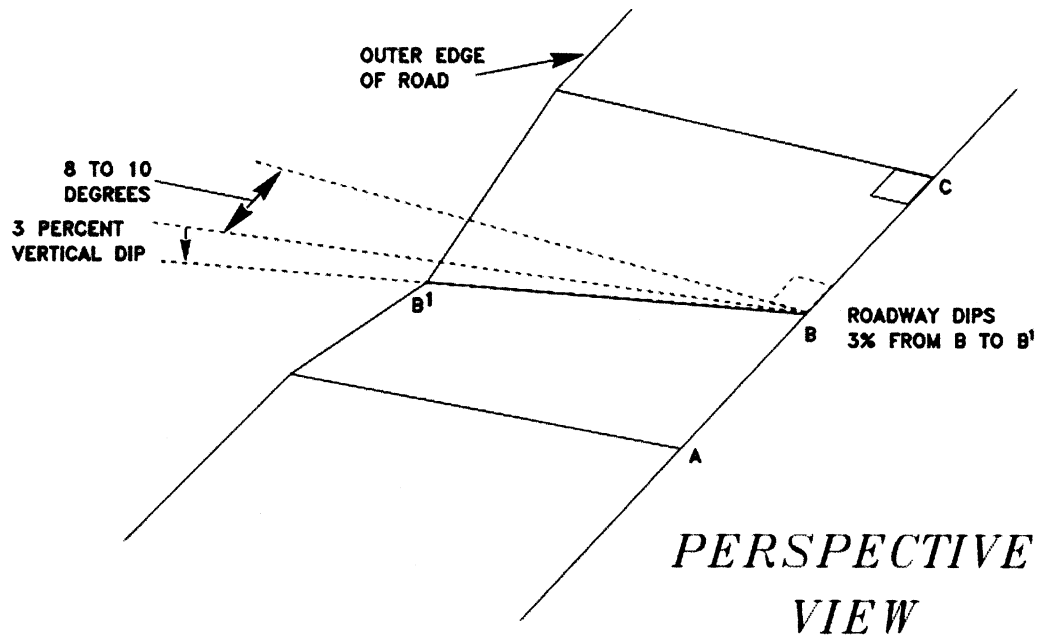


FIGURE 3.35.3

BROAD-BASE DIP



CROSS-SECTION

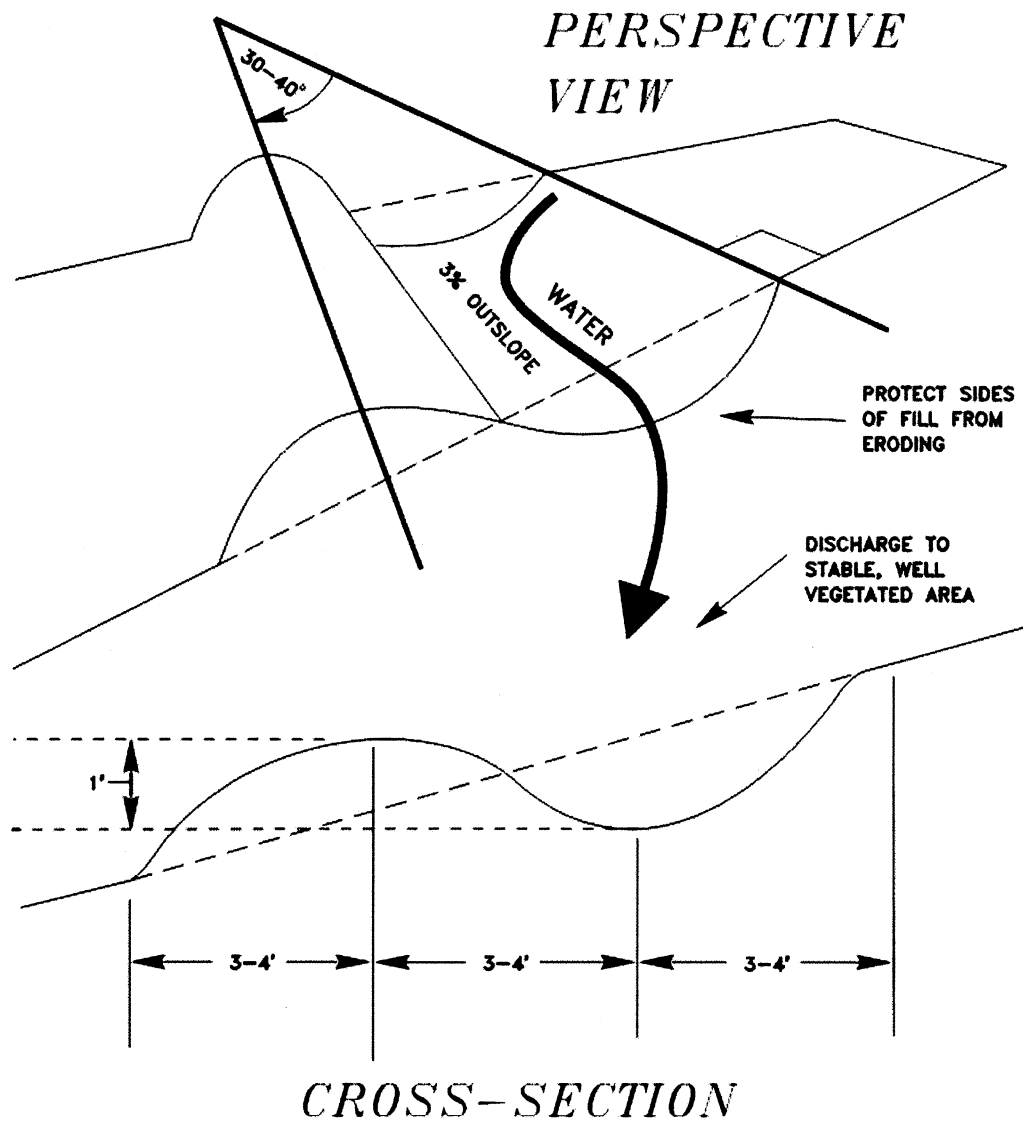


PERSPECTIVE VIEW

$$\text{SPACING} = 400/\% \text{ GRADE} + 75'$$

FIGURE 3.3.4

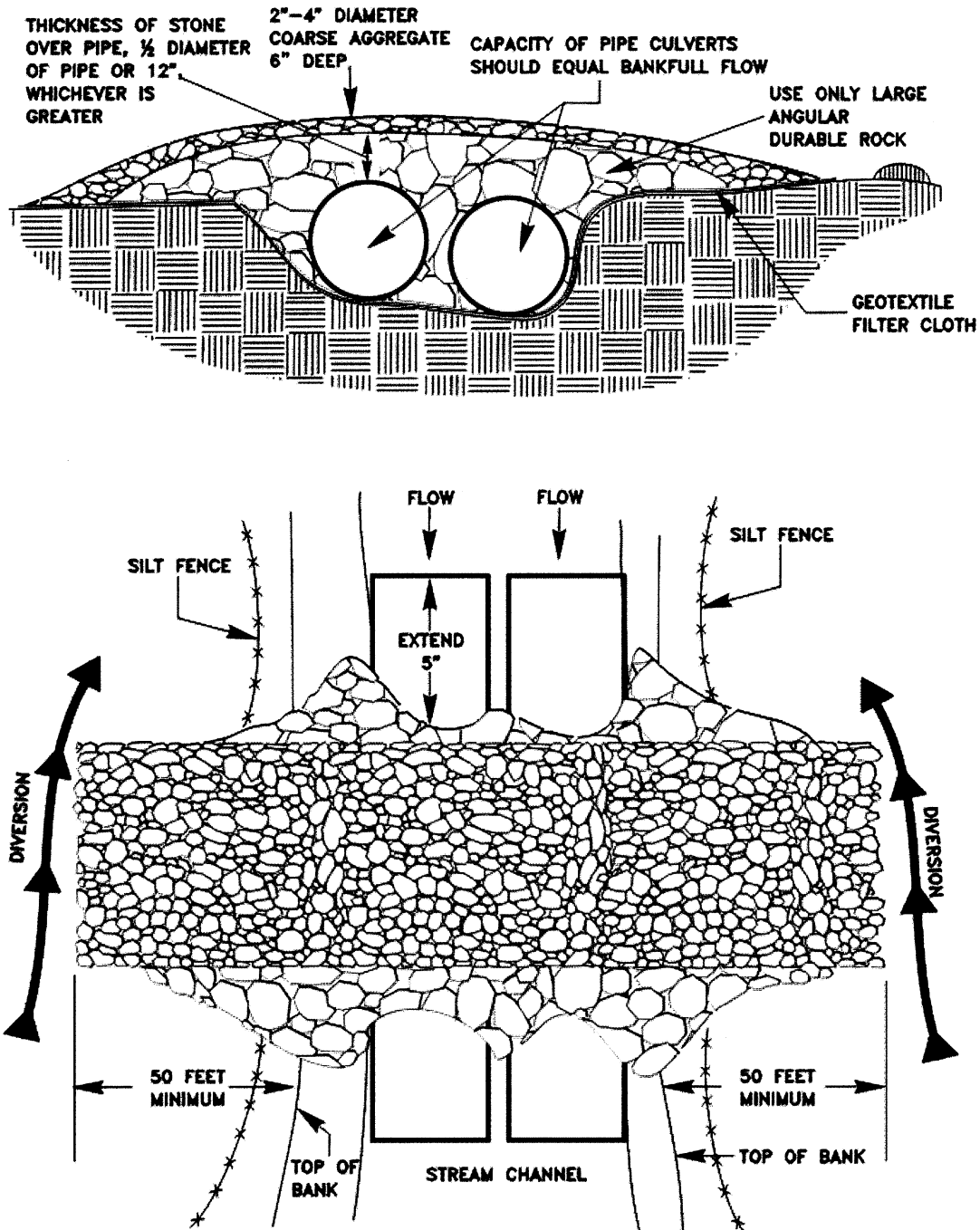
WATER BAR



INCREASE THE DISTANCE BETWEEN
THE BOTTOM OF THE DIP AND TOP
OF THE BERM FOR IMPROVE DRIVEABILITY

FIGURE 3.35.5

CULVERT STREAM CROSSING



FROM: VA DSWC

CHAPTER 4

HYDROLOGY

URBAN HYDROLOGY FOR SMALL WATERSHEDS (TR-55)

URBAN HYDROLOGY FOR SMALL WATERSHEDS – TR-55

The following information was developed by the United States Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division in Urban Hydrology for Small Watersheds TR-55, Technical Release 55 June 1986.

Preface

Technical Release 55 (TR-55) presents simplified procedures to calculate storm runoff volume, peak rate of discharge, hydrographs, and storage volumes required for floodwater reservoirs. These procedures are applicable in small watersheds, especially urbanizing watersheds, in the United States. First issued by the Soil Conservation Service (SCS) in January 1975, TR-55 incorporates current SCS procedures. This revision includes results of recent research and other changes based on experience with use of the original edition.

The major revisions and additions are:

- A flow chart for selecting the appropriate procedure;
- Three additional rain distributions;
- Expansion of the chapter on runoff curve numbers;
- A procedure for calculating travel times of sheet flow;
- Deletion of a chapter on peak discharges;
- Modifications to the Graphical Peak Discharge method and Tabular Hydrograph method;
- A new storage routing procedure;
- Features of the TR-55 computer program; and
- Worksheets.

This revision was prepared by Roger Cronshey, hydraulic engineer, Hydrology Unit, SCS, Washington, DC; Dr. Richard H. McCuen, professor of Civil Engineering, University of Maryland, College Park, MD; Norman Miller, head, Hydrology Unit, SCS, Washington, DC; Dr. Walter Rawls, hydrologist, Agricultural Research Service, Beltsville, MD; Sam Robbins (deceased), formerly hydraulic engineer, SCS, South National Technical Center (NTC), Fort Worth, TX; and Don Woodward, hydraulic engineer, SCS, Northeast NTC, Chester, PA. Valuable contributions were made by John Chenoweth, Stan Hamilton, William Merkel, Robert Rallison (ret.), Harvey Richardson, Wendell Styner, other SCS hydraulic engineers, and Teresa Seeman.

Revised June 1986

Update of Appendix A January 1999

A copy of the TR-55 Manual can be obtained at:

www.wcc.nrcs.usda.gov/hydro/hydro-tools-models-tr55.html

CHAPTER 5

DESIGN EXAMPLES

Sediment Basin Design Example

Problem statement: Design a sediment basin that captures a drainage area of 25 acres during construction. The disturbed project area equals the drainage area to the basin.

When locating your basin, try to capture as much of the disturbed area from the construction site as necessary, while diverting as much undisturbed runoff coming to the site as possible.

Calculate the resultant total area draining to basin = 25 acres.

Calculate the total disturbed area draining to basin = 25 acres.

Required wet storage = 25 ac. x 1800 cf/ac = 45,000 cf

Required dry storage = 25 ac. x 1800 cf/ac = 45,000 cf

The clean-out volume corresponds to the volume equal to half the wet storage volume.

Clean-out volume = 25 x 900 cf/ac = 22,500 cf.

Stage-Storage Chart (determined from the basin/pond geometry, which is not given for this example). Assumes the following:

Elevation (ft.)	Sum Volume (ac-ft.)
151	0.00
152	0.15
153	0.33
154	0.55
155	0.81
156	1.10
157	1.44
158	1.82
159	2.25
160	2.73
161	3.26
162	3.84
163	4.48
164	5.18
165	5.93
166	6.75

With a pond bottom of elevation 151, the corresponding elevation for the wet storage volume = 45,000 cf (1.033 ac-ft) is approximately 155.8 feet.

The clean-out elevation is the elevation corresponding to the clean-out volume = 22,500 cf (0.52 ac-ft), which is equal to approximately 153.9 feet. Show this elevation on the plans and provide a means of determining it in the field.

With the wet storage volume elevation set at 155.8, the corresponding elevation for the dry storage volume (cumulative 90,000 cf or 2.066 ac-ft) is approximately 158.6 feet.

Set the top of the temporary riser above this elevation so top of riser = 159.0.

A perforated riser with a hole or series of holes should be provided at the wet storage elevation. In order to dewater the sediment basin in 48 to 72 hours, perforations should be sized in the riser according to the following equation:

$$A_o = A_s \times (2h)^{0.5} / (T \times C_d \times 20,428)$$

Where

A_o = total area of dewatering holes, ft²

A_s – surface area of the basin, sq.ft.

H = head of water above the hole, ft

C_d = coefficient of contraction for an orifice, ~ 0.6

T = detention time needed to dewater the basin, hours

Using the basin geometry gives:

$$A_o = 21,000 \text{ sq.ft.} \times (2 \times 3.2 \text{ ft.})^{0.5} / (72 \times 0.6 \times 20428)$$

$A_o = 0.06 \text{ sq.ft.}$ which equals an orifice area with a diameter of 3.3 inches.

Use 3 – 1-inch holes

Compute the peak discharge from a 2-year and 25-year, 24-hour storm event.

Condition	Area	CN	Tc
	Acre		Hrs
Pre-developed	25	73	0.499
Post-developed	25	78	0.267

From TR-55 Worksheets 2 and 3

Perform Preliminary Hydrologic Calculations

The site is located in a county in West Virginia that has the following 24-hour rainfalls:

2-year, 24-hour rainfall = 2.75 inches

25-year, 24-hour rainfall = 4.78 inches

Condition	Q 2-yr	Q2-yr	Q 25-yr	Q 25-yr
Runoff	inches	cfs	inches	cfs
Post-developed	0.962	24.4	2.530	69.2

From TR-55 Worksheet 4 or 5b

Determine the maximum principal spillway capacity for a Q2 of 24.4 cfs

- Try a riser with a diameter of 36-inches and a barrel with a diameter of 24 inches, trying to keep the diameter of the riser = 1.5 x the diameter of the barrel to improve the efficiency of the principle spillway system.
- Solving the weir equation for the riser with a perimeter, $L = 9.4248$ feet and an area, $A = 7.06858$, gives an $H = 0.88$ feet. So the 2-year storm will pass through the temporary riser with an H of 0.88 feet.
- Check the pipe barrel performance for the 2-year event with an assumed size of 24-inches, a pipe length of 100 feet, a pipe slope of 10%, and a roughness coefficient of $n=0.024$.
- Solving the pipe equation for inlet control gives $Q = 45.4$ cfs (refer to Sediment Basin Outlet results).
- Solving the pipe equation for outlet control gives $Q = 44.0$ cfs (refer to Sediment Basin Outlet results).
-

For the 25-year design storm:

Condition	Q 25-yr	Q 25-yr
Runoff	inches	cfs
Post-developed	2.530	69.2

From TR-55 Worksheet 4 or 5b

- Knowing the Runoff Q (inches) from TR-55 Worksheet 2 and the Area (in square miles), compute the Runoff Volume $V_r = Q (A) 53.33$
 $= 2.53 \times 0.03906 \times 53.33 = 5.27$ ac. ft.

Stage-Storage Chart Using the stage-storage chart for a runoff volume of 5.27 ac-ft.-

Elevation	Sum Volume
(ft.)	(ac-ft.)
151	0.00
152	0.15
153	0.33
154	0.55
155	0.81
156	1.10
157	1.44
158	1.82
159	2.25
160	2.73
161	3.26
162	3.84
163	4.48
164	5.18
165	5.93
166	6.75

With a pond bottom of elevation 151, the corresponding elevation for the 25-year runoff volume = 5.27 ac-ft is approximately 164.1 feet. Set the emergency spillway at an elevation at least 1 foot minimum above the top of the temporary riser elevation of 159.0 feet, , while ensuring a minimum freeboard of 1' above the top of the basin elevation which is 164 feet. Try setting the emergency spillway at 161.00.

Use the Design Data for Earth Spillways (USDA-SCS) to determine the spillway width for the associated head. A width of 28 feet using the earth spillway design data allows for the passage of 56 cfs with 1 foot of head, and 179 cfs with 2 foot of head, assuming a z of 2 and an n value of 0.040. (See the Sediment Basin Outlet results).

Follow the recommendations for providing a core trench if necessary, anti-seep collars as needed, provide an allowance for settlement of the embankment, and provide baffles as needed.

Sediment Basin Outlet Results

Elevation	Orifice Outlet						36" Riser Outlet								24" Barrel Pipe				Emergency Spillway		Overtopping the Dam		Total Discharge	Storage
							Orifice		Weir		Orifice		Weir		Inlet		Outlet							
(ft)	H1 (ft)	Q (cfs)	H (ft)	Q (cfs)	H (ft)	Q (cfs)	H2 (ft)	Q (cfs)	H3 (ft)	Q (cfs)	H (ft)	Q (cfs)	H (ft)	Q (cfs)	H4 (ft)	Q (cfs)	H5 (ft)	Q (cfs)	H6 (ft)	Q (cfs)	H (ft)	Q (cfs)	Q (cfs)	Ac-ft.
151	0	0	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0.0	0.00
152	1	0	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0.0	0.15
153	2	0	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0.0	0.33
154	3	0	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0.0	0.55
155	4	0	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0.0	0.81
156	5	0	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0.0	1.10
157	6	0	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0.0	1.44
158	7	0	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0.0	1.82
159	8	0	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0.0	2.25
160	9	0	0	0	0	0	1	34.0	1	29.2	0	0	0	0	9	45.4	19	44.0	0	0	0	0	29.2	2.73
161	10	0	0	0	0	0	2	48.1	2	82.6	0	0	0	0	10	47.8	20	45.2	0	0	0	0	45.2	3.26
162	11	0	0	0	0	0	3	59.0	3	151.8	0	0	0	0	11	50.2	21	46.3	1	56	0	0	102.3	3.84
163	12	0	0	0	0	0	4	68.1	4	233.7	0	0	0	0	12	52.4	22	47.4	2	179	0	0	226.4	4.48
164	13	0	0	0	0	0	5	76.1	5	326.7	0	0	0	0	13	54.5	23	48.4	3	361	0	0	409.4	5.18

Orifice Equation
 Inv. =
 centerline =
 C=
 A=
 $Q=CA((2gH)^{1/2})$

Riser Orifice Equation
 Inv. = 159
 C= 0.6
 A= 7.0686
 $Q=CA((2gH)^{1/2})$

Riser Weir Equation
 Inv.= 159
 C= 3.1
 L= 9.4248
 $Q=CL(H^{3/2})$

Barrel Inlet Control
 Inv. = 150
 centerline = 151
 C= 0.6
 A= 3.1416
 $Q=CA((2gH)^{1/2})$

Barrel Outlet Control
 Inv. Out= 140
 Centerline= 141
 L= 100
 km= 0.024
 kp= 0.0246
 A= 3.1416
 $Q=A[(((2gH)/(1+km+kpL))^{1/2})]$

Emergency Spillway taken from USDA-SCS
 Earth Spillway Data
 Width = 28', z=2, n=0.040

Stormwater Management Pond Design Example

Problem statement: Design a stormwater management extended detention pond that will provide control of the channel protection volume (1-yr) event with a 24-hour extended detention time, the overbank protection volume (10-year) event, and also safely pass the 100-year event.

Step 1 – Compute runoff control volumes from the SCS approach.

Be sure to check to see if there is a Water Quality Volume (WQv) requirement, and compute as required (for example, there is a WQv requirement in Berkeley County). The following example assumes there is no water quality volume requirement.

Develop Site Hydrologic and Hydrologic Input Parameters. Any hydrologic models using SCS procedures, such as TR-20, HEC-HMS, or HEC-1, can be used to perform preliminary hydrologic calculations. Chapter 4 of the manual contains TR-55 Urban Hydrology for Small Watersheds that gives instructions and examples in determining the Runoff Coefficient, and Time of Concentration. TR-55 methodology is used in this design example.

Condition	Area	CN	Tc
	Acre		Hrs
Pre-developed	38	73	0.499
Post-developed	38	78	0.267

From TR-55 Worksheets 2 and 3

Perform Preliminary Hydrologic Calculations

The site is located in a county in West Virginia that has the following 24-hour rainfalls:

1-year, 24-hour rainfall = 2.35 inches

10-year, 24-hour rainfall = 4.20 inches

100-year, 24-hour rainfall = 5.75 inches

Condition	Q 1-yr	Q1-yr	Q 10-yr	Q 100-yr
Runoff	inches	cfs	cfs	cfs
Pre-developed	0.49	29.2	115.3	210.7
Post-developed	0.69	62.8	197.2	335.3

From TR-55 Worksheet 4 or 5b

Compute Channel Protection Volume, (Cpv)

For stream channel protection, provide 24 hours of extended detention for the 1-year event.

Utilize SCS approach to compute channel protection storage volume

- Initial abstraction (I_a) for CN of 78 is 0.564 [$I_a = (200/CN)-2$]
- $I_a/P - (0.564)/2.35 \text{ inches} = 0.24$
- $T_c = 0.267 \text{ hours}$
- $q_u = 645 \text{ csm/in}$ (Type II storm)

Knowing q_o , q_i , q_u and T (extended detention time), find q_o/q_i for the 1-year design event. For a Type II rainfall distribution, and using TR-55 Worksheet 6a:

- Peak outflow discharge/peak inflow discharge (q_o/q_i) = $29.2/62.8 = 0.465$
- Using q_o/q_i and TR-55 Figure 6-1, find V_s/V_r , where V_s equals channel protection storage (C_{pv}) and V_r equals the volume of runoff in inches.
- $V_s/V_r = 0.295$
- Knowing the Runoff Q (inches) from TR-55 Worksheet 2 and the Area (in square miles), compute the Runoff Volume $V_r = Q (A) 53.33$
 $= 0.692 \times 0.1406 \times 53.33 = 5.19 \text{ ac. ft.}$
- Storage Volume $V_s = V_r (V_s/V_r) = 5.19 \times 0.295 = 1.53 \text{ ac.ft}$ or 66,647 cf.

Compute Overbank Flood Protection Volume, (Q10-yr)

Knowing q_o , q_i , q_u and T (extended detention time), find q_o/q_i for the 10-year design event. For a Type II rainfall distribution, and using TR-55 Worksheet 6a:

- Peak outflow discharge/peak inflow discharge (q_o/q_i) = $115.3/197.2 = 0.585$
- Using q_o/q_i and TR-55 Figure 6-1, find V_s/V_r , where V_s equals overbank flood protection volume storage and V_r equals the volume of runoff in inches.
- $V_s/V_r = 0.250$
- Knowing the Runoff Q (inches) from TR-55 Worksheet 2 and the Area (in square miles), compute the Runoff Volume $V_r = Q (A) 53.33$
 $= 2.048 \times 0.1406 \times 53.33 = 15.36 \text{ ac. ft.}$
- Storage Volume $V_s = V_r (V_s/V_r) = 15.36 \times 0.250 = 3.84 \text{ ac.ft}$ or 167,270 cf.

Analyze Safe Passage of the 100-Year Design Storm (Q100)

Check to see if there are any local requirements or field observations that would advocate controlling the 100-year storm. If so, storage estimates would have been made similar to the volumes in the previous steps.

Step 2 – Determine pond location and preliminary geometry. Keep in mind the recommendations of keeping the length to width ratio greater than 2:1, making the distance between the inflows and outflow of the pond as maximum as possible, and providing sediment forebays, safety ledges and other features recommended in the local jurisdiction.

Step 3 – Set water surface elevation for Channel Protection Event.

Use TR-55 Worksheet 6A to develop a stage/storage chart for the pond based on the preliminary geometry.

Stage-Storage Chart (determined from the basin/pond geometry, which is not given for this example) Assumes the following:

Elevation (ft.)	Sum Volume (ac-ft.)
151	0.00
152	0.15
153	0.33
154	0.55
155	0.81
156	1.10
157	1.44
158	1.82
159	2.25
160	2.73
161	3.26
162	3.84
163	4.48
164	5.18
165	5.93
166	6.75

Determine the maximum storage elevation corresponding to the storage volume computed in Step 1 for the 1-year channel protection event. From the stage-storage chart, the corresponding water surface elevation for the 1-year channel protection design event = 157.3.

Next, determine the size of a low-flow orifice by defining the average release rate to empty 1.53 ac-ft in 24 hours.

$$Q = (1.53 \text{ ac-ft} \times 43,560 \text{ ft}^2/\text{ac}) / (24 \text{ hrs} \times 3600 \text{ sec/hr}) = 0.771 \text{ cfs}$$

With the pond bottom set at elevation 151.0 feet, that gives an average head of 3.15 ft, as the pond empties from 157.3 feet to 151.00 feet. Solve the orifice flow equation:

$$Q = C A ((2 g h)^{1/2})$$

where

Q = discharge, cfs

C = discharge coefficient, 0.62

A = cross sectional area of the orifice, ft²

h = total head, using an average head of 3.15 ft to empty the volume.

Solving for the area, A, gives an orifice diameter of approximately 4 inches.

Step 4 – Set water surface elevation for Overbank Protection Volume.

From the stage/storage chart, determine the maximum storage elevation corresponding to the 10-year design event storage volume.

From the stage-storage chart, the corresponding water surface elevation for the 10-year design event = 162.0 feet.

Set the elevation of the riser above the 1-year water surface elevation but below the 10-year water surface elevation and then calculate the size of the riser by solving the weir and orifice equations.

- Set the crest elevation at 160.0 feet, which gives a head of 2.0 feet. At this elevation, the low flow orifice head is 10.833', measured to the centerline of the orifice. Solving the orifice equation, the low flow orifice $Q = 1.4$ cfs.
- The maximum outflow $Q = 115.3 - 1.4$ cfs = 113.9 cfs (Pre-developed 10-year flow minus the orifice flow)
- Solving the weir equation for the riser gives an $L = 13.01$ feet. In order to make sure that the barrel pipe controls the flow before the riser is submerged, choose a riser with a slightly larger L . Therefore, select a 60-inch riser with a perimeter, $L = 15.7$ ft and an area, $A = 19.63$ square feet.
- Design the pipe barrel based on the 10-year storm event.
- Corresponding 10-year water surface elevation from above = 162.0 feet.
- Invert elevation = 150.0 feet.
- Head = 12.0 feet
- Determine the slope of the outlet pipe; Slope = 10%.
- Maximum $Q = 115.3$ cfs
- Assuming CMP, with a Manning's roughness $n = 0.024$, determine the diameter barrel to pass 115.3 cfs.
- Try a diameter $D = 36$ -inches.
- Solving the pipe equation for inlet control gives $Q = 110.3$ cfs (refer to Detention Basin Outlet results).
- Solving the pipe equation for outlet control gives $Q = 121.6$ cfs (refer to Detention Basin Outlet results).

Next, develop and complete the stage-discharge storage summary (see the Detention Basin Outlet result) up to the preliminary 10-year water surface elevation = 162.0 feet and route the 10-year post-developed condition inflow by hand or using computer software.

Step 5 - Design the emergency spillway based on safely passing the 100-year storm event with a minimum of 1 foot of freeboard.

Set the emergency spillway elevation above the 10-year water surface elevation, but at least a minimum of 2' below the top of the embankment. Setting the crest elevation at elevation 16 feet gives a head of 1.0 feet.

The maximum Q_{100} inflow = 210.7 cfs – 125 cfs (barrel outflow) = 85.7 cfs.

Use the Design Data for Earth Spillways (USDA-SCS) to determine the spillway width for the associated head. A width of 28 feet using the earth spillway design data allows for the passage of 56 cfs with 1 foot of head, and 179 cfs with 2 foot of head, assuming a z of 2 and an n value of 0.040. (See the Detention Basin Outlet results).

There are several excellent examples in various stormwater management manuals available on the internet for designing a stormwater management pond as well as other best management practices. This example only illustrates the preliminary, basic design for a stormwater management pond.

Detention Basin Outlet Results

Elevation	4" Orifice Outlet						60" Riser Outlet								36" Barrel Pipe				Emergency Spillway		Overtopping the Dam		Total Discharge	Storage
							Orifice		Weir		Orifice		Weir		Inlet		Outlet							
(ft)	H (ft)	Q (cfs)	H (ft)	Q (cfs)	H (ft)	Q (cfs)	H (ft)	Q (cfs)	H (ft)	Q (cfs)	H (ft)	Q (cfs)	H (ft)	Q (cfs)	H (ft)	Q (cfs)	H (ft)	Q (cfs)	H (ft)	Q (cfs)	H (ft)	Q (cfs)	Q (cfs)	Ac-ft.
151	0	0	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0.00	0.00
152	0.8333	0.38	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0.38	0.15
153	1.8333	0.57	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0.57	0.33
154	2.8333	0.71	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0.71	0.55
155	3.8333	0.82	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0.82	0.81
156	4.8333	0.92	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0.92	1.10
157	5.8333	1.01	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	1.01	1.44
158	6.8333	1.10	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	1.10	1.82
159	7.8333	1.18	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	1.18	2.25
160	8.8333	1.25	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	1.25	2.73
161	9.8333	1.32	0	0	0	0	1	94.52	1	48.7	0	0	0	0	9.5	104.9	19.5	118.5	0	0	0	0	50.0	3.26
162	10.833	1.38	0	0	0	0	2	133.67	2	137.7	0	0	0	0	10.5	110.3	20.5	121.5	0	0	0	0	110.3	3.84
163	11.833	1.45	0	0	0	0	3	163.71	3	252.9	0	0	0	0	11.5	115.4	21.5	124.5	0	0	0	0	115.4	4.48
164	12.833	1.51	0	0	0	0	4	189.04	4	389.4	0	0	0	0	12.5	120.3	22.5	127.3	1	56	0	0	176.3	5.18
165	13.833	1.56	0	0	0	0	5	211.35	5	544.1	0	0	0	0	13.5	125.1	23.5	130.1	2	179	0	0	304.1	5.93
166	14.833	1.62	0	0	0	0	6	231.52	6	715.3	0	0	0	0	14.5	129.6	24.5	132.9	3	361	0	0	490.6	6.75
Orifice Equation Inv. = 151 centerline = 151.17 C= 0.6 A= 0.087 sf Q=CA((2gH)^1/2) Riser Orifice Equation Inv. = 160 C= 0.6 A= 19.635 Q=CA((2gH)^1/2) Riser Weir Equation Inv.= 160 C= 3.1 L= 6.283 Q=CL(H^3/2) Barrel Inlet Control Inv. = 150 centerline = 151.5 C= 0.6 A= 7.0686 Q=CA((2gH)^1/2) Barrel Outlet Control Inv. Out= 140 Centerline= 141.5 L= 100 km= 0.024 kp= 0.0246 A= 7.0686 Q=A[(((2gH)/(1+km+kpL)))^1/2] Emergency Spillway taken from USDA-SCS Earth Spillway Data Width = 28', z=2, n=0.040																								

CHAPTER 6

SAMPLE PLAN –
INDIVIDUAL HOUSE SITE

SAMPLE PLAN –
SMALL COMMERCIAL DEVELOPMENT SITE

SAMPLE PLAN –
UTILITY LINE CROSSING

6.0 – Individual House

Sample Sediment and Erosion Control Plan

Primary Concerns Related to Erosion and Sedimentation

Water Quality

Sediment is the number one pollutant, by volume, of surface waters in the state of West Virginia. It impacts water quality by degrading the habitat of aquatic organisms and fish, by decreasing recreational value, and by promoting the growth of nuisance weeds and algae.

Flooding

Sediment accumulation in streams, lakes, and rivers reduces their capacity to contain stormwater, which can result in increased flooding.

Local Taxes

Sediment that finds its way into streets, storm sewers, and ditches results in additional maintenance costs for local, state, and federal governments.

Property Values

Sediment deposits not only impair water quality but also damage property, thus reducing its use and value.

Sample Erosion and Sediment Control Plan

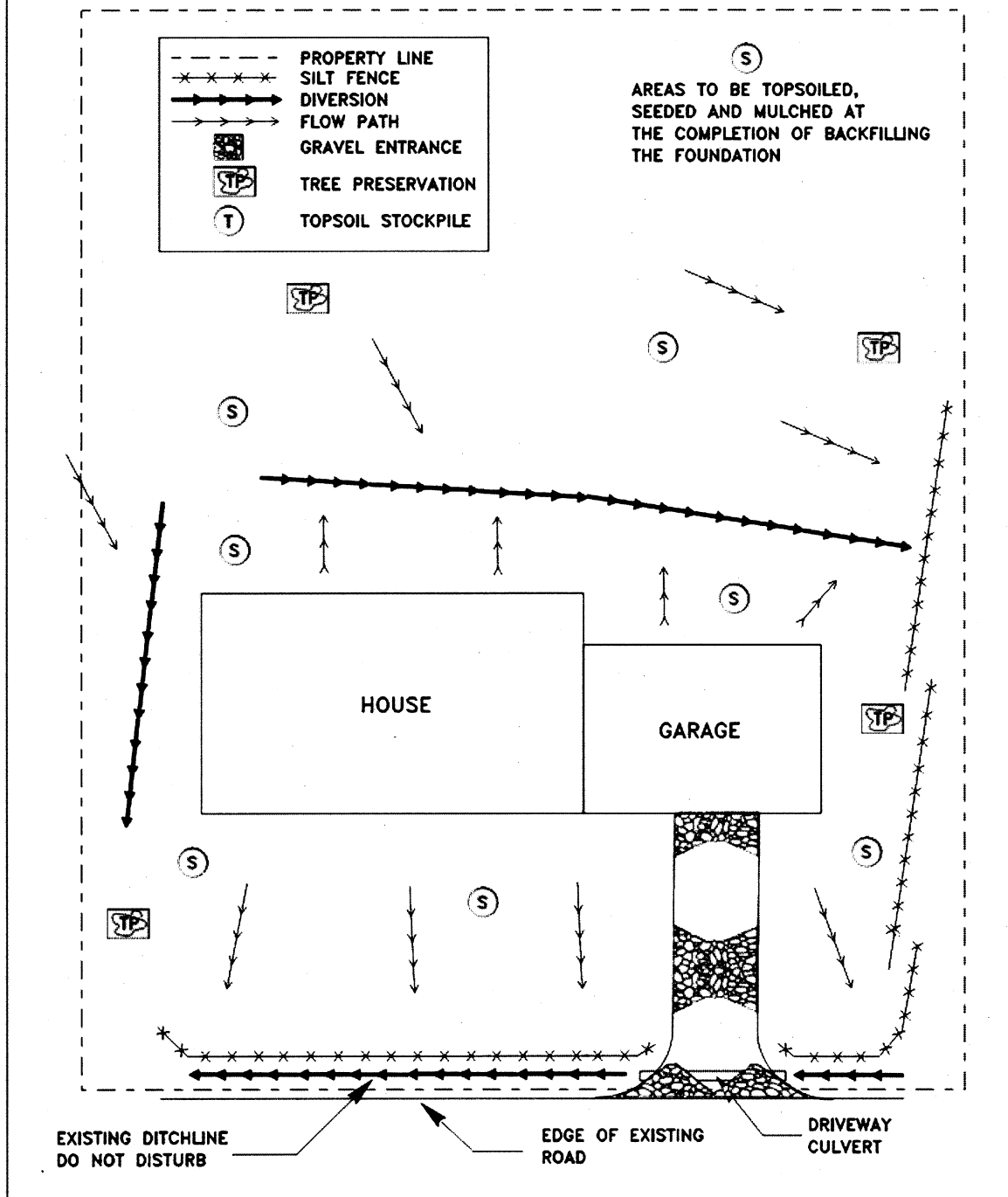
Every building site is unique and poses its own potential erosion hazards. In many instances, additional or alternative control methods are necessary if the lot is adjacent to a creek, lake, or wetland; slopes are greater than six percent; receives runoff from adjacent areas; and/or more than one acre of ground is disturbed.

NOTES:

1. It is the responsibility of the property owner and contractor to comply with State laws and local and county ordinances regarding construction site erosion and sediment control.
2. This plan is only a sample plan and is not intended to be all-inclusive or address every situation; additional or modified practices may be required on some sites.
3. Erosion or sediment control measures must be functional and maintained throughout construction.
4. Maintain positive drainage away from the structure(s).

FIGURE 6.1

INDIVIDUAL HOUSE LOT SEDIMENT CONTROL PLAN



Controlling Building Site Erosion & Sedimentation

Erosion control is important on any building site regardless of its size. Usually, principles and methods for controlling erosion and reducing offsite sedimentation are relatively simple and inexpensive. Here are four basic steps to follow when developing a building site.

Evaluate the Site

Inventory and evaluate the resources on the lot before building. Location of structures should be based on the lot's natural features. Identify trees that you want to save and vegetation that will remain during construction. Also identify areas where you want to limit construction traffic. Wherever possible, preserve existing vegetation to help control erosion and off-site sedimentation.

Select & Install Initial Erosion/ Sediment Control Practices

Determine the specific practices needed, and install them before clearing the site. Among the more commonly used practices are vegetative filter strips, silt fences, gravel drives, and inlet protection.

Develop a Maintenance Program

Maintenance of all practices is essential for them to function properly. Practices should be inspected twice a week and after each rainfall event. When a problem is identified, repair or replace the practice immediately. If frequent repairs are required (such as Silt Fence being knocked down), another more substantial practice may need to be selected. In addition, any sediment that is tracked onto the street should be scraped and deposited in a protected area. Do not flush sediment from the street with water.

Revegetate the Site

Providing a vegetative cover is the most important practice in preventing erosion and sediment. Therefore, establish vegetation as soon as possible. A well-maintained lot has a higher sale potential.

Building Lot Drainage

The best time to provide for adequate lot drainage is before construction begins. With proper planning, most drainage problems can be avoided. That's important because correcting a problem after it occurs is usually much more difficult and costly. Here's what it takes to ensure good lot surface and subsurface drainage.

Surface Drainage

- Position the structure a minimum of 18 inches above street level.

- Divert stormwater runoff away from the foundation by grading the lawn to provide at least six inches of vertical fall in the first ten feet of horizontal distance.
- Construct side and rear yard swales to take surface water away from the structure.
- Do not fill in existing drainage channels and roadside ditches, since that could result in wetness problems on someone else's property and/or damage to adjacent road surfaces.

Subsurface Drainage

- Provide an outlet for foundation or footer drains and for general lot drainage by using storm sewers (where allowed), or obtain drainage easements if you must cross adjoining properties.

Construction Sequence for Erosion & Sediment Control Practices

1. Evaluate the Site

Before construction, evaluate the site; mark vegetative areas and trees to be protected, unique areas to preserve, on-site septic system absorption fields, and vegetation suitable for filter strips, especially in perimeter areas.

Identify Vegetation to be Saved

Select and identify the trees, shrubs and other vegetation to be saved (see Step 2: "Vegetative Filter Strips").

Protect Trees & Sensitive Areas

- To prevent root damage, do not grade, burn, stock pile topsoil, or park vehicles near trees or in areas marked for preservation.
- Place plastic mesh or snow fence barriers around the trees' driplines to protect the area below their branches.
- Place a physical barrier, such as plastic fencing, around the area designated for a septic system absorption field (if applicable).

2. Install Perimeter Erosion and Sediment Controls

Identify the areas where sediment-laden runoff could leave the construction site, and install perimeter controls to minimize the potential for off-site sedimentation. It's important that perimeter controls are in place before any earthmoving activities begin.

Protect Down-Slope Areas with Vegetative Filter Strip

- On slopes of less than six percent, preserve a 20-to 30-foot wide (minimum) vegetative buffer strip around the perimeter of the property, and use it as a filter strip for trapping sediment.
- Do not mow filter strip vegetation shorter than four inches.

Protect Down-Slope Areas with Silt Fence and Other Appropriate Practices

- Use silt fencing along the perimeter of the lot's downslope side(s) to trap sediment. Refer to silt fence practices.

Install Stabilized Construction Entrance

- Restrict all lot access to this drive to prevent vehicles from tracking mud onto roadways or destroying perimeter controls. Refer to Stabilized Construction Entrances.

3. Prepare the site for construction

Prepare the site for construction and for installation of utilities. Make sure all contractors (especially the excavating contractor) are aware of areas to be protected.

Salvage and Stockpile Topsoil or Subsoil

- Remove topsoil (typically the upper four to six inches of the soil material) and stockpile.
- Remove subsoil, including any excavated material associated with basement construction, and stockpile separately from the topsoil.
- On small building sites, it may not be feasible to stockpile soil material on each individual lot due to space limitations. In these situations, soil material should be transported to protected areas designated on the overall construction plan or those areas designated by the developer.
- Locate the stockpiles away from any downslope street, driveway, stream, lake, wetland, ditch or drainageway.
- Immediately after stockpiling, temporary seed the stockpiles with annual rye or winter wheat and/or install sediment barriers around the perimeter of the piles.

4. Build Structure(s) and Install Utilities

Construct the home and install the utilities; also install the sewage disposal system and drill water well (if applicable); then consider the following:

Install Downspout Extenders

- Although not required, downspout extenders are highly recommended as a means of preventing lot erosion from roof runoff.
- Add the extenders as soon as the gutters and downspouts are installed.
- Be sure the extenders have a stable outlet, such as a paved area, or a well vegetated area. Do not route runoff directly to a street in winter due to the formation of ice.

Refer to temporary downspout extenders diagram.

5. Maintain Control Practices

Maintain all erosion and sediment control practices until construction is completed and the lot is stabilized.

- Inspect the control practices daily and after each storm event, making any needed repairs immediately.
- Toward the end of the each workday, sweep or scrape up any soil tracked onto roadway(s). Do not flush mud down the street with water.

6. Revegetate Building Site

Immediately after all outside construction activities are completed, stabilize the lot with sod, seed, and/ or mulch.

Redistribute the Stockpiled Subsoil and Topsoil

- Spread the stockpiled subsoil to rough grade.
- Spread the stockpiled topsoil to a depth of four to six inches over rough-graded areas.
- Fertilize and lime according to soil test results or recommendations of a seed supplier or a professional landscaping contractor. Fertilize and lime if needed according to soil test (or apply 10 lb./1000 sq. ft. of 10-10-10 fertilizer).

Seed or Sod Bare Areas

- Contact local seed suppliers or professional landscaping contractors for recommended seeding mixtures and rates.
- Follow recommendations of a professional landscaping contractor for installation of sod.
- Rake lightly to cover seed with ¼" of soil. Roll lightly.
- Water newly seeded or sodded areas every day or two to keep the soil moist. Less watering is needed once grass is two inches tall.

Mulch Newly Seeded Areas

- Spread straw mulch on newly seeded areas, using one and one half to two bales of straw per 1,000 square feet. The mulch should cover to where the ground is just visible.
- On flat or gently sloping land, anchor the mulch by crimping it two to four inches into the soil. On steep slopes, anchor the mulch with netting or tackifiers. An alternative to anchored mulch would be the use of erosion control blankets.

Temporary Seeding

If the site will not be permanently seeded anytime soon, sow 40 lbs of Annual Rye (year round) or 170 lbs. of Winter Wheat (fall and winter) per acre on all disturbed soils immediately upon backfilling the foundation.

7. Remove Remaining Temporary Control Measures

Once the sod and/or vegetation is well established, remove any remaining temporary erosion and sediment control practices, such as:

- Remove downspout extenders. Or, shorten to outlet on an established vegetated area, allowing for maximum filtration.
- Remove storm sewer inlet protection measures.

Individual Erosion & Sediment Control Practices for Homebuilders

Silt Fence

1. Install silt fence parallel to the contour of the land.
2. Extend ends upslope to allow water to pond behind fence.
3. Excavate a trench 4-inches wide, 8-inches deep.
4. Install fence with posts on the down slope side.
5. Place 12-inches of fabric in the trench, extending the bottom four inches toward the upslope side.
6. Join silt fence sections by using a wrap joint.
7. Backfill trench with soil materials and compact.
8. Inspect at least weekly and after each storm event, repairing as needed and removing sediment deposits when they reach one-half the fence height.

Note: Silt fence has a life expectancy of six months to one year, whereas straw bale barriers have a limited life of three months or less.

Stabilized Construction Entrance

1. Place six inches of 2" to 4" coarse aggregate over a stable subgrade.
2. Construct the drive at least 12-feet wide and 50-feet long or the distance to the foundation.
3. Add stone as needed to maintain six inches of clean depth.
4. To improve stability or if wet conditions are anticipated, place geotextile fabric on the graded foundation.

Temporary Downspout Extenders

1. Install extenders as soon as gutters and downspouts are installed to prevent erosion from roof runoff.
2. Use non-perforated (un-slotted) drainage tile.

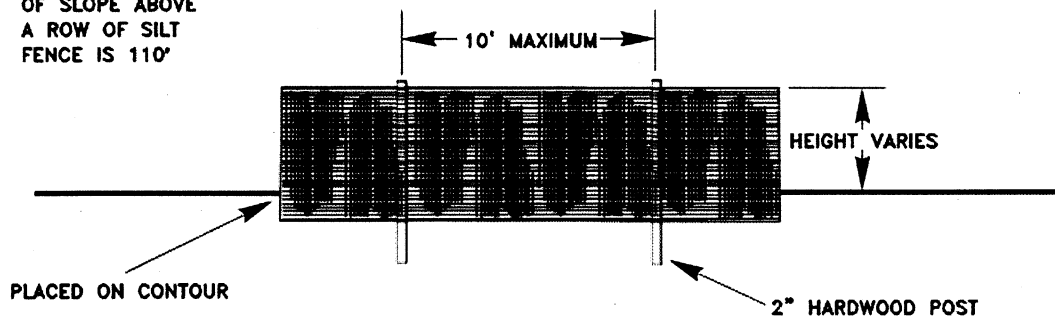
3. Route water to a stable grassed or paved area or to the storm sewer. Do not route water directly to a street or sidewalk in the winter due to the formation of ice.
4. Remove downspout extenders after vegetation is established.

For more detailed information of these and other practices, the West Virginia Erosion and Sediment Control Manual is available to assist you in making informed decisions.

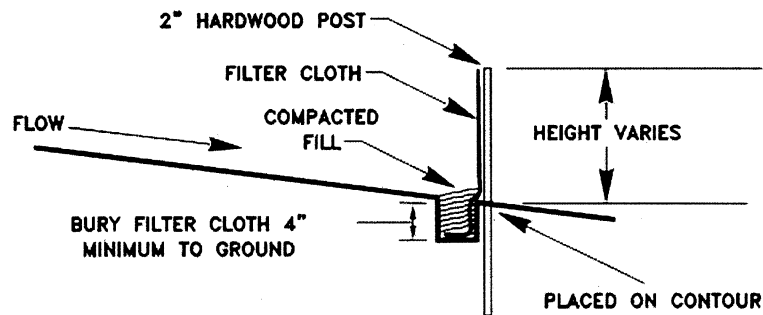
FIGURE 6.2

SILT FENCE

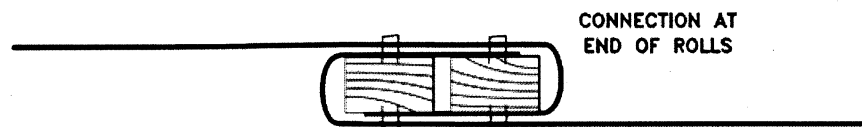
NOTE:
THE MAXIMUM LENGTH
OF SLOPE ABOVE
A ROW OF SILT
FENCE IS 110'



FRONT ELEVATION



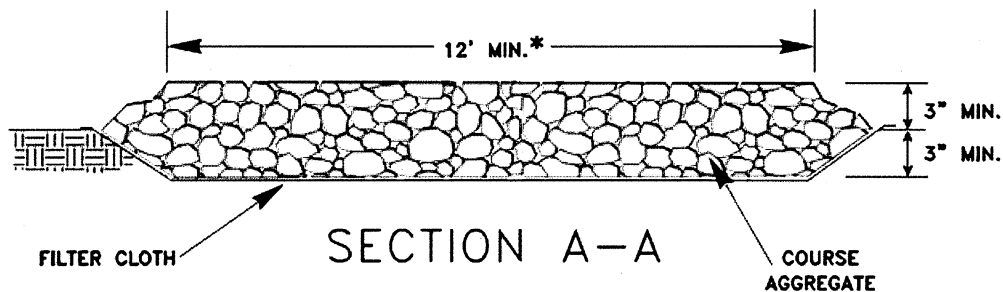
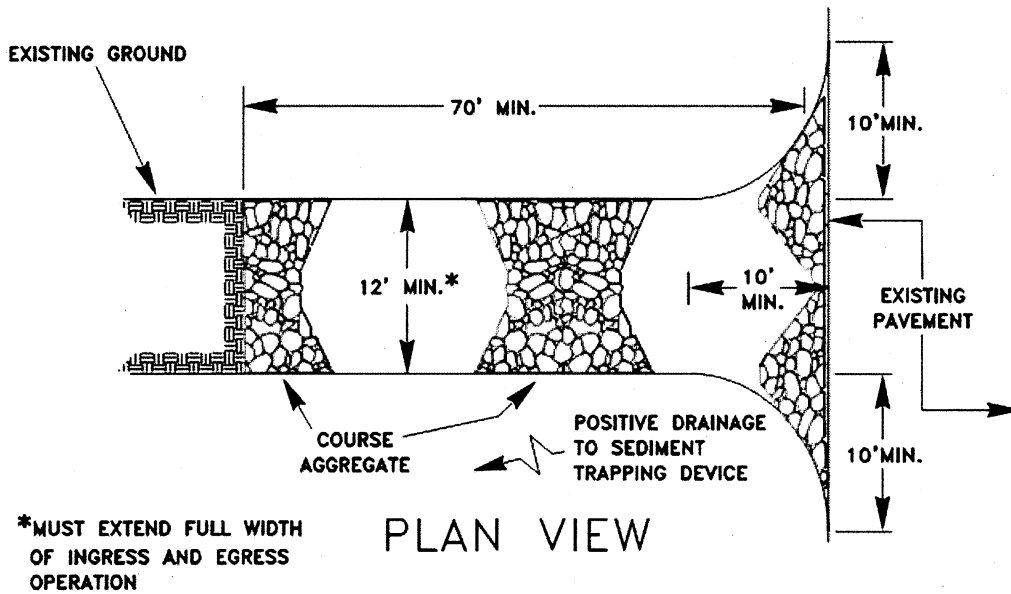
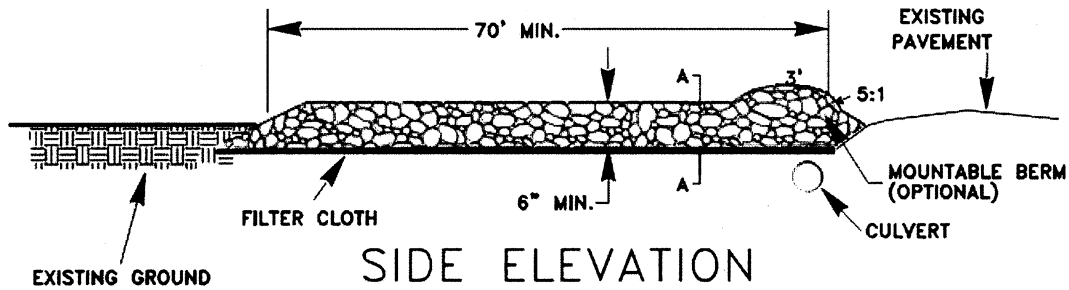
SIDE ELEVATION



TOP VIEW

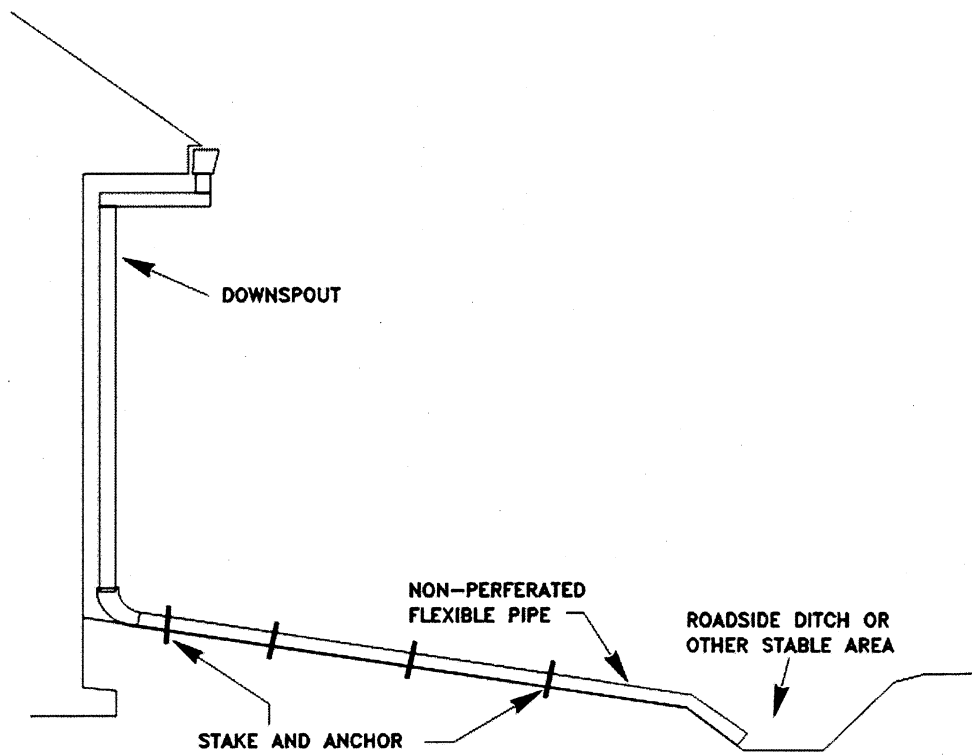
FIGURE 6.3

STONE CONSTRUCTION ENTRANCE



SOURCE: ADAPTED from 1983 Maryland Standards for Soil Erosion and Sediment Control and Va. DSWC

FIGURE 6.4



CHAPTER 7

STREAM RESTORATION STANDARD GUIDELINES AND SPECIFICATIONS

Chapter 7 – Stream Restoration BMPs

Introduction

The Natural Stream Design (NSD) approach to stream restoration uses the characteristics of a stable stream to design the restoration of an unstable one. Some of the stream characteristics that should be identified are the bed and bank materials (clay, sand, gravel, cobble and bedrock), stream pattern, channel gradient, dimension and size of the floodplain.

NSD projects require federal and state permits for in-stream construction. Therefore, NSD projects are thoroughly reviewed by the resource agencies to assure that the project will have a net positive benefit on the aquatic resource. The NPDES program was designed to eliminate and/or dramatically reduce stormwater and associated sediment from upland residential, commercial or industrial construction projects from entering the watercourse. NSD projects aim to enhance/restore stable dimensions, patterns, and profiles to stream channels as well as to enhance/restore floodplains and riparian zones. Methods commonly employed involve the construction of new channel reaches, installation of in-stream structures (rock vanes, log vanes, cross vanes, J-hooks) and construction of floodplain benches. These activities take place in or immediately adjacent to the active stream channel. Best Management Practices (BMPs) for upland construction or other in-stream construction projects are not always practical or appropriate for NSD projects. Therefore, a set of BMPs specifically for NSD projects that reduce turbidity to reasonable, practical and acceptable levels during construction of the stream restoration project have been developed. In addition to the BMPs developed for NSD projects, other appropriate BMPs as defined in Chapter Three may be utilized in developing the Storm Water Pollution Prevention Plan (SWPPP).

Conditions where Practice Applies

NSD is a broad term that encompasses a variety of projects that have the common goal of improving the quality of the stream ecosystem. Channelization and dredging to increase the flow capacity of the stream is not considered a NSD-type project. Impacts associated with channel construction such as increased turbidity, disturbance of channel substrates and floodplain alteration can be visually dramatic. However, these temporary impacts are mitigated by long-term restoration of the impaired channel to a more natural stable condition.

**Planning
Considerations**

NSD projects may be relatively simple habitat improvement projects using structures such as cross vanes designed to improve pool habitat, or simple bank stabilization projects using rock/log vanes. Other NSD projects will be more complex and may physically alter the dimension, pattern, and/or profile of the stream.

Enhancement Projects – This category generally includes riparian buffer establishment; non-point source removal activities (livestock exclusion, removal of adjacent agriculture fields from further production, elimination of future timber harvest); bank revegetation; and/or removal or reduction of impervious surfaces in the watershed. The category also incorporates activities that augment channel stability, water quality and stream ecology in accordance with a reference condition where appropriate. These activities may include in-stream and/or streambank activities, but fall short of restoring one or more of the geomorphic variables, which include dimension, pattern and profile. Examples may include stabilization of streambanks using bioengineering techniques; creation of bankfull benches; and introduction of in-stream habitat.

Restoration Projects – These projects involve the conversion of an unstable, altered or degraded stream corridor, including adjacent riparian zones (buffers) and flood-prone areas, to a natural stable condition based on historical, recent and future watershed conditions. This process is typically based on a reference condition/reach for the stream valley type and includes restoration of the appropriate geomorphic dimension (cross-section), pattern (sinuosity), and profile (channel slope). This process supports reestablishing physical, biological and chemical integrity, including transport of the water and sediment produced by the stream's watershed in order to achieve dynamic equilibrium.

**Construction
Criteria**

The following general practices are accepted methods to be used to reduce temporary impacts associated with construction of NSD type projects. These practices are general in nature and some may be included as special conditions in the 404/401 permit. Some general BMP's may have more detailed specifications listed in following sub-sections. Other practices may be approved on a case by case basis.

1. On-site pre-application and/or pre-construction meetings are strongly encouraged to review each project, permit application and the selected BMP(s). These meetings should include the project designer, project sponsor(s), construction contractor(s), USACE, DNR, and DEP permitting and/or enforcement personnel and other appropriate personnel.

2. Clean and inspect equipment prior to arriving on the construction site and before leaving the site to minimize transferring invasive species and contaminating the aquatic system with fluids.
3. If it's necessary for maneuvering equipment prune overhanging vegetation prior to construction. All pruned vegetation should be cut clean.
4. Minimize construction time, and maximize efficiency by:
 - a. Utilizing the proper size, type and quantity of equipment
 - b. Ensuring that the sufficient type, quality and quantity of materials are on-site during construction
 - c. Ensuring sufficient personnel are on-site during construction
 - d. Preparing and following an effective sequence of construction
 - e. Minimizing down time. Once the project is under construction, it should be completed without undue delay.
5. Preserving riparian vegetation (including sod) is critical for minimizing site disturbance, reduction of upland sediment inputs, and post-construction project stability (see appropriate BMPs in Chapter Three).
6. Use upland transportation corridors to minimize impacts to the riparian zone.
7. Work in-the-dry or from the top of bank whenever feasible and practical. Minimize the amount of time and extent of disturbance in the channel as much as possible.
8. Pump-around may be used when feasible and practical.
9. Update field map with minor field modifications daily.
10. While the permit is in effect, project sites must be stabilized according to the approved Erosion and Sediment Control Plan for the 1-year, 24-hour rainfall event, **or bankfull event for NSD projects**. If a storm event exceeds the 1-year, 24-hour rainfall limit **or bankfull**, follow "upset procedures" in General Permit conditions.
11. Practice contemporaneous site reclamation to the extent feasible and practical during construction. Stabilize all

disturbed areas concurrently with restoration activities (see appropriate BMPs in Chapter Three).

12. Follow manufacturer specifications on equipment and materials, or provide the justification to vary from them in NPDES permit application.

7.01- IN-STREAM STRUCTURES, RIFFLES AND POOLS

Introduction

In-stream structures, and profile alterations such as riffles and pools, are constructed to provide bank stabilization, habitat enhancement, improved sediment transport and stream restoration. Types of structures may include cross vanes, rock vanes, j-hooks, and possibly log structures. In-stream structures and profile alterations are constructed to provide long-term stability to the stream reach.

Conditions Where Practice Applies

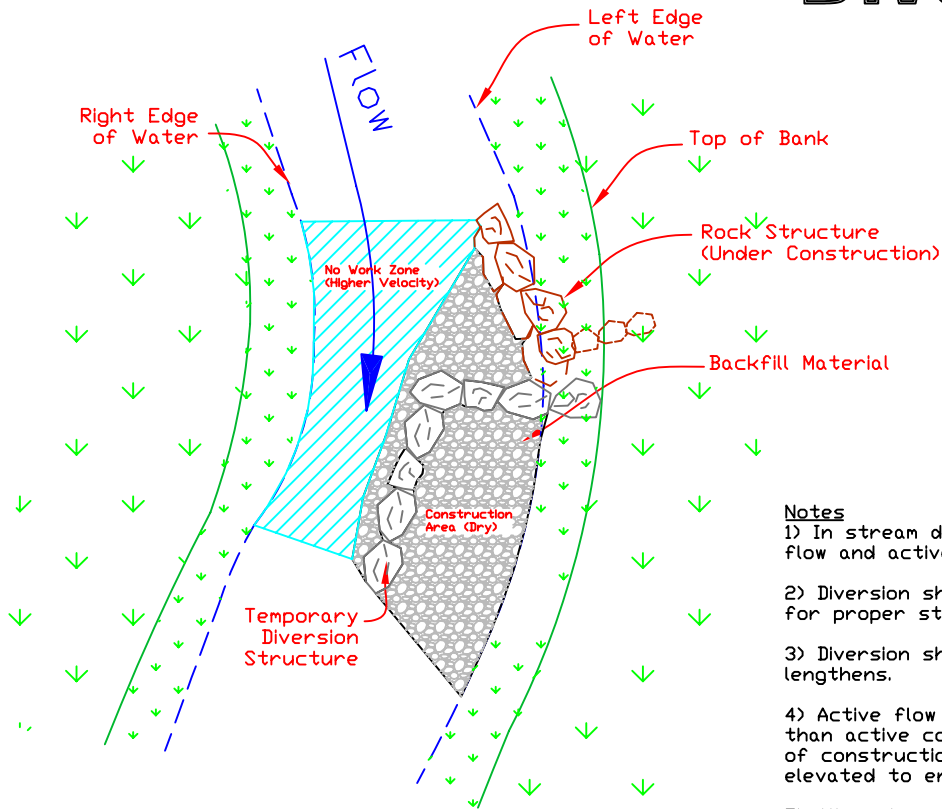
These techniques should be practiced, all or in part, during all phases of stream restoration projects. The practices that are determined most effective and feasible to sediment and erosion control for the specific site should be exercised.

Construction Specifications:

1. Where practical and feasible, in-stream work should be done on the side of the stream where the structure is being built.
2. Tracks of stationary equipment working in the stream should be parallel to stream flow when practical and feasible, to do so.
3. Minimize drop height when placing material in the channel.
4. Minimize use of temporary stream diversion/deflection structures (see drawings, attached) to reduce additional stream impacts. When used, deflection structures should:
 - a. Deflect flow away from the side of stream where structures are being placed and/or profile is being altered.
 - b. Be composed of native channel material if available adjacent to structure, and if channel material is to be removed anyway. This saves the impact of hauling in clean fill, while also hauling out channel material. If native channel material is not to be removed from an adjacent location, clean non-erodible rock with 15% or less of fines of like material should be imported to build deflection structures.
 - c. Serve as a platform upon which equipment can be stationed to build in-stream structure.
6. Use appropriately-sized equipment to build structures, with hydraulic thumbs to place rock. Equipment that is smaller than necessary will take more time; equipment that is larger than necessary will have more impact on the site.
7. Construction should be sequenced and specified effectively and efficiently to complete the project.

8. Where site conditions permit, turbidity curtains may be utilized per manufacturer's recommendations around structures under construction.
9. Geotextile (woven or non-woven) fabric should be placed behind structures and backfilled in channels with gravel beds (or finer particles).
10. Work in-the-dry or from the top of bank whenever feasible and practical. Minimize the amount and extent of disturbance in the channel as much as possible.
11. Pump-around may be used when feasible and practical.

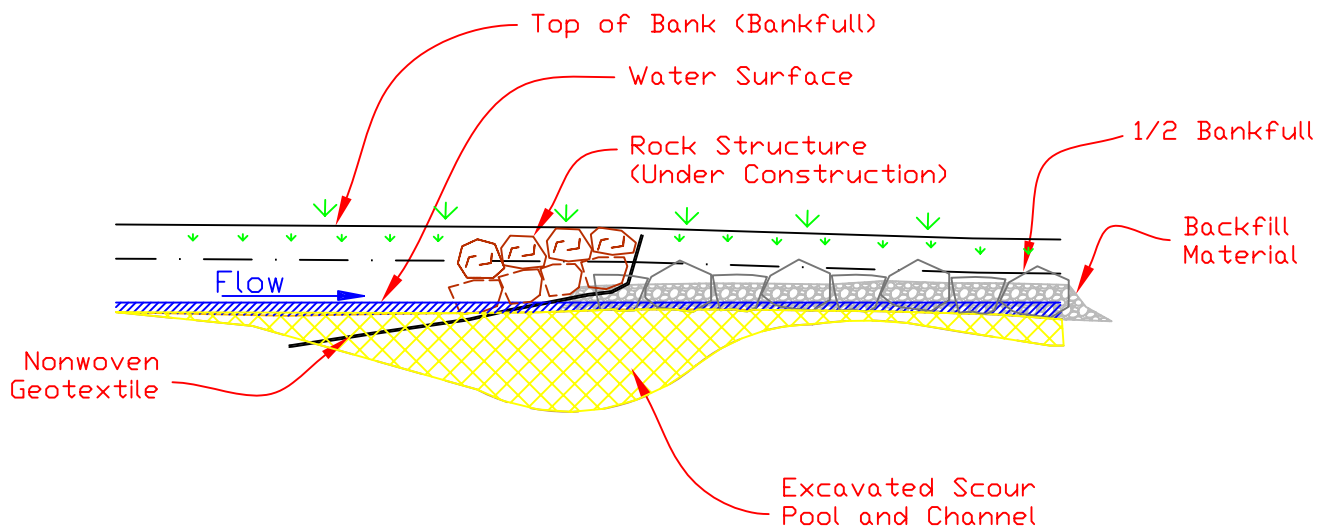
In Stream Diversion (Dry)



PLAN VIEW

Notes

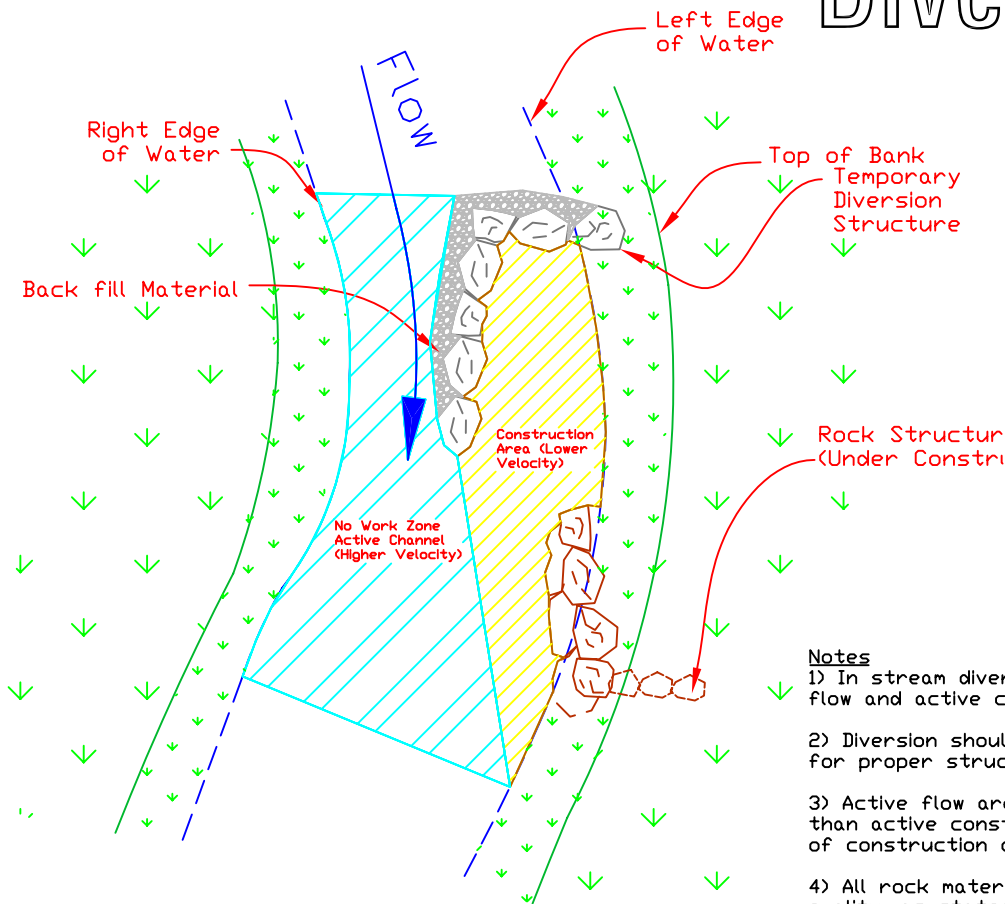
- 1) In stream diversion to act as barrier to the active flow and active construction area.
- 2) Diversion should be placed below structure and allow for proper structure placement.
- 3) Diversion shall expand up stream as structure lengthens.
- 4) Active flow area shall have a thalweg depth greater than active construction area to allow for dewatering of construction area. Active construction area will be elevated to ensure for a dry working area.
- 5) All rock materials shall be of proper size and quality, as stated in construction specifications.
- 6) All rock and fabric material used in construction of diversion should be removed immediately after completion of project.



PROFILE VIEW

Figure 7.01.2

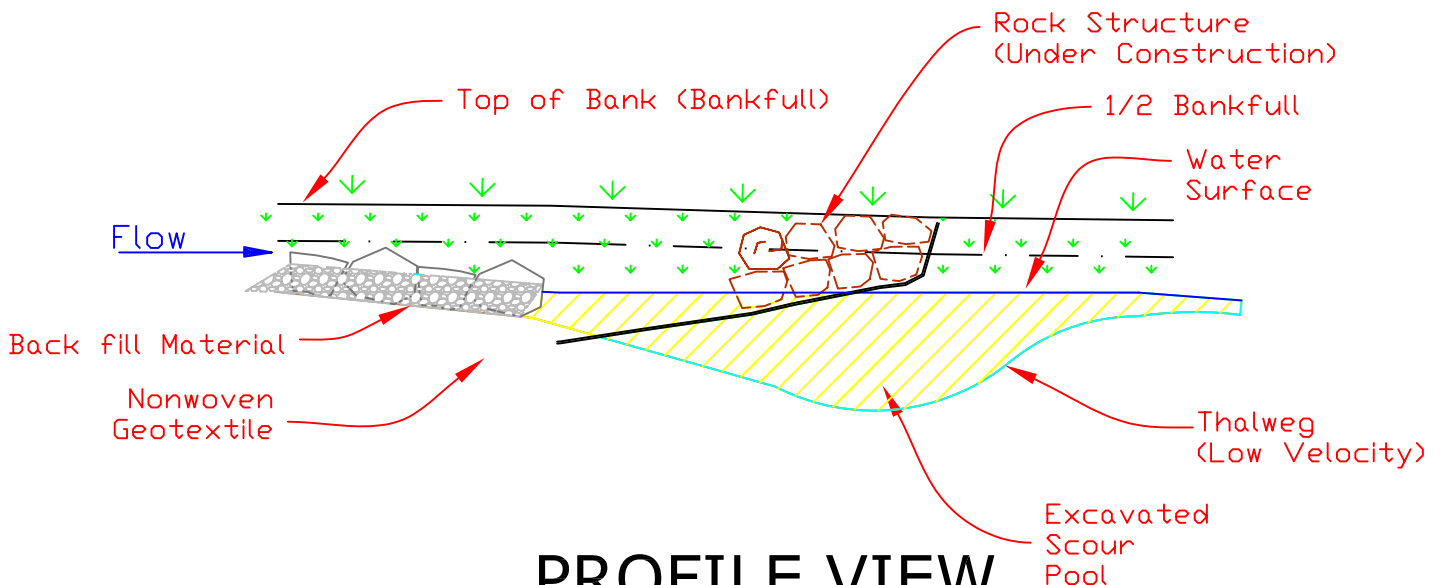
In Stream Diversion (wet)



PLAN VIEW

Notes

- 1) In stream diversion to act as barrier to the active flow and active construction area.
- 2) Diversion should be placed above structure and allow for proper structure placement.
- 3) Active flow area shall have a thalweg depth greater than active construction area to allow for dewatering of construction area.
- 4) All rock materials shall be of proper size and quality, as stated in construction specifications.
- 5) All rock and fabric material used in construction of diversion shall be removed immediately after completion of project.



PROFILE VIEW

7.02 - CONSTRUCTED BENCHES AND FLOODPLAINS

Introduction

Construction of new benches and floodplains improves both the lateral and vertical stability of the reach by allowing the stream to access the floodplain, and reduces the bank height ratio. Stabilizing banks also reduces turbidity from on-going bank erosion. BMPs exercised during construction should be site specific.

Conditions Where Practice Applies

Minimizing project area disturbance is critical to sediment and erosion control during stream restoration projects. Site specific factors influencing BMPs include quality of riparian buffer, bank material, bed material, bankfull width, bankfull depth, floodprone width, stream gradient, discharge and bank height.

Construction Specifications

1. New bankfull benches and floodplains should be seeded and mulched. Choose seed appropriate to season, region and site conditions (see appropriate BMPs in Chapter Three).
2. Install berms or silt fences along transportation routes on new benches or floodplains.
3. When constructed benches are composed of fine soils, they should be back-sloped away from the channel (using a slope of 20:1) until final grading and seeding. The back-sloped areas should be drained into ditches or sumps. Any dewatering must be through appropriate devices (see appropriate BMPs in Chapter Three).
4. Stabilize bench and floodplain slopes, and justify stabilization method according to slope material.

7.03 – NEW CHANNEL CONSTRUCTION

Introduction

Restoring natural pattern, dimension and profile may sometimes require the construction of an entirely new stream channel, or sections of new channel tied into the existing channel. Building new channel is often combined with creating suitable floodplain and establishing a riparian zone. The new stream channel will be constructed with a stable pattern and profile and appropriate dimensions based on reference conditions and design parameters. The new floodplain and riparian zone will also be established based on site and reference conditions, and will support the physical, biologic, and chemical restoration goals of the project. The construction of the new channel and floodplain must incorporate BMPs to control stormwater and associated sediment inputs.

Conditions Where Practice Applies

This restoration alternative should be applied to any new channel construction or relocation.

Construction Specifications

1. Construction should occur “in the dry”, out of the existing flow, whenever possible.
2. Construction should be sequenced to effectively and efficiently complete the project.
3. When constructed benches are composed of fine soils, they should be back-sloped away from the channel (using a slope of 20:1) until final grading and seeding. The back-sloped areas should be drained into ditches or sumps to pump out, as necessary. Follow existing NPDES permit requirements about filtering all pumped discharge into streams.
4. Install sediment and erosion control at downstream end of active construction zone.
5. Stabilize new channel and bank slopes before releasing flow into the new channel, and justify stabilization method according to slope material.
6. Where feasible, release of the flow into the new channel should be a staged process. This can be accomplished by gradually removing the barrier between the old and the new channel, which allows more control of the stream flow.
7. If the abandoned channel will be backfilled, the process should proceed from upstream to downstream, and existing BMPs for seeding and mulching should be followed (Chapter Three). If the abandoned channel will not be backfilled, it must be stabilized.

8. Material excavated from the new channel should be placed in stockpile area(s) with appropriate sediment and erosion control, and utilized or disposed of in accordance with permittee's NPDES registration.
9. Disturbance to riparian vegetation adjacent to the new stream channel should be minimized when possible.

7.04 –TRANSPORTING MATERIALS ON THE STREAM BED

Introduction

Preserving riparian vegetation (including sod) is critical in minimizing site disturbance, upland sediment and turbidity inputs. Depending on local site conditions, constructing the access road along the riparian corridor may result in greater impacts than using sections of the stream bed to transport material. Examples of local site conditions where transporting material on the stream bed may be justified include but are not limited to infrastructure or other physical constraints that restrict transportation activities beyond the stream channel, critical and/or fragile riparian environments, and impact-resistant stream beds composed of bedrock or cobble. Any use of the stream bed as a route to transport materials must be clearly justified and explained in the NPDES permit application. If transporting materials on the stream bed would create considerable turbidity issues, the use of multiple stream access points may be a suitable alternative (see appropriate BMPs in Chapter Three).

Conditions Where Practice Applies

The use of the stream bed as a route for transportation of materials is limited to stream beds composed of bedrock, cobble, or large gravel, and where a transportation route on the stream bed will cause less impact than a transportation route in adjacent uplands.

Construction Specifications

When using the stream bed as a route to transport materials:

1. Use equipment of the appropriate type and size to transport material efficiently and effectively. Equipment must be no wider than the bottom width of the channel.
2. Equipment with low ground pressure is recommended to minimize stream impacts.
3. Inspect equipment daily. Low toxicity oil and coolant is recommended.
4. Limit transportation to low-flow periods (considering both daily and seasonal conditions).
5. Keep equipment out of the water where possible.
6. Limit transportation activities to one route in any single stream reach.
7. Minimize the number of turns and trips in the channel.
8. Minimize transportation activities in the rain.

9. Limit the number of stream access points and crossings to the fewest possible.
10. Locate, design and construct stream access points to minimize erosion and sedimentation into the stream. Provide adequate sediment and erosion control at stream access points.
11. Plan material storage areas and transportation routes to allow work to be done in an efficient and effective manner.
12. Stabilize all stream access and turn-around points immediately following the completion of the in-stream work.

CHAPTER 8

STEEP SLOPE CONSTRUCTION GUIDELINES IN AREAS OF HIGH SLIP POTENTIAL SOILS

Chapter 8 – Steep Slope Construction Guidelines in areas of High Slip Potential Soils

Introduction

Landslide issues at many construction sites in West Virginia illustrate the importance making some changes to the storm water permitting process in order to identify potential problems and incorporate additional requirements to reduce the number of future slips.

Conditions Where Practice Applies

High slip potential soils are a key factor with the majority of slips at construction projects in West Virginia (see **Appendix D** for table showing West Virginia High Slip Potential Soils by County).

Planning Considerations

Dewatering a critical slope is usually simple, cost efficient and will potentially provide an effective means to stabilize a slope and prevent slips.

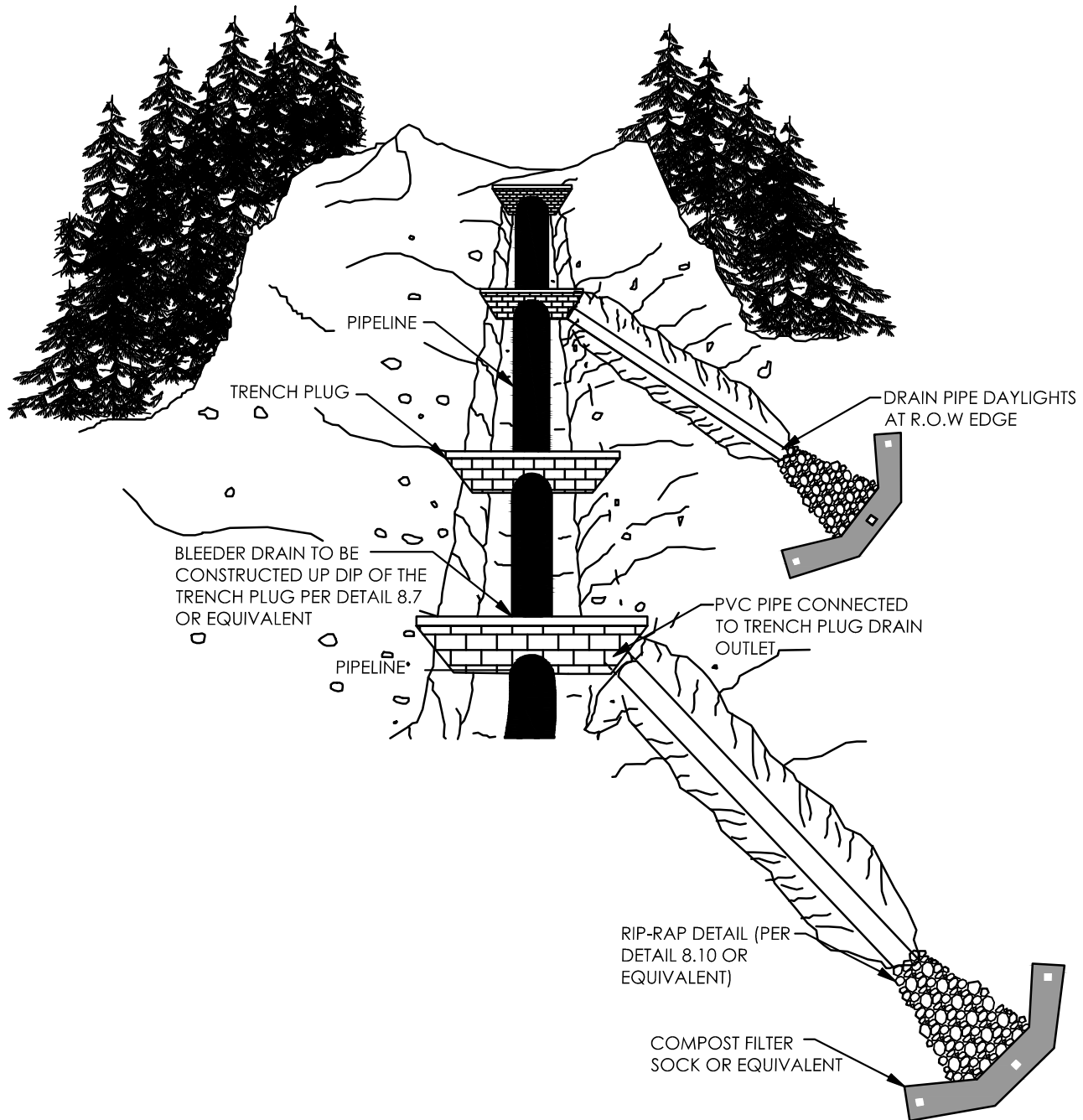
The following provides a description of BMP's employed to protect slopes in high slip potential areas at or greater than 3:1 and to minimize soil erosion and/or slips due to seeps, springs and surface runoff that can percolate into soil strata during and after earth disturbance and trenching excavation. This moisture infiltration has the potential to cause slips by saturating the soils resulting in lower resistance to movement while decreasing the angle of repose. The methods proposed for water management is to direct flows away from potentially unstable areas by installing horizontal drains to passively drain water from the slope area and prevent saturation of slope materials. The following construction criteria is technical guidance on the design of bleeder drains however on a case by case basis, other techniques may be satisfactory.

**Construction
Criteria**

There are three (3) areas where these drains will be required:

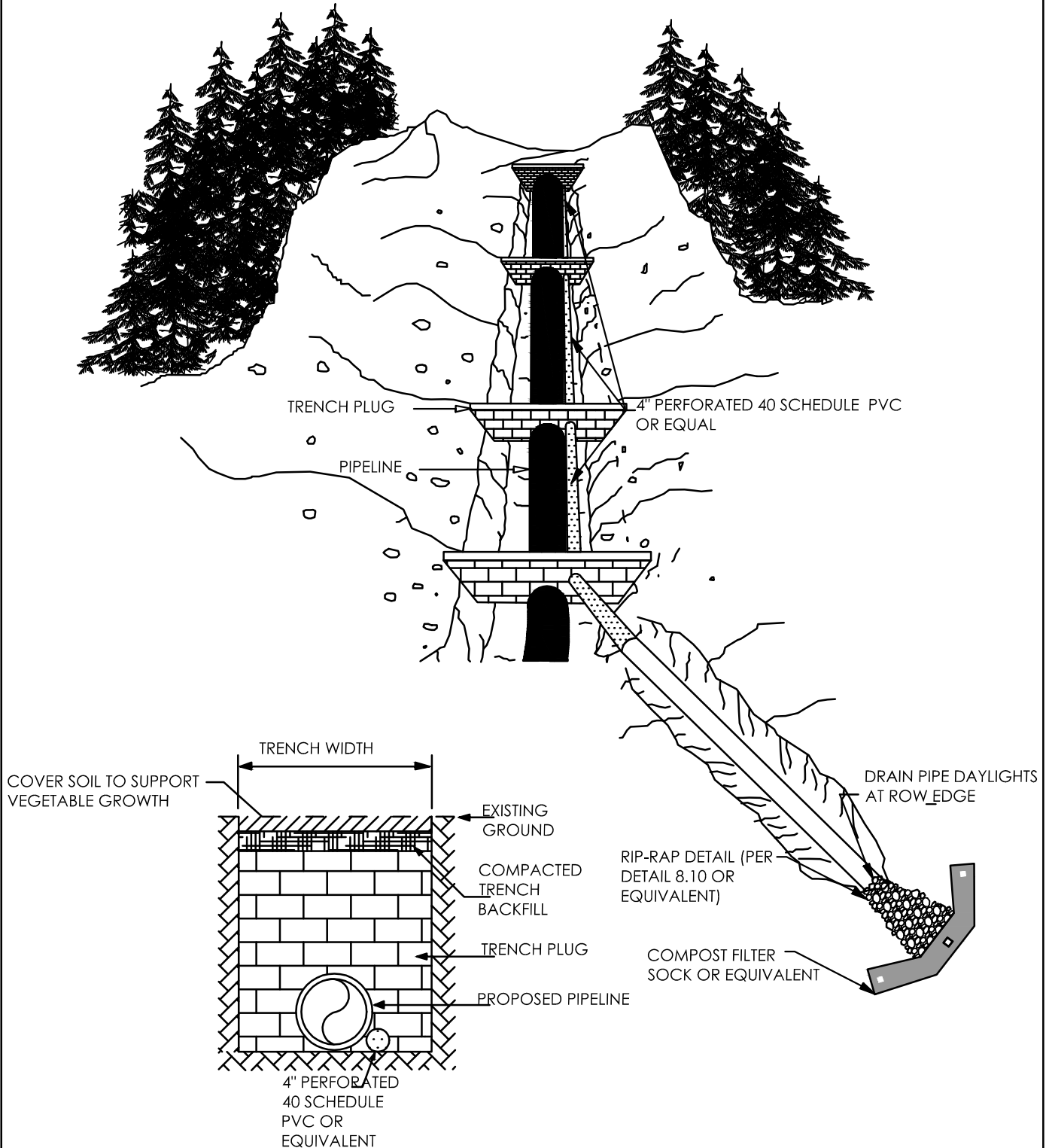
1. In order to avoid the consequences of a “dam” behind trench plugs caused by ground water or surface water infiltrating the backfilled trench, water management is required to prevent soil saturation of the trench area by installing passive bleeder drains. (See Exhibits 8.4 thru 8.7 for bleeder drain illustrations).
2. A drain shall be installed at low topographical areas where the existing ground slopes perpendicular to the ROW are greater than 3:1 and with significant contributing drainage area Two (2) acres or more. (See Exhibits 8.8 and 8.9).
3. A drain shall be installed at seepage areas encountered during construction and positioned upslope from backfilled trench to intercept water before it seeps into the backfilled trench. (See Exhibits 8.11 and 8.12).

Where trenching activities are proposed in high slip potential soils and in areas where existing ground slopes are greater than 3:1, bleeder drains shall be installed to passively drain water from the trench area. The following illustration shows a drain placed at every second trench plug.



SLIP PREVENTION: BLEEDER DRAIN AND OUTLET DETAIL

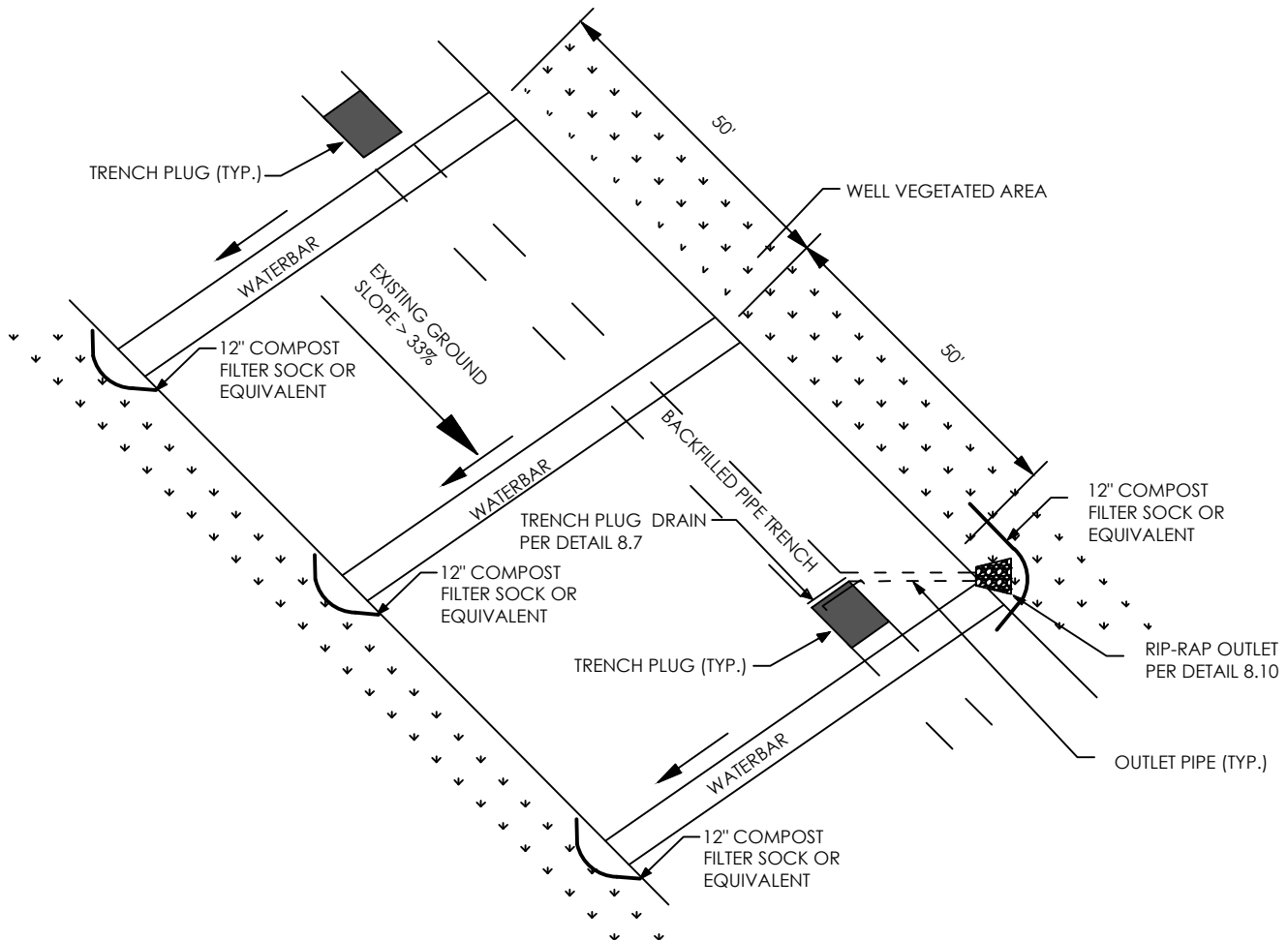
A bleeder drain placed parallel along the pipeline is an effective way to passively drain water from the backfilled trench area. This technique will reduce the number of outlets and control the placement of outlets. The following illustration shows this method.



NOT TO SCALE

SLIP PREVENTION: BLEEDER DRAIN PARALLEL TO PIPELINE

The outlets associated with pipeline trench drains are typically used in conjunction with right-of-way diversions. Used in this manner, additional outlets and sediment filter controls will not be needed. Spacing for trench plugs in high slip potential soils is related to the severity of the ROW slopes. Trench plug drains shall be installed at every other trench plug on slopes that are 30% or greater.



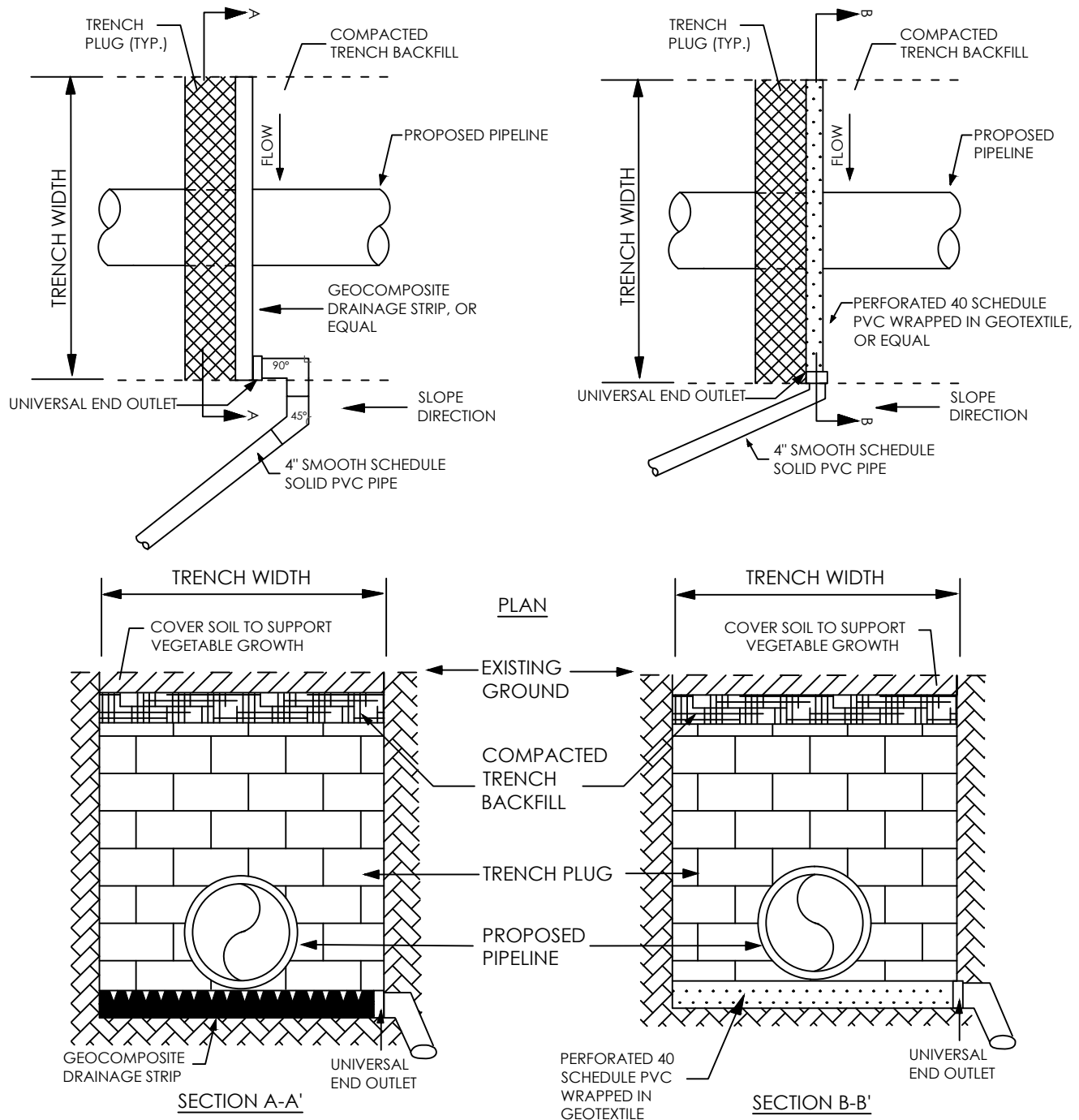
Spacing of Trench Plugs (Drains to be installed at every other Plug)

Percent Slope	Spacing in Feet
<5	*
5 - 15	500
15 - 25	300
25 - 35	200
➤ 35	100

NOT TO SCALE

SLIP PREVENTION: TRENCH PLUG DRAIN OVERVIEW

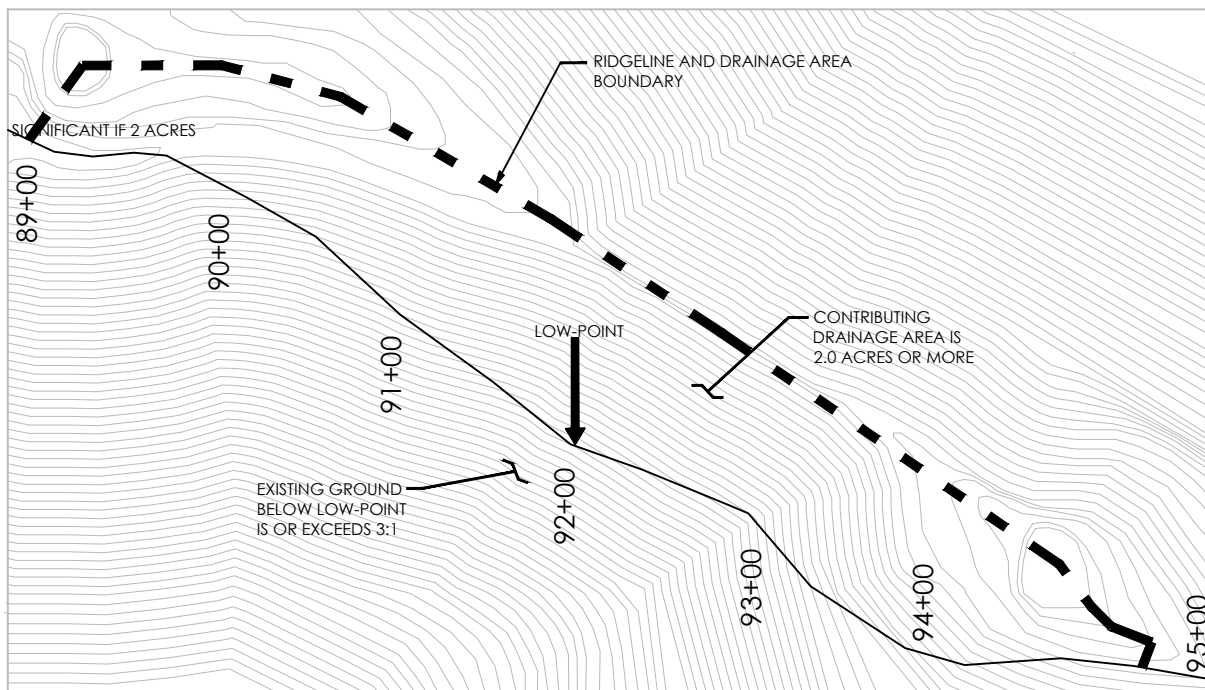
Two (2) types of trench plug drains are illustrated below. Geocomposite Drainage Strips or Perforated Schedule 40 PVC placed behind the trench plug and below the pipeline are effective ways to passively drain water. Both methods show Schedule 40 PVC discharge pipe at a minimum of a 2% grade.



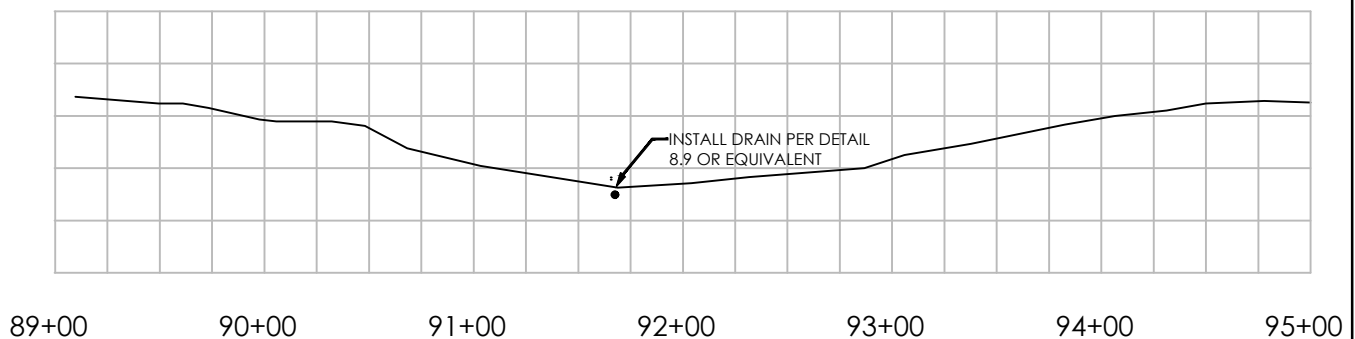
NOT TO SCALE

SLIP PREVENTION: TRENCH PLUG DRAIN DETAILS

Bleeder drains will sometimes be required at low points associated with side hill construction activities in high slip potential soils. Drainage from the undisturbed profile can infiltrate the backfilled soil within the trench and drain to a low point with the potential of saturating the soil. A drain shall be installed at low topographical areas where the existing ground slopes perpendicular to the ROW are greater than 3:1 and with significant contributing drainage area two (2) acres or more. Unusual conditions will be reviewed on a case by case basis.



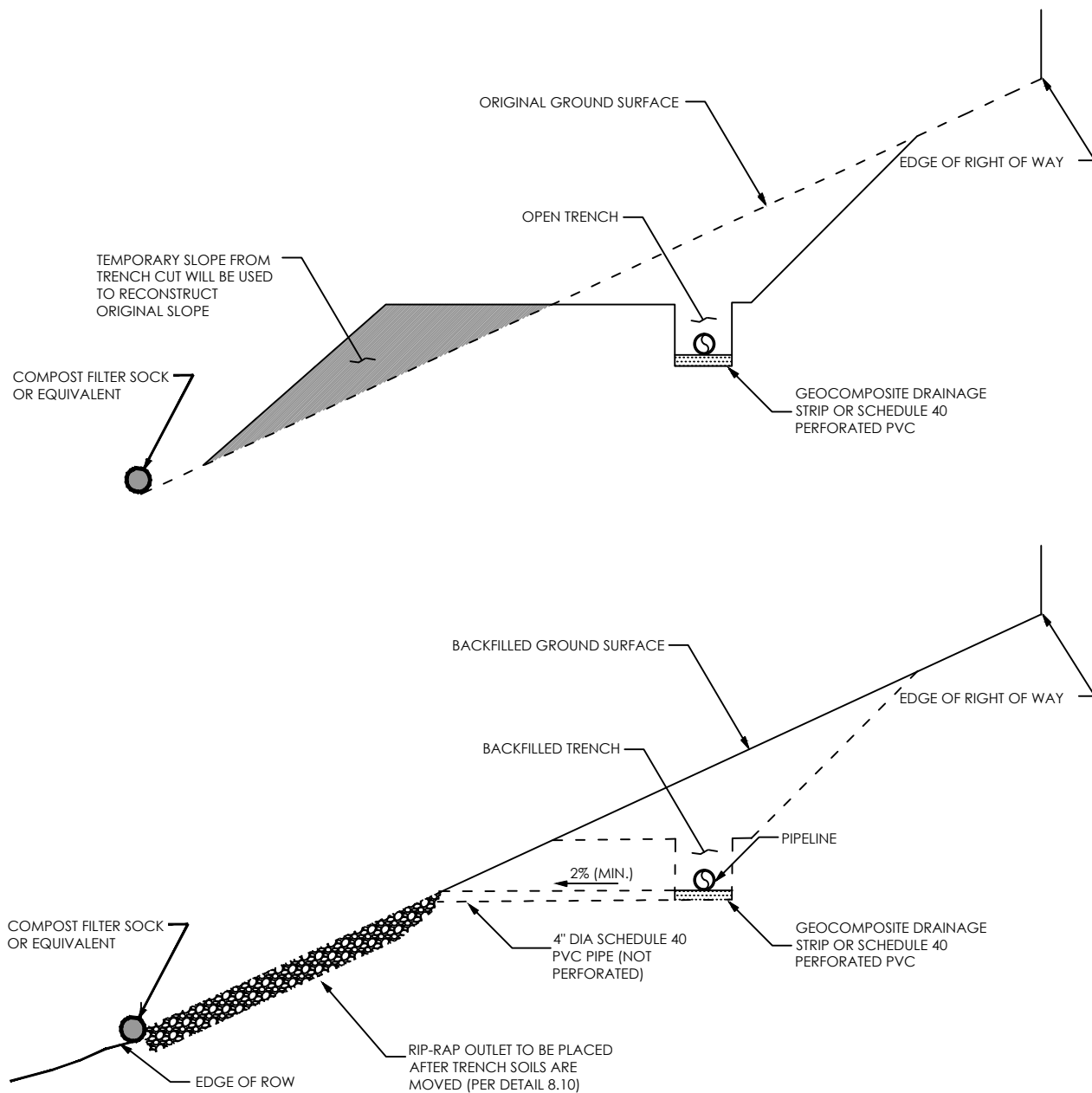
PROPOSED PIPELINE PLANVIEW



PROPOSED PIPELINE PROFILE

SLIP PREVENTION: SIDE HILL CONSTRUCTION

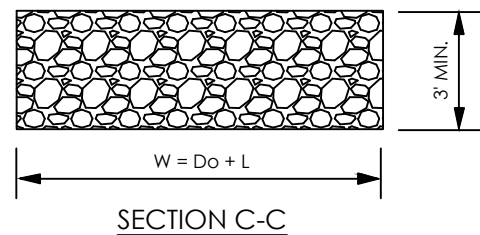
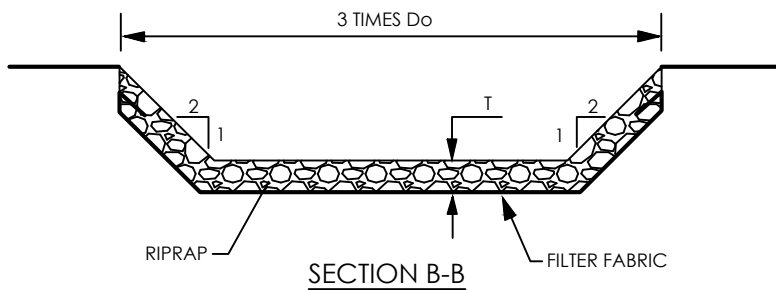
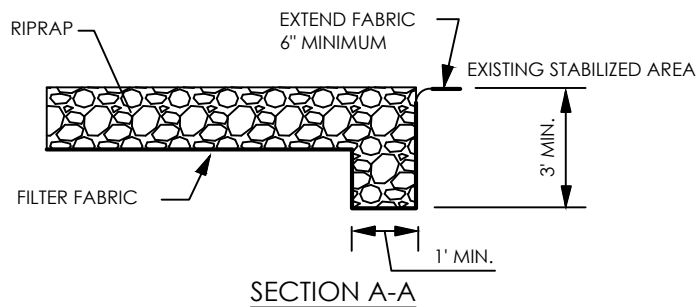
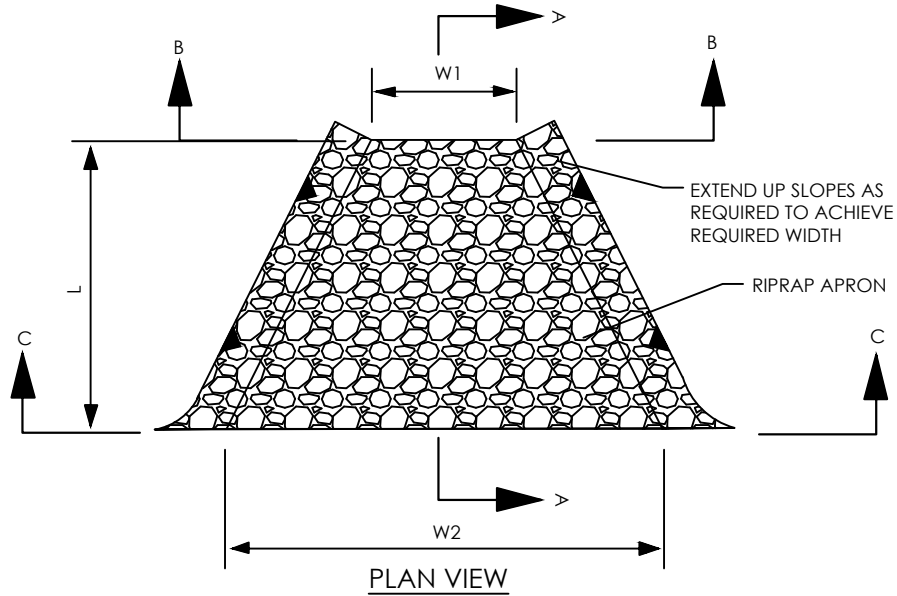
Two (2) types of low point drains are illustrated below. Geocomposite Drainage Strips or Perforated Schedule 40 PVC placed below the pipeline are effective ways to passively drain water. Both methods show Schedule 40 PVC discharge pipe at a minimum of a 2% grade.



NOT TO SCALE

SLIP PREVENTION: SIDE HILL CONSTRUCTION DRAIN

Outlet protection structures prevent scour and erosions at discharge outlets by dissipating the energy and reducing velocities. The illustration below show a typical application of an apron lined with rock riprap.

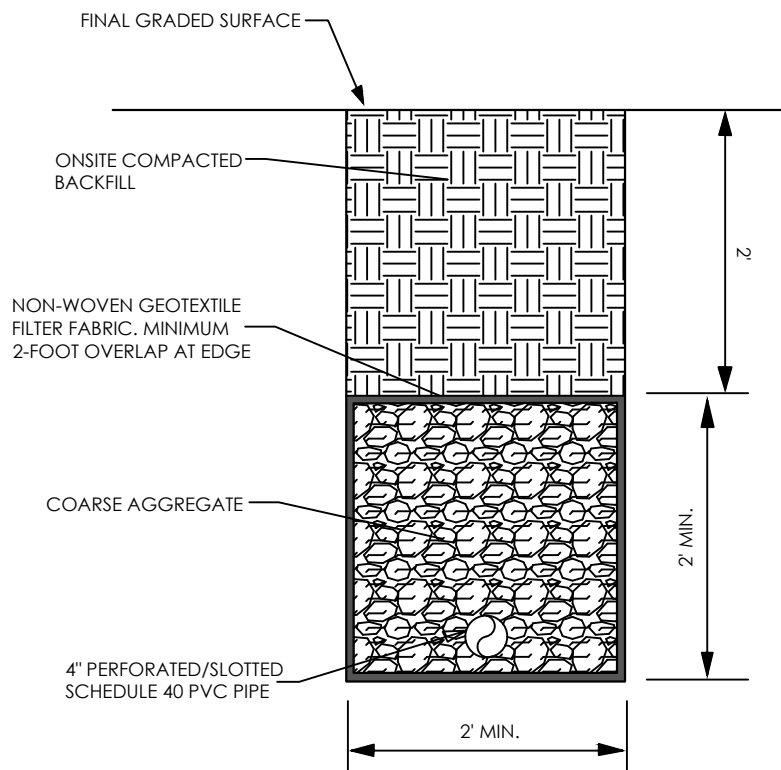


APRON ID	L* (FT)	W1 (FT)	W2 (FT)	D50 (IN)	T (FT)	RIPRAP	CY OF STONE
DRAIN OUTLET	4	2	6	3	1	R - 3	2.00

NOT TO SCALE

SLIP PREVENTION: DRAIN OUTLET RIP-RAP OUTLET

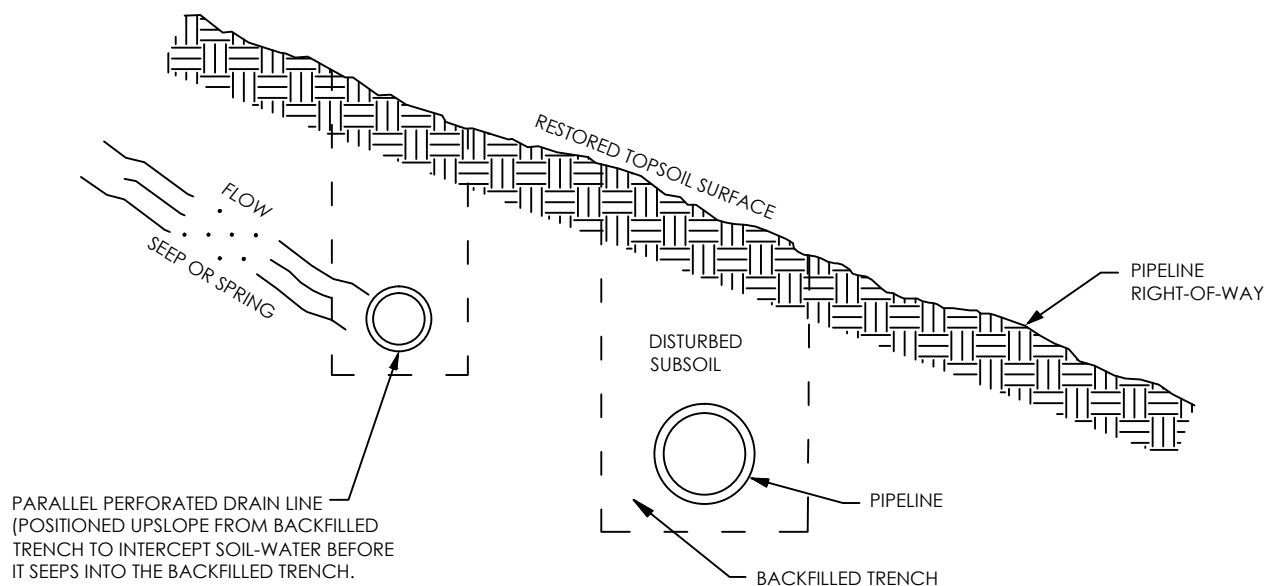
French drains can be constructed to passively drain water away from the trench area. These drains can be installed at seepage areas encountered during construction. These drains should be sloped at a minimum of 2% to the outlet locations



NOT TO SCALE

SLIP PREVENTION: SUBSURFACE DRAIN (FRENCH DRAIN)

Parallel drainage tiles can be installed at seepage areas encountered during construction. The drains may be perforated PVC or geocomposite drain strips placed between the seepage area and the pipeline to intercept soil-water before it seeps into the open or backfilled trenchline. These drains should be sloped at a minimum of 2% to the outlet locations.



NOT TO SCALE

SLIP PREVENTION: SEEP INTERCEPT DRAIN PARALLEL TO TRENCH

APPENDIX A

GLOSSARY

GLOSSARY

AASHTO - American Association of State Highway & Transportation Officials (Formerly AASHO.)

ACCEPTABLE OUTLET - That point where storm water runoff can be released into a watercourse or drainage way of adequate capacity without causing scour or erosion.

ACID SOIL - A soil giving an acid reaction throughout most or all of the portion occupied by roots. (Precisely, below a pH of 7.0; practically, below a pH of 6.6.)

ALLUVIAL FAN - A sloping, fan shaped mass of sediment deposited by a stream where it emerges from an upland onto a plain.

ALLUVIUM - A general term for all detrital material deposited or in transit by streams, including gravel, sand silt, clay and all variations and mixtures of these. Unless otherwise noted, alluvium is unconsolidated.

ANGLE OF REPOSE - The stable angle between the horizontal and the maximum slope that a soil assumes through natural processes that will not slough.

ANTI-SEEP COLLAR - An impermeable diaphragm usually of sheet metal or concrete constructed at intervals within the zone of saturation along the conduit of a principal spillway to increase the seepage length along the conduit and thereby prevent piping or seepage along the conduit.

ANTI-VORTEX DEVICE - A device, usually a vertical or horizontal plate, carefully designed and placed at the entrance of a pipe to prevent the formation of a vortex in the water at the pipe entrance.

APRON - A floor or lining to protect a surface from erosion, for example, the pavement below chutes, spillways, or at the toes of dams.

ASPECT - The direction a slope faces - a physiographic feature of steep slopes which influences plant growth and adaptation.

ATTERBERG LIMITS - Atterberg limits are soil properties measured for soil materials passing the No. 40 sieve.

Liquid Limits (LL) - the liquid limit is the water content corresponding to the arbitrary limit between the liquid & plastic states of consistency of a soil.

Plastic Limits (PL) - The plastic limit is the water content corresponding to an arbitrary limit between the plastic and semisolid states of consistency of a soil.

Plasticity Index (PI) - The plasticity index is the numerical difference between the liquid limit and plastic limit.

BAFFLES - Vanes, guides, grids, grating or similar devices placed in a conduit to deflect or regulate flow and effect a more uniform distribution of velocities.

BARREL - The usually mild sloping closed conduit used to convey water under or through a dam; part of a principal spillway.

BASE FLOW - The stream discharge from ground water accretion.

BEDLOAD - The sediment that moves by sliding, rolling or bounding on or very near the streambed; sediment moved mainly by tractive or gravitational forces or both but at velocities less than the surrounding flow.

BERM - A shelf that breaks the continuity of a slope.

BIODEGRADABLE - Capable of being broken down (degraded) by common soil organisms.

BLIND DRAIN - A type of drain consisting of an excavated trench refilled with pervious material, such as coarse sand, gravel or crushed stone, through whose voids water percolates and flows to an outlet. Often referred to as a French drain because of its initial development and widespread use in France.

BRACKISH (WATER) - Slightly to moderately salty water.

BULKHEAD - A wall made from wood, steel, concrete, etc. for protection of shoreline from waves or currents.

CALCIUM SULFATE - Gypsum. A hydrated form used to treat high sodium soils. CaSO_4

CHANNEL - A natural stream that conveys water; a ditch or channel excavated for the flow of water.

CHANNEL IMPROVEMENT - The improvement of the flow characteristics of a channel by clearing, excavation, realignment, lining, or other means in order to increase its water carrying capacity.

CHANNEL STABILIZATION - Erosion prevention and stabilization of velocity distribution in a channel using jetties, drops, revetments, structural linings, vegetation and other measures.

CHANNEL STORAGE - Water temporarily stored in channels while en route to an outlet.

CHECK DAM - A small dam construction in a gully or other small watercourse to decrease the stream flow velocity (by reducing the channel gradient), minimize channel scour, and promote deposition of sediment.

CHUTE - A high velocity, open channel for conveying water to a lower level without erosion.

CLAY (SOILS) - 1. A mineral soil separate consisting of particles less than 0.002 millimeter in equivalent diameter. 2. A soil texture class. 3. (Engineering) A fine grained soil (more than 50 percent passing the No. 200 sieve) that has a high plasticity index in relation to the liquid limit. (Unified Soil Classification System)

COMPACTION - To unite firmly. With respect to construction work with soils, engineering compaction is any process by which the soil grains are rearranged to decrease void space and bring them into closer contact with one another, thereby increasing the weight of solid material per unit of volume, increasing the shear and bearing strength and reducing permeability.

CONDUIT - Any channel intended for the conveyance of water, whether open or closed.

CONTOUR - 1. An imaginary line on the surface of the earth connecting points of the same elevation. 2. A line drawn on a map connecting points of the same elevation.

COOL (SLOPE EXPOSURE) - A slope facing north or east, or a slope shaded during the hot part of the day.

CORE TRENCH - A trench, filled with relatively impervious material intended to reduce seepage of water through porous strata.

CRADLE (ENGINEERING) - A structure usually of concrete shaped to fit around the bottom and sides of a conduit to support the conduit, increase its strength and in dams, to fill all voids between the underside of the conduit and the soil.

CREST - 1. the top of a dam, dike, spillway or weir, frequently restricted to the overflow portion. 2. The summit of a wave or peak of a flood.

CRITICAL AREA OR SITE - Sediment producing, highly erodible or severely eroded areas.

CRITICAL DEPTH (HYDRAULICS) - Depth of flow in a channel of specified dimensions at which specific energy is a minimum for a given discharge.

CROWN (OF SLOPE) - Top of slope; apex.

CRUSHED STONE - Aggregate consisting of angular particles produced by mechanically crushing rock.

CULM - The stem of grasses, sedges and rushes which is jointed and usually hollow in grasses and usually solid in sedges and rushes.

CULTIPACKER SEEDER - A farm tool equipped with a seed box which drops the seed between cultipacker rollers to place the seed to firm soil where they will be pressed into soil by the second corrugated roller.

CUT - Portion of land surface or area from which earth has been removed or will be removed by excavation; the depth below original ground surface to excavated surface.

CUT-AND-FILL - Process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas.

CUTOFF - A wall or other structure, such as a trench, filled with relatively impervious material intended to reduce seepage of water through porous strata.

CUTTINGS - A small shoot cut from a plant to start a new plant.

CYCLONE (SEEDER) - A hand turned or tractor drawn seeder that broadcasts seed onto the seed bed by a rotary motion that slings the seed outward from the seeder.

DAM - A barrier to confine or raise water for storage or diversion, to create a hydraulic head, to prevent gully erosion, or for retention of soil, sediment or other debris.

DEBRIS - Broken remains of plants, objects and rocks that form trash or remains.

DECIDUOUS - Plants that shed their leaves annually as opposed to evergreen.

DEPOSITION - The accumulation of material dropped because of a slackening movement of the transporting agent, water or wind.

DESICCATION - Drying out as of root systems of plants before they are planted.

DESILTING AREA - An area of grass, shrubs or other vegetation used for inducing deposition of silt and other debris from slowing water, located above a pond, field or other area needing protection from sediment accumulation. (See filter strip.)

DETENTION DAM - A dam constructed for the purpose of temporary storage of stream flow or surface runoff which releases the stored water at controlled rates.

DIKE (ENGINEERING) - An embankment to confine or control water, for example, one built along the banks of a river to prevent overflow or lowlands; a levee.

DISTURBED AREA - An area in which the natural vegetative soil cover has been removed or altered and, therefore, is susceptible to erosion.

DIVERSION - A channel with a supporting ridge on the lower side constructed across the slope to divert water from areas where it is in excess to sites where it can be used or disposed of safely. Diversions differ from terraces in that they are individually designed.

DOLOMITIC (LIMESTONE) - Liming materials that contain more than 6 percent magnesium (mg); high magnesium lime.

DRAIN (NOUN) - 1. A buried pipe or other conduit (subsurface drain). 2. A ditch or channel (open drain) for carrying off surplus surface water or groundwater.

DRAIN (VERB) - 1. To provide channels, such as open ditches or closed drains, so that excess water can be removed by surface flow or internal flow. 2. To lose water (from the soil) by percolation.

DRAINAGE - 1. The removal of excess surface water or ground water from land by means of surface or subsurface drains. 2. Soils characteristics that affect natural drainage.

DRAINAGE AREA (WATERSHED) - All land and water area from which runoff may run to a common (design) point.

DRAUGHTY (SOIL OR SLOPE) - Lacking moisture during part of the growing season during a typical year.

DROP INLET SPILLWAY - An out fall structure in which the water drops through a vertical riser connected to a discharge conduit.

DROP SPILLWAY - An out fall structure in which the water drops over a vertical wall onto an apron at a lower elevation.

DROP STRUCTURE - A structure for dropping water to a lower level and dissipating surplus energy; a fall. The drop may be vertical or inclined.

DRY STORAGE - The 1800 cubic feet of storage in a trap or basin that is dewatered after rain events.

EMERGENCY SPILLWAY - A dam spillway designed and constructed to discharge flow in excess of the principal spillway design discharge.

ENERGY DISSIPATOR - A designed device such as an apron of rip rap or a concrete structure placed at the end of a water transmitting apparatus such as pipe, paved ditch or paved chute for the purpose of reducing the velocity, energy and turbulence of the discharged water.

ENTRANCE HEAD - The head required to cause flow into a conduit or other structure, including both entrance loss and velocity head.

EROSION - 1. The wearing away of the land surface by running water, wind, ice, or other geol cal agents, including such processes as gravitational creep. 2. Detachment and movement of soil or rock fragments by water, wind, ice or gravity. The following terms are used to describe different types of water erosion:

Accelerated erosion - Erosion much more rapid than normal, natural or geological erosion, primarily as a result of the influence of the activities of man or, in some cases, of other animals or natural catastrophes that expose base surfaces, for example, fires.

Gully erosion - The erosion process whereby water accumulates in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths, ranging from 1 or 2 feet to as much as 75 to 100 feet.

Rill erosion - An erosion process in which numerous small channels only several inches deep are formed. See rill.

Sheet erosion - The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not subsequently removed by surface runoff.

EROSIVE VELOCITIES - Velocities of water that are high enough to wear away the land surface. Exposed soil will generally erode faster than stabilized soils. Erosive velocities will vary according to the soil type, slope, structural or vegetative stabilization used to protect the soil.

ESTHETIC (AESTHETIC) - Pleasing in appearance; showing good taste.

EVERGREEN - Plants that have leaves or needles yearlong as opposed to those that lose their leaves during part of the year.

EXCELSIOR BLANKET - An erosion retardant material made from excelsior strands held together with net like stands of plastic or other material.

EXPOSURE (SLOPE) -

North - Slopes facing in any compass direction clockwise between N45W and S45E.

South - Those slopes that face in any compass direction clockwise between S45E and N45W.

FILTER STRIP - A strip of permanent vegetation above ponds, diversions and other structures to retard flow of runoff water, causing deposition of transported material, thereby reducing sediment flow.

FINES (SOIL) - Generally refers to the silt and clay size particles in soil.

FREEBOARD (HYDRAULICS) - The distance between the maximum water surface elevation anticipated in design and the top of retaining banks or structures. Freeboard is provided to prevent overtopping due to unforeseen conditions.

GABION - A flexible woven-wire basket composed of two to six rectangular cells filled with small stones. Gabions may be assembled into many types of structures such as revetments, retaining walls, channel liners, drop structures and groins.

GABION MATTRESS - A thin gabion, usually six or nine inches thick, used to line channels for erosion control .

GRADE - 1. The slope of a road, channel or natural ground. 2. The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared for the support of construction, like paving or laying a conduit. 3. To finish the surface of a canal bed, roadbed, top of embankment or bottom of excavation.

GRAFTING - A method of propagating plants by joining wood from one plant to another plant to get more desirable growth on the second plant.

GRASSED WATERWAY - A natural or constructed waterway, usually broad and shallow covered with erosion resistant grasses, to convey surface water down the slope.

GRAVEL - 1. Aggregate consisting of mixed sizes of 1/4 inch to 3 inch particles which normally occur in or near old streambeds and have been worn smooth by the action of water. 2. A soil having particle sizes, according to the Unified Soil Classification System, ranging from the No. 4 sieve size angular in shape as produced by mechanical crushing.

GRAVEL FILTER - Washed and graded sand and gravel aggregate placed around a drain or well screen to prevent the movement of fine materials from the aquifer into the drain or well.

GROIN - A shore protection structure built (usually perpendicular to the shoreline) to trap littoral drift or retard erosion of the shoreline.

GROUND COVER - Plants which are low-growing and provide a thick growth which protects the soil as well as providing some beautification of the area occupied.

GULLY - A channel or miniature valley cut by concentrated runoff through which water commonly flows only during and immediately after heavy rains or during the melting of snow. The distinction between gully and rill is one of depth. A gully is sufficiently deep that it would not be obliterated by normal tillage operations, whereas a rill is of lessor depth and would be smoothed by ordinary farm tillage.

HEAD (HYDRAULICS) - 1. The height of water above any plane of reference. 2. The energy, either kinetic or potential, possessed by each unit weight of a liquid expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. Used in various terms such as pressure head, velocity head, and head loss.

HERBACEOUS PERENNIAL (PLANTS) - A plant whose stems die back to the ground each year.

HERBICIDE - Chemical formulation used to control weeds or brush.

HULLED (SEED) - Hullless seed, such as sericea lespedeza. Seed are usually processed after threshing to take off outer hull to facilitate scarification and quicken germination.

HYDRAULIC GRADE LINE - In a closed conduit a line joining the elevations to which water could stand in risers or vertical pipes connected to the conduit at their lower end and open at their upper end. In open channel flow, the hydraulic grade line is the free water surface.

HYDRAULIC GRADIENT - The slope of the hydraulic grade line. The slope of the free surface of water flowing in an open channel.

HYDRAULIC JUMP - The sudden turbulent rise in water level from a flow stage below critical depth to flow stage above critical depth, during which the velocity passes from super critical to sub-critical.

HYDROGRAPH - A graph showing variation in stage (depth) or discharge of a stream of water over a period of time.

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HYDROSEEDER - A machine designed to apply seed, fertilizer, lime and short fiber wood or paper mulch to the soil surface.

HYDRO-SEEDING - Seeding with a hydroseeder.

INFLOW PROTECTION - A water handling device used to protect the transition area between any water conveyance (dike, swale, or swale dike) and a sediment trapping device.

INTERCEPTOR DRAIN - A surface or subsurface drain, or a combination of both, designed and installed to intercept flowing water.

LIME - Basic calcareous materials used to raise pH of acid soils for benefit of plants being grown. May be either ground limestone or hydrated lime.

LITTORAL DRIFT - The sedimentary material moved in the littoral zone under the influence of waves and currents.

MANNING'S FORMULA (HYDRAULICS) - A formula used to predict the velocity of water flow in an open channel or pipeline:

MULCH - Covering on surface of soil to protect and enhance certain characteristics, such as water retention qualities.

MULCH ANCHORING TOOL - A tool that looks like a dull disk designed to press straw and similar mulches into the soil to prevent loss due to wind, water or gravity.

NETTING (MULCH) - Paper or cotton material used to hold mulch material on the soil surface.

NITROGEN - FIXING (BACTERIA) - Bacteria having the ability to fix atmospheric nitrogen, making it available for use by plants. Inoculation of legume seeds is one way to insure a source of these bacteria for specified legumes.

NON-EROSIVE VELOCITY - Controlling the velocity of water to prevent detachment and movement of soil or rock. Erosive velocity will vary according to the soil type, slope, structural or vegetative stabilization used to protect the soil.

NORMAL DEPTH - Depth of flow in an open conduit during uniform flow for the given conditions. (See uniform flow.)

NOXIOUS WEEDS - Harmful; undesirable; hard to control.

a. Restricted - May be sold in the trade but are limited to very small amounts as undesirable connates.

b. Prohibited - Prohibited from sale.

OUTFALL - The point where water flows from a conduit, stream or drain.

OUTLET - The point at which water discharges from such things as a stream, river, lake, tidal basin, pipe, channel or drainage area.

OUTLET CHANNEL - A waterway constructed or altered primarily to carry water from man-made structures such as terraces, subsurface drains, diversions and impoundments.

OVERFALL - Abrupt change in stream channel elevation; the part of a dam or weir notch over which the weir notch over which the water flows.

PAPER FIBER - A short fiber mulch material usually applied by hydroseeder along with fertilizer and seed.

PARENT MATERIAL - The unconsolidated rock material from which the soil profile develops.

PENDULOUS - More or less hanging or inclined downward.

PERMANENT SEEDING - Results in establishing perennial vegetation which may remain on the area for many years.

PERMISSIBLE VELOCITY (HYDRAULICS) - The highest average velocity at which water may be carried safely in a channel or other conduit. The highest velocity that can exist through a substantial length of a conduit and not cause scour of the channel. A safe, non-eroding or allowable velocity.

pH - A number denoting the common logarithm of the reciprocal of the hydrogen ion concentration. A pH of 7.0 denotes neutrality, higher values indicate alkalinity, and lower values indicate acidity.

PHREATIC LINE - The upper surface of the zone of saturation in an embankment is the phreatic (zero pressure) surface; in cross-section, this is called the phreatic line.

PIPING - Removal of soil material through subsurface flow channels or pipes developed by seepage water.

PLUGS - Pieces of turf or sod, usually cut with a round tube, which can be used to propagate the turf or sod by vegetative means.

PROJECTION - In sediment basins or other dams the perpendicular distance that the anti-seep collar extends from the outside surface of the pipe or pipe cradle.

RECP – See Rolled Erosion Control Products

RETENTION - The amount of precipitation on a drainage area that does not escape as runoff. It is the difference between total precipitation and total runoff.

REVTMENT - Facing of stone or other material, either permanent or temporary, placed along the edge of a stream or shoreline to stabilize the bank and to protect it from the erosion action of water.

RHIZOME - Any prostrate, more or less elongated stem growing partly or completely beneath the surface of the ground; usually rooting at the nodes and becoming upcurved at the apex.

RIGHT-OF-WAY - Right of passage, as over another's property. A route that is lawful to use. A strip of land acquired for transport or utility construction.

RILL - A small channel cut by concentrated runoff but through which water commonly flows only during and immediately after rains or during the melting of snow. A rill is usually only a few inches deep (but no more than a foot) and, hence, no obstacle to tillage operations.

RIP RAP - Broken rock, cobbles, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves); also applies to brush or pole mattresses, or brush and stone, or similar materials used for soil erosion control.

ROLLED EROSION CONTROL PRODUCTS - Rolled Erosion Control Products (RECPs) are temporary or permanent erosion control nets, blankets and three-dimensional matrixes made from a wide variety of natural (such as jute, coir and straw) and manmade materials alone or in combination.

ROUGHNESS COEFFICIENT (HYDRAULICS) - A factor in velocity and discharge formulas representing the effect of channel roughness on energy losses in flowing water. Manning's is a commonly used roughness coefficient.

RUNOFF (HYDRAULICS) - That portion of the precipitation on a drainage area that is discharged from the area in the stream channels. Types include surface runoff, ground water runoff or seepage.

SALINE SOIL - A non-alkali soil containing sufficient soluble salts to impair plant growth.

SAND - 1. (Agronomy) A soil particle between 0.05 and 2.0 millimeters in diameter. 2. A soil textural class. 3. (Engineering) According to the Unified Soil Classification System, a soil particle larger than the No. 200 sieve (0.074mm) and passing the No. 4 sieve (approximately 1/4 inch).

SCD - Soil Conservation District.

SEDIMENT - Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

SEDIMENTATION - Deposition of detached soil particles.

SEDIMENT DISCHARGE (SEDIMENT LOAD) - The quantity of sediment, measured in dry weight or by volume, transported through a streamcross-section in a given time. Sediment discharge consists of both suspended load and bedload.

SEEPAGE - 1. Water escaping through or emerging from the ground. 2. The process by which water percolates through the soil.

SEEPAGE LENGTH - In sediment basins or ponds, the length along the pipe and around the anti-seep collars that is within the seepage zone through an embankment. (See phreatic line.)

SHA - Maryland State Highway Administration.

SHEET FLOW - Water, usually storm runoff, flowing in a thin layer over the ground surface.

SIDE SLOPES (ENGINEERING) - The slope of the sides of a canal, dam or embankment. It is customary to name the horizontal distance first, as 1.5 to 1, or frequently, 1 1/2: 1, meaning a horizontal distance of 1.5 feet to 1 foot vertical.

SILT - 1. (Agronomy) A soil separate consisting of particles between 0.05 and 0.002 millimeter in equivalent diameter. 2. A soil textural class. 3. (Engineering) According to the Unified Soil Classification System a fine grained soil (more than 50 percent passing the No. 200 sieve) that has a low plasticity index in relation to the liquid limit.

SLURRY - A thickened, aqueous mixture of such things as seed, fertilizer, short fiber mulch or soil.

SMALL GRAIN MULCH MATERIAL - Straw material from oats, barley, wheat, or rye.

SOD - A piece of earth containing grass plants with their matted roots. Turf.

SOIL - 1. (Agronomy) the unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. 2. (Engineering) Earth and rock particles resulting from the physical and chemical disintegration of rocks, which may or may not contain organic matter. It includes fine material (silts and clays), sand and gravel.

SOIL TEST - Chemical analysis of soil to determine needs for fertilizers or amendments for species of plant being grown.

SPECIFIC ENERGY - The average energy per unit weight of water at a channel section as expressed with respect to the channel bottom.

SPILLWAY - An open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled to regulate the discharge of excess water.

SPREADER (HYDRAULICS) - A device for distributing water uniformly in or from a channel.

STABILIZATION - Providing adequate measures, vegetative and/or structural that will prevent erosion from occurring.

STABILIZED AREA - An area sufficiently covered by erosion resistant material such as a good cover of grass, or paving by asphalt, concrete, or stone, in order that erosion of the underlying soil does not occur.

STABILIZED GRADE - The slope of a channel at which neither erosion nor deposition occurs.

STABLE (STREAM OR CHANNEL) - The condition of a stream, channel or other water course in which no erosion or deposition occurs; adequately protected from erosion.

STAGE (HYDRAULICS) - The variable water surface or the water surface elevation above any chosen datum.

STATIC HEAD - Head resulting from elevation differences, for example, the difference in elevation in headwater and tailwater in a hydroelectric plant.

STILLING BASIN - An open structure or excavation at the foot of an outfall, conduit, chute, drop, or spillway to reduce the energy of the descending stream of water.

STOLON - A trailing or reclining above ground stem capable of rooting and/or sending up new shoots from the nodes.

STRUCTURAL - Relating to something constructed or built by man.

STRUCTURAL (SOIL) - The combination or arrangement of primary soil particles into secondary particles, units or peds. (Dune sand is structureless)

SUBCRITICAL FLOW - Flow at velocities less than critical velocity.

SUBGRADE - The soil prepared and compacted to support a structure or a pavement system.

TAILWATER (HYDRAULICS) - Water, in a river or channel, immediately downstream from a structure.

TEMPORARY SEEDING - A seeding which is made to provide temporary cover for the soil while waiting for further construction or other activity to take place.

TERRACE - An embankment or combination of an embankment and channel constructed across a slope at a suitable spacing to control erosion by diverting or storing surface runoff instead of per-
ting it to flow uninterrupted down the slope. Normally used only on cropland.

TEXTURE (SOIL) - The relative proportions of various soil separates in a soil material.

THATCH - A tightly intermingled layer of living and dead stems, leaves and roots of grasses.

TIME OF CONCENTRATION - Time required for water to flow from the most remote point of a watershed, in a hydraulic sense, to the outlet.

TOE (OF SLOPE) - Where the slope stops or levels out. Bottom of the slope.

TOE WALL - Downstream wall of a structure, usually to prevent flowing water from eroding under the structure.

TOPSOIL - Fertile or desirable soil material used to top dress roadbanks, subsoils, parent material, etc.

TRAP EFFICIENCY - The capability of a reservoir to trap sediment. The ratio of sediment trapped to the sediment delivered, usually expressed in percent.

TRASH RACK - Grill, grate or other device at the intake of a channel, pipe, drain or spillway for the purpose of preventing oversize debris from entering the structure.

UNHULLED (SEED) - Seed still encased with a hull. Example: Sericea lespedeza before it is rendered hullless by mechanically removing the hull.

UNIFIED SOIL CLASSIFICATION SYSTEM (ENGINEERING) - A classification system based on the identification of soils according to their particle size, gradation, plasticity index and liquid limit.

UNIFORM FLOW - A state of steady flow when the mean velocity and cross-sectional area are equal at all sections of a reach.

UNIVERSAL SOIL LOSS EQUATION - An equation used for the design of water erosion control system: $A = RKLS\bar{C}P$ where A is average annual soil loss in tons per acre per year; R is rainfall factor; K is soil erodibility factor; L is length of slope; S is percent of slope; C is cropping and management factor; and P is conservation practice factor.

UPLIFT (HYDRAULICS) - The upward force of water on the base or underside of a structure.

VARIETY - A variant within a species which reproduces true by seed or vegetative propagation.

VELOCITY HEAD (HYDRAULICS) - Head due to the velocity of a moving fluid, equal to the square of the mean velocity divided by twice the acceleration due to gravity (32.16 feet per second per second).

WATER SURFACE PROFILE (HYDRAULICS) - The longitudinal profile assumed by the surface of a stream flowing in an open channel; the hydraulic grade line.

WEEP-HOLES (ENGINEERING) - Openings left in retaining walls, aprons, linings or foundations to permit drainage and reduce pressure.

WET STORAGE - The wet storage area is the 1800 cubic feet in the permanent pool of water in a sediment trap or basin.

WETTED PERIMETER (HYDRAULICS) - The length of the line of intersection of the plane or the hydraulic cross-section with the wetted surface of the channel

WING WALL - Side wall extensions of a structure used to prevent sloughing of banks or channels and to direct and confine overflow.

WOOD FIBER - A short fiber mulch material, usually applied with a hydro-seeder in an aqueous mixture.

From VA

APPENDIX B

MISCELLANEOUS

Appendix B

Endangered species by stream

Applicants should notify the US Fish & Wildlife Service due to the presence or possible presence of endangered/threatened species when projects will discharge to the stream segments shown below:

- Kanawha River (Kanawha Falls to river mile 89.0 near Boomer) – Fayette County (Tubercled-blossom pearlymussel, *Epioblasma torulosa torulosa*; Pink mucket pearlymussel, *Lampsilis abrupta*; and Fanshell, *Cyprogenia stegaria*) (Virginia spiraea, *Spiraea virginiana*)
- Millers Camp Branch of Marsh Fork and associated palustrine emergent scrub-Shrub wetlands – Raleigh County (Virginia spiraea, *Spiraea virginiana*)
- Potts Creek – Monroe County (James spinymussel, *Pleurobema collina*)
- South Fork Potts Creek – Monroe County (James spinymussel, *Pleurobema collina*)
- Elk River – Braxton, Clay and Kanawha Counties (Pink mucket pearlymussel; *Lampsilis abrupta*; Northern riffleshell, *Epioblasma torulosa rangiana*; and Clubshell, *Pleurobema clava*)
- Cacapon River – Morgan County (Harperella, *Ptilimnium nodosum*)
- Back Creek – Morgan County (Harperella, *Ptilimnium nodosum*)
- Meathouse Fork Middle Creek – Doddridge County (Clubshell, *Pleurobema clava*)
- Hackers Creek of West Fork River – Lewis County (Clubshell, *Pleurobema clava*)
- Middle Island Creek – Doddridge, Tyler and Pleasants Counties (Clubshell, *Pleurobema clava*)
- Wetlands – Berkeley County Northeastern bulrush, *Scirpus ancistrochaetu*
- Ohio River – Cabell, Mason and Wood Counties (Pink mucket pearlymussel, *Lampsilis abrupta*; and Fanshell, *Cyprogenia stegaria*)
- Gauley River – Nicholas and Fayette Counties (Virginia spiraea, *Spiraea virginiana*)
- Bluestone River – Mercer and Summers Counties (Virginia spiraea, *Spiraea virginiana*)
- Greenbrier River – Pocahontas and Greenbrier Counties (Virginia spiraea, *Spiraea virginiana*)
- Meadow River – Greenbrier and Fayette Counties (Virginia spiraea, *Spiraea virginiana*)
- Dingess Branch of Marsh Fork and associated palustrine emergent and scrub-shrub wetlands – Raleigh County

West Virginia MS4 Communities

WVR030011

Village of Barboursville
P.O. Box 266
Barboursville, WV 25504-0266
CABELL COUNTY

WVR030009

City of Beckley/Beckley Sanitary Board
P.O. Box 2494
Beckley, WV 25802 – 2492
RALEIGH COUNTY

WVR030015

Town of Belle
1100 East Dupont Avenue
Belle, WV 25015 [waiver]
KANAWHA COUNTY

WVR030026

City of Benwood
430 Main Street
Benwood, WV 26031
MARSHALL COUNTY

WVR030019

Berkeley County Public Service Sewer District
P.O. Box 944
Martinsburg, WV 25402
BERKELEY COUNTY

WVR030025

Village of Bethlehem
P.O. Box 6339
Wheeling, WV 26003
OHIO COUNTY

WVR030008

City of Bluefield/Bluefield Sanitary Board
P.O. Box 4100
Bluefield, WV 24701
MERCER COUNTY

WVR030014

City of Ceredo
P.O. Box 691
Ceredo, WV 25507
WAYNE COUNTY

WVR030006

City of Charleston
P.O. Box 2749
Charleston, WV 25330-2749
KANAWHA COUNTY

WVR030040

Town of Chesapeake
12404 MacCorkle Ave, SE
Chesapeake, WV 25315 [waiver]
KANAWHA COUNTY

WVR030034

City of Clarksburg
222 West Main Street
Clarksburg, WV 26301
HARRISON COUNTY

WVR030031

City of Dunbar/Dunbar Sanitary Board
P.O. Box 483
Dunbar, WV 25064
KANAWHA COUNTY

WVR030038

City of Fairmont
200 Jackson Street
Fairmont, WV 26555-1428
MARION COUNTY

WVR030045

Fairmont State University
1201 Locust Avenue
Fairmont, WV 26554
MARION COUNTY

WVR030012

Federal Correctional Institution – Morgantown
446 Greenbag Road
Morgantown, WV 26507
MONONGALIA COUNTY

WVR030018

City of Follansbee
P.O. Box 606
Follansbee, WV 26037 [waiver]
BROOKE COUNTY

WVR030024

City of Glen Dale
402 Wheeling Avenue
Glen Dale, WV 26038 [waiver]
MARSHALL COUNTY

WVR030033

City of Huntington
P.O. Box 1659
Huntington, WV 25717
CABELL COUNTY

WVR030010

City of Hurricane/Storm Water Board
P.O. Box 1086
Hurricane, WV 25526
PUTNAM COUNTY

WVR030039

City of Kenova
P.O. Box 268
Kenova, WV 25530
WAYNE

WVR030037

City of Marmet
P.O. Box 15037
Marmet, WV 25315 [waiver]
KANAWHA COUNTY

WVR030043

Marshall University
One John Marshall Drive
Huntington, WV 25755
CABELL COUNTY

WVR030017

City of Martinsburg
P.O. Box 828
Martinsburg, WV 25401
BERKELEY COUNTY

WVR030036

City of McMechen
47 Ninth Street
McMechen, WV 26040 [waiver]
MARSHALL COUNTY

WVR030003

Town of Milton
1139 Smith Street
Milton, WV 25541
CABELL COUNTY

WVR030007

City of Montgomery
706 Third Avenue
Montgomery, WV 25136 [waiver]
FAYETTE COUNTY

WVR030030

Morgantown Utility Board
P.O. Box 852
Morgantown, WV 28507-0852
MONONGALIA COUNTY

WVR030013

City of Moundsville/Moundsville Sanitary Board
P.O. Box 480
Moundsville, WV 26041
MARSHALL COUNTY

WVR030027

City of Nitro
20th Street & 2nd Avenue
Nitro, WV 25143
KANAWHA/PUTNAM COUNTY

WVR030029

City of Parkersburg
One Government Square
Parkersburg, WV 26102
WOOD COUNTY

WVR030035

Town of Poca
P.O. Box 586
Poca, WV 25159 [waiver]
PUTNAM

WVR030005

City of St. Albans
1499 MacCorkle Avenue
St. Albans, WV 25177
KANAWHA COUNTY

WVR030001

City of South Charleston
4th Avenue & D Street
South Charleston, WV 25303
KANAWHA COUNTY

WVR030023

Town of Star City
370 Broadway Avenue
Star City, WV 26505
MONONGALIA COUNTY

WVR030046

Veterans Administration – Huntington Medical
Center
1540 Spring Valley Road
Huntington, WV 25704
WAYNE COUNTY

WVR030047

Veterans Administration – Martinsburg
Medical Center
510 Butler Avenue
Martinsburg, WV 25413
BERKELEY COUNTY

WVR030032

City of Vienna
P.O. Box 5097
Vienna, WV 26105
WOOD COUNTY

WVR030021

City of Weirton
200 Municipal Plaza
Weirton, WV 26062
HANCOCK COUNTY

WVR030028

City of Wellsburg
70 Seventh Street
Wellsburg, WV 26070 [waiver]
BROOKE COUNTY

WVR030022

City of Westover
500 Dupont Road
Westover, WV 26505
MONONGALIA COUNTY

WVR030016

City of Wheeling
1500 Chapline Street
Wheeling, WV 26003
OHIO COUNTY

WVR030020

City of Williamstown
100 West 5th Street
Williamstown, WV 26187
WOOD COUNTY

WVR030004

WV Department of Transportation
1900 Kanawha Boulevard East
Bldg. 5, Room A-125
Charleston, WV 25305
STATEWIDE COVERAGE

WVR030041

WV Turnpike Authority
P.O. Box 1469
Charleston, WV 25325-1469
KANAWHA, RALEIGH & MERCER
COUNTIES

WVR030042

West Virginia University
P.O. Box 6551
Morgantown, WV 26506
MONONGALIA COUNTY

WVR030044

West Virginia State University
P.O. Box 1000
Institute, WV 25313
KANAWHA COUNTY

Updated May 2011

APPENDIX C

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APPENDIX C

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<http://yosemite.epa.gov/R10/WATER.NSF/0/17090627a929f2a488256bdc007d8dee?OpenDocument>

Links change over time; if you find a broken link please notify the Stormwater Program.

APPENDIX D

West Virginia High Slip Potential Soils by County

BARBOUR		
Name	Symbol	Soil Slip Potential
Belmont and Cateache gravelly silt loams, 20 to 35 percent slopes, very stony	BcE	HIGH
Belmont and Cateache gravelly silt loams, 35 to 65 percent slopes, very stony	BcF	HIGH
Bethesda channery silt loam, 15 to 35 percent slopes	BeE	HIGH
Bethesda-Rock outcrop complex, very steep, very stony	BoF	HIGH
Clarksburg silt loam, 15 to 25 percent slopes	CID	HIGH
Dekalb channery loam, 25 to 35 percent slopes	DaE	HIGH
Dekalb channery loam, 35 to 65 percent slopes	DaF	HIGH
Dekalb channery loam, 15 to 35 percent slopes, very stony	DbE	HIGH
Dekalb channery loam, 35 to 65 percent slopes, very stony	DbF	HIGH
Ernest silt loam, 15 to 25 percent slopes	EnD	HIGH
Ernest silt loam, 3 to 20 percent slopes, extremely stony	ErC	HIGH
Gilpin channery silt loam, 25 to 35 percent slopes	GcE	HIGH
Gilpin channery silt loam, 25 to 35 percent slopes, severely eroded	GcE3	HIGH
Gilpin channery silt loam, 35 to 65 percent slopes	GcF	HIGH
Gilpin-Dekalb complex, 15 to 35 percent slopes, very stony	GdE	HIGH
Gilpin-Dekalb complex, 35 to 65 percent slopes, very stony	GdF	HIGH
Gilpin-Upshur complex, 15 to 25 percent slopes	GuD	HIGH
Gilpin-Upshur complex, 15 to 25 percent slopes, severely eroded	GuD3	HIGH
Gilpin-Upshur complex, 25 to 35 percent slopes	GuE	HIGH
Gilpin-Upshur complex, 25 to 35 percent slopes, severely eroded	GuE3	HIGH
Gilpin-Upshur complex, 35 to 70 percent slopes	GuF	HIGH
Itmann channery clay loam, very steep	ItF	HIGH
Janelew channery silt loam, 15 to 35 percent slopes	JnE	HIGH
Janelew-Rock outcrop complex, very steep, very stony	JoF	HIGH
Westmoreland silt loam, 25 to 35 percent slopes	WmE	HIGH
Westmoreland silt loam, 25 to 35 percent slopes, severely eroded	WmE3	HIGH
Westmoreland silt loam, 35 to 60 percent slopes	WmF	HIGH
Westmoreland silt loam, 35 to 60 percent slopes	WmF3	HIGH

BRAXTON		
Name	Symbol	Soil Slip Potential
Vandalia silt loam, 25 to 35 percent slopes	VaE	HIGH
Vandalia silt loam, 15 to 35 percent slopes, very stony	VxE	HIGH

BROOKE		
Name	Symbol	Soil Slip Potential
Berks channery silt loam, 25 to 35 percent slopes, severely eroded	BeE3	High
Berks soils, 35 to 65 percent slopes	BkF	High
Brooke silty clay loam, 15 to 25 percent slopes	BoD	High
Brookside silt loam, 15 to 25 percent slopes	BrD	High
Clarksburg silt loam, 15 to 25 percent slopes	CkD	High
Guernsey silt loam, 8 to 15 percent slopes	GuC	High
Guernsey silt loam, 15 to 25 percent slopes	GuD	High
Guernsey silt loam, 15 to 25 percent slopes, severely eroded	GuD3	High
Westmoreland silt loam, 25 to 35 percent slopes	WeE	High
Westmoreland silt loam, 35 to 60 percent slopes	WeF	High

CABELL		
Name	Symbol	Soil Slip Potential
Gilpin silt loam, 25 to 35 percent slopes	GIE	HIGH
Gilpin-Upshur complex, 15 to 25 percent slopes	GuD	HIGH
Gilpin-Upshur complex, 25 to 35 percent slopes	GuE	HIGH
Gilpin-Upshur complex, 35 to 70 percent slopes	GuF	HIGH
Vandalia silt loam, 15 to 25 percent slopes	VaD	HIGH

CALHOUN		
Name	Symbol	Soil Slip Potential
Vandalia silt loam, 15 to 25 percent slopes	VaD	HIGH

CLAY		
Name	Symbol	Soil Slip Potential
Cedarcreek very channery loam, very steep, very stony	CeF	HIGH
Fairpoint channery loam, very steep, very stony	FpF	HIGH
Gilpin-Upshur silt loams, 15 to 25 percent slopes	GuD	HIGH
Gilpin-Upshur silt loams, 25 to 35 percent slopes	GuE	HIGH
Gilpin-Upshur complex, 35 to 70 percent slopes, very stony	GxF	HIGH
Itmann channery clay loam, very steep	ItF	HIGH
Vandalia silt loam, 15 to 25 percent slopes	VaD	HIGH
Vandalia silt loam, 25 to 35 percent slopes	VaE	HIGH

DODDRIDGE		
Name	Symbol	Soil Slip Potential
Gilpin-Upshur silt loams, 15 to 25 percent slopes	GuD	HIGH
Gilpin-Peabody complex, 25 to 35 percent slopes	GpE	HIGH
Gilpin-Peabody complex, 15 to 35 percent slopes, very stony	GsE	HIGH
Gilpin-Peabody complex, 35 to 70 percent slopes, very stony	GsF	HIGH
Gilpin-Upshur-Urban land complex, 15 to 25 percent slopes	GyD	HIGH
Vandalia silt loam, 15 to 25 percent slopes	VaD	HIGH
Vandalia silt loam, 25 to 35 percent slopes	VaE	HIGH
Vandalia silt loam, 15 to 35 percent slopes, very stony	VsE	HIGH
Vandalia-Urban land complex, 15 to 25 percent slopes	VuD	HIGH

FAYETTE		
Name	Symbol	Soil Slip Potential
Berks-Highsplint-Sharondale complex, 35 to 80 percent slopes, very stony	BhG	High
Cateache-Pipestem complex, 35 to 80 percent slopes, very stony	CcG	High
Gilpin-Highsplint-Berks complex, 35 to 90 percent slopes, extremely stony	GhG	High
Layland-Clifftop complex, 35 to 70 percent slopes, very stony	LdF	High
Layland-Dekalb-Guyandotte complex, 35 to 70 percent slopes, extremely stony	LeF	High
Layland-Dekalb-Rock outcrop complex, 55 to 80 percent slopes, extremely stony	LgG	High

Name	Symbol	Soil Slip Potential
Layland-Rock outcrop complex, 35 to 70 percent slopes, very rubbly	LkF	High
Lithic Udorthents-Rock outcrop complex, cut land, 5 to 100 percent slopes	LxG	High
Udorthents, graded, 15 to 55 percent slopes	UgF	High

GILMER		
Name	Symbol	Soil Slip Potential
Vandalia silt loam, 15 to 25 percent slopes	VaD	High
Vandalia silt loam, 15 to 35 percent slopes, very stony	VsE	High

HARRISON		
Name	Symbol	Soil Slip Potential
Clarksburg silt loam, 15 to 25 percent slopes	CID	HIGH
Clarksburg silt loam, 15 to 25 percent slopes, severely eroded	CID3	HIGH
Culleoka silt loam, 25 to 35 percent slopes	CuE	HIGH
Culleoka silt loam, 25 to 35 percent slopes, severely eroded	CuE3	HIGH
Culleoka silt loam, 35 to 60 percent slopes, severely eroded	CuF3	HIGH
Dekalb extremely stony sandy loam, very steep	DSF	HIGH
Ernest silt loam, 15 to 25 percent slopes	EnD	HIGH
Ernest very stony silt loam, 15 to 35 percent slopes	EsD	HIGH
Faywood silty clay loam, 15 to 25 percent slopes	FaD	HIGH
Faywood silty clay loam, 25 to 35 percent slopes	FaE	HIGH
Faywood silty clay loam, 35 to 60 percent slopes	FaF	HIGH
Gilpin silt loam, 25 to 35 percent slopes	GIE	HIGH
Gilpin silt loam, 35 to 70 percent slopes	GIF	HIGH
Gilpin very stony silt loam, 15 to 35 percent slopes	GsE	HIGH
Gilpin very stony silt loam, very steep	GTF	HIGH
Gilpin-Upshur complex, 15 to 25 percent slopes	GuD	HIGH
Gilpin-Upshur complex, 15 to 25 percent slopes, severely eroded	GuD3	HIGH
Gilpin-Upshur complex, 25 to 35 percent slopes	GuE	HIGH
Gilpin-Upshur complex, 25 to 35 percent slopes, severely eroded	GuE3	HIGH
Gilpin-Upshur complex, 35 to 70 percent slopes, severely eroded	GuF3	HIGH
Guernsey silt loam, 8 to 15 percent slopes	GyC	HIGH

Name	Symbol	Soil Slip Potential
Guernsey silt loam, 15 to 25 percent slopes	GyD	HIGH
Guernsey silt loam, 15 to 25 percent slopes, severely eroded	GyD3	HIGH
Upshur silty clay, 15 to 25 percent slopes, severely eroded	UhD3	HIGH
Vandalia silty clay loam, 15 to 25 percent slopes	VaD	HIGH
Vandalia silty clay loam, 15 to 25 percent slopes, severely eroded	VaD3	HIGH
Westmoreland silt loam, 25 to 35 percent slopes	WmE	HIGH
Westmoreland silt loam, 25 to 35 percent slopes, severely eroded	WmE3	HIGH
Westmoreland silt loam, 35 to 60 percent slopes	WmF	HIGH

HANCOCK		
Name	Symbol	Soil Slip Potential
Berks channery silt loam, 25 to 35 percent slopes, severely eroded	BeE3	High
Berks soils, 35 to 65 percent slopes	BkF	High
Brooke silty clay loam, 15 to 25 percent slopes	BoD	High
Brookside silt loam, 15 to 25 percent slopes	BrD	High
Clarksburg silt loam, 15 to 25 percent slopes	CkD	High
Guernsey silt loam, 8 to 15 percent slopes	GuC	High
Guernsey silt loam, 15 to 25 percent slopes	GuD	High
Guernsey silt loam, 15 to 25 percent slopes, severely eroded	GuD3	High
Westmoreland silt loam, 25 to 35 percent slopes	WeE	High
Westmoreland silt loam, 35 to 60 percent slopes	WeF	High

JACKSON		
Name	Symbol	Soil Slip Potential
Culleoka-Lowell complex, 25 to 35 percent slopes	CuE	High
Gilpin-Peabody complex, 35 to 65 percent slopes, severely eroded	GIF3	High
Gilpin-Peabody complex, 35 to 65 percent slopes, very stony	GmF	High
Gilpin-Peabody-Rock outcrop complex, 35 to 65 percent slopes, very stony	GoF	High
Gilpin-Upshur silt loams, 15 to 25 percent slopes	GpD	High
Gilpin-Upshur complex, 15 to 25 percent slopes, severely eroded	GpD3	High

Name	Symbol	Soil Slip Potential
Gilpin-Upshur silt loams, 25 to 35 percent slopes	GpE	High
Gilpin-Upshur complex, 25 to 35 percent slopes, severely eroded	GpE3	High
Peabody-Gilpin complex, 35 to 65 percent slopes	PgF	High
Peabody-Gilpin complex, 35 to 65 percent slopes, severely eroded	PgF3	High
Upshur silt loam, 15 to 25 percent slopes	UeD	High
Upshur-Gilpin complex, 15 to 25 percent slopes	UgD	High
Upshur-Gilpin complex, 15 to 25 percent slopes, severely eroded	UgD3	High
Upshur-Gilpin complex, 25 to 35 percent slopes	UgE	High
Upshur-Gilpin complex, 25 to 35 percent slopes, severely eroded	UgE3	High
Vandalia silt loam, 15 to 25 percent slopes	VdD	High
Vandalia silt loam, 25 to 35 percent slopes	VdE	High
Vandalia silty clay loam, 15 to 25 percent slopes, severely eroded	VsD3	High
Vandalia silty clay loam, 25 to 35 percent slopes, severely eroded	VsE3	High
Vandalia silt loam, 15 to 35 percent slopes, very stony	VtE	High
Vandalia silt loam, 15 to 35 percent slopes, bouldery	VxE	High

MASON		
Name	Symbol	Soil Slip Potential
Culleoka-Lowell complex, 25 to 35 percent slopes	CuE	High
Gilpin-Peabody complex, 35 to 65 percent slopes, severely eroded	GIF3	High
Gilpin-Peabody complex, 35 to 65 percent slopes, very stony	GmF	High
Gilpin-Peabody-Rock outcrop complex, 35 to 65 percent slopes, very stony	GoF	High
Gilpin-Upshur silt loams, 15 to 25 percent slopes	GpD	High
Gilpin-Upshur complex, 15 to 25 percent slopes, severely eroded	GpD3	High
Gilpin-Upshur silt loams, 25 to 35 percent slopes	GpE	High
Gilpin-Upshur complex, 25 to 35 percent slopes, severely eroded	GpE3	High
Peabody-Gilpin complex, 35 to 65 percent slopes	PgF	High
Peabody-Gilpin complex, 35 to 65 percent slopes, severely eroded	PgF3	High
Upshur silt loam, 15 to 25 percent slopes	UeD	High
Upshur-Gilpin complex, 15 to 25 percent slopes	UgD	High

Name	Symbol	Soil Slip Potential
Upshur-Gilpin complex, 15 to 25 percent slopes, severely eroded	UgD3	High
Upshur-Gilpin complex, 25 to 35 percent slopes	UgE	High
Upshur-Gilpin complex, 25 to 35 percent slopes, severely eroded	UgE3	High
Vandalia silt loam, 15 to 25 percent slopes	VdD	High
Vandalia silt loam, 25 to 35 percent slopes	VdE	High
Vandalia silty clay loam, 15 to 25 percent slopes, severely eroded	VsD3	High
Vandalia silty clay loam, 25 to 35 percent slopes, severely eroded	VsE3	High
Vandalia silt loam, 15 to 35 percent slopes, very stony	VtE	High
Vandalia silt loam, 15 to 35 percent slopes, bouldery	VxE	High

JEFFERSON		
Name	Symbol	Soil Slip Potential
Bagtown very flaggy sandy loam, 25 to 45 percent slopes, extremely stony	BgE	High
Bagtown very flaggy loam, 25 to 65 percent slopes, rubbly	BnF	High
Bagtown-Stumtowntown-Rock outcrop complex, 25 to 65 percent slopes	BoF	High
Hagerstown-Opequon-Rock outcrop complex, 15 to 35 percent slopes	HgE	High
Rock outcrop-Opequon complex, 25 to 60 percent slopes	ReF	High
Weverton-Rock outcrop complex, 15 to 45 percent slopes, very stony	WoE	High
Bagtown very flaggy sandy loam, 25 to 45 percent slopes, extremely stony	BgE	High

KANAWHA		
Name	Symbol	Soil Slip Potential
Vandalia silt loam, 15 to 25 percent slopes	VaD	High
Vandalia silt loam, 25 to 35 percent slopes	VaE	High
Vandalia silty clay loam, 15 to 25 percent slopes, severely eroded	VdD3	High

LEWIS		
Name	Symbol	Soil Slip Potential
Bethesda-Rock outcrop complex, steep, very stony	BrE	High
Gilpin silt loam, 25 to 35 percent slopes	GaE	High
Gilpin silt loam, 35 to 70 percent slopes	GaF	High
Gilpin-Dekalb association, very steep, very stony	GDF	High
Gilpin-Upshur silt loams, 15 to 25 percent slopes	GuD	High
Gilpin-Upshur silt loams, 25 to 35 percent slopes	GuE	High
Gilpin-Upshur silt loams, 35 to 70 percent slopes, severely eroded	GwF3	High
Janelew channery silt loam, steep	JaE	High
Vandalia silt loam, 15 to 25 percent slopes	VaD	High
Vandalia silt loam, 25 to 35 percent slopes	VaE	High
Westmoreland-Upshur complex, 25 to 35 percent slopes, severely eroded	WuE3	High

LINCOLN		
Name	Symbol	Soil Slip Potential
Beech loam, 15 to 25 percent slopes	BeD	High
Beech loam, 25 to 35 percent slopes	BeE	High
Gilpin silt loam, 25 to 35 percent slopes	GiE	High
Gilpin-Upshur silt loams, 15 to 25 percent slopes	GpD	High
Gilpin-Upshur silt loams, 25 to 35 percent slopes	GpE	High
Gilpin-Upshur silt loams, 35 to 70 percent slopes	GpF	High

MARSHALL		
Name	Symbol	Soil Slip Potential
Brookside silt loam, 15 to 25 percent slopes	BrD	High
Brookside silt loam, 25 to 35 percent slopes	BrE	High
Culleoka-Dormont-Peabody complex, 15 to 25 percent slopes	CpD	High
Culleoka-Dormont-Peabody complex, 25 to 35 percent slopes	CpE	High
Culleoka-Dormont-Peabody complex, 35 to 65 percent slopes, very stony	CrF	High
Culleoka-Peabody complex, 15 to 25 percent slopes	CyD	High
Dormont silt loam, 25 to 35 percent slopes	DoE	High
Dormont-Culleoka complex, 25 to 35 percent slopes	DrE	High
Dormont-Culleoka complex, 35 to 70 percent slopes, very stony	DsF	High

Name	Symbol	Soil Slip Potential
Gilpin-Dormont silt loams, 35 to 70 percent slopes, very stony	GdF	High
Guernsey silt loam, 15 to 25 percent slopes	GuD	High
Guernsey silt loam, 8 to 15 percent slopes	GuC	High
Urban land-Brookside complex, 15 to 25 percent slopes	UmD	High

MARION		
Name	Symbol	Soil Slip Potential
Buchanan and Ernest very stony soils, 15 to 25 percent slopes	BeD	High
Clarksburg silt loam, 15 to 25 percent slopes	CkD	High
Culleoka-Westmoreland silt loams, 25 to 35 percent slopes	CwE	High
Culleoka-Westmoreland silt loams, 35 to 65 percent slopes	CwF	High
Dekalb channery loam, 25 to 35 percent slopes	DaE	High
Dekalb very stony loam, 15 to 35 percent slopes	DdE	High
Dekalb very stony loam, 35 to 65 percent slopes	DdF	High
Dormont and Guernsey silt loams, 8 to 15 percent slopes	DgC	High
Dormont and Guernsey silt loams, 15 to 25 percent slopes	DgD	High
Ernest silt loam, 15 to 25 percent slopes	ErD	High
Gilpin silt loam, 25 to 35 percent slopes	GaE	High
Gilpin silt loam, 35 to 65 percent slopes	GaF	High
Gilpin-Culleoka silt loams, 25 to 35 percent slopes	GcE	High
Gilpin-Culleoka silt loams, 35 to 65 percent slopes	GcF	High
Gilpin-Culleoka-Upshur silt loams, 15 to 25 percent slopes	GuD	High
Gilpin-Culleoka-Upshur silt loams, 25 to 35 percent slopes	GuE	High
Gilpin-Culleoka-Upshur silt loams, 35 to 65 percent slopes	GuF	High
Gilpin-Culleoka-Upshur complex, 15 to 25 percent slopes, severely eroded	GwD3	High
Gilpin-Culleoka-Upshur complex, 25 to 35 percent slopes, severely eroded	GwE3	High
Upshur-Belmont very stony silt loams, 35 to 65 percent slopes	UbF	High
Westmoreland silt loam, 25 to 35 percent slopes	WeE	High
Westmoreland silt loam, 35 to 60 percent slopes	WeF	High

MONONGALIA		
Name	Symbol	Soil Slip Potential
Buchanan and Ernest very stony soils, 15 to 25 percent slopes	BeD	High
Clarksburg silt loam, 15 to 25 percent slopes	CkD	High
Culleoka-Westmoreland silt loams, 25 to 35 percent slopes	CwE	High
Culleoka-Westmoreland silt loams, 35 to 65 percent slopes	CwF	High
Dekalb channery loam, 25 to 35 percent slopes	DaE	High
Dekalb very stony loam, 15 to 35 percent slopes	DdE	High
Dekalb very stony loam, 35 to 65 percent slopes	DdF	High
Dormont and Guernsey silt loams, 8 to 15 percent slopes	DgC	High
Dormont and Guernsey silt loams, 15 to 25 percent slopes	DgD	High
Ernest silt loam, 15 to 25 percent slopes	ErD	High
Gilpin silt loam, 25 to 35 percent slopes	GaE	High
Gilpin silt loam, 35 to 65 percent slopes	GaF	High
Gilpin-Culleoka silt loams, 25 to 35 percent slopes	GcE	High
Gilpin-Culleoka silt loams, 35 to 65 percent slopes	GcF	High
Gilpin-Culleoka-Upshur silt loams, 15 to 25 percent slopes	GuD	High
Gilpin-Culleoka-Upshur silt loams, 25 to 35 percent slopes	GuE	High
Gilpin-Culleoka-Upshur silt loams, 35 to 65 percent slopes	GuF	High
Gilpin-Culleoka-Upshur complex, 15 to 25 percent slopes, severely eroded	GwD3	High
Gilpin-Culleoka-Upshur complex, 25 to 35 percent slopes, severely eroded	GwE3	High
Upshur-Belmont very stony silt loams, 35 to 65 percent slopes	UbF	High
Westmoreland silt loam, 25 to 35 percent slopes	WeE	High
Westmoreland silt loam, 35 to 60 percent slopes	WeF	High

MORGAN		
Name	Symbol	Soil Slip Potential
Blackthorn very gravelly sandy loam, 35 to 55 percent slopes, rubbly	BqF	High
Buchanan loam, 15 to 35 percent slopes, extremely stony	BxE	High

Name	Symbol	Soil Slip Potential
Caneyville silt loam, 8 to 15 percent slopes	CIC	High
Caneyville silt loam, 15 to 25 percent slopes	CID	High
Caneyville silt loam, 25 to 35 percent slopes	CIE	High
Caneyville silty clay loam, 35 to 65 percent slopes	CnF	High
Hazleton-Dekalb complex, 15 to 35 percent slopes, extremely stony	HaE	High
Hazleton-Dekalb complex, 35 to 65 percent slopes, extremely stony	HaF	High
Hazleton-Dekalb-Rock outcrop complex, 35 to 65 percent slopes, rubbly	HdF	High
Hazleton-Dekalb-Rock outcrop complex, 35 to 65 percent slopes, very rubbly	HeF	High
Hazleton-Lehew-Dekalb complex, 35 to 65 percent slopes, extremely stony	HIF	High
Murrill gravelly loam, 15 to 25 percent slopes	MrD	High
Murrill loam, 15 to 35 percent slopes, extremely stony	MsE	High
Rock outcrop-Opequon complex, 55 to 100 percent slopes	ReG	High
Rock outcrop-Rough complex, 55 to 100 percent slopes	RgG	High
Rushtown channery silt loam, 35 to 65 percent slopes	RuF	High
Schaffemaker-Vanderlip loamy sands, 15 to 35 percent slopes, very bouldery	SnE	High
Schaffemaker-Vanderlip loamy sands, 35 to 65 percent slopes, very bouldery	SnF	High
Sideling gravelly loam, 15 to 35 percent slopes, extremely stony	SxE	High
Sideling gravelly loam, 15 to 35 percent slopes, rubbly	SyE	High

NICHOLAS		
Name	Symbol	Soil Slip Potential
Cliffstop channery silt loam, 35 to 70 percent slopes, very stony	CnF	High
Cliffstop-Buchanan complex, 35 to 70 percent slopes, extremely stony	CoF	High
Cliffstop-Dekalb complex, 15 to 35 percent slopes, extremely stony	CpE	High
Gilpin silt loam, 35 to 70 percent slopes	GIF	High
Layland-Cliffstop complex, 35 to 70 percent slopes, very stony	LdF	High
Pineville-Cliffstop complex, 55 to 70 percent slopes, extremely stony	PfG	High

Name	Symbol	Soil Slip Potential
Berks-Highsplint-Sharondale complex, 35 to 80 percent slopes, very stony	BhG	High
Highsplint channery loam, 15 to 35 percent slopes, very stony	HgE	High
Laidig-Clifftop complex, 15 to 35 percent slopes, very stony	LcE	High
Layland-Laidig complex, 15 to 35 percent slopes, rubbly	LhE	High
Layland-Laidig complex, 15 to 35 percent slopes, very rubbly	LkE	High
Layland-Rock outcrop complex, 35 to 70 percent slopes, very rubbly	LmF	High
Lithic Udorthents-Rock outcrop complex, cut land, 5 to 100 percent slopes	LxG	High
Udorthents, graded, 15 to 55 percent slopes	UgF	High

OHIO		
Name	Symbol	Soil Slip Potential
Berks channery silt loam, 25 to 35 percent slopes, severely eroded	BeE3	High
Berks soils, 35 to 65 percent slopes	BkF	High
Brooke silty clay loam, 15 to 25 percent slopes	BoD	High
Brookside silt loam, 15 to 25 percent slopes	BrD	High
Clarksburg silt loam, 15 to 25 percent slopes	CkD	High
Guernsey silt loam, 8 to 15 percent slopes	GuC	High
Guernsey silt loam, 15 to 25 percent slopes	GuD	High
Guernsey silt loam, 15 to 25 percent slopes, severely eroded	GuD3	High
Westmoreland silt loam, 25 to 35 percent slopes	WeE	High
Westmoreland silt loam, 35 to 60 percent slopes	WeF	High

PLEASANTS		
Name	Symbol	Soil Slip Potential
Cedarcreek channery silt loam, steep, stony	CeE	High
Gilpin-Upshur complex, 15 to 25 percent slopes	GpD	High
Gilpin-Upshur complex, 25 to 35 percent slopes	GpE	High
Gilpin-Upshur complex, 35 to 70 percent slopes	GpF	High
Gilpin-Upshur complex, 15 to 25 percent slopes, severely eroded	GwD3	High

Name	Symbol	Soil Slip Potential
Gilpin-Upshur complex, 25 to 35 percent slopes, severely eroded	GwE3	High
Gilpin-Upshur-Rock outcrop complex, 35 to 70 percent slopes	GxF	High
Vandalia silt loam, 15 to 25 percent slopes	VaD	High
Vandalia silt loam, 15 to 25 percent slopes, very stony	VbD	High

PUTNAM		
Name	Symbol	Soil Slip Potential
Gilpin-Upshur complex, 15 to 25 percent slopes	GuD	High
Gilpin-Upshur complex, 25 to 35 percent slopes	GuE	High
Gilpin-Upshur complex, 35 to 70 percent slopes	GuF	High
Vandalia silt loam, 15 to 25 percent slopes	VaD	High
Vandalia silt loam, 25 to 35 percent slopes	VaE	High
Vandalia silty clay loam, 15 to 25 percent slopes, severely eroded	VdD3	High

Raleigh		
Name	Symbol	Soil Slip Potential
Berks-Highsplint-Sharondale complex, 35 to 80 percent slopes, very stony	BhG	High
Cateache-Pipestem complex, 35 to 80 percent slopes, very stony	CcG	High
Gilpin-Highsplint-Berks complex, 35 to 90 percent slopes, extremely stony	GhG	High
Layland-Cliff-top complex, 35 to 70 percent slopes, very stony	LdF	High
Layland-Dekalb-Guyandotte complex, 35 to 70 percent slopes, extremely stony	LeF	High
Layland-Dekalb-Rock outcrop complex, 55 to 80 percent slopes, extremely stony	LgG	High
Layland-Rock outcrop complex, 35 to 70 percent slopes, very rubbly	LkF	High
Lithic Udorthents-Rock outcrop complex, cut land, 5 to 100 percent slopes	LxG	High
Udorthents, graded, 15 to 55 percent slopes	UgF	High

RITCHIE		
Name	Symbol	Soil Slip Potential
Vandalia silty clay loam, 20 to 30 percent slopes, severely eroded	VdD3	High

ROANE		
Name	Symbol	Soil Slip Potential
Vandalia silt loam, 15 to 25 percent slopes	VaD	HIGH

TAYLOR		
Name	Symbol	Soil Slip Potential
Clarksburg silt loam, 15 to 25 percent slopes	CID	HIGH
Clarksburg silt loam, 15 to 25 percent slopes, severely eroded	CID3	HIGH
Culleoka silt loam, 25 to 35 percent slopes	CuE	HIGH
Culleoka silt loam, 25 to 35 percent slopes, severely eroded	CuE3	HIGH
Culleoka silt loam, 35 to 60 percent slopes, severely eroded	CuF3	HIGH
Dekalb extremely stony sandy loam, very steep	DSF	HIGH
Ernest silt loam, 15 to 25 percent slopes	EnD	HIGH
Ernest very stony silt loam, 15 to 35 percent slopes	EsD	HIGH
Faywood silty clay loam, 15 to 25 percent slopes	FaD	HIGH
Faywood silty clay loam, 25 to 35 percent slopes	FaE	HIGH
Faywood silty clay loam, 35 to 60 percent slopes	FaF	HIGH
Gilpin silt loam, 25 to 35 percent slopes	GIE	HIGH
Gilpin silt loam, 35 to 70 percent slopes	GIF	HIGH
Gilpin very stony silt loam, 15 to 35 percent slopes	GsE	HIGH
Gilpin very stony silt loam, very steep	GTF	HIGH
Gilpin-Upshur complex, 15 to 25 percent slopes	GuD	HIGH
Gilpin-Upshur complex, 15 to 25 percent slopes, severely eroded	GuD3	HIGH
Gilpin-Upshur complex, 25 to 35 percent slopes	GuE	HIGH
Gilpin-Upshur complex, 25 to 35 percent slopes, severely eroded	GuE3	HIGH
Gilpin-Upshur complex, 35 to 70 percent slopes, severely eroded	GuF3	HIGH
Guernsey silt loam, 8 to 15 percent slopes	GyC	HIGH
Guernsey silt loam, 15 to 25 percent slopes	GyD	HIGH
Guernsey silt loam, 15 to 25 percent slopes, severely eroded	GyD3	HIGH

Name	Symbol	Soil Slip Potential
Upshur silty clay, 15 to 25 percent slopes, severely eroded	UhD3	HIGH
Vandalia silty clay loam, 15 to 25 percent slopes	VaD	HIGH
Vandalia silty clay loam, 15 to 25 percent slopes, severely eroded	VaD3	HIGH
Westmoreland silt loam, 25 to 35 percent slopes	WmE	HIGH
Westmoreland silt loam, 25 to 35 percent slopes, severely eroded	WmE3	HIGH
Westmoreland silt loam, 35 to 60 percent slopes	WmF	HIGH

TYLER		
Name	Symbol	Soil Slip Potential
Cedarcreek channery silt loam, steep, stony	CeE	High
Gilpin-Upshur complex, 15 to 25 percent slopes	GpD	High
Gilpin-Upshur complex, 25 to 35 percent slopes	GpE	High
Gilpin-Upshur complex, 35 to 70 percent slopes	GpF	High
Gilpin-Upshur complex, 15 to 25 percent slopes, severely eroded	GwD3	High
Gilpin-Upshur complex, 25 to 35 percent slopes, severely eroded	GwE3	High
Gilpin-Upshur-Rock outcrop complex, 35 to 70 percent slopes	GxF	High
Vandalia silt loam, 15 to 25 percent slopes	VaD	High
Vandalia silt loam, 15 to 25 percent slopes, very stony	VbD	High

UPSHUR		
Name	Symbol	Soil Slip Potential
Gilpin-Upshur silt loams, 15 to 25 percent slopes	GuD	High
Gilpin-Upshur silt loams, 25 to 35 percent slopes	GuE	High
Gilpin-Upshur silt loams, 35 to 65 percent slopes	GuF	High
Gilpin-Upshur complex, 15 to 25 percent slopes, severely eroded	GwD3	High
Gilpin-Upshur complex, 25 to 35 percent slopes, severely eroded	GwE3	High
Vandalia silt loam, 15 to 25 percent slopes	VaD	High
Westmoreland-Upshur silt loams, 25 to 35 percent slopes	WuE	High
Westmoreland-Upshur silt loams, 35 to 65 percent slopes	WuF	High

WEBSTER		
Name	Symbol	Soil Slip Potential
Clifftop channery silt loam, 35 to 70 percent slopes, very stony	CnF	High
Clifftop-Dekalb complex, 15 to 35 percent slopes, extremely stony	CpE	High
Clifftop-Laidig association, very steep, extremely stony	CSF	High
Pineville-Clifftop complex, 55 to 70 percent slopes, extremely stony	PfG	High

WETZEL		
Name	Symbol	Soil Slip Potential
Gilpin-Peabody complex, 15 to 25 percent slopes	GpD	High
Gilpin-Peabody complex, 25 to 35 percent slopes	GpE	High
Gilpin-Peabody complex, 35 to 70 percent slopes	GpF	High
Gilpin-Rock outcrop complex, very steep	GrF	High
Vandalia silty clay loam, 15 to 25 percent slopes	VaD	High
Vandalia silty clay loam, 25 to 35 percent slopes	VaE	High
Vandalia silty clay loam, 15 to 25 percent slopes, extremely stony	VbD	High
Vandalia-Urban land complex, 15 to 25 percent slopes	VuD	High

WIRT		
Name	Symbol	Soil Slip Potential
Peabody-Gilpin complex, 40 to 55 percent slopes	PgF	High
Peabody-Gilpin complex, 30 to 55 percent slopes, severely eroded	PgF3	High
Peabody-Gilpin complex, 30 to 55 percent slopes, very stony	PvF	High
Upshur-Gilpin complex, 20 to 30 percent slopes	UgD	High
Upshur-Gilpin complex, 20 to 30 percent slopes, severely eroded	UgD3	High
Upshur-Gilpin complex, 30 to 40 percent slopes	UgE	High
Upshur-Gilpin complex, 30 to 40 percent slopes, severely eroded	UgE3	High
Vandalia silty clay loam, 20 to 30 percent slopes, severely eroded	VaD3	High

WOOD		
Name	Symbol	Soil Slip Potential
Peabody-Gilpin complex, 40 to 55 percent slopes	PgF	High
Peabody-Gilpin complex, 30 to 55 percent slopes, severely eroded	PgF3	High
Peabody-Gilpin complex, 30 to 55 percent slopes, very stony	PvF	High
Upshur-Gilpin complex, 20 to 30 percent slopes	UgD	High
Upshur-Gilpin complex, 20 to 30 percent slopes, severely eroded	UgD3	High
Upshur-Gilpin complex, 30 to 40 percent slopes	UgE	High
Upshur-Gilpin complex, 30 to 40 percent slopes, severely eroded	UgE3	High
Vandalia silty clay loam, 20 to 30 percent slopes, severely eroded	VaD3	High

Counties with no known High Slip Potential Soils:

Berkeley, Boone, Grant, Hardy, Greenbrier, Hampshire, Mineral, Logan, Mingo, McDowell, Mercer, Monroe, Pendleton, Pocahontas, Preston, Randolph, Summers, Tucker, Wyoming



The INGAA Foundation, Inc.

Mitigation of Land Movement in Steep and Rugged Terrain for Pipeline Projects: Lessons Learned from Constructing Pipelines in West Virginia

Prepared By: Golder Associates, Inc.



Prepared For: The INGAA Foundation, Inc.

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Executive Summary

Land movement, particularly in variable, steep, and rugged terrain, can pose a threat to the integrity of a pipeline if those threats are not mitigated. The INGAA Foundation Inc. contracted Golder Associates Inc. to review mitigation efforts on pipeline alignments or rights of way (ROWs), in an effort to educate and inform those in the pipeline industry about the threats of land movement and outline practical mitigative measures.

Golder has provided geotechnical and hydrotechnical engineering and geologic hazard assessment support to pipeline companies in the Appalachian Basin and has used its experience, expertise and technical resources from previous work in the area to develop this document. Many areas in Appalachia, and particularly West Virginia, contain conditions with rugged terrain that is variable, steep, rugged, geologically diverse, and can be very wet. All of these factors can contribute to land movement that could threaten new and existing pipelines and ROW corridors. While this report specifically addresses issues found in Appalachia, the concepts outlined in this document are applicable to other areas in the U.S. and Canada with similar hydrologic, topographic and geologic conditions.

This study identifies a number of critical items when mitigating land movement on pipeline ROWs. These include:

- The importance of identifying landslide and erosion hazards, and incorporating that information into the design, planning and construction phases of a project. Mitigation efforts should be tailored to address site-specific conditions as well as to balance costs with practicality of installation, operation and mitigation of risk. Note, the identification and characterization of landslide and erosion hazards represents a science all by itself, and is not directly addressed herein. This document focuses on the mitigation efforts related to these hazards;
- The critical role of route selection in identifying and avoiding hazards that may impact pipelines and ROWs. Careful planning and routing is always preferred to avoid or minimize potential threats from landslide and erosion hazards, but mitigation is usually required when such hazards cannot be avoided;
- The need to incorporate site-specific mitigation measures into the project planning process, to address threats to the pipeline and the ROW. The cause of any given landslide or erosion hazard is commonly the result of several contributing factors. Defining the governing geologic hazard and geotechnical/hydrotechnical engineering processes that are contributing to the land movement is critical in supporting the selection, planning, and design of an effective mitigation plan. Ultimately, the owner/operator must decide on the acceptable level of risk for any given mitigation package;
- The association between land movement and surface and subsurface water in combination with changes in the local ground conditions from recent or historical changes in geologic conditions and/or construction-related activities. Examples of mitigation options that address these conditions include re-grading the ROW surface to improve site conditions, modifying local surface drainage, conveyance of sub-surface drainage, modified ROW backfill materials, deformable backfill in the pipeline trench, removal of unstable soil and replacement with engineered performance materials, ground surface erosion protection, slope breakers, trench breakers, special pipeline coatings and protective sleeve-wraps, modified ROW configurations, monitoring and special pipeline design. These options are typically used in combination to develop a strategy for addressing the identified hazards at any given site;
- Structural measures are also available to address unstable slopes, such as retaining walls, soldier piles, sheet piles, wire mesh systems, mechanically stabilized earth systems and other mechanical structures. These options can be costly, have special equipment and access requirements in order to install in steep slope conditions, may limit future access or

- expansion in constrained ROW corridors, and may also have special long-term maintenance requirements;
- Reducing ground disturbance through minimized ROW footprints, appropriately sized and applicable equipment, and planning construction during optimal seasonal conditions (i.e. dry versus wet) can minimize mitigation requirements;
 - Consideration of the landslide and erosion processes, and the origin of the source(s) of water relative to the constructed pipeline ROW. In particular, mitigation measure selection should consider the disturbed temporary ground surface from the initial grading of the ROW and subsequent construction work and not just the finished and restored ROW surface;
 - Organizing mitigation options into a framework of Typical Scenarios and supporting Typical Details that are consistent with how the ROW is built (i.e. ridge top, planar slopes, side slope, etc.). This allows for rapid development of conceptual site-specific mitigation plans during project planning and design;
 - Designing to mitigate for all or only portions of targeted threats from land movement, thereby allowing the owner/operator to decide and select the level of mitigated risk, and allowing time for the owner/operator to plan, assess and make risk-based decisions on how to best manage the asset.

The most effective mitigation strategy requires recognition of the multiple factors governing a site, and may require long-term performance monitoring before full mitigation can be achieved. In some situations, the mitigation may not be intended to provide a long-term permanent mitigation and full elimination of the hazard. Instead, the pipeline ROW is mitigated to an acceptable level of risk. As such, mitigation measures should be tailored to address the site specific and potentially variable conditions, consider the risk tolerance of the owner/operator, consider the costs and benefits of long-term and short-term solutions, and incorporate construction considerations into the planning and design efforts and integrate with the construction process.

While mitigation efforts will not prevent every landslide or all erosion hazards, comparison of mitigated versus un-mitigated cost risk suggest that a comprehensive program of proactive mitigation and implementation on a system-wide scale can significantly reduce overall risk in a pipeline system, and can provide compounding benefits over time.

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- SHEET 1110, SIDE SLOPE (NORMAL)
- SHEET 1120, SIDE SLOPE (OBLIQUE)
- SHEET 1130, RIDGE TOP
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Appendix A-2 Typical Details (42 Sheets)

- | | |
|----------------------------|---------------------------|
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| ■ 1B-ENHANCED DRAIN | ■ 4D-SLEEVE |
| ■ 1C-TARGETED SEEP DRAINS | ■ 5A-SLOPE BREAKER |
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| ■ 1E-DRAIN PIPE OUTFALL | ■ 5C-SLOPE BREAKER CH'S |
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| ■ 1H-STEEP CONVEYANCE | ■ 6B-BROW DITCH |
| ■ 2A-GRADING TEMP ROW | ■ 6D-ARMORED CHANNEL |
| ■ 2B-STABLE WEDGE | ■ 8A-ROCK GUARD |
| ■ 2C-COMPACT FILL | ■ 10A-BENCHS |
| ■ 2D-DRY SOILS/BACKFILL | ■ 11A-GEODETIC MONITORING |
| ■ 2E-REMOVE UNSTABLE SOIL | ■ 11B-STRAIN GAUGES |
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1.0 INTRODUCTION

This document was developed in coordination with Golder Associates Inc. (Golder) and the INGAA Foundation, Inc. (INGAA), for the purpose of presenting ideas and concepts for mitigation of land movement on pipeline alignments and rights-of-way (ROWs). The background and technical basis for topics outlined herein are based on Golder's experience providing geotechnical and hydrotechnical engineering and geologic hazard assessment support to Williams Ohio Valley Midstream (OVM) projects in northern West Virginia (Williams 2015). Golder also has more than three decades of experience working with clients on similar landslide and erosion hazard pipeline projects in the northwestern United States. The northern West Virginia region (see dashed box, Figure 1-1) and the surrounding Appalachian Basin have a high incidence of landslides, as mapped by Radbruch-Hall et al. (1982), and shown by the red areas in Figure 1-1. This region is also mapped as having high landslide susceptibility (Radbruch-Hall et al. 1982). The potential high landslide incidence and susceptibility highlight the need for increased awareness of landslide hazards in the design, planning and construction of pipelines in West Virginia.

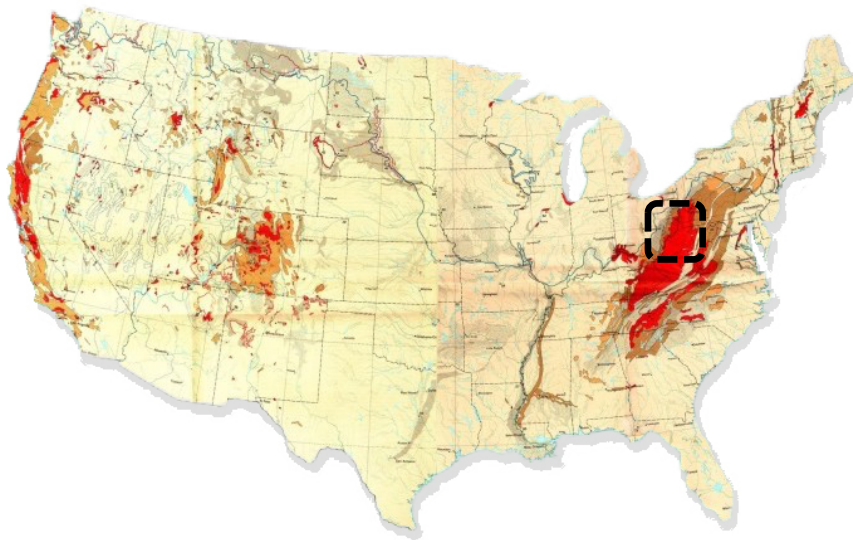


Figure 1-1: Landslide Incidence and susceptibility across the US (Radbruch-Hall, et al., 1982, USGS Professional Paper 1183)

The unique conditions in West Virginia include mountainous terrain that is variable, steep, rugged, geologically diverse, and can be very wet. All of these conditions contribute to land movement that could threaten new and existing pipelines and ROW corridors. The specific natural conditions observed in West Virginia provide the basis for development of mitigation efforts associated with land movement. Specifically, observed topographic conditions were used to define typical pipeline construction-related scenarios (i.e. ridge top, planar slopes, side slope, etc.) and corresponding typical mitigation measures for land movement. These construction scenarios can be used during the project design and planning phases or concurrently during pipeline installation as varying conditions are encountered. These mitigation efforts can be used in other areas around the United States with similar hydrologic, topographic and geologic conditions.

1.1 Project Objective

The objective of this study is to communicate the key topics to be considered when planning and implementing mitigation of land movement (i.e. landslides and erosion related hazards) that may threaten a pipeline including:

- The importance of identifying landslide and erosion hazards, and incorporating that information into the design, planning and construction phases of a project. Note: the identification and characterization of landslide and erosion hazards represents a science all by itself, and is not directly addressed in this document. This document focuses on the subsequent mitigation efforts;
- The critical role of route selection in identifying and avoiding hazards that may impact pipelines and ROWs;
- The need to incorporate site-specific mitigation measures into the project planning process, to address threats to the pipeline and the ROW. Ultimately, the owner/operator must decide on the acceptable level of risk for any given mitigation package;
- The association between land movement and surface and subsurface water in combination with changes in the local ground conditions from recent or historical changes in geologic conditions and/or construction-related activities. Therefore, mitigation measures should be tailored to address these site specific conditions;
- Reducing ground disturbance through minimized ROW footprints, appropriately sized and applicable equipment, and planning construction during optimal seasonal conditions (i.e. dry versus wet) can minimize mitigation requirements;
- Consideration of the landslide and erosion processes, and the origin of the source(s) of water relative to the constructed pipeline ROW. In particular, mitigation measure selection should consider the disturbed temporary ground surface from the initial grading of the ROW and subsequent construction work and not just the finished and restored ROW surface;
- Organizing mitigation options into a framework of Typical Scenarios and supporting Typical Details that are consistent with how the ROW is built (i.e. ridge top, planar slopes, side slope, etc.). This allows for rapid development of conceptual site-specific mitigation plans during project planning and design; and,
- Designing to mitigate for all or only portions of targeted threats from land movement, thereby allowing the owner/operator to decide and select the level of mitigated risk, and allowing time for the owner/operator to plan, assess and make risk-based decisions on how to best manage the asset.

There are many more parts of a pipeline project that address planning, design, and construction that are not specifically addressed in this study, such as (but not limited to): geologic hazard identification and characterization, environmental assessments, permitting, land access and acquisition, detailed design of the pipeline and associated facilities, materials specifications, safety and integrity considerations. These topics are important and need to be incorporated in the overall project planning process, but are outside the scope of this study.

1.2 Structure of the Study

This study is organized into Planning and Mitigation sections. The Planning section summarizes the routing process and key topics that are incorporated into selection of the optimal pipeline alignment. While Planning is not the primary focus of this document, and more detailed information can be found in other supporting studies, it is important to describe the key planning and routing issues and how these issues transition into the development of mitigation recommendations. Therefore, planning is described in a general sense as a precursor to the mitigation section. The discussion is focused on the key pieces of information, data and concepts that help identify hazards that may result in land movement, or could potentially impact the pipeline and the ROW. Ultimately, where identified hazards cannot be avoided, the planning and routing process allows the owner/operator to determine where potential hazards exist along a given pipeline alignment and serves as the starting point to mitigate those potential hazards.

The Mitigation section of the study, the primary focus of this document, discusses practical means for addressing landslide- and erosion-related hazards commonly observed along ROW alignments in OVM. Understanding the problem and defining the processes governing the hazard(s) is paramount to

selecting the most effective and fit-for-purpose mitigation response. This section describes an approach using Typical Scenarios and supporting Typical Details, which allows for organizing, selecting and communicating appropriate conceptual mitigation measures. The Mitigation section provides a background overview of mitigation concepts, and a more detailed discussion of mitigation guidelines for specified Typical Scenarios encountered along the pipeline ROW and descriptions of corresponding Typical Details (i.e. individual typical mitigation measures). This section also includes a discussion that covers general relative costs in terms of cost risk associated with mitigating land movement

1.3 Limitations

Recommendations outlined herein are based on experience with geologic, geotechnical and hydrotechnical conditions typical to the geology, topography and hydrology of the area in and around the Williams OVM system in West Virginia (as described in Section 2.1), and as such are primarily applicable to addressing similar hazards observed in this area. At any given site, mitigation efforts should engage technical experts with experience in addressing the identified hazards and implementing the appropriate kinds of mitigation measures. Any recommendations should include an appropriate level of site-specific investigation, characterization, technical assessment and engineering to support continued planning, design and construction efforts.

2.0 PLANNING

The planning phase of any pipeline project consists of numerous tasks, including a project needs analysis and modeling, open season (FERC projects), project justification analysis, authorization and certification through regulatory agencies, environmental reviews, corridor reviews, routing alternatives and reviews, ROW negotiation and acquisition, surveys, design of line pipe and facilities, etc. (INGAA 2013). While this study focuses on mitigation efforts (Figure 2-1), it is important to understand where mitigation fits into the overall process for addressing hazards.

The following discussion addresses the routing portion of the pipeline project planning process. Routing is a critical step in the design and planning phases. Since routing identifies the location that a proposed pipeline will traverse the landscape, this routing portion of the project should also identify and define the hazards that the pipeline may encounter, and should dictate the level of effort needed to mitigate for hazards in the design, construction and operation of the pipeline.

The basic conceptual approach to address landslide and erosion-related hazards is shown in Figure 2-1. Routing occurs during the initial steps when the hazards are identified, and subsequent characterization and assessment studies are completed to better understand how the identified hazards may impact or threaten selected pipeline alignments.



Figure 2-1: Conceptual Approach to Geologic Hazard Management

Once hazards are identified and characterized, mitigation can be developed to address the hazards. Subsequent monitoring is needed to track the performance of the selected mitigation approach. When issues with the previously installed mitigation occur (i.e. subsequent operation and maintenance activities), or new hazards develop, the process continues by identifying the new hazards and characterizing them to better understand what new or additional mitigation is needed. This process is generally implemented in phases, and can move in either direction in the process, but it is typically more efficient when the sequential steps link to each other as shown.

2.1 Understanding the Project Setting

Understanding regional and site-specific geologic settings is critical for development of landslide and erosion mitigation recommendations and plans. The area of northern West Virginia that forms the basis for this study is located in the northern un-glaciated plateau section (i.e. the low plateau) of the Appalachian Basin (WVGES 2015). The eastern and southern portions of the Appalachian Basin transition into mountains (i.e. the high plateau). Our experience working in the low plateau area indicates that there exists a high potential for landslide and erosion related hazards. On a regional

scale, this area corresponds to the red areas extending across much of the Appalachian basin, and in particular across much of West Virginia shown in Figure 1-1.

The local bedrock geology in northern West Virginia is mapped as the Dunkard Group, which is characterized by non-marine cyclic sequences of alternating sedimentary units (Nicholson et al. 2007). The Dunkard Group sedimentary rock is generally flat-lying, and consists of sandstone, claystone, siltstone, mudstone, shale, limestone and coal.

The alternating sedimentary bedrock layers have varying degrees of strong and weak physical properties, which dictate the rate at which the layers weather and erode. Through geologic processes of uplift and subsequent incision through the sequenced sedimentary layers, the increased strength of the limestone and sandstone units results in steeper exposure faces versus the claystone, siltstone, shale and coal units which erode to flatter sloping exposures. As a result of the varying rates of weathering and erosion in the alternating layers, the terrain has evolved to a stepped and benched configuration (Figure 2-2). Note in Figure 2-2 the location of a constructed pipeline ROW following a local ridge-line through the stepped and benched topography.

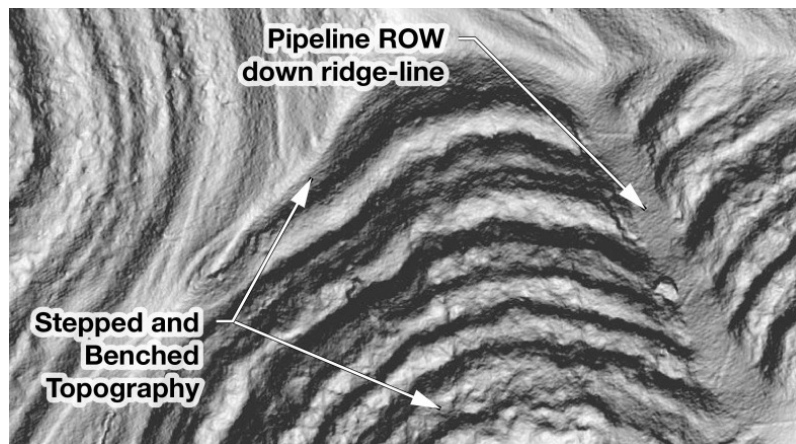


Figure 2-2: LiDAR hillshade example of stepped and benched topography in northern West Virginia [Notes: (1) Pipeline ROW following ridge down slope; (2) See discussion of LiDAR in Section 2.4; (3) Disturbed terrain along and below the benches describes landslide movement] (Williams 2015)

The benches can be well-defined where sequential sedimentary units alternate from strong to weak materials. They can also weather and erode to more consistent planar slopes where the units are less differentiated and weathering and residual soils are more prevalent, or the combination of weathering and in-filling has backfilled the benches.

Colluvium, accumulating and mantling the broader and flatter-sloped bedrock benches, along with the underlying residual soil from weathering of the sedimentary bedrock, result in ground conditions that are very sensitive and easily destabilized by saturation of soils from surface and subsurface water. The sedimentary layering of bedrock also governs groundwater flow conditions, creating generally flat or bedded horizontal pathways that tend to discharge groundwater in seeps and springs along the transitions between bedrock units. The benches can intercept and route surface flows. These surface and subsurface flow paths can be easily intercepted and changed through surface disturbance. These unique geologic conditions govern the dynamics of landslide and erosion hazards addressed in this study, and form the basis for the approach and methods of mitigation discussed herein.

2.2 Challenges of Routing in West Virginia

Routing includes the planning and decision making processes to select an alignment for a pipeline. The corresponding ROW design, planning and construction efforts incorporate a long list of variables addressing topography (with focus on variable, steep and difficult terrain), environmental resources, cultural resources, wetlands, rivers and streams, surface soils, subsurface geology, shallow bedrock, protected areas, developed areas, public properties, homes, wells, septic systems, existing ROWs, existing pipelines, roads, and surface and underground mining activities (where applicable).

In the mountains of West Virginia, the optimal routing alignments are along ridge tops and valley bottoms, which can often already be occupied with residential and commercial development, pushing pipeline corridors to more challenging alignments along sidehills and sloping terrain. This makes it difficult to find the combination of “good ground” that offers the shortest length alignment and meets the project needs. Existing infrastructure has developed to take advantage of the stability of the higher ridge top areas, which is why roads, homes and businesses are located in these areas. The rugged nature of the terrain in this region does not allow for much additional open and stable ground away from the already limited ridge top areas, which may push newer infrastructure into more challenging terrain.

From the simple perspective of project length, pipeline alignments in areas prone to land movement may be doubled or tripled to avoid identified hazards, or an alternate alignment may actually encounter more hazards by trying to avoid or traverse around a single targeted hazard. Because all hazards cannot be avoided and because the planning process must weigh the costs of longer alignments to avoid hazards versus cost of mitigation of the hazard, decisions are frequently made to mitigate a hazard in the design, construction or operational phases of a project.

2.3 Routing – An Art and a Science

The general approach to routing a pipeline includes: collecting available data, completing a desk-top assessment, ground verification of the preferred and alternative alignments, collecting more data (as needed) and going through the final assessments and reviews to determine the final alignment. It is difficult to generalize the routing conditions that apply to any given pipeline project, because every project is unique, having its own site-specific conditions. As such, routing a pipeline should be considered as much an art as a science, based on expertise of local conditions. Project planners should recognize that a standard approach to route all pipelines does not exist and that some level of project-specific planning is needed to fit the project needs (ASCE 1965). However, some qualitative guidelines, skills, experience, and expertise that may apply include the following:

- Sufficient knowledge to understand the engineering planning that supports the proposed project;
- Ability to work with planners to develop alternative routing alignments;
- Knowledge of pipeline design and construction practices;
- Understanding what is needed to maintain a pipeline over the operational lifespan;
- Understanding and knowledge of the environment and use of subject-matter-experts (SMEs) that work in specific environmental fields;
- Ability to consider input and advice from geologists, geotechnical and hydrotechnical engineers, and environmental SMEs;
- Awareness of local issues and concerns in the proposed pipeline route area(s);
- Knowledge of the rules, regulation and laws in the project area(s);
- Awareness of the political, landowner and regulatory stakeholder issues along the proposed pipeline route that may influence alignment;

- Skills, expertise and experience to explain the proposed route to stakeholders, in both official or informal communications, and the ability to consider criticism of proposals and develop reasonable alternatives; and,
- Detailed preparations and technical support efforts that will help develop the basis for routing decisions, making it possible to discuss and defend such decisions.

2.3.1 Initial Routing Considerations

The pipeline corridor selection depends on supply locations and delivery markets, with an end goal of finding the most economical route that balances regulatory, environmental, engineering and operational requirements (INGAA 2013). Routing may use existing pipeline corridors, which in some situations may have already taken the best route location. In some cases, even short offsets of tens or hundreds of feet can make the difference between a good or bad route. These kinds of micro-routing adjustments can address targeted sites, but may not address regional conditions that have persistent landslide or erosion hazards.

Where broader, more prevalent landslide and erosion hazard conditions exist in combination with sensitive environmental resources and topographic features such as large rivers, lakes, mountain ranges, manmade structures, populated areas, and existing infrastructure, the options for routing are much more limited and challenging. Localized site-specific land owner input and requirements for access across properties can further add limitations that push alignments into less than desirable routing scenarios. Where the pipeline and the ROW intersect landslide and erosion hazards, and other routing inputs do not allow for avoiding the hazards, mitigation may be needed.

2.4 Conceptual Routing Approach

Any routing study includes some aspect of the following basic steps:

- Preliminary Route identification relative to possible hazards, and review of option(s);
- Desktop assessment and review of routing option(s) and corresponding hazards;
- Field reconnaissance of routing option(s);
- Selection/evaluation of route(s) (note that review and assessment of options may include risk-based methods); and,
- Design and planning of targeted mitigation measures to address identified hazards (addressed in subsequent sections of this study).

The simplest approach to route a pipeline is to locate the alignment on ridge tops, or in flat valley bottom areas, or when going between these two areas to traverse straight down planar valley slopes. Landslide and ROW surface erosion hazards associated with land movement are not typically located along ridge tops or in flat valley bottom areas, although valley bottom areas can have other types of hazards, most notably stream and river crossings and associated bank erosion and lateral channel migration hazards. Landslide and erosion hazards are more commonly found, or created, on steep slopes and where the proposed alignment intersects existing landslide and erosion hazards in planar, oblique alignment and side-hill conditions. While disturbance of the ground and construction of the ROW can trigger landslides, reactivate existing native landslides, or result in erosion, the failure to mitigate for potential instability in steep and rugged terrain can result in failure of construction backfill and ROW restoration efforts. Careful planning to identify these at-risk areas in the project planning phase or during construction is needed, and where the risk of land movement is high enough, targeted mitigation should be employed to address identified hazards.

The routing process should include the identification and review of potential hazards along proposed corridor or alignments, as well as consider the logistics for constructing the pipeline in the types of terrain and conditions encountered along the selected or alternate route(s). In particular, the feasibility of a given route relies heavily on the ability to construct the pipeline in a safe, economical and practical

manner. To accomplish this, a certain amount of temporary ROW is needed to support construction, particularly in challenging terrain scenarios mentioned above (i.e. oblique and sidehill conditions), and then a corresponding permanent ROW is needed to maintain pipeline access. Routing review for proposed or alternate alignments needs to consider the construction feasibility relative to the required temporary and permanent ROW width when making decisions on route placement. The constructed ROW and methods used to build the ROW directly affect the stability of the disturbed ROW footprint and subsequent restoration work, and directly impact the potential for land movement.

Typical routing efforts start with desktop work using publicly available data and information, and are supplemented with ground reconnaissance and helicopter or fixed-wing reconnaissance of possible routes. Subsequent site surveys, or other more detailed site investigations or mapping efforts, are conducted as route options are pushed through the review process.

A generalized routing process can be organized into a series of logical decision steps designed to fit the purpose of any project. An example of a routing decision process flowchart developed by Williams is shown in Figure 2-3. The Williams process is designed to incorporate available relevant information, assess conditions, and identify possible impacts and hazards to the pipeline and ROW, to provide for iterative reviews and development of alternatives. A brief summary of the process is outlined below.

The following provides a summary of the conceptual routing approach steps from Figure 2-3:

- After the project kick-off, the initial step in the process is to develop desk-top reviews and feasibility studies for preferred and alternate routes. The feasibility studies may include geologic hazard assessments using specialized mapping and data sets that highlight landslide, subsidence, erosion, or other applicable hazards, and thereby support evaluation of multiple routing alternatives to allow selection of the optimal available option;
- Once a corridor and/or applicable options have been identified, preliminary permission for access to possible route alignments is secured to review, survey and assess conditions on the ground. Studies at targeted sites may be needed, including environmental, geotechnical or hydrotechnical engineering, or geologic assessments and investigations to assess site-specific conditions, and to consider constructability. This series of steps is typically an iterative process, that incorporates technical and environmental assessments with ground-based reviews of the proposed alignment to work out special planning considerations and support continued project planning, design, permitting and construction efforts. As ground conditions are better understood, site-specific field evaluations can be completed and re-route assessments considered. Any review of options on the ground requires continued coordination for land access and authorizations from property owners along the primary or alternate alignments;
- When routing modifications are needed, the process must reconsider feasibility, and may require additional studies and land access and coordination with technical experts and with land owners to further vet a re-route option(s);
- Once a route is approved, the operator then conducts more detailed civil surveys, completes environmental surveys, finalizes maps and alignment sheets, completes easements and completes detailed “on the ground” inspection of the full alignment;
- A final design review is completed after the final project alignment is established. Any issues with the route that may impact final approval can iterate back through the route modification process; and,
- After completing the final route review, and no additional routing modifications are needed, then the route is finalized and issued for construction.

This example of the routing process is intended to provide ideas and a framework for the general components of an applicable approach, and recognizes the details and specific steps would still need to be developed for any given project. The routing approach for each project should be developed to

best fit the purpose of that project, include input and consultation from the project team, in particular getting input from the regulatory and environmental SMEs on the project, to address the anticipated regulatory planning and review.

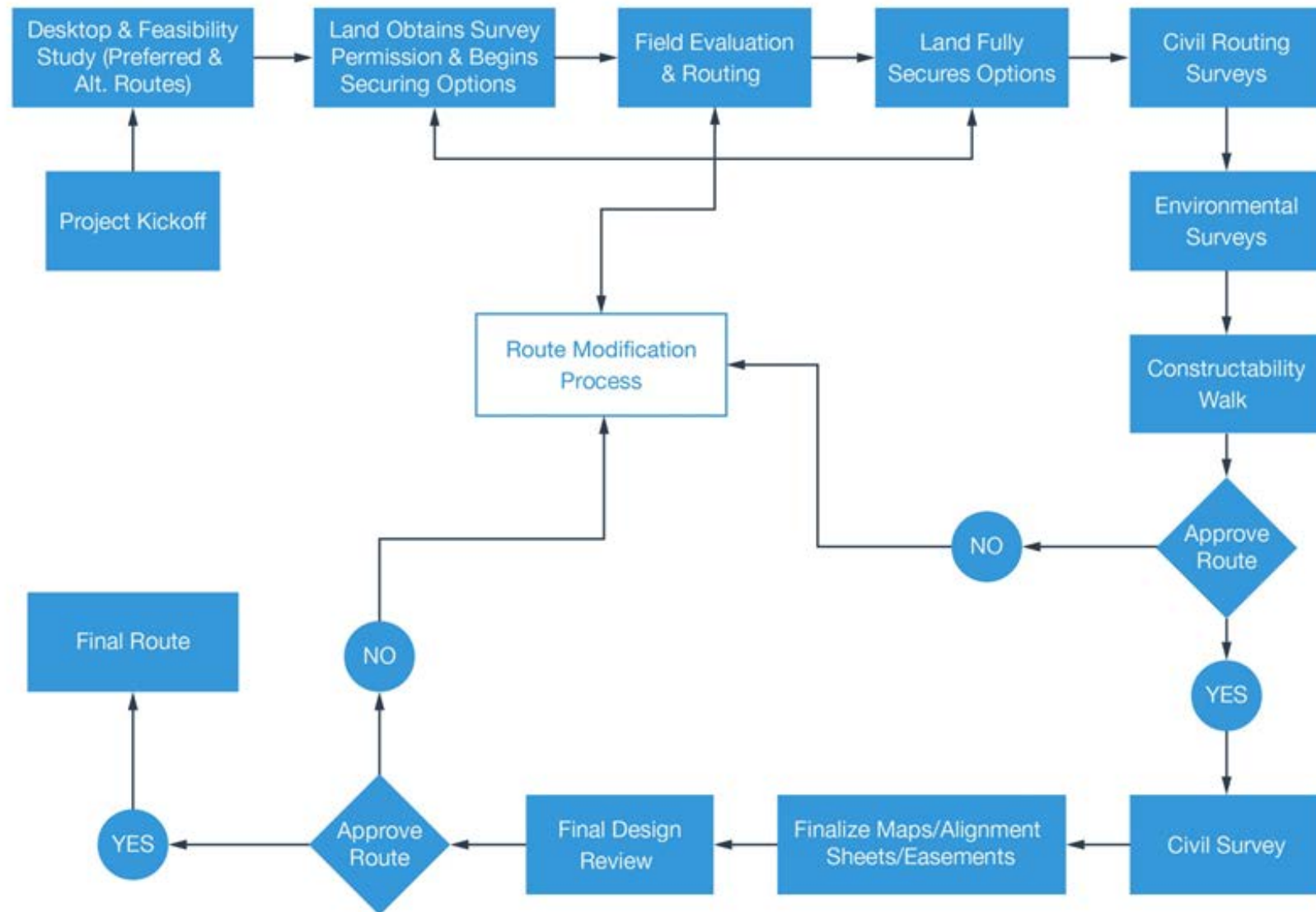


Figure 2-3: Conceptual Williams Project Planning and Routing Approach (Williams 2015)

2.5 New Tools for Routing and Monitoring

Routing traditionally relies on experienced SMEs who can assess ground conditions. Their work is supported by walking, driving, or airborne reconnaissance work, and review of publicly available topographic maps, geologic mapping resources, and remote sensing imagery to assess alignment options. Some new tools have been incorporated into pipeline routing studies in recent years, including airborne light detection and ranging (LiDAR) mapping techniques. LiDAR and satellite-based interferometric synthetic aperture radar (InSAR) have been used in some applications for monitoring. This study is not intended to provide a detailed discussion of LiDAR and InSAR technologies, only to provide a high-level overview of these new tools. The following sections provide only brief summaries of these topics.

2.5.1 LiDAR

Airborne LiDAR is an active laser scanning system that measures the time of flight of an emitted laser signal returned from a target, and uses it to determine elevations and to develop digital elevation models (DEMs) of the ground surface (Fugro 2011, ESRI 1995-2013). Airborne LiDAR systems can be used to acquire three-dimensional data characterizing landform elevations along defined corridors or mapping areas (Figure 2-4). This has obvious advantages for mapping ground conditions along pipeline alignments, by allowing remote acquisition of detailed ground conditions to support project design, planning and construction efforts.

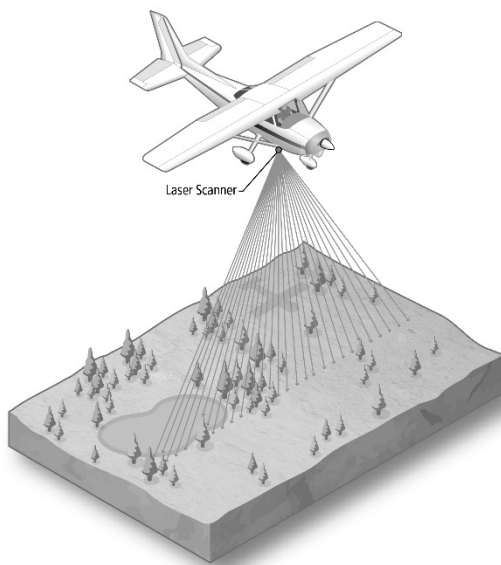


Figure 2-4: Airborne LiDAR data collection system schematic (Williams 2015)

LiDAR works by emitting multiple laser pulses over the same area, such that some pulses are reflected off intermediate surfaces (i.e. variable height vegetation, buildings, power lines, etc.) and some of the pulses find the underlying ground surface (Figure 2-5). The resulting data can be processed to differentiate the “returns,” and classify data that represent the ground surface. The resulting “bare Earth model” can show detailed topographic and geomorphic landforms that can be used to look for potentially hazardous landslide and erosion related processes, as well as support the continued engineering assessment and development of mitigation plans to address threats. This is especially useful for identifying and assessing potential geologic hazards, because LiDAR can detect the subtle ground morphologies that define natural and human-triggered landslide and erosion hazards (i.e. scarps, settlement, hummocky terrain, depletion zones, accumulation zones, sag ponds, disrupted drainage, etc.).

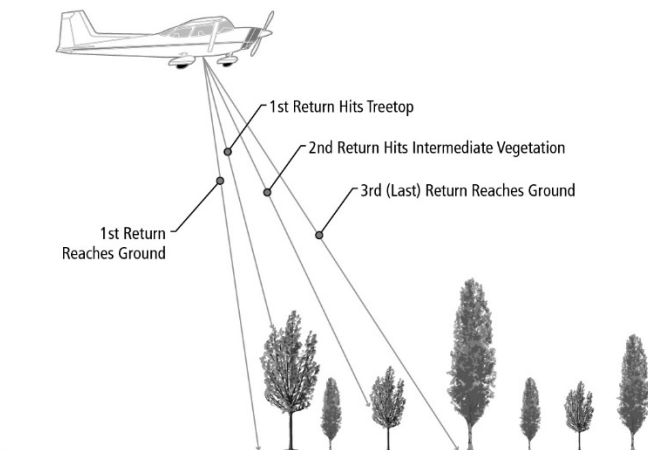


Figure 2-5: Multiple Returns from LiDAR Laser Pulses (Williams 2015)

The planning and design for the specification of LiDAR mapping data acquisition is critical. In particular, the acquisition of LiDAR mapping laser pulses can be blocked, diffused, or degraded in dense vegetation and/or rugged terrain. The specification for LiDAR mapping typically incorporates the following types of parameters (Watershed Sciences 2010, USGS et al. 2008):

- Laser Pulse Rate;
- Returns per Pulse;
- On-ground Laser Beam Diameters;
- Scan Angle;
- Aircraft Altitude;
- Aircraft Speed;
- Ground Swath Width;
- Swath Overlap;
- Aggregate Pulse Density (i.e. "points per m²", or ppsm);
- Flight Line Direction;
- GPS Bare-line Length;
- GPS PDOP; and
- Survey Conditions.

LiDAR data acquisition should consider "leaf-on" versus "leaf-off" conditions in areas where deciduous trees can dramatically change the effective and available "view" of the ground from the perspective of the data acquisition platform (i.e. fixed wing or helicopter aircraft). The preferable season for data acquisition is during leaf-off conditions, which can be a narrow window in late winter or early spring with no snow covering the ground. This is also a good time to capture the effects of winter-time landslide and erosion processes. Other seasons for LiDAR data acquisition can be fall through early winter after the leaves have fallen off the trees, the low-lying bushes and grass are thinned out or dead, and no snow cover exists. In times of no snow cover, data acquisition can continue through the winter months into spring until leaves start to come in and the bushes and grasses grow, creating a dense ground cover. The actual leaf-off period depends on the site and geographic region. LiDAR specifications can be relaxed during leaf-off, because there is better access for laser pulses to reflect from the ground surface.

LiDAR technology is changing rapidly, resulting in improvements in both hardware and software associated with data acquisition and processing. The final specification for a LiDAR mapping data acquisition mission typically incorporates some, or all of the parameters listed above, and should be planned in coordination with an experienced mapping professional to best fit the seasonal conditions and mapping requirements of the project area. A common parameter used to provide planning level guidance to project team members and mapping contractors is the “aggregate Pulse Density,” which is often referred to as the “points per square meter” (ppsm). Typical points ppsm parameters are listed as follows:

- Open country with low-level and sparse brush or ground cover: ~2-4 ppsm;
- Leaf-on rolling moderate terrain in light trees and brush: ~8-10+ ppsm;
- Leaf-off rugged terrain in trees and bush: ~10-15 ppsm; and,
- Leaf-on rugged terrain in trees and bush: ~15-20 ppsm.

The processing of LiDAR data is typically completed by specialty mapping contractors for defined dataset specifications, to develop the bare Earth DEM data that strips away vegetation and provides a view of the underlying ground. This data can be further processed to support routing and other project related work.

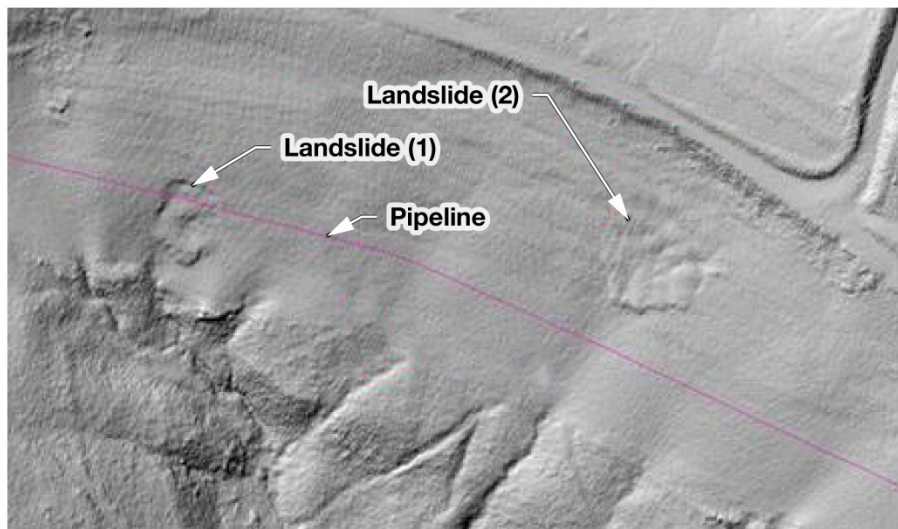


Figure 2-6: Example of LiDAR hillshade data presentation highlighting landslides across and adjacent to a pipeline alignment (Williams 2015)

LiDAR data allow for desk-top review of proposed routes, or existing ROWs, to identify possible landslide and erosion hazards. Figure 2-6 shows an example using “hillshade” views derived from LiDAR DEM data to review a pipeline alignment for possible landslide hazards. In Figure 2-6, landslide (1) crosses the pipeline alignment and would be reviewed for an increased potential threat to the existing pipeline, or in the case of a proposed alignment, this hazard would be considered for mitigation measures. Landslide (2), located away from the pipeline alignment, may have a lower threat potential and therefore not require further studies or mitigation.

LiDAR data can also be used for periodic monitoring of landslide and erosion hazards on existing pipeline ROWs (i.e. post construction). Such repeated LiDAR monitoring can be used in programs to compare and identify areas where there are differences in the elevations, which could correspond with possible land movement, landslides, erosion areas, or subsidence areas, creating a tool in which new hazards can be delineated and previously identified hazards can be monitored. In this case, sequential resultant data can be configured as a “heat map,” whereby changes in ground elevations are highlighted to depict possible landslide, erosion or subsidence activity (Williams 2015). These areas of movement would then

need to be reviewed and field-verified to confirm the actual conditions and governing reasons for the topographic changes.

An example of this tool is illustrated in Figures 2-7 through 2-9. Figure 2-7 shows an example of a LiDAR-derived hillshade view of a site where a valve set is located along a recently constructed pipeline alignment (i.e. before land movement). Figure 2-8 shows the same location approximately one year later, clearly showing land movement (in the dashed box) along the outside slope of the constructed pad (i.e. post land movement). Figure 2-9 shows an example of a “heat map” depicting the difference in ground elevations resulting from the failure of the pad embankment.

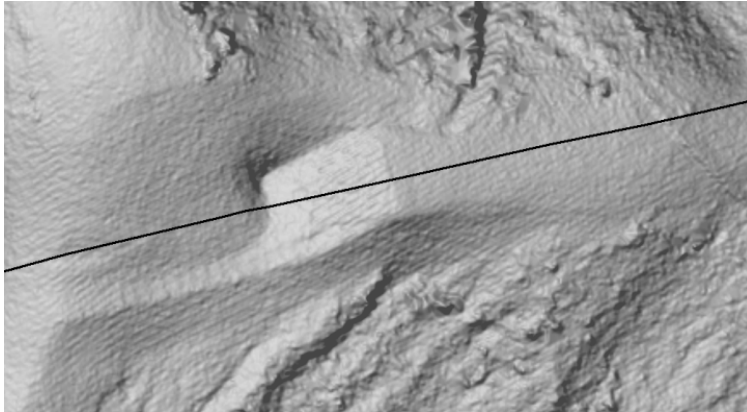


Figure 2-7: Example of Pre-movement LiDAR derived hillshade (Williams 2015)

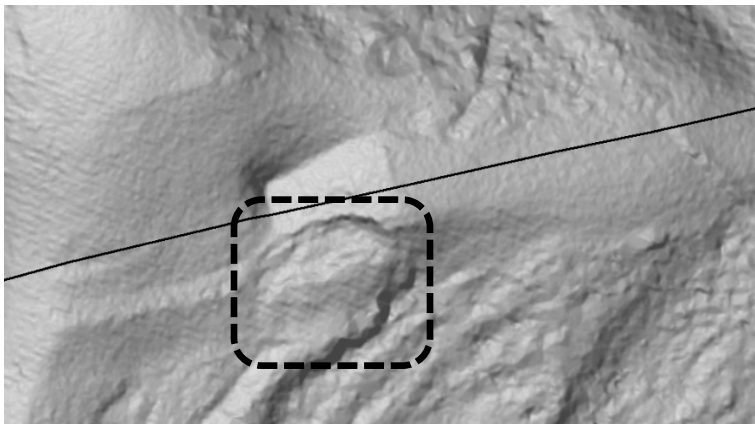


Figure 2-8: Example of Post-movement LiDAR derived hillshade (Williams 2015)

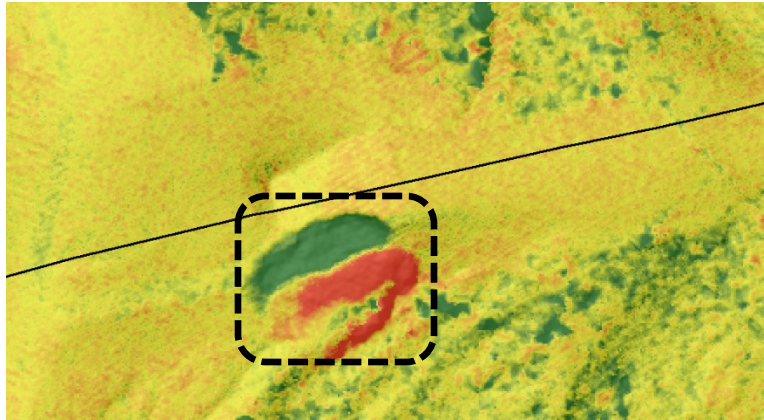


Figure 2-9: Example of “heat-map” showing comparison of successive data sets (Williams 2015)

The heat map is developed by comparing successive LiDAR mapping data sets. It shows the upslope depletion zone as the green shaded area (loss of elevation), and the downslope depositional zone as the red shaded area (gain of elevation). Acquisition of successive datasets, combined with review of compiled heat map results, allows for rapid monitoring assessment of possible land movement in a pipeline system.

2.5.2 InSAR

InSAR is a form of side-looking radar that uses a moving platform, typically satellite-based, to look at an angle toward the ground, perpendicular to its direction of travel (PRCI 2009). The phase of the returned signal is measured and used to estimate ground elevation. Comparison of successive datasets allows for identification of ground deformation. Datasets are generated by regularly scheduled satellite passes at approximate monthly timescales, such that data for a given site can be requested, where available, from historical archives. Typical applications of InSAR are focused on ground deformations resulting from earthquakes, volcanoes and large-scale subsidence (PRCI 2009). It is not generally used as a tool for looking at routing or land movement or other related hazards for pipeline alignments.

There are several factors that can affect the suitability of using InSAR data for a given site. When the moisture content and/or height of vegetation changes between datasets, this change can be detected as ground movement. Polar orbiting satellites collecting InSAR data have a “look direction” that is generally east or west, making them more sensitive to identifying movement along slopes facing the same direction, and less sensitive to slopes facing north and south. Steep slopes may also be difficult to monitor using InSAR due to layover, foreshortening, and shadow effects related to the satellite incidence angle (PRCI 2009). The use of corner reflectors (~1 meter orthogonal metal structures set on immobile foundations) can help in addressing some of these issues, but requires placement of a structure at targeted locations.

Depending on the site conditions and intent for use of the data relative to a given project, InSAR may be more applicable as a historical monitoring tool for tracking possible ground elevation changes where the data limitations fit the site conditions, rather than a tool for supporting routing assessments for new projects. The suitability of InSAR should be reviewed on a case-by-case basis, to best determine the suitability and feasibility for any given project application.

2.6 Typical Land Movement Processes

The typical landslide- and erosion-related land movement observed in the Williams OVM system in West Virginia include rock fall (typically from bench edges), ROW backfill “blowouts” (typically resulting from excessive groundwater seepage resulting in saturation of soils in the pipeline trench or within the restored ROW fills along sloped terrain), rotational and translational slides, debris flows, and slope soil creep. Shallow translational landslides appear to be the most common, and are often described by local residents as “slips” because of the locally, self-described nature of the observed ground deformations. While this represents local terminology, the correct technical description is as the applicable technically defined landslide or erosion process.

Landslide hazards typically pose a greater threat to pipeline integrity, because the nature and magnitude of ground movement may impose differential loading on the pipeline(s) that can exceed pipe strength capacity. Slope erosion hazards typically have a lower potential for integrity threat to pipeline(s), but often have an increased potential environmental impact (e.g. sediment delivery to water bodies), and increased potential for pipe corrosion or mechanical coating damage.

Native landslide or erosion hazards are common in the terrain and ground conditions throughout the OVM system and can exist prior to pipeline construction. They can be triggered or exacerbated through construction activities and related disturbance. Native landslide or erosion hazards, or hazards that result from failed backfill or other construction-related disturbance, can be activated or accelerated by:

- Constructing the ROW through a landslide which can leave portions of the landslide up- or downslope of the ROW;
- Excavating through the toe of a landslide;
- Placing soil surcharge (i.e. temporary or permanent spoil piles) on the landslide causing it to re-activate; or
- Changing the surface or near-surface hydrologic conditions at the site that can impact landslides on the ROW, or in areas away from the ROW.

The following descriptions provide a general overview and conceptual schematics and descriptions for the various common landslide types and processes, recognizing that correctly characterizing the mode of land movement is critical to define the corresponding relevant mitigation options. Landslide and erosion hazards observed in northern West Virginia are not limited to steep sloping terrain, but can also occur in lower sloping ground depending on the level of ground disturbance, occurrence of surface- and groundwater, local soil conditions, etc. Site-specific assessments are typically needed, with input from SME's, to confirm site geologic, geotechnical, and hydrotechnical conditions.

Rock falls, rock slides and rock block failures (Figure 2-10) typically occur where stronger bedrock units transition to weaker or weathered units and become undercut. Rock falls and slides are also commonly controlled by failure planes (e.g., joints, faults) within the rock mass. Slopes where bedrock failures occur are typically high-angle.

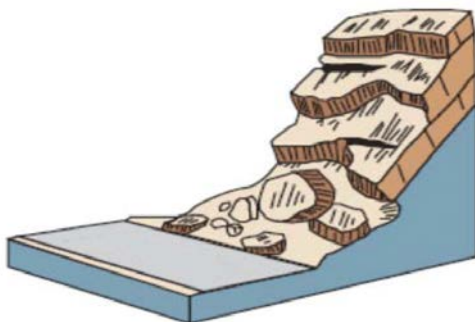


Figure 2-10: Example Rock Slide (USGS 2004)

Rotational landslides (Figure 2-11) have the traditional arc-shaped failure surface that typically intersects through residual soils on flatter benched weaker bedrock units. Slopes where failures occur can range from low- to high-angle, where benches have become overloaded with colluvium, through placement of excess spoils; or in areas where higher slopes are created by deeply-incised erosion processes, such as at large rivers and streams that have cut deeper, and have steeper valley geometries. They tend to be deep-seated, and in the context of this study, they are considered shallow where they occur above the buried pipeline and deep-seated where they engage or extend below the pipeline.

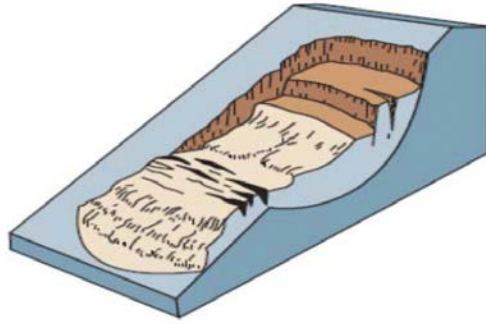


Figure 2-11: Example Rotational Landslide (USGS 2004)

The majority of land movement observed in northern West Virginia involve shallow translational landslides (Figure 2-12) that occur where native landslides are intercepted by disturbance through construction of the ROW, or from failure of the ROW backfill materials. Slopes where translational failures occur can range from low- to high-angle. These translational slides are typically limited to the depth of the backfill, or depth of residual soil in flatter-sloping and benched conditions. This may or may not engage the buried pipeline, depending on the placement of the pipeline relative to the backfill or residual soil conditions.

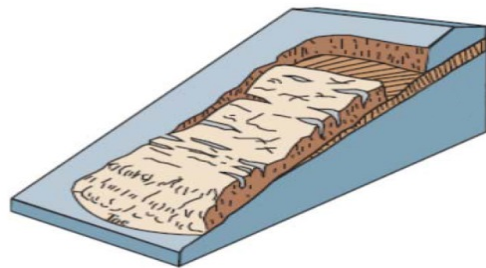


Figure 2-12: Example Shallow Translational Landslide (USGS 2004)

The ground can become unstable and result in earth flows or debris flows where the local soil, either in native slope areas or the disturbed ROW backfill materials, becomes over-saturated from near surface groundwater (i.e. seeps, springs, seasonal runs, etc.), or increased, focused surface discharges from seasonal response to precipitation or changes resulting from construction (Figure 2-13). Earth flows are typically slower and will be saturated with water, but are predominately soil and rock and other local materials. Debris flows have higher water saturation and can fail and move very rapidly, as well as have long run-out lengths.



Figure 2-13: Example Earth or Debris Flow (USGS 2004)

Slow earth flows, also called slope creep (Figure 2-14), are usually extremely slow moving, with a steady downslope trend. Slope creep is generally very shallow (e.g., < 1 meter [3 ft] thick), and occurs in the regolith, the soil layer overlying bedrock. Slopes where slope creep occurs can be low- or high angle. Slope creep may be seasonal, occurring with seasonal saturation events in the surface soils, or continuous or progressive where it may lead to landslide displacement. Slope creep is commonly expressed by the formation of “pistol-butted” tree trunks in forested areas.

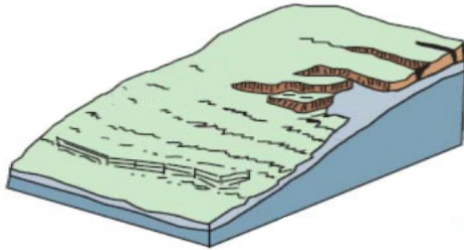


Figure 2-14: Example Slope Soil Creep (USGS 2004)

Slope creep is typically localized, but can be observed to occur in multiple localized areas in similar topographic conditions. The velocity of slope creep is extremely slow to very slow. Creep generally occurs shallower than typical pipeline burial depths, and thus rarely poses a threat to buried pipelines.

2.6.1 Hazard Classification

To prioritize sites for further investigation, assessment, mitigation and monitoring, a hazard classification scheme is needed that defines and differentiates the nature and characteristics of the identified landslide or erosion hazard(s). The hazard classification scheme for any given pipeline system, or for a specific site needs to be custom built to fit the purpose and needs of the project. Typically, a hazard classification scheme is qualitative, and takes into account the type, nature, proximity, magnitude and level of activity of the hazard, as well as the degree to which the hazard affects, engages or can engage the pipeline.

Making the hazard classification system too complex can complicate current and future efforts. Keeping the classification system as simple as possible is preferred. In some situations, a simple range of hazard classification levels from high to moderate to low is sufficient. In other situations, a more complex system that recognizes pipeline integrity versus possible environmental threats may be needed to address the required site and project conditions. This topic is limited in discussion because it represents a technical specialty in of itself and is not the focus of this study. Appropriate time and effort should be taken in developing a hazard classification scheme to catalog hazards and their relative risks to the pipeline. Engaging a geosciences professional in the development of the classification system for a given project is recommended.

2.6.2 Hazards Database and GIS information

Developing an inventory of identified landslide and erosion hazards in a pipeline system or project area provides a basis for tracking changes and provides a reference for developing mitigation and monitoring strategies on a system-wide scale. As more information is collected, some form of database is needed to organize the information and data, and allow for practical and orderly queries and management of the data. A database platform can be developed for this purpose. This provides a simple and practical tool to support operations, maintenance and emergency response. The database should contain landslide and erosion related site information, geospatial data, pipeline integrity, or potential environmental impact information, field investigation reports and photographs, slope monitoring data, and documentation for mitigation and remedial construction efforts at identified sites. The database can be housed in any number of commercially available software platforms, depending on what best fits the owner's information management and integrity operations requirements.

Geospatial data should be created and stored to provide a spatial representation of the identified sites using a geographic information system (GIS) platform. LiDAR images are often used as a baseline mapping data set to show topographic features and landslide size, shape and location relative to other features of interest, such as pipelines, permanent easement boundaries, property boundaries and construction boundaries, as well as the location of critical features such as roads, structures and water bodies. Site-specific survey or other publically available mapping data can also be used to develop baseline mapping information.

The geospatial data should include available pipeline information such as pipeline name, product (gas, liquids, etc.), pipeline diameter, and milepost or engineering stationing. Base maps included in GIS should include available current or historical aerial imagery, current or historical geologic maps, current or historical topographic maps, and may include site-specific slope analysis maps developed using GIS tools (where applicable).

3.0 MITIGATION OVERVIEW

The following sections assume that routing efforts to avoid hazards for a given project corridor have been exhausted, but hazards still remain along the alignment that cannot be avoided. Mitigation should be 'fit for purpose,' meaning the level of protection should match the site conditions and should balance costs with practicality of installation, operation and mitigation of risk. Ultimately, the owner/operator must decide on the acceptable level of risk for any given mitigation strategy that is used for an identified hazard(s).

All reasonable mitigation options should be considered in the design and planning process, to best fit the purpose of the project, and to best mitigate the hazard threatening the pipeline. Experience with OVM suggests that in most cases the occurrence of land movement is associated with surface and subsurface water, in combination with changes in the local ground conditions from recent or historical activities related to construction or geologic conditions conducive to land movement. Therefore, the mitigation strategies presented in subsequent sections of this report target sources of surface and subsurface water, as well as understanding and improving local site conditions. Based on experience in OVM, examples of mitigation options include: re-grading the ROW surface to reduce soil loading or otherwise improve site conditions; modifying local surface drainage to reduce discharge to the site; collection and conveyance of sub-surface drainage contributing to land movement; modified ROW backfill materials; deformable backfill in the pipeline trench; removal of unstable soil and replacement with engineered performance materials; ground surface erosion protection with slope breakers, trench breakers, sack-crete breakers; special pipeline coatings and protective sleeve-wraps; modified ROW configurations; monitoring; special pipeline design (i.e. increased pipeline wall thickness, material, bend geometries); and targeted monitoring (PRCI 2009). These options are generally not singular components of a mitigation approach, and are typically combined to develop a strategy for addressing the identified hazards at any given site.

Structural measures are available to address unstable slopes, such as retaining walls, soldier piles, sheet piles, wire mesh systems, mechanically stabilized earth systems and other mechanical structures. In specific instances, structural measures may be preferable. However, these structural measures typically were not developed for pipeline applications, but were originally intended to be used on roads, bridges and other infrastructure developments. These options can be costly, require site-specific designs, have special equipment and access requirements for installation, require specialized/proprietary construction techniques that can be unforgiving if not precisely installed, may be unable to be field-fit to unexpected site conditions, may limit future access or expansion in constrained ROW corridors, and may also have special long-term maintenance requirements. Therefore, this document presents an approach that uses materials and methods frequently used in pipeline construction, does not require specialized equipment, can be modified in the field to fit site conditions, and easily can be adapted with future expansions.

The cause of any given landslide or erosion hazard is commonly the result of several contributing factors. Defining the governing geologic hazards, and geotechnical/hydrrotechnical engineering processes that contribute to the movement is critical in supporting the selection, planning and design of an effective mitigation plan. The process is most effective when considering the approaches discussed earlier in this study (Section 2.0, and Figure 2-1). The most effective mitigation strategy requires recognition of the multiple factors governing any given site and may require long-term performance monitoring before full mitigation can be achieved.

In some situations, the mitigation may not be intended to provide a long-term permanent mitigation and full elimination of the hazard. Instead, the rate at which a potential threat could engage or engages the pipeline is delayed or prolonged to an acceptable level of risk (e.g. use of deformable backfill and monitoring to schedule stress relief excavations over time). As such, mitigation measures should be tailored to address the site specific and potentially variable conditions, consider the risk tolerance of owner/operator, consider the costs and benefits of long-term and short-term solutions, and incorporate construction.

Pipeline projects have a unique construction planning and execution process, typically characterized by a series of sequential steps to build the ROW and install the pipeline. A successful mitigation effort, whether at a single site or on a larger project scale, must integrate with the construction process. Mitigation strategies should always account for overall construction considerations in the planning and design efforts.

The following sections address these topics and outline general guidelines for mitigation.

3.1 Typical Construction Sequence

A typical construction sequence for building cross-country pipelines includes the following general steps:

- Pre-construction survey;
- ROW clearing and grading;
- Trenching;
- Pipeline stringing and bending;
- Welding, pipeline coating and weld inspection;
- Lowering the pipeline and backfilling;
- Testing; and
- ROW restoration.

These steps are generalized, but represent the basic sequential components of construction activities that occur when building pipelines. A simplified graphical depiction of the construction process, such as the one provided by Williams (Figure 3-1), is commonly included in planning and permitting documents in the early stages of a pipeline project.

Mitigation efforts typically occur during the ROW clearing and grading, trenching and ROW restoration phases of work. This conceptual sequence of construction shows generally flat ROW conditions, which is typically not the case in rugged and steep terrain. The presence of rugged terrain can increase the complexity of the work and requires added planning of construction activities during the implementation of landslide and erosion mitigation efforts. For example, drainage improvements may need to be installed as temporary measures in early phases of the work to maintain a usable ROW, and may then be damaged or require modifications resulting from intermediate construction activities, requiring final drainage measures to be installed with the final restoration work.

Pre-construction activities need to include planning for the sequencing of construction activities in steep, rugged, mountainous terrain that is common on many pipeline projects, particularly where mitigation of landslides and erosion hazards should be integrated into the overall process. This may also be a consideration in challenging wet or winter weather conditions, or where construction is interrupted by winter conditions and temporary measures are installed to carry through until construction starts again. When designing and planning the mitigation work, the designer should understand how the proposed mitigation will integrate with the planned sequence of construction to maintain the most efficient, functional, and cost effective installation of the measures.

The following sections define and discuss general ROW construction scenarios that are consistent with the conceptual pipeline construction sequence.

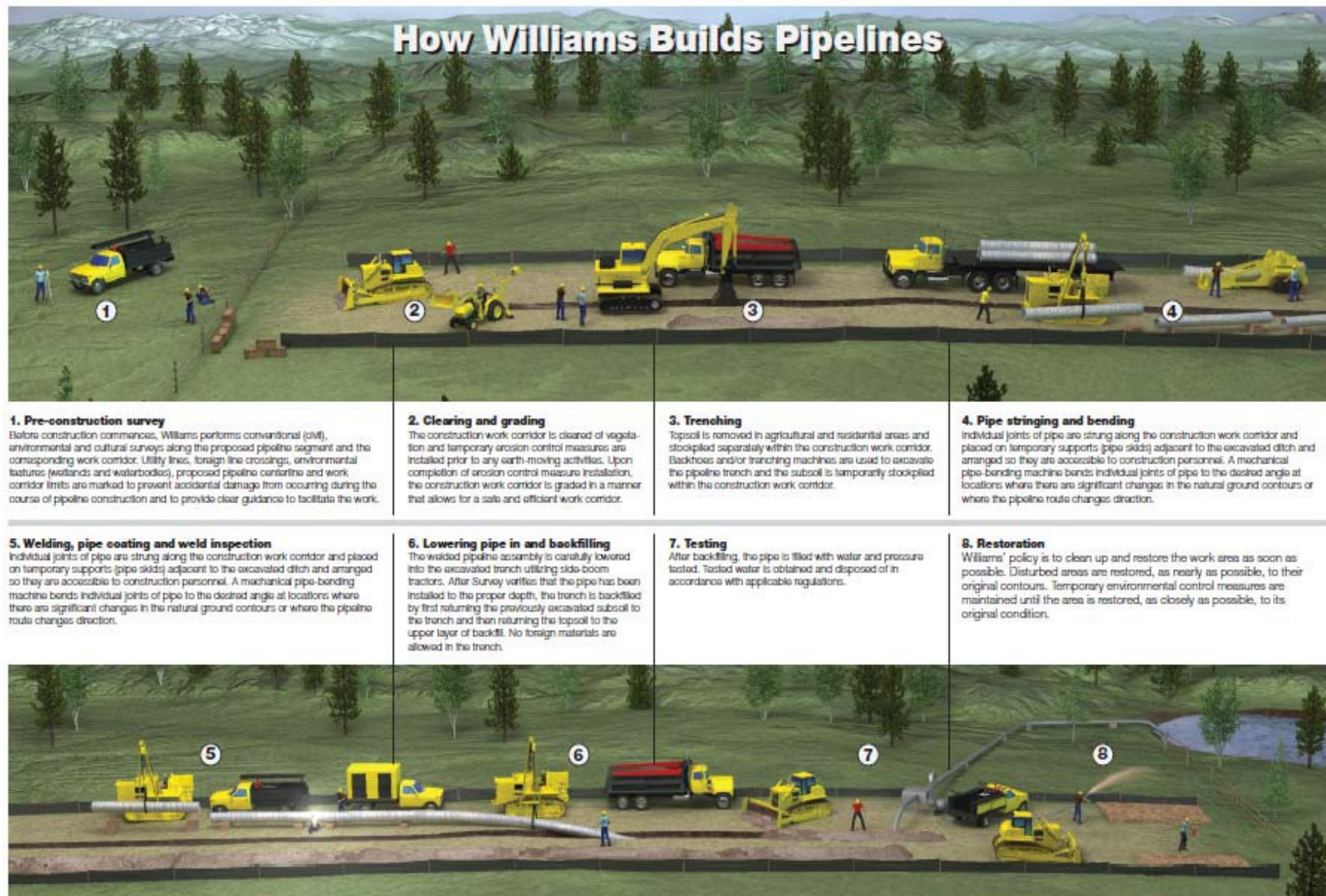


Figure 3-1: Williams Typical Construction Sequence (Williams 2015)

3.2 ROW Construction Scenarios

Looking at a simplified model of typical pipeline construction in mountainous terrain, consistent with the general model for pipeline routing and pipeline construction sequencing (Figure 3-1), we can identify several key construction planning related scenarios for building the ROW (Figure 3-2): on flat valley bottom ground; on ridge tops; on planar slopes (connecting between flat ground and ridge top alignments); and on sidehill slopes and oblique angles (alignment traverses planar slopes and cannot employ ideal routing principals [i.e. straight down the slope]).

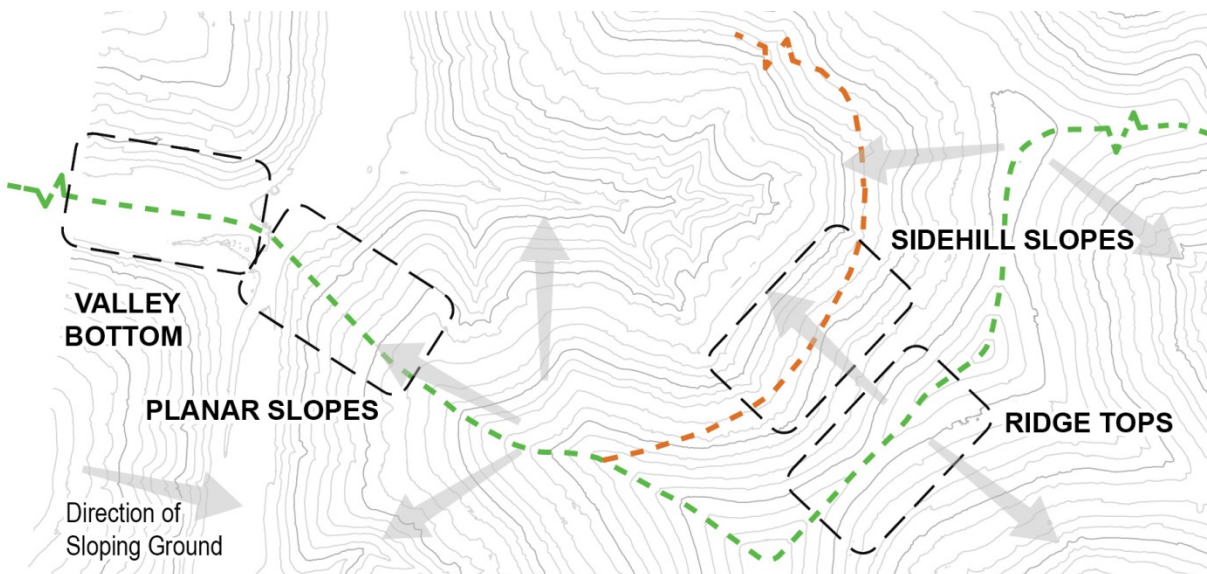


Figure 3-2: Typical Basic Pipeline Construction Scenarios in Mountainous Terrain (Williams 2015)

3.2.1 Valley Bottom ROW Construction

Building ROW on flat valley bottom areas (Figure 3-3) is least likely to encounter land movement hazards, as the ground is typically flat or mildly sloped and not prone to landslide-related hazards. Surface erosion or other challenges from existing infrastructure, rivers, or streams may exist, but not the landslide characteristics of earth or debris flows that would initiate in steeper ground. These valley bottom areas can be subject to depositional and run-out scenarios from earth and debris flows, but typically do not impact the pipeline in such areas.

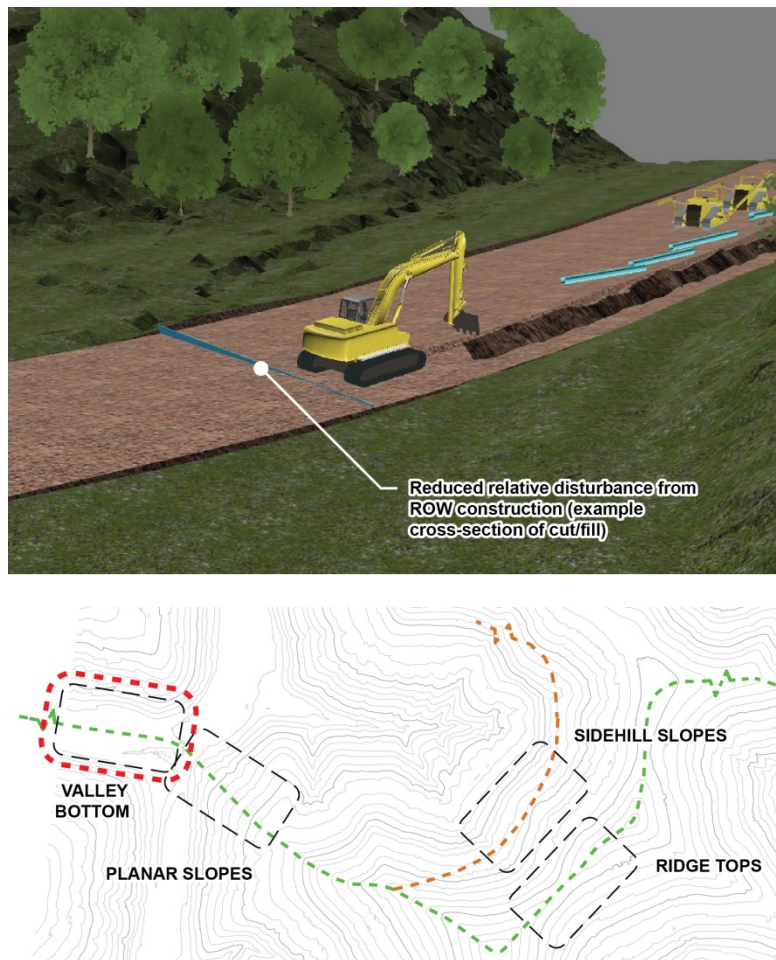


Figure 3-3: Typical Valley Bottom ROW Construction (and inset showing conceptual location of the construction scenario referenced on Figure 3-2) (Williams 2015)

The general magnitude of disturbance necessary to construct the pipeline ROW is represented by the stylized section shown in Figure 3-3 (just behind the excavator), and represents the cut/fill necessary to remove the topsoil and level the ROW for access. Additionally, trenching in generally flat ground does not require special planning or equipment or contingencies for design or restoration. Valley bottom areas are subject to the highest potential accumulation of surface run-off from upslope areas, inherently because they are typically at the bottom elevation of a valley in ridge-valley terrain. As such, valley bottom construction typically encounters floodplains and associated rivers and streams; as well as seeps/artesian conditions, ponded water, lakes, and wetlands.

3.2.2 Planar Slope ROW Construction

Building ROW in planar slopes (Figure 3-4) is generally similar to flat ground, except the ground may be inclined steeply, which requires enhanced construction planning and results in a higher potential for landslide and erosion related hazards. The general magnitude of disturbance necessary to build the pipeline ROW is represented by the stylized section shown in Figure 3-4 (just ahead of the excavator). This may increase to address longitudinal changes in the ROW profile, especially in benched topography or on planar slopes that change grade due to local geology or other topographic variations.

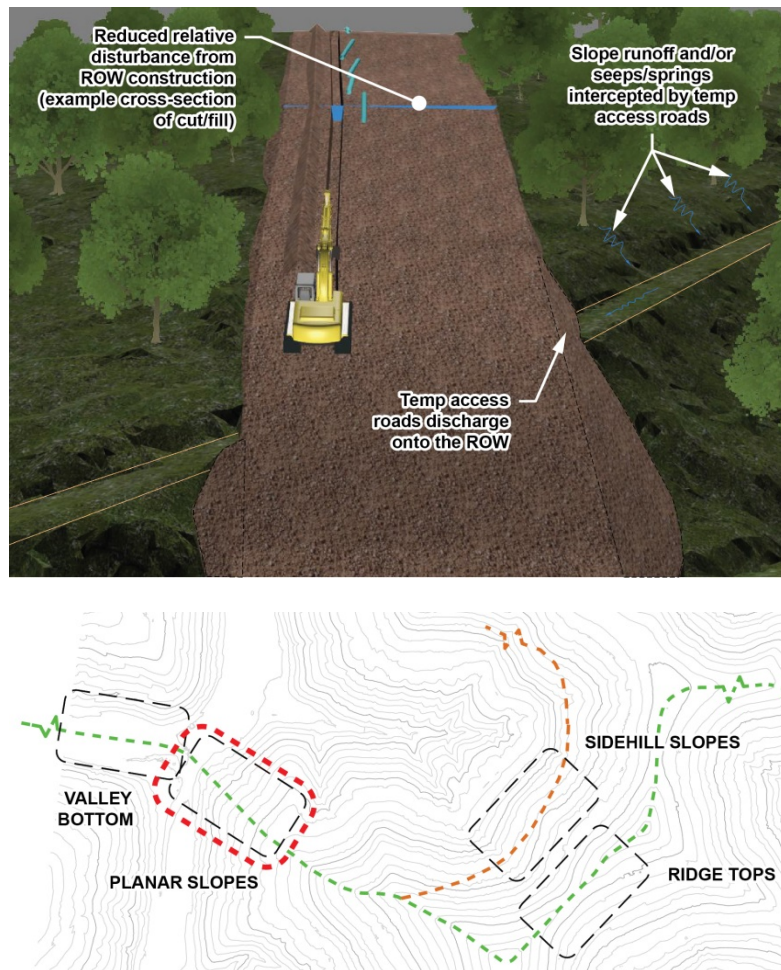


Figure 3-4: Typical Planar Slope ROW Construction (and inset showing conceptual location of the construction scenario referenced on Figure 3-2) (Williams 2015)

Where planar slopes are oriented along the 'fall line' of the slope, there is a minimized contribution of upslope surface run-off. As such, planar slopes are particularly sensitive to access roads and other transportation access points that can re-direct surface and intercept sub-surface water back to the ROW from adjacent off-site upslope contributing basin areas that would not normally discharge onto the disturbed ROW (Figure 3-4). Erosion and landslide hazards can be re-activated or triggered from increased sources of water collected in the pipeline trench or re-directed along the surface of the disturbed ROW. Trench breakers and slope breakers (water bars) are critical in these scenarios as a minimum first line of defense for short- and long-term mitigation.

3.2.3 Ridge Top ROW Construction

Building ROW on ridge tops (Figure 3-5) or inclined ridge tops (i.e. steep sloping ridges) is the preferred location for pipeline routing in rugged ridge-and-valley terrain. The ridge top alignment is generally the most stable ground. It has changed the least over geologic timescales, making it the least likely location for landslide and erosion type hazards.

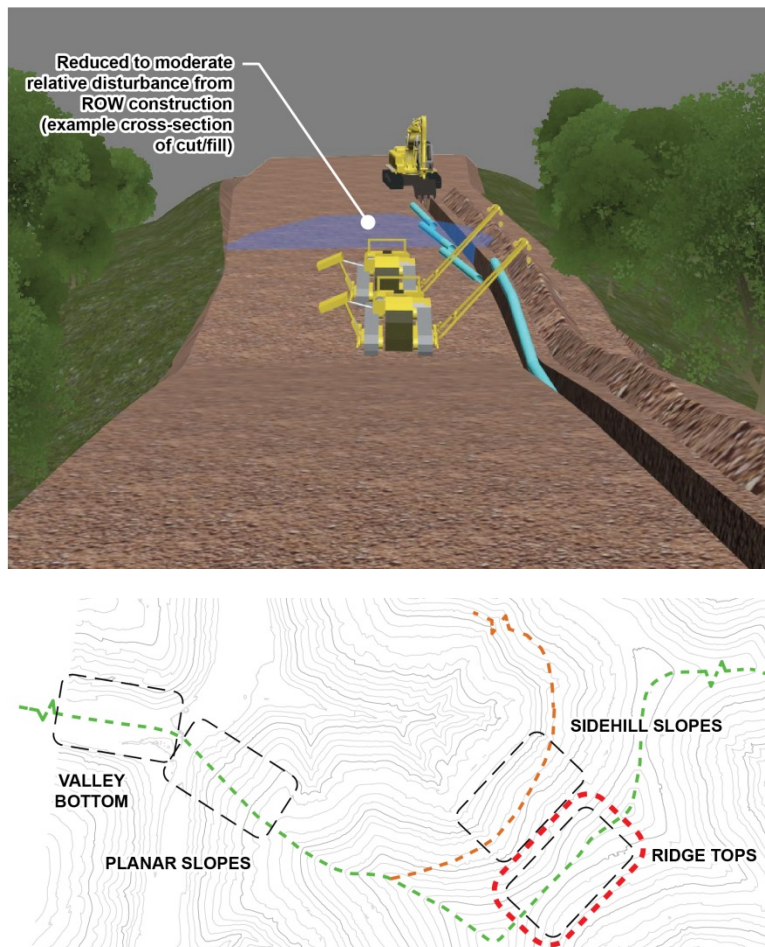


Figure 3-5: Typical Ridge Top ROW Construction (and inset showing conceptual location of the construction scenario referenced on Figure 3-2) (Williams 2015)

This stable ground is largely due to the lack of contributing drainage basin area discharging to the disturbed ROW (i.e. no slopes or basin draining to it). Potential sources of water that may require mitigation are limited to precipitation and the reduced potential of a seep or spring located along the ridge.

The general magnitude of disturbance necessary to build the pipeline ROW on ridge tops is represented by the stylized section shown in Figure 3-5 (just ahead of the side booms). This is somewhat larger than the valley bottom flat areas or planar slopes but still relatively small in comparison to the following described scenarios. The challenge for ridge top areas is the management of temporary construction spoils and limiting the loss of the spoils to the adjacent steep valley sides sloping away from the ridge.

3.2.4 Sidehill ROW Construction

Building ROW in sidehill conditions presents the greatest challenge for the design, planning and mitigation of landslide and erosion hazards (Figure 3-6). The conceptual figure depicts a full sidehill geometry, where the alignment is running parallel to the slope contours. Similar issues would exist with sidehill alignments traversing the slope at oblique angles (relative to the fall line straight down the slope). The general magnitude of disturbance necessary to build the sidehill pipeline ROW is represented by

the stylized section shown between the excavator and the side booms in Figure 3-6. This demonstrates how sidehill construction has the largest relative volume of excavated materials, and the corresponding largest footprint of disturbance area for any of the typical construction scenarios.

To construct a temporary flat ROW surface that provides access and allows for handling and installation of the pipeline, and to develop the necessary permanent and temporary ROW widths, significant additional ROW excavations are required toward the upslope direction. In steep sidehill conditions, this upslope excavation depth can be deep, resulting in a compounding effect where a wider ROW is needed to work in the steep and rugged terrain. Therefore, side hill excavation generates more spoils that need to be managed.

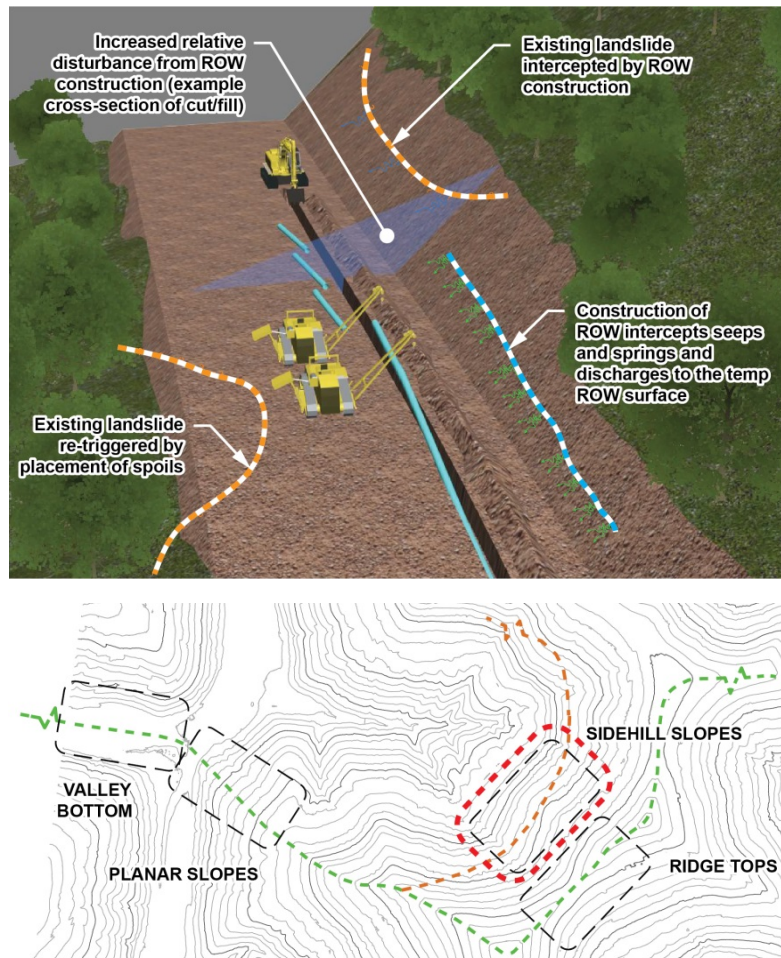


Figure 3-6: Typical Sidehill ROW Construction (and inset showing conceptual location of the construction scenario referenced on Figure 3-2) (Williams 2015)

The deep excavation on the upslope side of the ROW can intercept seeps, springs, surface flow channels and run-off. All of this water is directed down onto the temporary ROW surface during construction, and this temporary ROW surface can direct seepage in the post restoration scenario. Construction of the temporary ROW surface will dictate how surface and subsurface sources of water will interact with the restored construction backfill as the ROW transitions into the operations life cycle phase. Where surface and subsurface sources of water are not addressed (i.e. mitigated) during the construction and restoration of the ROW, these sources of water can discharge into the ROW backfill materials and result in saturated and unstable conditions, which is frequently the governing factor in land movement along the ROW post construction (and post restoration of the ROW).

Mitigation efforts should account for the way the ROW was constructed, including the configuration, size and methods used to build the temporary ROW surface. Mitigation efforts also should account for where the source of water may be originating, namely along the historical temporary ROW surface, which could be very different from the post restoration ROW surface.

3.2.5 Temporary ROW Surface Intercepts Surface and Subsurface Water

The construction of the temporary ROW surface will dictate how surface and subsurface sources of water interact with the restored ROW construction backfill. Seepage flows or springs that followed preferential bedded surfaces typical of the local geology and benched topography express themselves at locations along the ground surface, where these locations are representative of conditions before ROW construction and ground disturbance. That seepage at the ground surface then follows the slope away, depending on the pre-constructed topography at the site. When the temporary ROW surface is constructed, the seepage flows follow along the same geologic bedding and benched topography, but are now expressed along the new surface where the upslope excavation of the temporary ROW surface intercepts the flow paths (Figure 3-7). The constructed temporary ROW surface acts as a preferential flow path, following along the steep cut slope on the uphill side and then along the bottom flat width of the temporary ROW surface.

Backfill and restoration of the ROW uses spoil materials that cannot re-establish the previous bedded geology and corresponding seepage flow characteristics. The backfill is inherently different than the pre-disturbed condition, even if placed with compaction and matching the pre-disturbed contours. Placed backfill tends to saturate when water is added from surface or subsurface sources. After the temporary ROW is backfilled and restored, the temporary excavated ROW surface continues to intercept seepage flows expressed along the steep cut slope, or from seepage through the backfill, and continues to act as a preferential flow path. The new location where the seepage flow discharges along the temporary ROW surface is typically beneath the backfilled materials and at the point where the outboard side of the temporary ROW surface daylights at the ground surface. This new discharge point is farther downslope from where it previously discharged along the pre-project ground.

Mitigation installed at the point where seeps and springs are observed in the post-restoration condition does not directly address the source of the flows, allows the backfill to continue saturating, and increases the potential for landslides, erosion and slope failure of the ROW backfill materials. To be most effective, the mitigation needs to be installed at the location where seepage intersects the temporary excavated ROW surface, and where seepage follows and accumulates on the flat portion of the temporary ROW surface and infiltrates into the pipeline trench, and in other areas where the geometry of the temporary ROW surface delivers water in such a way that it can saturate the ROW backfill.

Depending on how long the pipeline trench/ROW is expected to be left open/unrestored, there may be a need to install temporary drains to address intercepted seeps and springs along the upslope temporary ROW surface or in the pipeline trench. These temporary actions would occur during the clearing and grading, and during the trenching phase of work, for typical planar slope, ridge top and sidehill ROW work scenarios. These temporary mitigation measures may need to function for the duration of the construction activities, and may be damaged or need to be re-constructed or modified in response to other pipeline construction activities. The temporary measures would then be repaired or re-built or additional mitigation measures installed for the final restoration of the ROW. For the final mitigation measures to be effective, they must be installed at the source of the water as described above and not where water is expressed on the ground surface of the restored ROW.

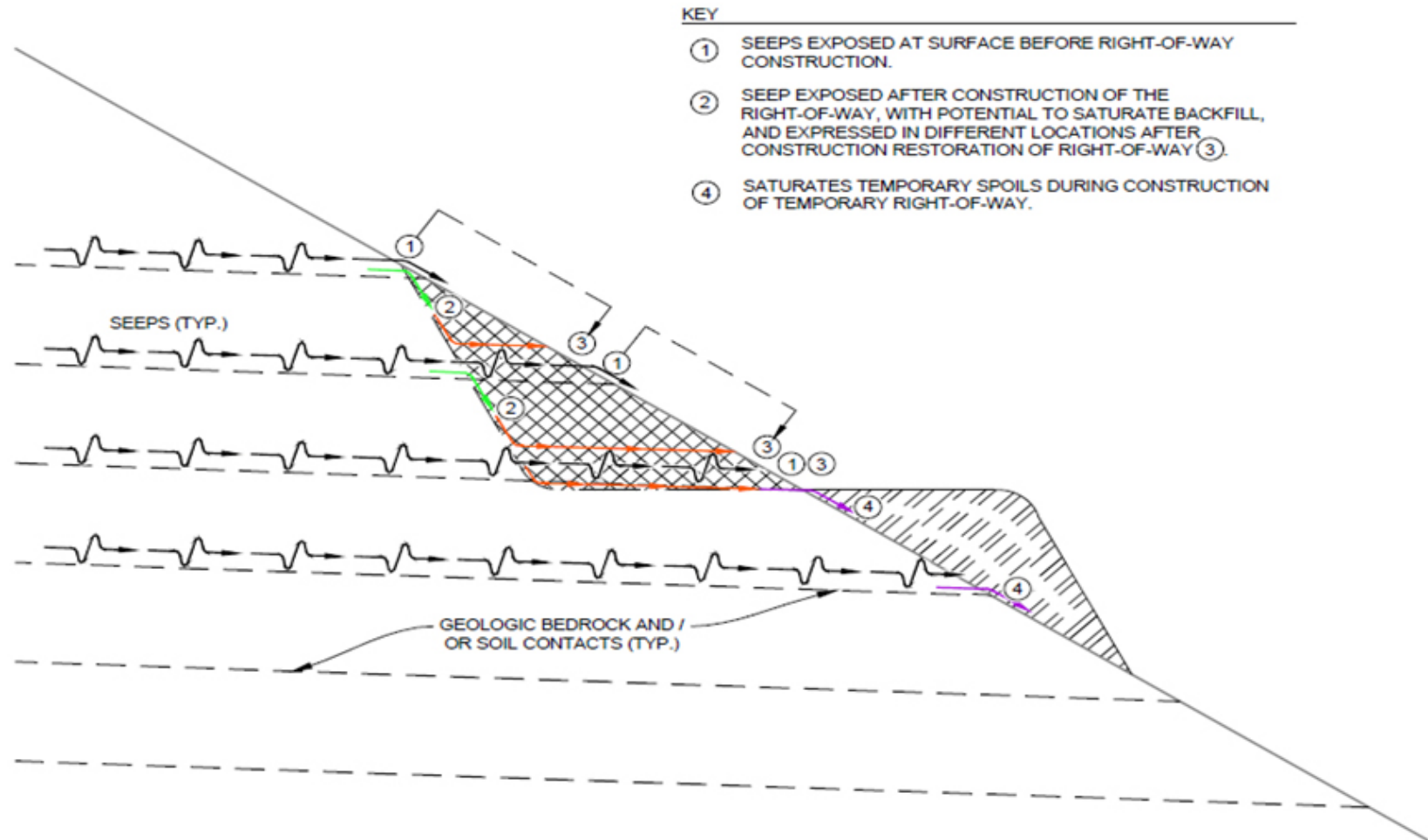


Figure 3-7: Temporary ROW Surface Interaction with Seeps and Springs (Williams 2015)

3.2.6 Comparison of Relative ROW Disturbance in Sidehill Scenarios

A comparison of the typical sections showing the relative disturbance areas for each of the previously discussed ROW construction scenarios (see Figures 3-3, 3-4, 3-5, and 3-6) is shown in Figure 3-8. The comparison highlights the relative increase in excavation volume and corresponding relative increased footprint for the disturbed areas of the ROW in the sidehill scenario. These areas should be identified early in the project design and planning processes, and minimized to the greatest extent possible. Where they cannot be avoided, operators should implement mitigation measures that best fit the site conditions in order to address potential sources of water and to stabilize the ROW backfill materials.

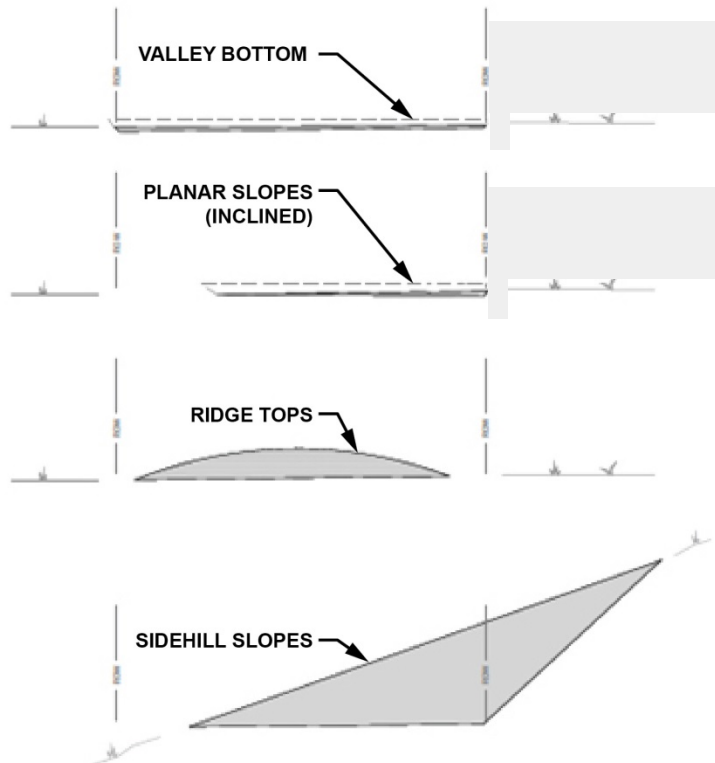


Figure 3-8: Conceptual Comparison of Relative Disturbance Areas (Williams 2015)

3.3 Sequencing Mitigation with Construction

Installing mitigation for existing or potential landslide or erosion hazards should be implemented to incorporate the temporary constructed ROW surface. Depending on how long the ROW is expected to be left open, there may be a need to install drains to address intercepted seeps and springs along the upslope temporary ROW surface or in the pipeline trench. These actions would occur during the clearing and grading, and the trenching phases of work (Figure 3-1) for typical planar slope, ridge top and sidehill ROW work scenarios. These temporary mitigation measures may need to function for the duration of the construction activities, and may be damaged or modified, requiring final mitigation measures to be installed in the restoration phase of the work.

The restoration phase of pipeline construction involves final backfill, finish grading and installation of final erosion control measures (i.e. slope breakers, erosion control fabric, mulching, tracking, vegetation, etc.). Final land movement mitigation measures must be installed at this time but may require building new drains or re-establishing the temporary drains installed in the clearing and grading or trenching phases of work. For these final mitigation measures to be effective, they must be installed at the source

of the water, not at the surface of the already backfilled ROW and should be coordinated with the other phases of pipeline construction.

3.4 General Guidance Using Typical Scenarios for Landslide Mitigation

Development of conceptual recommendations for landslide and erosion mitigation can be organized into “Typical Scenarios” that are consistent with pipeline construction, and related to how the ROW is built. General examples are described in the previous section for valley bottom, planar slopes, ridge top and sidehill scenarios. This section provides a general overview on conceptual mitigation approaches for landslide and erosion hazards using Typical Scenarios as a basis for developing conceptual level plans and specifying mitigation measures (i.e. Typical Details). Guidance on which Typical Details are applicable for specified Typical Scenarios is addressed in Section 4.0 of this document.

This approach allows for rapid development of site-specific conceptual mitigation plans during project design and planning and supports review and planning for project budgets and bidding. The approach also allows for development of conceptual mitigation plans concurrent with pipeline installation as conditions are encountered during construction.

The following provides a general summary of the Typical Scenarios discussed herein and related to landslide hazards:

- Sidehill in Stable Trench (Appendix A-1, Sheet 1710) – The pipeline is oriented perpendicular to the orientation of the landslide in a sidehill configuration (Figure 3-9). In this scenario, the pipeline is installed in a “stable trench,” indicating the pipeline is below the landslide failure plane, in unyielding native soil and/or bedrock materials. This is a preferred scenario. It mitigates the threat to the pipeline by avoiding the hazard and staying deep enough to allow any land movement to occur independent of the pipeline. However, mitigation often is still necessary to prevent land movement and disturbance on and off the ROW.
- Sidehill in Un-Stable Trench (Appendix A-1, Sheet 1720) - The pipeline is also oriented perpendicular to the orientation of the landslide in a sidehill configuration (Figure 3-9). In this scenario, the pipeline is installed in a potentially “unstable trench,” indicating the pipeline is within the landslide mass (i.e. above the failure plane) in active landslide materials. This scenario is frequently associated with active ROW backfill materials, as well as native landslide movement. The accumulated strain can be greater where the pipeline passes across the lateral or vertical limits of a landslide, or, at the lateral boundaries of the landslide with the surrounding stable ground where shear stresses tend to be concentrated. This is not the preferred scenario. It represents an increased potential threat to the integrity of the pipeline.
- Planar in Stable Trench (Appendix A-1, Sheet 1730) - The pipeline is oriented longitudinal to the orientation of the landslide along a planar slope (Figure 3-10). In this scenario, the pipeline is installed in a “stable trench,” indicating the pipeline is below the landslide failure plane in unyielding native soil and/or bedrock materials. This is a preferred scenario. It mitigates the threat to the pipeline by avoiding the hazard and staying deep enough to allow any land movement to occur independent of the pipeline. However, mitigation often is still necessary to prevent land movement and disturbance on and off the ROW.
- Planar in Un-Stable Trench (Appendix A-1, Sheet 1740) - The pipeline is oriented longitudinal to the orientation of the landslide along a planar slope (Figure 3-10). In this scenario, the pipeline is installed in a potentially “unstable trench,” indicating the pipeline is within the landslide mass (i.e. above the failure plane) in active landslide materials. This scenario is frequently associated with active ROW backfill materials, as well as native landslide movement. The accumulated strain can be greater where the pipe passes across the lateral or vertical limits (vertical displacement is common

in this scenario) of a landslide, at the lateral or vertical boundaries of the landslide with the surrounding stable ground where shear stresses tend to be concentrated. This is not the preferred scenario. It represents an increased potential threat to the integrity of the pipeline.

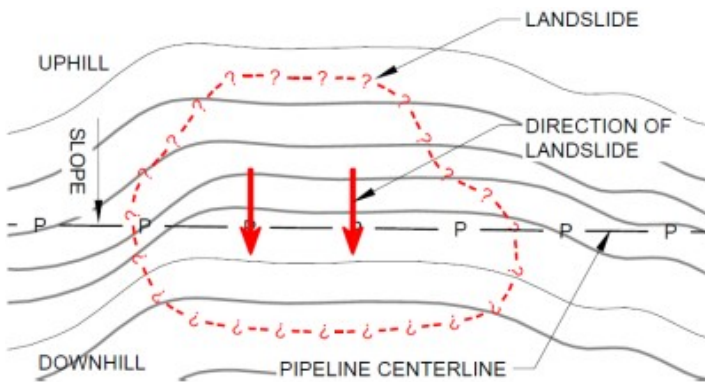


Figure 3-9: Conceptual Schematic for Sidehill Landslide (Williams 2015)

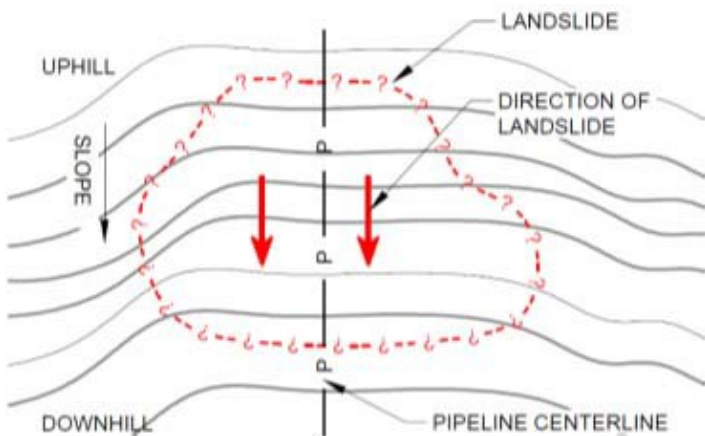


Figure 3-10: Conceptual Schematic for Planar Landslide (Williams 2015)

3.4.1 General Approach for Mitigation of Land Movement using Typical Scenarios

The following outlines the general approach for mitigating land movement for Side Slope and Planar Slope Typical Scenarios (as outlined and discussed above):

1. The final configuration of any ROW restoration measures should be determined based on the conditions encountered at the time of construction, and may change or vary and require additional measures to mitigate hazardous landslide conditions that are identified during the work. The volumes, grade, elevations and quantities will vary depending on the site conditions encountered.
2. Landslides at any given site should be evaluated on a case-by-case basis and should incorporate the site-specific conditions. Mitigation recommendations should be specific to each site and should incorporate appropriate site investigations and assessment, review, mapping, characterization and delineation of site-specific landslide features in order to understand the site-specific processes and dynamics of the landslide at that site.

3. If possible, look to re-route and avoid the landslide site. If re-routes are not possible, then consider additional mitigation measures.
4. Investigate the landslide site to confirm depth to failure zone, extents and limits of the landslide mass, etc. This may be accomplished by: site-specific sub-surface drilling; geophysical surveys; use of LiDAR to map surficial landslide features; digging test-pits; manual probes; or through excavations of the temporary ROW surface. Although sub-surface investigations are often preferred, the timing, access or site conditions may not allow specialized equipment access, and it is common for investigation activities to include test-pit or other localized excavation methods (using rubber-tire or tracked excavators) to quickly map out landslide conditions and confirm depths of the active landslide zone and the corresponding depth to bedrock.
5. If possible, install the pipeline trench in stable bedrock or unyielding and intact native soils.
6. Where the depth to stable bedrock or stable native soils is too deep, or it is not feasible to install the pipeline at that depth, then the following measures should be considered:
 - a. Install a deformable backfill around the pipeline (PRCI 2009), which allows for improved drainage along the pipeline trench, and allows the backfill to deform around the pipeline in response to continued land movement and thereby attenuates for accumulated strain in the pipeline;
 - b. Install monitoring on the pipeline to track potential increases in strain in the pipeline (i.e. strain gauges);
 - c. Install other monitoring at the site to track potential land movement (i.e. geodetic monitoring, regular visual monitoring, inclinometers, piezometers, extensometers, etc.);
 - d. Install enhanced drainage measures in the trench to mitigate for subsurface flows and target identified sources of water that may be discharging to the site;
 - e. Modify surface water draining to the site to mitigate for discharges from streams, creeks, runs, gullies or other sources of surface run-off that may be contributing water to the site and exacerbating land movement;
 - f. Install trench breakers and slope breakers to mitigate for trench seepage and to divert intercepted trench flows along the surface to safe discharge points;
 - g. Reduce the loading on the site by removing and/or reducing the excess backfill materials to off-site locations. Spoil placement should be carefully planned to avoid triggering land movement in other locations;
 - h. Compact backfill materials at the site to achieve optimal moisture content and to provide increased strength. Added compaction can increase strength and stability of the backfill and reduce infiltration of water into the backfill, thereby further mitigating for potential for land movement;
 - i. Wet backfill materials may require drying the soils using special additives to allow the materials to be re-used and worked at the site. Over-saturated materials may require extensive time and space to dry. Use of lime-kiln dust or cement-kiln additives may be needed (pending environmental requirements);
 - j. Where local materials cannot be re-used, use of a small angular (i.e. free-draining) rock backfill for ROW restoration (not in the pipeline trench) may be installed. Rock materials allow for reconstruction of slopes and grades in wet conditions and can be placed to establish desired grading and re-contouring at the site. Rock backfill can also be re-used and re-placed during future maintenance activities; and,

- k. Where needed, install shear trenches in planar and oblique sidehill scenarios where continued land movement is expected and targeted relief of differential ground movement is possible.
7. Complete an as-built survey to identify and map out the installed mitigation measures at the site, including documentation, drawings, and database information as discussed earlier.
8. Develop a site monitoring plan to track potential changes at the site.

Refer also to the corresponding Typical Scenario sheets in Appendix A-1.

3.4.2 General Approach for Mitigation of Land Movement using Typical Details

The following outlines general guidance for mitigation efforts. This section is limited to describing general categories for mitigation measures (i.e. subsurface drainage, surface drainage, grading, etc.), more detailed guidance and discussion is provided in the Applied Guidance Section 4.0.

3.4.2.1 Subsurface Drainage

The mitigation of subsurface water is one of the most important components of any plan for a specific site. As previously discussed, any subsurface drainage improvements should focus on how the ROW was constructed and install drains to address changes in the subsurface expression and discharge characteristics relative to the temporary ROW surface, and not just the surface expression of flows in the post-restoration ROW surface.

Targeted drainage measures can be configured to fit site-specific conditions. There should be flexibility in how the drainage is designed and installed in order to allow for incorporating the measures into the construction sequence. This may require temporary drains during the initial grading and trenching, and then final drains with completion of the trenching and lowering of the pipeline, and during the restoration phase of work.

Examples of subsurface drainage measures include (but are not limited to):

- French drains that incorporate drain rock with perforated collection pipes to capture and convey water in the trench or other targeted areas;
- Enhanced drains using drain rock with perforated collection and tightline conveyance pipes that can be designed to target certain areas and increase the efficiency and performance of capturing and conveying water. These can be used in the trench or at other areas to mitigate for water;
- Targeted seep drains using drain rock, piping, and/or other materials to build collection and conveyance drains at identified sources of water in the ROW cut or trench. These are often combined with other installed drainage systems to evacuate the water; and,
- Bleeder drains, which cut notches in the outboard trench wall along the bottom of the trench at low spots or intervals along sloping trenches. These drains allow accumulated seepage from sources of water or conveyance along the trench to evacuate the ROW backfill, and not “pool” in the trench or backfill material. They are often constructed using drain rock and may include piping and trench breakers to facilitate flow. They may require added excavation to find a slope-to-drain grade through local high ground.
- Trench breakers are often coordinated with drainage improvements to specifically to address seepage along the trench line, and also coordinated with surface drainage management (i.e. slope breakers), more discussion is included below.

All these variations on drains allow for the collection and evacuation of subsurface seepage, and may be modified and/or combined to fit site conditions.

3.4.2.2 Surface Drains, Runoff Improvements, and Channels

Surface water run-off to a site can contribute flows in relatively small constant incremental discharges, and have larger volume and duration peak discharges during storm events. While many landslide and erosion sites fail in response to storm events, often the contributing factor to failure is the constant and incremental small discharge (i.e. base flows) to a site. Therefore surface drainage plans may have to accommodate a range of flow conditions.

Surface drainage measures may include (but are not limited to):

- Collection and diversion channels, ditches, brow ditches, berms, slope breakers (discussed in more detail below), swales, etc. that intercept and convey base flows and mitigate for saturation of the ROW backfill or other targeted landslide prone terrain at a site;
- Runoff improvements by grading the ROW and surrounding ground to manage or enhance run-off away from the site, or control/manage how surface and subsurface flows are captured or possibly infiltrate into the ROW backfill. This may include changing slopes and cut-fill to mitigate for concentration of aggregate surface runoff, and is often coordinated with installation of slope breakers (discussed in more detail below);
- Armored channels with drain pipes allow for conveyance of high flows and protect against erosion (i.e. the armoring) during peak events while the drain pipes in the channel pick up the lower seepage base flows that would otherwise be slowed and tend to infiltrate in oversized armor rock rather than; and,
- Armored channels in steep ground allow for collection and conveyance of surface runoff and other point sources of water (i.e. seeps, springs, etc.) that may be prone to erosion. Armoring may include riprap materials, sack-crete lining and/or re-construction of steep trench and ROW backfill in bedrock conditions, integrating local erosion resistant geologic units (i.e. bedrock) in the channel, etc.

3.4.2.3 Grading, Backfill Improvements, and Surface Treatments

Any site-specific mitigation plan will include some form of grading and surface mitigation slope work. Examples include:

- Grading to reduce the overburden on the site and thereby minimize or reduce driving forces on a potential landslide;
- Maintaining a stable outboard wedge of soil or bedrock material along the downslope side of ROW to maintain a stable trench;
- Compaction of backfill materials during ROW restoration;
- Drying, moisture conditioning, use of soil additives to soils during ROW backfill and restoration work to improve construction feasibility and stability of materials;
- Removing unsuitable soils when they cannot be used in the backfill or cannot be dried sufficiently;
- Using free-draining rock backfill (typically small to medium sized angular riprap) to replace unsuitable soil materials and re-build ROW slopes, to fit variable slope geometries, to provide a stable backfill configuration at a range of low to high angle slopes, and able to be reused during future maintenance/operation activities, etc.;
- Using sack-crete materials to re-build localized trench backfill, ROW slopes, transitions between soil and bedrock units, and ROW backfill, which can be often integrated with drainage improvements to mitigate for sources of surface or subsurface water;
- Tracking or other surface erosion control treatments for disturbed final ground surfaces;
- Re- vegetation;

- Installing erosion control fabric, silt socks, silt logs, “coir” products, and/or other erosion control devices; and
- Placement of rock armoring, typically using medium to large-sized riprap rock materials, on steep or erosion prone slopes to stabilize and address potential surface erosion, integrate with transitions from soil to bedrock units, or re-build localized over-steepened ROW slopes.

3.4.2.4 Breakers

The use of trench and slope breakers for ROW restoration is a critical component to any restoration or mitigation plan, and should be considered a minimum component to typical mitigation planning, design and construction efforts.

3.4.2.4.1 Trench Breakers

Trench breakers are typically installed at spacing and dimensions that fit slope conditions. Steeper slopes require tighter spacing, and vice-versa for flatter slopes. Consideration should be given to the grade of the slope versus the grade of the pipeline trench, whereby steep slopes with flat pipeline trench grades (e.g. steep planar slopes with pipeline alignment at oblique or sidehill orientation) would allow for wider spacing of breakers, and steep slopes with corresponding steep pipeline trench grades (e.g. steep planar where the pipeline follows the slope down the fall line resulting in similar grades) slopes would require closer spacing of breakers. Technical guidance on the specific placement and spacing of trench breakers is lacking, leaving much to the discretion of the designer, and relying on professional experience for placement configuration and spacing.

Sandbag breakers are recommended for targeted landslide and erosion hazard sites where special geotechnical and hydrotechnical engineering and geologic hazard mitigation efforts are needed. Other materials may be considered in more typical pipeline construction scenarios where hazards do not exist. The use of sandbags to construct breakers allows for a close fit around the pipeline without creating a rigid and potentially load transferring connection to the pipeline, allows for some seepage of water through the breaker structure in a slow and controlled manner that passively dissipates accumulated seepage behind the breaker over time, and can adapted to fit and conform to variable trench geometries during construction and can adjust to changes in the trench geometry over time, while still maintaining their function.

Foam breakers are generally not recommended for landslide or erosion mitigation work at targeted sites, and in particular to mitigate for potential accumulation of trench seepage or drainage issues. Potential drawbacks of using foam breakers include: foam material creates a dam in the trench that holds back and accumulates seepage resulting in saturation of the backfill; they tend to ‘grab’ the pipeline and create a positive connection that can potentially transfer loading from the surrounding soil backfill through the breaker to the pipeline; they are typically placed without a key along the trench walls; they are rigid and do not conform well to changes in trench geometry over time which can result in cracks and gaps around the sides and bottom (where there is no key); and they can form cracks and break as the backfill changes over time which may negate their intended function and can also focus seepage flows and result in piping failures. If foam breakers are used, additional drains should be added to the individual breakers, as well as between multiple breakers, to collect and evacuate accumulations of seepage.

3.4.2.4.2 Slope Breakers

Slope breakers are typically coordinated with trench breakers, such that trench seepage is temporarily (i.e. in the short-term) intercepted by trench breakers and discharged to the ground surface (i.e. seepage builds up behind the trench breaker over a short period of time) until it ‘daylights’ at the ground surface), where slope breakers placed just downslope of the trench breakers divert the water to the side of the ROW into a stable and erosion protected area. Slope breakers should also be coordinated with

permanent and temporary access roads, to avoid concentration from multiple sources of water on the ROW or at locations along the edge of the ROW.

Slope breakers are typically constructed using the local ROW soils to form low berms (i.e. water bars) that reach across the disturbed ROW surface. Steep ground or limited supply of local materials to build slope breakers may require constructing them using sand bags, sack-crete, or even rock materials in order to develop the intended function. In planar (i.e. generally flat) sloping ground, slope breakers are typically configured as linear sloping berms with an upslope-side ditch that conveys surface flows, that are placed in parallel configurations down the slope at uniform or variable spacing to fit the slope grades (i.e. steeper grades have closer spacing, and flatter grades have increased spacing). Breakers are typically oriented to discharge surface flows off the ROW, not back onto the ROW, and to avoid discharging flows onto downslope breakers. Where discharges cannot be directed off the ROW, then an armored channel or other conveyance may be needed to carry flows (down the slope) to a suitable discharge location. The upslope-side of the breaker may be armored with riprap, erosion control cloth, vegetated, or even include drains to address seeps or increased runoff. The discharge point at the down-gradient end of the breaker may have a small erosion resistant pad of armor rock or method of erosion protection, bedrock, or may discharge to stable native vegetation. In variable ground conditions, the slope breaker configurations may include alternating the orientation to discharge on opposite sides of the ROW, overlap individual breakers to cover changes in ground topography in order to manage runoff, or create “chevron” shaped breakers that conform to variable topographic conditions. The final geometry and configuration often requires site-specific review and planning to be fit for purpose.

Sack-crete or similar materials are frequently used to build slope breakers, re-build the ROW where slope breakers are needed, or to stabilize trench and ROW backfill in steep ground conditions. As such, they can come in many forms and shapes to fit variable site conditions. These structures are typically built using individually stacked bags of sack-crete to form a structure that fits varying ground conditions. They are often used to re-establish, re-contour or stabilize trench backfill in bedrock conditions where the finer grained trench padding, bedding and backfill is used through cuts into bedrock. Because sack-crete breakers are essentially impermeable, these structures require additional drainage measures to collect and evacuate potential accumulation of trench and ROW backfill seepage flows. This is typically required to address the modified trench excavation in bedrock conditions, which can create focused trench seepage where it was previously not occurring (i.e. used to be bedrock or similar impervious material, and now has a trench with pervious backfill). Adding drainage measures to the trench should be an essential part of the planning, design, and construction effort.

3.4.2.5 Monitoring

Monitoring is a critical component of any site plan, and may be needed after installing mitigation measures. The monitoring plan for a given site must be developed based on the site specific requirements. Typical components include:

- Periodic visits and reconnaissance at sites;
- Geodetic monitoring points (i.e. survey bench marks) to track potential ground movement;
- Slope inclinometers to track ground movement at depth;
- Standpipe piezometers to track changes in groundwater conditions; and
- Strain gauges installed on the pipeline to measure and track potential accumulation of strain in the pipeline.

Monitoring may also include aerial mapping to track changes in ground conditions using remote sensing methods for a targeted site or at a larger pipeline system scale.

3.4.2.6 Stress Relief Excavations

Where landslide movement results in lateral and vertical displacement of the ground around a pipeline, the movement can result in strain accumulation in the pipeline. The accumulated strain can be greater where the pipeline passes across the lateral or vertical limits of a landslide, or at the boundaries of the landslide with the surrounding stable ground. These locations are where landslide shear stresses tend to be concentrated.

An option for mitigating the accumulated strain in the pipeline in this scenario includes excavating the trench backfill material and surrounding local soil within the landslide mass, and extending some distance beyond the transition zone into the stable ground. The removal of the backfill and nearby soil allows the pipeline to physically rebound to a pre-deformation geometry that eliminates, or significantly reduces, the accumulated strain in the pipeline. This is commonly referred to as “stress relief excavation,” or also “strain relief excavation.” There may be more complex interactions of the soil mass within and outside the landslide mass that result in combinations of horizontal and vertical displacements. These more complex relationships of ground movement must be assessed and determined on a case-by-case basis, and are specific to the site conditions. The landslide and pipeline interactions are addressed in simple terms herein, for the purpose of describing the concept of this mitigation option. Additional planning and design is needed to implement this type of mitigation action.

The following discussion does not address operational or safety planning for a given site. These requirements are assumed to be addressed by the owner/operator to fit the site-specific requirements.

Stress relief excavations typically start in the middle of the landslide mass and extend in one or both directions toward the lateral landslide limits, and to some point into the immobile ground beyond the landslide limits where rebound of the pipeline is no longer observed. This is the ideal situation but certainly not the only way to complete this work. The implementation plan for stress relief excavations may need to be modified to fit site conditions, in particular to allow for access and practical mobilization of equipment and project resources, as well as to maintain a safe working site. Access to complete the work is a common challenge; most landslide sites are located in difficult terrain and may have limited access once the excavation has been started.

For example, starting the stress relief excavation on one side of the landslide and moving through it and into the other side may eliminate access to the start point, or may remove ROW materials, or place spoils in a way that makes it difficult to return to the start point if additional excavations along the pipeline are needed again at the start point. Careful planning is needed to coordinate the construction work with the planned mitigation requirements, as well as for related monitoring efforts, to best fit the purpose and site conditions.

Stress relief excavations are commonly implemented as an immediate response action shortly after pipeline displacement is identified, in order to re-establish a baseline condition; and subsequent stress relief excavations may be implemented as a recurring operational activity over time, which may span years or decades. Trench drainage improvements are commonly installed at the same time the stress relief excavations are completed (and the trench and ROW are backfilled).

The use of stress relief excavations as a mitigation technique over the long term typically includes monitoring. Monitoring for stress relief excavation efforts can include a range of methods to address slope (i.e., landslide) movement, and the effects on the pipeline, such as:

- Periodic site reconnaissance (visual monitoring) of the landslide;
- Geodetic surveys of slope monitoring points placed on and surrounding the landslide;
- In-situ monitoring of landslide deformation (i.e. slope inclinometers);
- Tracking of local ground water levels (i.e. piezometers) installed in the landslide; and

- Strain gauges installed directly on the pipeline to measure and record potential accumulation of strain in the pipeline.

The use of strain gauges is critical and recommended as a minimum monitoring tool in conjunction with stress relief excavations. This allows the owner/operator to track potential accumulation of strain in the pipeline, and determine when additional stress relief excavations are needed. It also allows for the monitoring of strain reduction during stress relief excavation.

The accumulation of strain in the pipeline can be attenuated (i.e. for an increment of ground movement around the pipeline, a corresponding reduced amount of movement that actually displaces the pipeline) by installing select “deformable” backfill. The select, deformable backfill allows for some movement of the backfill relative to the pipeline as the ground around it moves, before the movement begins to impact the pipeline. The use of deformable backfill does not preclude continued stress relief excavations, or other site mitigation work. It does typically extend the time between successive stress relief excavation efforts.

The amount of attenuation of ground movement by the select backfill is not expected to be a one-to-one relationship. The typical performance goal is only to reduce relative displacement of the pipeline, and the actual amount of reduced displacement should be tracked through monitoring and addressed through maintenance activities, as needed. Select deformable backfill is typically a loosely placed, granular, clean sand-type material with little or no fines (i.e., < 5 percent fines). The select deformable backfill is placed in a sloped wall trench all around the pipeline, allowing for more material along the horizontal and/or vertical direction and orientation of the expected ground movement. Typical dimensions for deformable backfill relative to the pipeline should match, at a minimum the expected horizontal and/or vertical ground displacement. The properties of the select backfill also have enhanced drainage performance, which may be incorporated into the overall mitigation planning and design for the site, and are addressed in detail in subsequent sections herein.

4.0 APPLIED MITIGATION GUIDANCE

The following sections provide applied mitigation guidance for the Typical Scenarios listed below, along with corresponding discussion and guidance on supporting Typical Details (i.e. individual mitigation measures) for mitigation of landslide and erosion hazards (Williams 2015). The following Typical Scenarios are addressed:

- Side Slopes, sub classified normal (Appendix A-1, Sheet 1110) and oblique (Appendix A-1, Sheet 1120) orientation to pipeline;
- Ridge Tops (Appendix A-1, Sheet 1130);
- Inclined Ridges (Appendix A-1, Sheet 1140);
- Planar Slopes (Appendix A-1, Sheets 1150 and 1160);
- Convergent Topography (Appendix A-1, Sheet 1170);
- Shallow Bedrock (Appendix A-1, Sheet 1500);
- Areas of Fill Soil (Appendix A-1, Sheet 1600); and
- Landslides (Appendix A-1, Sheets 1710, 1720, 1730, and 1740).

These Typical Scenarios help to define the geotechnical and hydrotechnical engineering and geologic hazard processes corresponding to each defined scenario, providing a practical framework for describing the hazards or threats that may be impacting the pipeline at a particular location. They support and guide informed decisions on conceptual design, selection and planning of individual mitigation measures needed at a site.

Each Typical Scenario includes a cross-section or topographic representation to help graphically describe the scenario and a library of corresponding Typical Details that are applicable to the defined scenario. The Typical Detail sheets look like “fly-sheets” or “cut sheets” and depict a single mitigation measure (i.e. silt fence, or compaction, or a targeted drain feature, etc.). This approach allows for easily adding or updating the library of measures, while maintaining the governing framework for defining and characterizing the applicable hazards and threats to the pipeline. The intent is not to use or implement all the Typical Details at any given site, but to offer options for solutions that should be selected based on the applicable site conditions.

The intent of the combined Typical Scenario and Typical Details package is to provide a conceptual framework for describing the site-specific hazards and applicable mitigation measures to address those hazards. The final selection of individual mitigation measures for any given site, and the proposed locations and extents where those measures should be installed, must be confirmed through site specific observations, investigations and studies, and should include careful consideration of construction processes. This information is typically combined with a site-specific topographic based plan (i.e. contour or site survey data), in order to provide coordinate locations and extents for specific mitigation measures relative to the topographic locations, or shown relative to site-specific cross-sections and profiles.

4.1 Side Slope Conditions

The portions of a pipeline route that cross side slopes may encounter more geotechnically sensitive areas versus routing straight up/down the fall line of a slope or along a ridge, because the route will likely cross more existing native landslides or landslide-susceptible slopes, intercept more catchment areas delivering run-off to the ROW, and intercept more potential near-surface seepage and groundwater. In addition, side slope areas typically require the construction of wide, benched work areas where the upslope side of the construction ROW is cut into the hillslope, the excavated material from which is then placed as temporary fill on the downslope side of the ROW. The cut into native slopes and placement of fill on native slopes can have a destabilizing effect on the native ground.

Side slopes have been further categorized herein as either 'side slope normal' or 'side slope oblique' based on the orientation of the proposed pipeline relative to the hillslope. Side slope normal describes areas where the proposed path of the pipeline and/or construction ROW and work zones are generally oriented parallel to the contours. Side slope oblique describes areas where the proposed path of the pipeline and construction ROW and work zones are generally oriented oblique (i.e. at an angle) to either the fall line or the contour of the slope. Special consideration is needed in side slope oblique areas because the surface water and groundwater being intercepted by the ROW and/or pipeline trench will be directed toward, and channelized by, the pipeline trench. Trench fill blowouts commonly occur in side slope oblique conditions if a sufficient amount of water is intercepted by the pipeline trench and adequate measures are not installed to slow and redirect surface and trench water flow. Generally, steep side slope conditions with shallow groundwater or surface water present are the most likely areas to experience landslides, trench backfill blowouts, and surface erosion.

4.1.1 Engineering/construction recommendations for side slope normal

In a side-slope normal scenario (Appendix A-1, Sheet 1110), the pipeline trench typically has a flat or shallow gradient, running along the contour of the slope. The construction disturbance, temporary excavation surface, and trench in a side-slope normal scenario intercept runoff and drainage. The accumulated seepage can cause the native soil and/or fill to become saturated. The result is unstable backfill that can be destabilized, and may retrogress outside the easement work area and may initiate or reactivate existing adjacent native landslides. Restoration measures in this scenario need to focus on reducing surface and near-surface flow to the trench and backfill. The accumulated seepage also must be drained from the backfill and trench in a practical and efficient way. The restoration measures may need to extend outside the actual ROW footprint to mitigate the possibility of initiating broader slope instability.

Typical conceptual restoration measures used in side slope normal conditions may include:

1. Generally re-contour the restored ROW to re-establish pre-construction contours (Appendix A-2, Sheet 2G), except where targeted site assessments recommend reducing backfill over unstable or landslide areas (Appendix A-2, Sheet 2H).
2. Grade the temporary ROW construction surface (Appendix A-2, Sheet 2A) so that it drains away from the inside of the cut. The objective is to minimize the potential for infiltrated water to accumulate, or tend to move along the transition from the disturbed ROW areas and the undisturbed temporary ROW surface (i.e. the native ground). An additional objective is to avoid a situation where the excavated colluvium and residual soils are stockpiled in a manner that traps water, causing the excavated soils to become saturated prior to backfilling the ROW. Temporary construction surfaces need to be incorporated into the final site drainage configuration to limit potential for saturation of the backfill and native soils.
3. Grade the temporary ROW surface and depth of the pipeline trench to allow for a stable outboard wedge of soils/rock material adjacent to the pipeline trench (to the out-slope side), see Appendix A-2, Sheet 2B. This maintains a protective stable section of ground on the outboard slope side of the pipeline trench that mitigates for potential raveling, degradation, landslide or other slope instability or erosion processes that may impact the pipeline.
4. Cut bleeder trenches (Appendix A-2, Sheet 1D) into the downslope side of the pipeline trench at an approximate 100-foot spacing, or to match the local topography. Bleeders should be cut down to the bottom of the pipeline trench excavation, and then slope to drain out through native soil or rock (i.e. not in fill) and discharge on stable ground. Bleeders can be enhanced by adding geotextile wrapped drain rock, and/or drainage pipe (i.e. French drains). The objective of bleeder trenches is to provide drainage relief points at regular intervals, so that as seepage accumulates, it finds an outlet from the trench.

5. Install brow ditches (Appendix A-2, Sheet 6B) excavated into the ground, slope breakers (Appendix A-2, Sheets 5A and 5B), a combination of built-up and excavated water bars and armored channels with drain pipes (Appendix A-2, Sheets 1F, 1H and 1E) along the upslope side of the ROW to intercept and divert surface run-off to stable locations away from the side slope areas. The need and layout of these depends on the topography, for instance if there is no stable location to discharge the intercepted water. In this case, rely more on other measures.
6. Where surface run-off from one or more slope breakers, or other surface or near surface water sources needs to be conveyed down steep slopes that may be subject to erosion, consider using armored channels with an apron at the discharge (Appendix A-2, Sheet 1F and 1E), or in steep terrain the armored channel and more robust drainage piping may be needed (Appendix A-2, Sheet 1H and 1E).
7. Compact the backfill (Appendix A-2, Sheet 2C) during side slope ROW reconstruction. This adds strength to the backfill to make it more stable, and reduces infiltration of water. Achieving compaction in steep and rugged terrain is difficult. Recommended methods include use of sheep's-foot rollers pulled behind a dozer, a self-propelled sheep's-foot compactor or sheep's-foot roller attached to an excavator arm.
8. Where the local soils are not suitable for backfill and/or compaction, for example due to the sensitive nature of the local fine-grained soils or excessive moisture content, it may be necessary to haul the unsuitable material off the site. These materials should not be stockpiled or spoiled in areas that may initiate or exacerbate landslides (Appendix A-2, Sheet 2E). Replace with a free-draining, angular, clean, small sized (i.e. min 4 to 8 inch) rock backfill (Appendix A-2, Sheets 2F and 3D). This kind of rock backfill can stand up at steep angles, does not hold water, is very stable, and adjusts to future changes in the site and ground conditions (i.e. settlement, continued slip movement, etc.). Drying soils (Appendix A-2, Sheet 2D) used as backfill materials can be achieved by spreading the soil in windrows and actively working the windrows until the soil achieves a suitable moisture content. Low humidity and warm temperatures are needed to make this work. An alternative is the use of lime or cement kiln dust, or a similar product, as an additive to wet soils to help facilitate more optimal moisture content. Lime or cement kiln dust is added and mixed with targeted soils, following the manufacturers recommendations, until a suitable soil condition is achieved. Use of the lime or cement kiln dust allows for working in wetter conditions. Mixing rates and methods need to be calibrated to site conditions and may require experimenting to find the right blend for implementation.
9. Install a French drain (Appendix A-2, Sheets 1A and 1E) along the inside catch of the constructed temporary ROW surface at the transition from disturbed soils (i.e. where the backfill starts) and the undisturbed native soils. Drains should discharge at stable locations downslope of the backfill areas so that it does not recharge the backfill.
10. Install drains (Appendix A-2, Sheet 1C and 1E) where seeps or other subsurface water sources are identified during temporary ROW construction.
11. Install slope breakers or other surface diversion berms to intercept surface run-off, or combine slope breakers/berms with armored channels to control run-off (Appendix A-2, Sheets 1E, 1F, 5A, 5B, 5C, and/or 6D).
12. Special consideration is needed to construct and restore drainage measures for existing, permanent and temporary access roads on a site-specific basis. Access roads may collect runoff from upslope areas, increasing the contributing basin area draining to any given site, and deliver water to the ROW, the pipeline trench or to other areas of concern. Use drainage measures such as slope breakers, water bars, grading to improve drainage, French drains, enhanced drains, armoring, armored ditches with drain pipes, rock fill, etc. (Appendix A-2, Sheet 5D) to manage and mitigate drainage issues.

13. Cover disturbed area with erosion control fabric (Appendix A-2, Sheet 3C) or other functional erosion resistant ground covering to mitigate over the short-term until the local vegetation can take over and establish itself. In especially unstable and steep slope conditions, erosion control products such as armor rock may be needed (Appendix A-1, Sheet 3D).
14. Track disturbed slopes (Appendix A-2, Sheet 3A) and re-vegetate all disturbed areas to provide long-term surface stabilization (i.e. replace the short-term erosion control fabric protection).

4.1.2 Engineering/construction recommendations for side slope oblique

In side-slope oblique scenarios (Appendix A-1, Sheet 1120), the same conditions apply as in the previous discussions for side slope normal scenarios, but intercepted seepage flows can be accelerated by the sloping gradient of the trench as it tracks along the side slope at the oblique angle. The higher seepage velocities result in an increased potential for instability and erosion issues (both “piping erosion” and surface erosion). All the recommended typical conceptual restoration measures for normal side slope conditions apply (as described above in 4.1.1), with the addition of the following to address the oblique conditions:

1. Drainage pipes in the pipeline trench are needed to mitigate for the increased gradient and seepage velocities resulting from the sloping trench (i.e. due to the oblique orientation of the trench along the side slope). The bleeder trenches used in side slope normal scenarios may not provide enough drainage relief, and on sloped ground may actually discharge back into the trench. Drainage pipes can be configured as French drains (Appendix A-2, Sheets 1A and 1E) for normal or low flow conditions, with discharge points at the edge of the ROW on stable ground and with erosion pads. Where excessive seepage along the trench may be a problem, then the piping configuration should be modified to include perforated drain pipes that collect water and feed into solid-smooth-interior-walled tightline pipes that convey it away (i.e. enhanced drains, Appendix A-2, Sheets 1B and 1E).
2. Install trench breakers (Appendix A-2, Sheet 4A), preferably using sandbags, at spacing and locations corresponding to the trench slope (not necessarily the ground slope, which may be much steeper). Where foam materials are used for the trench breakers, there should be drainage measures incorporated into breakers that mitigate for accumulation of seepage on the upslope side of the breaker, allowing it to drain through the breaker.

Modifications or alternatives to the above described measures that are feasible and maintain the function and intent as described and offer practical alternatives are encouraged.

4.2 Ridge Tops

Ridge tops (Appendix A-1, Sheet 1130) are defined as areas where the proposed path of the pipeline and/or construction ROW and work zones are located longitudinally (i.e. running along the ridge) along hilltops with average slopes that are shallow, generally not exceeding about 15 percent grade. Ridge tops are the preferable route for a pipeline because they avoid stream crossings, have little or no contributing catchment delivering water (i.e. minimizes seepage and drainage issues) and they avoid many of the sensitive geotechnical areas that will be encountered on side slopes and planar slopes. Landslides rarely occur at ridge tops. However, native landslides may be present on the side slopes on either side of the ridge top. If the pipeline or work areas deviate from the ridge top, or cross up and over it, then side slope conditions and landslide conditions may be encountered. Depth to bedrock is commonly shallow at ridge tops and may be encountered within the design pipeline depth.

4.2.1 Engineering/construction recommendations for ridge tops:

In ridge top scenarios, the backfill has less potential for becoming saturated and can drain to stable ground along either side of the ridge, reducing the potential for focusing seepage flows. Typical conceptual restoration measures used in ridge top conditions may include:

1. Generally re-contour the restored ROW to re-establish pre-construction contours (Appendix A-2, Sheet 2G), except where site assessments recommend reducing backfill over unstable or landslide areas (Appendix A-2, Sheet 2H).
2. Grade the temporary ROW construction surface (Appendix A-2, Sheet 2A) so that it drains away from the inside of the cut. The objective is to minimize the potential for infiltrated water to accumulate, or tend to move along the transition from the disturbed ROW areas and the undisturbed temporary ROW surface (i.e. the native ground). An additional objective is to avoid a situation where the excavated colluvium and residual soils are stockpiled in a manner that traps water, causing the excavated soils to become saturated prior to backfilling the ROW. Temporary construction surfaces need to be incorporated into the final site drainage configuration to limit potential for saturation of the backfill and native soils.
3. Grade the temporary ROW surface and depth of the pipeline trench to allow for a stable outboard wedge of soils/rock material adjacent to the pipeline trench (to the out-slope side, Appendix A-2, Sheet 2B). This maintains a protective stable section of ground on the outboard slope side of the pipeline trench that mitigates for potential raveling, degradation, landslide, or other slope instability or erosion processes that may impact the pipeline. On ridge tops, this may be on both sides of the pipeline trench.
4. Drying soils (Appendix A-2, Sheet 2D) used as backfill materials can be achieved by spreading the soil in windrows and actively working the windrows until the soil achieves a suitable moisture content. Low humidity and warm temperatures are needed to make this work. An alternative is the use of lime or cement kiln dust, or a similar product, as an additive to wet soils to help facilitate more optimal moisture content. Lime or cement kiln dust is added and mixed with targeted soils, following the manufacturers recommendations, until a suitable soil condition is achieved. Use of lime or cement kiln dust allows for working in wetter conditions. Mixing rates and methods need to be calibrated to site conditions and may require experimenting to find the right blend for implementation.
5. Compact the backfill during side slope ROW reconstruction. This adds strength to the backfill to make it more stable, and reduces infiltration of water.
6. Where the local soils are not suitable for backfill and compaction, for example due to the sensitive nature of the local fine-grained soils or excessive moisture content, it may be necessary to haul that unsuitable material off the site. These materials should not be stockpiled or spoiled in areas that may initiate or exacerbate landslides (Appendix A-2, Sheet 2E). Replace with a free-draining, angular, clean, small-sized (i.e. min 4- to 8-inch) rock backfill (Appendix A-2, Sheets 2F and 3D). This kind of rock backfill can stand up at steep angles, does not hold water, is very stable and will adjust to future changes in ground conditions (i.e. settlement, continued slip movement, etc.).
7. Special consideration is needed to construct and restore drainage measures for existing, permanent, and temporary access roads, on a site specific basis. Access roads may collect runoff from upslope areas, thereby increasing the contributing basin area draining to any given site, and deliver water to the ROW, the pipeline trench, or to other areas of concern. Use drainage measures, as described in this study, to manage and/or mitigate drainage issues, such as slope breakers, water bars, grading to improve drainage, French drains, enhanced drains, armoring, armored ditches with drain pipes, rock fill, etc. (Appendix A-2, Sheet 5D).

8. Cover disturbed area with erosion control fabric (Appendix A-2, Sheet 3C), or other functional erosion resistant ground coverings to mitigate over the short-term until the local vegetation can take over and establish itself.
9. Track disturbed slopes (Appendix A-2, Sheet 3A) and re-vegetate all disturbed areas to provide long-term surface stabilization (i.e. replace the short-term erosion control fabric protection).

Modifications or alternatives to the above described measures that are feasible and maintain the function and intent as described and offer practical alternatives are encouraged.

4.3 Inclined Ridges

Inclined ridges (Appendix A-1, Sheet 1140) are defined herein as areas where ridge tops have average slopes that generally exceed about 15 percent grade. Special construction planning and equipment may be needed to operate in these rugged and steep conditions. Inclined ridges commonly cross alternating zones of shallow bedrock and thick soils as a result of local geologic conditions. Native landslides are less-likely to be crossed where the pipeline follows an inclined ridge, and stream crossings are not likely. However, landslides originating in post-construction ROW backfill may occur if the nature and the placement method of the backfill are not adequate to achieve stability, especially if the post construction ROW grade is similar to the steep and often stepped topography of the adjacent native slopes. Near-surface groundwater may be encountered at cuts, especially where a cut is made into the interlayered, water-bearing bedrock units. If the pipeline and/or work areas deviate from the inclined ridge crest, side slope conditions may be encountered.

4.3.1 Engineering/construction recommendations for inclined ridges:

For inclined ridge top scenarios, similar to the ridge top scenario, there is less potential for the backfill to become saturated. Typically, water can drain to stable ground along either side of the ridge, reducing the potential for focusing seepage flows. As such, the recommendations described previously for ridge tops are the same. What the inclined condition creates is a gradient for seepage flows, requiring mitigation to slow and manage seepage flows along the trench. Typical conceptual measures used in inclined ridge conditions may include:

1. Generally re-contour the restored ROW to re-establish pre-construction contours (Appendix A-2, Sheet 2G), except where site assessment recommends reducing backfill over unstable or landslide areas (Appendix A-2, Sheet 2H).
2. Grade the temporary ROW construction surface (Appendix A-2, Sheet 2A) so that it drains away from the inside of the cut. The objective is to minimize the potential for infiltrated water to accumulate or tend to move along the transition from the disturbed ROW areas and the undisturbed temporary ROW surface (i.e. the native ground). An additional objective is to avoid a situation where the excavated colluvium and residual soils are stockpiled in a manner that traps water, causing the excavated soils to become saturated prior to backfilling the ROW. Temporary construction surfaces need to be incorporated into the final site drainage configuration to limit the potential for saturation of the backfill and native soils.
3. Grade the temporary ROW surface and depth of the pipeline trench to allow for a stable outboard wedge of soils/rock material adjacent to the pipeline trench (to the out-slope side, Appendix A-2, Sheet 2B). This maintains a protective stable section of ground on the outboard slope side of the pipeline trench that mitigates for potential raveling, degradation, landslide, or other slope instability or erosion processes that may impact the pipeline. On ridge tops, this may be on both sides of the pipeline trench.
4. Drying soils (Appendix A-2, Sheet 2D) used as backfill materials can be achieved by spreading the soil in windrows and actively working the windrows until the soil achieves a suitable moisture content. Low humidity and warm temperatures are needed to make this work. An alternative is the use of lime or cement kiln dust, or a

similar product, as an additive to wet soils to help facilitate more optimal moisture content. Lime or cement kiln dust is added and mixed with targeted soils, following the manufacturers recommendations, until a suitable soil condition is achieved. Use of lime or cement kiln dust allows for working in wetter conditions. Mixing rates and methods need to be calibrated to site conditions and may require experimenting to find the right blend for implementation.

5. Compact the backfill during side slope ROW reconstruction. This adds strength to the backfill to make it more stable, and reduces infiltration of water.
6. Where the local soils are not suitable for backfill and/or compaction, for example due to the sensitive nature of the local fine-grained soils or excessive moisture content, it may be necessary to haul that unsuitable material off the site. These materials should not be stockpiled or spoiled in areas that may initiate or exacerbate landslides (Appendix A-2, Sheet 2E). Replace with a free-draining, angular, clean, small-sized (i.e. min 4- to 8-inch) rock backfill (Appendix A-2, Sheets 2F and 3D). This kind of rock backfill can stand up at steep angles, does not hold water, is very stable, and will adjust to future changes in ground conditions (i.e. settlement, continued slip movement, etc.).
7. Install drains (Appendix A-2, Sheets 1C and 1E) where seeps or other subsurface water sources are identified during the temporary ROW construction.
8. Where surface run-off from one or more slope breakers or other water sources needs to be conveyed down steep slopes that may be subject to erosion, consider using armored channels with an apron at the discharge (Appendix A-2, Sheet 1F and 1E). For steep terrain the armored channel and more robust drainage piping may be needed (Appendix A-2, Sheet 1H and 1E).
9. Drainage pipes in the pipeline trench are needed to mitigate for the increased gradient and seepage velocities resulting from the sloping ridge top. Drainage pipes can be configured as French drains (Appendix A-2, Sheets 1A and 1E) in low seepage flow conditions, with discharge points at the edge of the ROW on stable ground and/or with erosion pads. Where excessive seepage along the trench may be a problem, then the piping configuration should be modified to include perforated pipes that collect water and feed into solid-smooth-interior-walled tightline pipes that convey it away (i.e. enhanced drains, Appendix A-2, Sheets 1B and 1E).
10. Install Slope breakers (a.k.a. water bars) along the ROW at spacing and orientations that intercept and direct surface run-off to stable and (preferably) vegetated areas along and off the ROW. Slope breaker spacing is typically governed by slope angle and/or the presence of trench breakers (Appendix A-2, Sheet 5A). In steep slope conditions, a slope breaker should be placed just below a trench breaker, so that seepage that is pushed to the surface by the trench breaker is then captured by the slope breaker and diverted off the ROW. Final spacing and placement of breakers should incorporate site specific information. Where excessive run-off may need to be mitigated, then slope breakers can be discharged to an armored ditch or diversion channel (Appendix A-2, Sheets 5C, 6D, 1F and 1E).
11. Install trench breakers (Appendix A-2, Sheet 4A), preferably using sandbags, at spacing and locations corresponding to the trench slope (not necessarily the ground slope, which may be much steeper). Where foam materials are used for the breakers, there should be drainage measures incorporated into breakers that mitigate for accumulation of seepage on the upslope side of the breaker, allowing it to drain through the breaker.
12. Install sack-crete breakers (Appendix A-2, Sheet 4C) in areas where the trench and slopes are steep and the breaker is needed to retain and/or stabilize the trench backfill. These structures may be configured to provide a foundation for imported backfill, retain backfill in the trench itself on steep terrain, or to stabilize larger portions

of the ROW area or larger trench and slope backfill areas. Because these structures can be large and encompass an extended length of the pipeline, install a sleeve interface (geotextile fabric, rock-shield, etc.) between the pipeline and the structure to provide a slip separation, and to avoid transfer of loading from the trench backfill through the structure to the pipeline (Appendix A-2, Sheet 4D).

13. Where the pipeline alignment passes through benched terrain, mitigate for complex backfill and drainage conditions by using rock fill, sack-crete breakers, enhanced drainage, or other measures, as needed (Appendix A-2, Sheet 10A). Benched topography can be very complex and may require site specific review to develop a practical and constructible mitigation and restoration package.
14. Special consideration is needed to construct and/or restore drainage measures for existing, permanent, and temporary access roads, on a site specific basis. Access roads may collect runoff from upslope areas, thereby increasing the contributing basin area draining to any given site, and deliver water to the ROW, the pipeline trench, or to other areas of concern. Use drainage measures, as described in this study, to manage and/or mitigate drainage issues, such as slope breakers, water bars, grading to improve drainage, French drains, enhanced drains, armoring, armored ditches with drain pipes, rock fill, etc. (Appendix A-2, Sheet 5D).
15. Cover disturbed area with erosion control fabric (Appendix A-2, Sheet 3C), or other functional erosion resistant ground coverings to mitigate over the short-term until the local vegetation can take over and establish itself.
16. Track disturbed slopes (Appendix A-2, Sheet 3A) and re-vegetate all disturbed areas to provide long-term surface stabilization (i.e. replace the short-term erosion control fabric protection).

Modifications or alternatives to the above described measures that are feasible and maintain the function and intent as described and offer practical alternatives are encouraged.

4.4 Planar Slopes

A planar slope (Appendix A-1, Sheet 1150) is defined as a slope where the proposed path of the pipeline and/or construction ROW and work zones generally follow the fall line down a slope, and includes limited grading to construct the temporary ROW. Refer to Appendix A-1, Sheet 1160 (Planar Slopes Deep Excavation) where deeper or more extensive excavations are needed to grade through variable topography along the slope. Where the pipeline alignment crosses at an angle along the slope, the condition is referred to as side slope (normal or oblique), refer to previous discussion in Section 4.1. Planar slopes commonly have alternating zones of shallow bedrock and thick soils as a result of local geologic conditions and may have stepped topography. Landslides may be present on planar slopes, but the destabilizing effect caused by pipeline construction may be less because the cut runs parallel to the direction of landslide movement, as opposed to side slope conditions where the cut is made perpendicular and across a landslide. Landslides originating in post-construction ROW may occur if the nature and the placement method of the backfill are not adequate to achieve stability, especially if the post construction ROW grade mimics the steep and often stepped topography of the adjacent native slopes. Surface run-off is common on planar slopes, accumulating on the ROW surface and increasing in volume with increasing length of slopes, such that all the run-off is delivered at the bottom of the slope. Near- surface groundwater may be encountered at cuts, especially where a cut is made into any water-bearing bedrock units.

4.4.1 Engineering/construction recommendations for planar slopes

Installing the pipeline down planar slopes typically connects the alignment between ridge tops and lower elevation flat terrain. Construction on planar slopes is common but may include long sections of ROW with steep gradients. The following recommended measures assume that clearing and grading of the temporary ROW surface is generally limited to removal of vegetation and topsoil, and grading for a

continuous vertical profile with little or no lateral side-cuts or excavation leveling latitudinal to the pipeline alignment (i.e. following down the fall line of the slope). Where lateral excavations are necessary, recommendations from the side slope scenarios should be considered. Bedrock steps and benches are a common topographic feature along planar slopes. Cutting through the ridges of these steps is often required to build the ROW and excavate the trench, and site specific plans may be required. These present some unique challenges for both short and long-term restoration. Typical conceptual restoration measures used in planar slope conditions may include:

1. Generally re-contour the restored ROW to re-establish pre-construction contours (Appendix A-2, Sheet 2G), except where site assessments recommend reducing backfill over unstable or landslide areas (Appendix A-2, Sheet 2H).
2. Grade the temporary ROW construction surface (Appendix A-2, Sheet 2A) so that it drains positively away from the inside of the cut. The objective is to minimize the potential for infiltrated water to accumulate, or tend to move along the transition from the disturbed ROW areas and the undisturbed temporary ROW surface (i.e. the native ground). An additional objective is to avoid a situation where the excavated colluvium and residual soils are stockpiled in a manner that traps water, causing the excavated soils to become saturated prior to backfilling the ROW. Temporary construction surfaces need to be incorporated into the final site drainage configuration to limit potential for saturation of the backfill and/or native soils.
3. Compact the backfill (Appendix A-2, Sheet 2C) during side slope ROW reconstruction. This adds strength to the backfill to make it more stable, and reduces infiltration of water. Achieving compaction in steep and rugged terrain is difficult. Recommended methods include use of sheep's-foot rollers pulled behind a dozer, a self-propelled sheep's-foot compactor, or sheep's-foot roller attached to an excavator arm.
4. Install drains (Appendix A-2, Sheets 1C and 1E) where seeps or other subsurface water sources are identified during the temporary ROW construction.
5. Where deeper excavations along the planar slope are required to construct the temporary ROW, resulting in cut slopes and lowered grades that cannot drain to an outboard natural slope (i.e. laterally confined drainage areas), then install armored channels with drains in shallow excavation areas (Appendix A-2, Sheet 1F or 1H in steep ground), or install French drains (Appendix A-2, Sheet 1A) in deeper excavation areas.
6. Where surface run-off from one or more slope breakers or other water sources needs to be conveyed down steep slopes that may be subject to erosion, consider using armored channels with an apron at the discharge (Appendix A-2, Sheet 1F and 1E). In steep terrain the armored channel and more robust drainage piping may be needed (Appendix A-2, Sheet 1H and 1E).
7. Where the local soils are not suitable for backfill and/or compaction, for example due to the sensitive nature of the local fine-grained soils or excessive moisture content, it may be necessary to haul that unsuitable material off the site. These materials should not be stockpiled or spoiled in areas that may initiate or exacerbate landslides (Appendix A-2, Sheet 2E). Replace with a free-draining, angular, clean, small sized (i.e. min 4- to 8-inch) rock backfill (Appendix A-2, Sheets 2F and 3D). This kind of rock backfill can stand up at steep angles, does not hold water, is very stable, will adjust to future changes in the ground conditions (i.e. settlement, continued slip movement, etc.).
8. Drying soils used as backfill materials can be achieved by spreading the soil in windrows and actively working the windrows until the soil achieves a suitable moisture content (Appendix A-2, Sheet 2D). Low humidity and warm temperatures are needed to make this work. An alternative is the use of lime or cement kiln dust, or a similar product, as an additive to wet soils to help facilitate more optimal moisture content.

Lime or cement kiln dust is added and mixed with targeted soils, following the manufacturers recommendations, until a suitable soil condition is achieved. Use of lime or cement kiln dust allows for working in wetter conditions. Mixing rates and methods need to be calibrated to site conditions and may require experimenting to find the right blend for implementation.

9. In cases where bedrock steps or benches (Appendix A-2, Sheet 10A) have been blasted or ripped to build the ROW and the trench, these spoil materials may be used, crushed, or re-processed to provide a more suitable backfill rock material that can be handled and placed as needed to rebuild and restore the ROW. Restoring rock benches to re-create the pre-project bench geometry may not be possible, and is typically very difficult to achieve. Backfill through rock benches should use angular rock materials to create safe slopes and provide the required cover over the pipeline trench. Use of fine-grained soils in rock cuts should be avoided, and would require additional special drainage measures and possible engineered stabilization of the soil backfill. Use of angular rock fill eliminates these requirements.
10. Drainage pipes in the pipeline trench are needed to mitigate for the increased gradient and seepage velocities resulting from the sloping trench (i.e. due to the oblique orientation of the trench along the side slope). Drainage pipes can be configured as French drains (Appendix A-2, Sheets 1A and 1E) in areas of low seepage flows or at inside cut areas along the temporary ROW constructed surface. Where excessive seepage along the trench may be a problem on steep slopes, the piping configuration should be modified to include perforated corrugated pipes that collect water and feed into solid-smooth-interior-walled tightline pipes that convey it away (i.e. enhanced drains, Appendix A-2, Sheets 1B and 1E). Drainage pipes should have discharge points at the edge of the ROW on stable ground and/or with erosion pads.
11. Install Slope breakers (a.k.a. water bars) along the ROW at spacing and orientations that intercept and direct surface run-off to stable and (preferably) vegetated areas along and off the ROW, away from sensitive areas such as landslides. Slope breaker spacing is typically governed by slope angle and/or the presence of trench breakers (Appendix A-2, Sheet 5A). In steep slope conditions, a slope breaker should be placed just below a trench breaker, so that seepage that is pushed to the surface by the trench breaker is then captured by the slope breaker and diverted off the ROW, and away from sensitive areas such as landslides. Final spacing and placement of breakers should incorporate site specific information. Where excessive run-off may need to be mitigated, then slope breakers can be discharged to an armored ditch or diversion channel (Appendix A-2, Sheets 5C, 6D, 1F and 1E).
12. Install trench breakers (Appendix A-2, Sheet 4A), preferably using sandbags, at a spacing and location corresponding to the trench slope (not necessarily the ground slope, which may be much steeper). Where foam materials are used for the breakers, there should be drainage measures incorporated into breakers that mitigate for accumulation of seepage on the upslope side of the breaker, allowing it to drain through the breaker.
13. Install sack-crete breakers (Appendix A-2, Sheet 4C) in areas where the trench and slopes are steep and the breaker is needed to retain and/or stabilize the trench backfill. These structures may be configured to provide a foundation for imported backfill, retaining backfill in the trench itself on steep terrain, or to stabilize larger portions of the ROW area or larger trench and slope backfill areas. Because these structures can be large and encompass an extended length of the pipeline, install a sleeve interface (geotextile fabric, rock-shield, etc.) between the pipeline and the structure to provide a slip separation, and to avoid transfer of loading from the trench backfill through the structure to the pipeline (Appendix A-2, Sheet 4D).
14. Special consideration is needed to construct and/or restore drainage measures for existing, permanent, and temporary access roads, on a site specific basis. Access

roads may collect runoff from upslope areas, thereby increasing the contributing basin area draining to any given site, and deliver water to the ROW, the pipeline trench, or to other areas of concern. Use drainage measures, as described in this study, to manage and/or mitigate drainage issues, such as slope breakers, water bars, grading to improve drainage, French drains, enhanced drains, armoring, armored ditches with drain pipes, rock fill, etc. (Appendix A-2, Sheet 5D).

15. Track disturbed slope areas (Appendix A-2, Sheet 3A), cover disturbed area with erosion control fabric (Appendix A-2, Sheet 3C), or use other functional erosion resistant ground coverings to mitigate over the short-term until the local vegetation can take over and establish itself.
16. Re-vegetate all disturbed areas to provide long-term surface stabilization (Appendix A-2, Sheet 3B) (i.e. to replace the erosion control fabric over the long-term).

Modifications or alternatives to the above described measures that are feasible and maintain the function and intent as described and offer practical alternatives are encouraged.

4.5 Convergent Topography

Convergent topography (Appendix A-1, Sheet 1170) is defined qualitatively as converging dish-shaped drainage basins that have steep slopes. In areas of convergent topography both water and hillslope materials (landslides, colluvium) are focused toward a central location that may intersect the ROW and pipeline trench. Areas of convergent topography are typically source areas for landslides due to increases in water, colluvium and frequently thicker units of residual soils. Depth to bedrock is typically greater in these locations. However, local geologic conditions may result in shallow bedrock conditions where erosion or landslides have removed the surface soils.

4.5.1 Engineering/construction recommendations for convergent topography

Typical conceptual restoration measures in these areas are the same as those described for side slope (Appendix A-1, Sheet 1110 and 1120) and planar slope (Appendix A-1, Sheet 1150 and 1160) conditions.

4.6 Shallow Bedrock

Shallow bedrock (Appendix A-1, Sheet 1500) is defined as areas along a proposed alignment that cross steep rugged terrain that may be underlain by generally flat-lying, alternating layers of sedimentary rock that may include (in areas around northern West Virginia) sandstone, siltstone, shale, limestone, and coal. The limestone and sandstone layers are generally stronger and more competent than the weaker shale, siltstone, and coal layers. The sandstone and limestone may not easily rip at the time of trench excavation and may require hammering, chipping, and blasting, depending on the thickness, jointing and weathering state of the rock. The weaker bedrock layers are typically rippable using standard construction methods.

The natural topography in northern West Virginia appears 'benched' or 'stair-stepped' as a result of differential weathering and erosion of the flat-lying bedrock layers that alternate between competent bedrock (limestone and sandstone) and the less-competent bedrock (shale, siltstone, and coal). The less competent rock layers are also prone to weathering and the steep slopes may have a thin to thick veneer of highly to completely weathered rock at the surface. More competent rock is likely found on steep slopes with the possible presence of cliff bands, and along narrow inclined ridges and narrow ridge tops.

4.6.1 Engineering/construction recommendations for Shallow Bedrock

Typical conceptual restoration measures used in shallow bedrock conditions may include (but is not limited to):

1. Typical bedrock trench conditions in generally flat terrain may have challenges generating enough material for padding/bedding and for backfill, where the spoils are large and angular resulting from the blasting, ripping or chipping excavations. Rock guard materials may be needed to provide additional protection around the pipeline to allow for irregularities in the trench bottom and oversized materials in the backfill (Appendix A-2, Sheet 8A).
2. In typical ground conditions, install trench breakers (Appendix A-2, Sheet 4A), preferably using sandbags, at a spacing and location corresponding to the trench slope (not necessarily the ground slope, which may be much steeper). Sandbag breakers allow normal seepage to slowly migrate through the breaker. Where needed, piping may be added to allow this slow movement of trench seepage water, and avoid excessive accumulations of seepage water on the upslope side of breakers. Where foam materials are used for the breakers, there should be drainage measures incorporated into breakers that mitigates for accumulation of seepage on the upslope side of the breaker, allowing it to drain through the breaker.
3. In steep rock trench conditions, the backfill may become unstable due to locally over-steepened slopes and/or the contribution of seepage water to the trench. In these conditions, sandbag (Appendix A-2, Sheet 4A) or sack-crete (Appendix A-2, Sheet 4C) trench breakers are effective at retaining trench backfill and stabilizing ROW backfill. The use of sack materials allows for building contour forming structures that have the mass and geotechnical properties to retain backfill soils or rock materials in steep conditions. Use of foam breaker materials is not recommended in steep conditions. Drainage piping should be added to breakers in steep conditions to collect and convey and evacuate accumulated seepage flows.
4. Trench breakers in steep rock trench conditions should have a sleeved interface, such as a geotextile fabric or rock shield material, between the breaker and the pipeline that breaks the bond that may develop between the breaker material and the pipeline (Appendix A-2, Sheet 4D). Where a tight and bonded connection between the pipeline and breaker occurs, the load from the backfill may be transferred to the pipeline, resulting in increased stress conditions.
5. Drainage pipes in the pipeline trench are needed to mitigate for the increased gradient and seepage velocities resulting from the sloping trench (i.e. due to the oblique orientation of the trench along the side slope). Drainage pipes can be configured as French drains (Appendix A-2, Sheets 1A and 1E) where seepage flows are low, with discharge points at the edge of the ROW on stable ground and/or with erosion pads. Where excessive seepage along the trench may be a problem, then the piping configuration should be modified to include perforated corrugated pipes that collect water and feed into solid-smooth-interior-walled tightline pipes that convey it away (i.e. enhanced drains, Appendix A-2, Sheet 1B).
6. Cut bleeder trenches (Appendix A-2, Sheet 1D) into the downslope side of the pipeline trench at an approximate 100-foot spacing, or to match the local topography. Bleeders should be cut down to the bottom of the pipe trench excavation, and then slope to drain out through native soil or rock (i.e. not in fill) and discharge on stable ground. Bleeders can be enhanced by adding geotextile wrapped drain rock, and/or drainage pipeline (i.e. French drains). The objective of bleeder trenches is to provide drainage relief points at regular intervals, so that as seepage accumulates, it finds an outlet from the trench.
7. Install slope breakers (a.k.a. water bars) along the ROW at spacing and orientations that intercept and direct surface run-off to stable and (preferably) vegetated areas along and off the ROW. Slope breaker spacing is typically governed by slope angle and the presence of trench breakers (Appendix A-2, Sheets 4A and 4C). In steep slope conditions, a slope breaker should be placed just below a trench breaker, so that seepage that is pushed to the surface by the trench breaker is then captured by the slope breaker and diverted off the ROW. Final spacing and placement of breakers should

incorporate site specific information. Where slope breakers are not possible, then consider using armored ditches with a drain pipe in the bottom to collect and convey surface run-off (Appendix A-2, Sheets 1F and 1E).

8. Install drains (Appendix A-2, Sheets 1C and 1E) where seeps or other subsurface water sources are identified during the temporary ROW construction.
9. Special consideration is needed to construct and/or restore drainage measures for existing, permanent, and temporary access roads, on a site specific basis. Access roads may collect runoff from upslope areas, thereby increasing the contributing basin area draining to any given site, and deliver water to the ROW, the pipeline trench or to other areas of concern. Use drainage measures, as described in this report, to manage and mitigate drainage issues, such as slope breakers, water bars, grading to improve drainage, French drains, enhanced drains, armoring, armored ditches with drain pipes, rock fill, etc. (Appendix A-2, Sheet 5D).
10. Where the pipeline alignment passes through benched terrain, mitigate for complex backfill and drainage conditions by using rock fill, sack-crete breakers, enhanced drainage or other measures, as needed (Appendix A-2, Sheet 10A). Bench topography can be very complex and may require site specific review to develop a practical and constructible mitigation and restoration package.

Modifications or alternatives to the above described measures that are feasible and maintain the function and intent as described and offer practical alternatives are encouraged

4.7 Areas of Fill Soils

Fill areas are non-standard sites where a significant amount of soil has been placed as a result of other construction-related, mining or other land modification not related to pipeline construction. (Appendix A-1, Sheet 1600). Smaller fills for road and residential/private development work are not addressed herein, because of their relative small size and corresponding relatively small potential for a hazard that may threaten a pipeline. The focus of this Typical Scenario is on larger scale fill areas, where the potential for a threat to the pipeline is increased, and the scale of the fill requires added planning and consideration. Common areas where fill is identified include existing drill pads and pipeline facility pads, valley fills where spoils have been placed as part of mining activities, large road fills, etc. These areas could be susceptible to landslides and erosion if the fill has any or all of the following characteristics:

- Not adequately drained;
- Not suitable material (silt/clay-rich, logs, debris);
- Improperly compacted; and,
- Wet at the time it was placed.

In the case of historical mining activities, the nature, characteristics, and extent of the fill, spoils, or modifications ground conditions can often be researched through publicly available mapping information or through coordination with applicable mining companies.

4.7.1 Engineering/construction recommendations for Areas of Fill Soils

In general, it is difficult to provide recommendations for mitigating fill areas, without having relevant site-specific information and considering site specific conditions. As such, fill areas should be addressed on a case-by-case basis, and typically require SME input on the type and nature of the fill; and typically require site specific investigations, analysis, engineering, and corresponding specialized mitigation measures. While fill areas are recognized as an important hazard to be considered, this issue is only addressed in a general sense herein.

4.8 Landslides

Geotechnically sensitive slopes and landslides may be destabilized as a result of pipeline construction when material previously acting to buttress the hillslope is removed along the cut side of the ROW. At these locations, landslides may retrogress and cause damage to property that is upslope of, and outside of, the work area. In addition, landslide-related displaced ground originating at a cut may slide into the work zone and into the pipeline trench creating potential pipeline integrity issues, worker safety issues, and/or work disruptions during construction. Likewise, temporary fill (i.e. spoils and stockpiles) placed on the downslope side of the work area may act as a surcharge load and consequently destabilize existing hillslopes and/or landslides located within and outside of the work zone. A new landslide created by construction activities or an existing landslide that is reactivated by construction activities may involve ground movement that extends tens of feet to hundreds of feet away from or downslope of the work zone and may be difficult and costly to mitigate once the slope begins moving.

In addition to the destabilizing effect of cutting into, or placing soil stockpiles on, existing geotechnically sensitive slopes, landslides may also be initiated in the ROW backfill where existing road ditches, access roads, surface run-off, pipeline trenches, drainage swales, or ephemeral stream channels are crossed by the ROW. In these locations, where multiple sources of water converge at or on the ROW, the surface water is concentrated and the backfill becomes saturated, loses strength, and may become unstable on the slope. Likewise, if near-surface groundwater that was intercepted at a cut is not adequately controlled, it can saturate the ROW backfill and may cause a landslide on the post-construction ROW. Mitigation strategies should therefore be developed for landslide sites that are crossed by the pipeline or fall within the ROW construction limits in order to address short-term construction impacts and long-term operation of the ROW and pipeline.

4.8.1 General Engineering/construction recommendations for Landslides

Identified landslides along a proposed pipeline alignment should be characterized, the potential hazard assessed, and the pipeline constructability through the landslide should be evaluated. In some cases, detailed mitigation recommendations may be required, based on site specific assessments, investigations, and review.

The following provides a brief summary of typical conceptual mitigation measures that may be employed at a landslide site, recognizing that any recommendations should incorporate site specific information:

1. Backfill around the pipeline using select “deformable” materials that allow for some movement of the backfill relative to the pipeline as the ground around it moves, before the movement begins to impact the pipeline, thereby attenuating accumulation of strain in the pipeline resulting from differential ground movement. Deformable backfill is typically a loose granular sand material with little or no fines. The deformable backfill is placed in a sloped wall trench all around the pipeline, allowing for more material along the direction and orientation (i.e. horizontal and vertical) of landslide movement relative to the pipeline. Typical dimensions for deformable backfill relative to the pipeline should match the expected horizontal and/or vertical ground displacement. A filter fabric layer should be included around the backfill to limit the migration of local fine-grained soils into the imported backfill materials (Appendix A-2, Sheet 12B). The properties of the select backfill also have enhanced drainage performance, which can further mitigate landslide hazards, addressed in the following points.
2. Generally re-contour the restored ROW to re-establish pre-construction contours (Appendix A-2, Sheet 2G), except where site assessments recommend reducing backfill over unstable or landslide areas (Appendix A-2, Sheet 2H).
3. Cut bleeder trenches (drains) (Appendix A-2, Sheet 1D) into the downslope side of the pipeline trench at approximately 100-foot spacing, or to match the local topography. Bleeders should be cut down to the bottom of the pipeline trench excavation, and then

slope to drain out through native soil or rock (i.e. not in fill) and discharge on stable ground. Bleeders can be enhanced by adding geotextile wrapped drain rock, and/or drainage pipeline (i.e. French drains). The objective of bleeder trenches is to provide drainage relief points at regular intervals, so that as seepage accumulates, it finds an outlet from the trench.

4. Install brow ditches (Appendix A-2, Sheet 6B) excavated into the ground, slope breakers (Appendix A-2, Sheets 5A and 5B), a combination of built-up and excavated water bars and/or armored channels with drain pipes (Appendix A-2, Sheets 1F, 1H - in steep terrain and 1E) along the upslope side of the ROW to intercept and divert surface run-off to stable locations away from the side slope areas. The need and layout of these depends on the topography. If there is no stable location to discharge the intercepted water, then rely more on other measures.
5. Where surface run-off from one or more slope breakers or other water sources needs to be conveyed down steep slopes that may be subject to erosion, consider using armored channels with an apron at the discharge (Appendix A-2, Sheet 1F and 1E). In steep terrain the armored channel and more robust drainage piping may be needed (Appendix A-2, Sheet 1H and 1E).
6. Grade the temporary ROW construction surface (Appendix A-2, Sheet 2A) so that it drains away from the inside of the cut. The objective is to minimize the potential for infiltrated water to accumulate, or tend to move along the transition from the disturbed ROW areas and the undisturbed temporary ROW surface (i.e. the native ground). An additional objective is to avoid a situation where the excavated colluvium and residual soils are stockpiled in a manner that traps water, causing the excavated soils to become saturated prior to backfilling the ROW. Temporary construction surfaces need to be incorporated into the final site drainage configuration to limit potential for saturation of the backfill and/or native soils.
7. Grade the temporary ROW surface and depth of the pipeline trench to allow for a stable outboard wedge of soils/rock material adjacent to the pipeline trench (to the out-slope side, Appendix A-2, Sheet 2B). This maintains a protective stable section of ground on the outboard slope side of the pipeline trench that mitigates for potential raveling, degradation, landslide, or other slope instability or erosion processes that may impact the pipeline.
8. Compact the backfill (Appendix A-2, Sheet 2C) during side slope ROW reconstruction. This adds strength to the backfill to make it more stable, and reduces infiltration of water. Achieving compaction in steep and rugged terrain is difficult. Recommended methods include use of sheep's-foot rollers pulled behind a dozer, a self-propelled sheep's-foot compactor, or sheep's-foot roller attached to an excavator arm.
9. Drying soils (Appendix A-2, Sheet 2D) used as backfill materials can be achieved by spreading the soil in windrows and actively working the windrows until the soil achieves a suitable moisture content. Low humidity and warm temperatures are needed to make this work. An alternative is the use of lime or cement kiln dust, or a similar product, as an additive to wet soils to help facilitate more optimal moisture content. Lime or cement kiln dust is added and mixed with targeted soils, following the manufacturers recommendations, until a suitable soil condition is achieved. Use of lime or cement kiln dust allows for working in wetter conditions. Mixing rates and methods need to be calibrated to site conditions and may require experimenting to find the right blend for implementation.
10. Haul materials off-site where the local soils are not suitable for backfill and compaction due to the sensitive nature of the local fine-grained soils or excessive moisture content. These materials should not be stockpiled or spoiled in areas that may initiate or exacerbate landslides (Appendix A-2, Sheet 2E). Replace with a free-draining, angular, clean, small sized (i.e. min 4 to 8 inch) rock backfill (Appendix A-2, Sheets 2F

and 3D). This kind of rock backfill can stand up at steep angles, does not hold water, is very stable, and will adjust to future changes in ground conditions (i.e. settlement, continued slip movement, etc.).

11. Final grading and ROW restoration in the area of the landslide should minimize cover depth over the pipeline (Appendix A-2, Sheet 2H). For instance, replacing deep fill soils over the pipeline in the post-landslide restoration condition may further exacerbate the problem. Cover depth over the deformable backfill should be minimized to the greatest extent possible, to further reduce soil backfill loading on the landslide area. This may require hauling excess spoils away from the site.
12. Drainage pipes in the pipeline trench collect and discharge seepage and near-surface flows within the trench excavation depth. Drainage pipes can be configured as French drains (Appendix A-2, Sheets 1A and 1E) running along the pipeline for low seepage flow conditions, or in specific locations to collect seepage trapped by grading of the temporary ROW or targeted seeps. Where excessive seepage along the trench may be a problem, then the piping configuration should be modified to include perforated corrugated pipes that collect water and feed into solid-smooth-interior-walled tightline pipes that convey it away (i.e. enhanced drains, Appendix A-2, Sheet 1B). Drainage piping can be configured to collect and convey seepage in targeted areas of the landslide, to make for more efficient discharge of flows or even to provide monitoring of specific areas (i.e. isolating piping from targeted areas to track corresponding flows from those areas). Discharge points should be located at the edge of the ROW on stable ground and/or with erosion pads (Appendix A-2, Sheet 1E).
13. Drains may be needed at specific locations to address localized seepage, springs, wet areas, or ponded water areas that influence a landslide (Appendix A-2, Sheet 1C). These may be configured as French drains (Appendix A-2, Sheets 1A and 1E) or other configurations of perforated and solid-wall pipes with sandbags and geotextile wrapped drain rock that are designed and built to address a specific-site condition. Special considerations should incorporate expected changes at the site and the impact of such changes on the pipe(s). For example, placement of collection or conveyance pipes across (i.e. perpendicular) a landslide shear boundary that is expected to move over the long-term may disrupt or break the pipe(s), causing discharge of flows back into the landslide. Piping should be located outside of the landslide boundaries. Where that is not possible, then piping should be parallel to landslide boundary geometries and cross the landslide footprint at the downstream side where water will flow away from the site in the event that piping is disrupted.
14. Where landslides are located on sloping ground, trench breakers (Appendix A-2, Sheet 4A) may enhance mitigation by managing trench seepage flows. Trench breakers for landslide projects should use sandbags. Foam material for breakers on landslide mitigation projects is not recommended. Drainage piping, as discussed previously, should be designed to allow for passage of seepage flows through the breakers, to collect and drain the seepage flows from the trench.
15. Trench dams (Appendix A-2, Sheet 4B) are trench breakers that are intended to interrupt and block seepage flows, and may be required to isolate landslide areas from seepage flows running along the trench. Drainage piping would be required to collect and divert the interrupted seepage flows to a discharge location off the ROW. Trench dams would be constructed of foam, sack-crete, or other impermeable materials. The use of trench dams is rare, as the intended function can typically be accomplished by the use of a traditional breaker, as described previously.
16. Install sack-crete breakers (Appendix A-2, Sheet 4C) in areas where the trench and slopes are steep and the breaker is needed to retain and stabilize the trench backfill. These structures may be configured to provide a foundation for imported backfill, retaining backfill in the trench itself on steep terrain, or to stabilize larger portions of the ROW area or larger trench and slope backfill areas. Because these structures can

- be large and encompass an extended length of the pipeline, install a sleeve interface, such as geotextile fabric or rock shield, between the pipeline and the structure to provide a slip separation, and to avoid transfer of loading from the trench backfill through the structure to the pipeline (Appendix A-2, Sheet 4D).
17. Where the pipeline alignment passes through benched terrain, mitigate for complex backfill and drainage conditions by using rock fill, sack-crete breakers, enhanced drainage, or other measures, as needed (Appendix A-2, Sheet 10A). Bench topography can be very complex and may require site specific review to develop a practical and constructible mitigation and restoration package.
 18. Install Slope breakers (a.k.a. water bars) along the ROW at spacing and orientations that intercept and direct surface run-off to stable and (preferably) vegetated areas off the ROW. Slope breaker spacing is typically governed by slope angle and/or the presence of trench breakers (Appendix A-2, Sheets 5A and 5B). In steep slope conditions, a slope breaker should be placed just below a trench breaker, so that seepage that is pushed to the surface by the trench breaker is captured by the slope breaker and diverted off the ROW. Final spacing and placement of breakers should incorporate site specific information. Where excessive run-off may need to be mitigated, then slope breakers can be discharged to an armored ditch or diversion channel (Appendix A-2, Sheets 5C, 6D, 1F and 1E).
 19. Geodetic monitoring at the site may include various ground surface geodetic monuments installed at the site that allow for subsequent ground-based surveys to track changes in ground or pipeline position (Appendix A-2, Sheet 11A).
 20. In scenarios where the pipeline is installed in a landslide and ground movement is expected, strain gauges may be required, depending on the site specific conditions and potential impacts to the pipeline(s) (Appendix A-2, Sheet 11B). Strain gauges monitor the accumulated strain in the pipeline that may be induced by differential ground movement. Strain gauges are attached to the pipe typically at locations where the pipeline crosses the lateral or vertical boundaries of a landslide; that is, at the boundaries of the landslide with the surrounding stable ground. These locations are where landslide shear stresses tend to be concentrated. Depending on the size of the landslide, one or more sets of strain gauges may be installed on the pipeline at other relevant locations. Monitoring of strain gauges at regular time intervals, and/or after identified movement events, may show that threshold stress conditions are achieved, which would trigger response actions including additional stress relief excavations and/or additional site assessment and mitigation work.
 21. Additional monitoring instrumentation may be required, depending on site specific studies, including inclinometers (Appendix A-2, Sheets 11C and 11D) or piezometers (Appendix A-2, Sheet 11E).
 22. In the event the pipe is installed in a landslide and post construction landslide-related ground movement appears to indicate a threat to the pipeline, then stress relief excavations may be needed. Stress relief excavations remove the soils constraining the pipeline, allowing it to rebound to the non-stress condition (Appendix A-2, Sheet 12A). Excavations start generally in the middle of the landslide and extend in either direction until no rebound is observed, and typically continue for a minimum of another 50 feet. Surveys may be required during the excavation work to track pipeline rebound, and to confirm before-and-after pipeline location and elevation.
 23. Where the pipeline is installed in unstable (i.e. landslide) ground, then use deformable backfill (Appendix A-2, Sheet 12B). Additional drainage mitigation measures are typically included with the same backfill, to collect and convey seepage away from the pipeline trench (Appendix A-2, Sheets 1B and 1E). Similarly, a shear trench, also using a deformable sand backfill material, may be needed to maintain separation of the pipeline from moving landslide masses (Appendix A-2, Sheet 12C).

24. Where the pipeline is installed in unstable, (i.e. landslide-prone) ground that cannot partially or totally be mitigated with measures as outlined above, or for other specific reasons it is necessary to take an alternative approach to mitigation of a landslide, then it may be necessary to avoid the unstable area by routing around it (Appendix A-2, Sheet 15A), or to excavate the unstable ground in order to completely remove the localized hazard (Appendix A-2, Sheet 15B). These options should only be employed through close coordination with the Pipeline Operator/Owner.
25. Special consideration is needed to construct and/or restore drainage measures for existing, permanent, and temporary access roads, on a site specific basis. Access roads may collect runoff from upslope areas, increasing the contributing basin area draining to any given site, and deliver water to the ROW, the pipeline trench, or to other areas of concern. Use drainage measures, as described in this study, to manage and/or mitigate drainage issues, such as slope breakers, water bars, grading to improve drainage, French drains, enhanced drains, armoring, armored ditches with drain pipes, rock fill, etc. (Appendix A-2, Sheet 5D).
26. Cover disturbed area with erosion control fabric (Appendix A-2, Sheet 3C), or other functional erosion resistant ground coverings to mitigate over the short-term until the local vegetation can take over and establish itself. In especially unstable and/or steep slope conditions armor rock may be needed (Appendix A-1, Sheet 3D).
27. Track disturbed slopes (Appendix A-2, Sheet 3A) and re-vegetate all disturbed areas to provide long-term surface stabilization (i.e. replace the short-term erosion control fabric protection).
28. Re-vegetate all disturbed areas to provide long-term surface stabilization (Appendix A-2, Sheet 3B) (i.e. to replace the erosion control fabric over the long-term).

Modifications or alternatives to the above described measures that are feasible and maintain the function and intent as described and offer practical alternatives are encouraged.

5.0 UNCERTAINTY IN FUTURE MITIGATION AND REPAIR COSTS

The following discussion on the uncertainty in future mitigation and repair costs is based on work in the Williams OVM system in northern West Virginia for land movement mitigation work completed between 2012 and 2015. These results were developed by evaluating actual costs for work performed on a representative sampling of sites in the period of time stated above, through a probabilistic risk-based assessment. Costs addressed in the assessment included actual landslide and erosion hazard related mitigation costs based on work performed (i.e. costs include equipment, materials, labor, access, permitting, design, environmental, operations, etc.); potential additional mitigation repair cost for future events, and potential long-term (i.e. post-mitigation) costs associated with continued maintenance, monitoring, or continued mitigation efforts associated with a given site (i.e. drainage improvements, stress relief excavations, etc.). It is recognized that recurring landslide and erosion hazards might continue to impact the pipeline and ROW, even where mitigation has previously been completed.

This discussion is intended to illustrate the value added to operation and maintenance efforts through a risk-based evaluation of landslide and erosion related hazards in a pipeline system similar to the subject work in OVM. Using data and analyses for work that incorporates the approach and methods described in this document, the mitigation cost risk (i.e. pre-emptive cost to mitigate or reduce the likelihood of a "failure") is generally an order of magnitude lower than the un-mitigated cost risk (i.e. cost to correct post "failure") for the landslide and erosion hazards that can threaten the pipeline and ROW. The results presented herein are representative of the types of landslide and erosion hazards and corresponding mitigation work completed in OVM. Detailed cost information is not presented. These results and information are provided for discussion and relative planning purposes only, and should not be used as a basis for final costing efforts.

Costs are aggregated for landslide and erosion hazards observed in OVM in terms of potential integrity threat to the pipeline and/or ROW. For purposes of discussion, they are grouped in terms of either low-hazard sites, or a combined moderate to high-hazard site classification, as described in Table 5-1. These groupings were selected to demonstrate the relative difference in cost risk observed for maintenance related work (i.e. low-hazard site classifications) with generally lower integrity threat potential, versus increased integrity and threat related scenarios (i.e. moderate to high-hazard site classifications) that would require added review and management level decisions related to operation and maintenance actions.

Table 5-1: General Pipeline Integrity Hazard Description

Definition	Classification
Pipeline crosses through active landslide or erosion hazard; pipeline likely stressed; further movement or expansion of the landslide will likely threaten the pipeline. Direct observed or measured evidence or indirect and circumstantial evidence of an active hazard suggests the pipeline may be under stress, and/or requires actions to mitigate the hazard.	Moderate to High
Shallow landslide or limited erosion hazard located on or near the ROW, or crosses alignment of pipeline in the ROW, pipeline appears to be in stable ground/trench (i.e. below landslide failure surface or erosion extent). Continued hazard activity or possible lateral expansion/retrogression across the pipeline may occur in the future, but will likely not affect the pipeline.	Low

Starting with available costing information (Williams 2015) and supplementing with assessments from SME's, a risk-based evaluation of potential costs for additional sites (i.e. sites not yet addressed or discovered) was conducted. Results are summarized in Figure 5-1, which shows that potential mitigation costs for low-hazard landslide and erosion hazard sites, as defined in Table 5-1, ranges from approximately \$40,000 to \$160,000, corresponding to the 20th and 80th percentiles, respectively (in 2014

USD). The potential mitigation costs for moderate to high-hazard landslide and erosion hazard sites that might impact and threaten the integrity of the pipeline range from approximately \$180,000 to \$600,000, corresponding to the 20th to 80th percentiles, respectively (in 2014 USD).

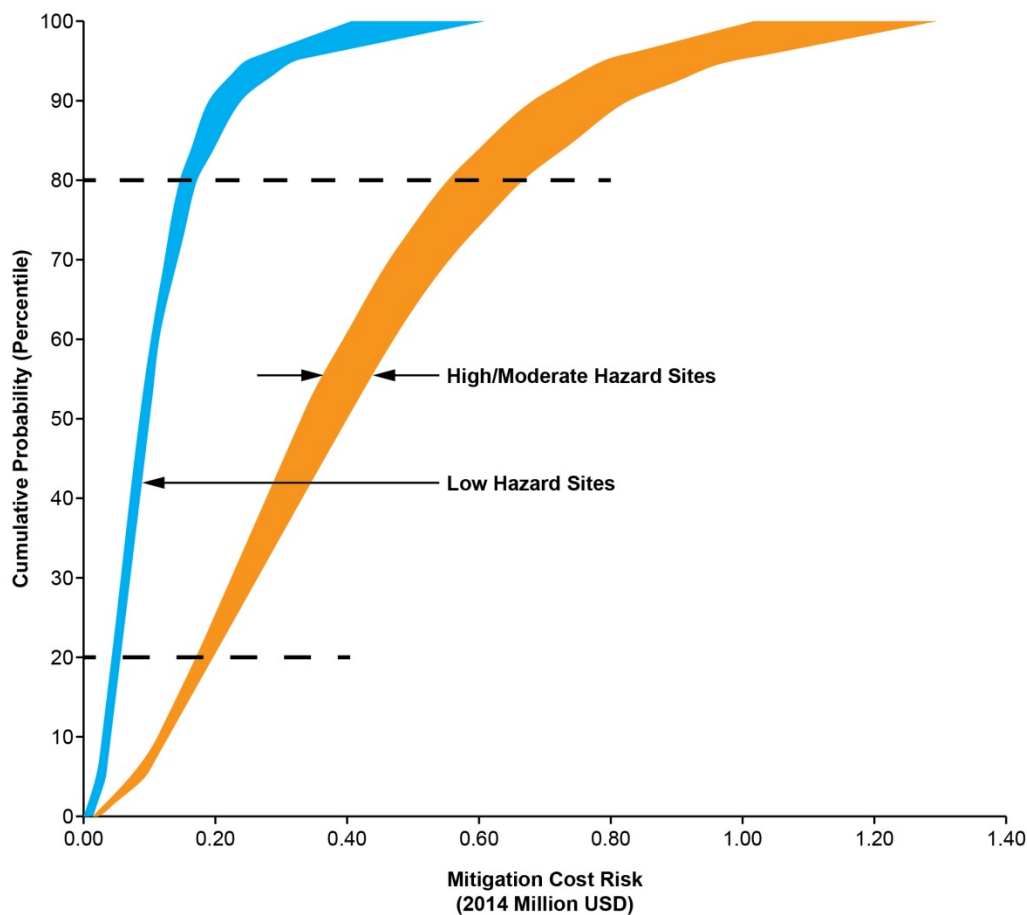


Figure 5-1: Mitigation Cost Risk

The same information was used to quantify the cost risk assuming no mitigation work is completed (i.e. un-mitigated risk). Multiple variables were considered in the assessment of risk, including the potential modes and likelihoods for geologic hazard related failures (i.e. both construction related and native landslide and erosion hazards). Risk related to other types of failures such as defective pipeline materials, pipeline construction defects, and accidents were acknowledged, but not included in this assessment. General categories of variables included: type, size, and proximity of the hazard site, construction cost (including site access) to repair land movement to the pipeline right-of-way assuming methods and approaches as outlined in this study, construction and materials cost to repair damage to the pipelines, the potential for rupture, construction and materials to re-route segments of the pipeline alignment around the site, consideration of future rupture after a site has been mitigated, staffing and overhead costs, loss of revenue associated with pipeline ruptures, cost to remediate hydrocarbon releases from ruptures, and potential environmental impacts.

The results in Figure 5-2 show that potential un-mitigated cost risks for low-hazard landslide and erosion sites, as defined in Table 5-1, are as high as approximately \$800,000, corresponding to the 80th percentile (in 2014 USD); and there is little or no cost risk associated with low-hazard sites below the 50th percentile. This suggests that the cost to mitigate low-hazard sites (at OVM) is likely to be more

than the cost to repair a failure. Therefore, a corresponding reduced level of response might be warranted. The moderate to high-hazard sites have an increased potential to impact and/or threaten the integrity of the pipeline, and therefore represent an increased need for response, with an un-mitigated cost risk ranging from approximately \$0.5M to \$7M, corresponding to the 20th and 80th percentile, respectively (in 2014 USD). The greater uncertainty (range) in cost risk reflects a wide potential range in adverse impacts for higher-hazard sites.

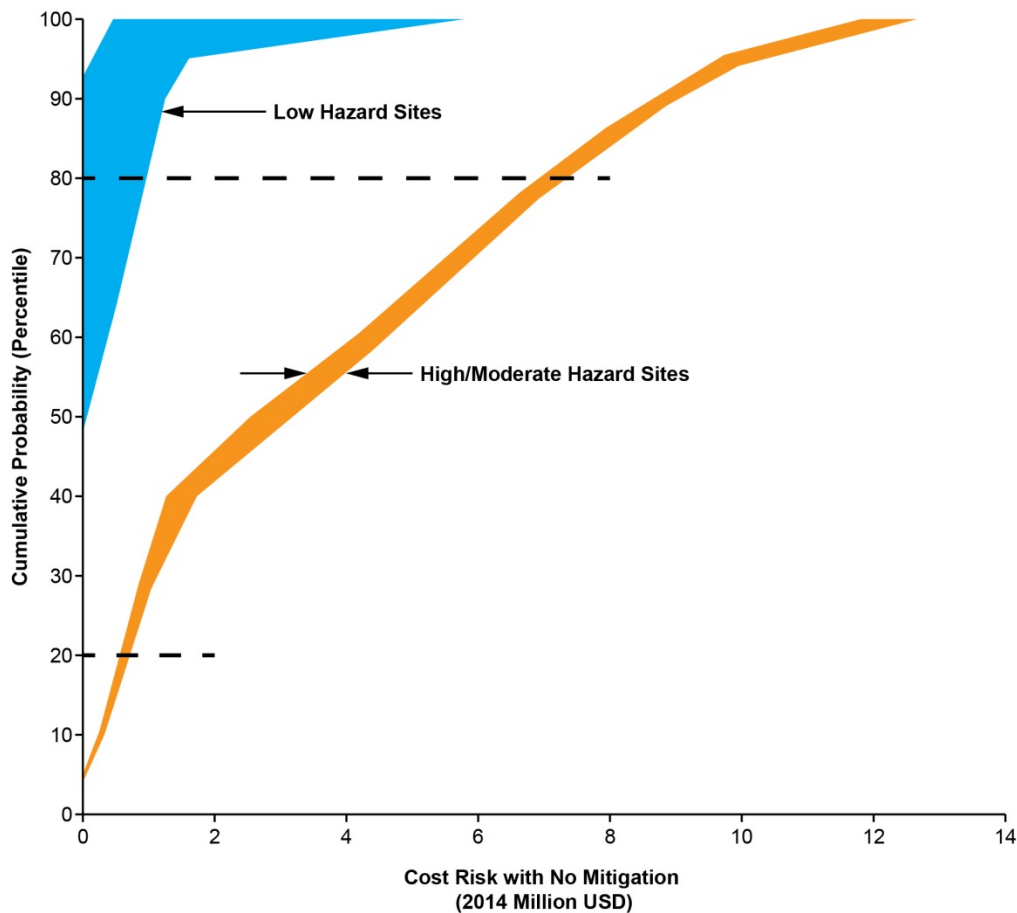


Figure 5-2: Un-mitigated Cost Risk

These cost risk results should be considered within the context of available data (which is representative of generally shallow translational landslides and similar erosion hazards typical of northern West Virginia in OVM and as discussed throughout this study), and the assessments of SME's involved in the risk assessments. Within that context, they show a clear and significant differential in mitigated versus un-mitigated cost risk associated with landslide and erosion hazards.

Mitigation efforts do not preclude continued land movement or continued occurrence of landslides and erosion hazards, but the results suggest that a comprehensive program of proactive mitigation can significantly reduce operator and owner risk in a pipeline system and implementation of a comprehensive system-wide program can provide compounding benefits over time.

6.0 CONCLUSIONS

Landslide and erosion hazards along a proposed pipeline alignment need to be identified, characterized and incorporated into every phase of a project. While careful planning and routing of proposed pipelines is always preferred to avoid potential threats from landslide and erosion hazards, mitigation may be required when hazards cannot be avoided. In some situations, the mitigation may not be intended to provide a long-term permanent mitigation and full elimination of the hazard. Instead, the pipeline ROW is mitigated to an acceptable level of risk (e.g. use of deformable backfill and monitoring to schedule stress relief excavations over time). As such, mitigation measures should take into consideration the risk tolerance of the owner/operator, consider the costs and benefits of long-term and short-term solutions and incorporate construction considerations into the planning and design efforts.

Experience with OVM suggests that in most cases the occurrence of land movement in this region is associated with surface and subsurface water in combination with recent or historical changes in geologic conditions and construction related activities. This combination of contributing conditions is so common that we were able to develop sets of Typical Scenarios and Typical Details which enabled us to create site-specific mitigation designs. During the Scenario and Detail development process, we identified a number of critical items to consider when mitigating land movement on pipeline ROWs.

These include:

- The importance of identifying landslide and erosion hazards, and incorporating that information into the design, planning and construction phases of a project. Mitigation efforts should be tailored to address site-specific conditions as well as to balance costs with practicality of installation, operation and mitigation of risk. Note, the identification and characterization of landslide and erosion hazards represents a science all by itself, and is not directly addressed herein. This document focuses on the mitigation efforts related to these hazards;
- The critical role of route selection in identifying and avoiding hazards that may impact pipelines and ROWs. Careful planning and routing is always preferred to avoid or minimize potential threats from landslide and erosion hazards, but mitigation is usually required when such hazards cannot be avoided;
- The need to incorporate site-specific mitigation measures into the project planning process, to address threats to the pipeline and the ROW. The cause of any given landslide or erosion hazard is commonly the result of several contributing factors. Defining the governing geologic hazard and geotechnical/hyrotechnical engineering processes that are contributing to the land movement is critical in supporting the selection, planning, and design of an effective mitigation plan. Ultimately, the owner/operator must decide on the acceptable level of risk for any given mitigation package;
- The association between land movement and surface and subsurface water in combination with changes in the local ground conditions from recent or historical changes in geologic conditions and/or construction-related activities. Examples of mitigation options that address these conditions include re-grading the ROW surface to improve site conditions, modifying local surface drainage, conveyance of sub-surface drainage, modified ROW backfill materials, deformable backfill in the pipeline trench, removal of unstable soil and replacement with engineered performance materials, ground surface erosion protection, slope breakers, trench breakers, special pipeline coatings and protective sleeve-wraps, modified ROW configurations, monitoring and special pipeline design. These options are typically used in combination to develop a strategy for addressing the identified hazards at any given site;
- Structural measures are also available to address unstable slopes, such as retaining walls, soldier piles, sheet piles, wire mesh systems, mechanically stabilized earth systems and other mechanical structures. These options can be costly, have special equipment and access requirements in order to install in steep slope conditions, may limit future access or

- expansion in constrained ROW corridors, and may also have special long-term maintenance requirements;
- Reducing ground disturbance through minimized ROW footprints, appropriately sized and applicable equipment, and planning construction during optimal seasonal conditions (i.e. dry versus wet) can minimize mitigation requirements;
 - Consideration of the landslide and erosion processes, and the origin of the source(s) of water relative to the constructed pipeline ROW. In particular, mitigation measure selection should consider the disturbed temporary ground surface from the initial grading of the ROW and subsequent construction work and not just the finished and restored ROW surface;
 - Organizing mitigation options into a framework of Typical Scenarios and supporting Typical Details that are consistent with how the ROW is built (i.e. ridge top, planar slopes, side slope, etc.). This allows for rapid development of conceptual site-specific mitigation plans during project planning and design;
 - Designing to mitigate for all or only portions of targeted threats from land movement, thereby allowing the owner/operator to decide and select the level of mitigated risk, and allowing time for the owner/operator to plan, assess and make risk-based decisions on how to best manage the asset.

The most effective mitigation strategy requires recognition of the multiple factors governing a site, and may require long-term performance monitoring before full mitigation can be achieved. In some situations, the mitigation may not be intended to provide a long-term permanent mitigation and full elimination of the hazard. Instead, the pipeline ROW is mitigated to an acceptable level of risk. As such, mitigation measures should be tailored to address the site specific and potentially variable conditions, consider the risk tolerance of the owner/operator, consider the costs and benefits of long-term and short-term solutions, and incorporate construction considerations into the planning and design efforts and integrate with the construction process.

While mitigation efforts will not prevent every landslide or all erosion hazards, comparison of mitigated versus un-mitigated cost risk suggest that a comprehensive program of proactive mitigation and implementation on a system-wide scale can significantly reduce overall risk in a pipeline system, and can provide compounding benefits over time.

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West Virginia Geological & Economic Survey (WVGES), <http://www.wvgs.wvnet.edu/>, accessed publically available web site July 2015.

8.0 DEFINITIONS

The following provides brief definitions of selected terminology either addressed or related to the topics discussed herein, in order to support discussions of these topics. The reader is encouraged to research any listed definition when more details or specific information is needed. These definitions are based on our experience working in the oil and gas industry, or other sources of pipeline related expertise (Hosmanek 1984):

Armoring – installing small diameter, angular, riprap materials; use of geotextile or other biodegradable materials; or installation of vegetation; to protect against erosion of soils on temporary ROW surfaces or on the final restored ROW surface. Often installed in conjunction with conveyance of surface flows, in defined conveyance channels; or to protect steep slope areas from unraveling in response to runoff.

Bleeder drain – a drainage mitigation method that uses a gravity drainage pathway excavated at the low spot in a pipeline trench, that conveys seepage flows away from the trench, and may use drain rock backfill wrapped in filter fabric to create the drainage pathway (e.g. french drain). Typically installed in sidehill conditions where the pipeline gradient is flat.

Cost Risk – in this context, uncertain costs resulting from potential future landslide or erosion failures and the related potential impacts (e.g., costs of emergency response, environmental clean-up and fines, lost revenue, planning, design, engineering, and construction efforts to correct failure, etc.). Unmitigated cost risk reflects the uncertain cost impacts associated with sites that have not been mitigated (as defined elsewhere) in an attempt to reduce the likelihood and/or consequences of a failure. Mitigation cost reflects the cost to mitigate a hazard (as discussed elsewhere) in an attempt to reduce the probability and/or impacts associated with failure (i.e., to reduce the unmitigated cost risk).

Cover depth – the measurement from top of a pipeline to ground level along the ROW.

Convergent topography – convergent U-shaped or closed drainage basins that have steep slopes, and focus surface run-off back onto a focused area at the bottom of the valley or corresponding toe of the slope(s). This results in increased and concentrated surface and near sub-surface flows and sources of water.

Cut and Fill – the cut down high ground and/or fill in low ground to achieve a uniform or design grade.

Deformable backfill - Backfill around the pipeline using select “deformable” materials that allow for some movement of the pipeline through the backfill (i.e. the lower strength loose backfill fails and deforms around the pipeline more readily than native undisturbed higher strength soils) in response to continued land movement, thereby attenuating accumulation of stress in the pipeline resulting from displacement of the pipeline by landslide movement. Deformable backfill is typically a loose granular sand material with little or no fines. The deformable backfill is placed in a sloped wall trench all around the pipeline, in dimensions that match the expected displacement, and allowing for select material along the direction and orientation (i.e. horizontal and/or vertical) of landslide movement relative to the pipeline.

Easement – a right that one individual or company has to access land typically representing the ROW footprint; may be differentiated by temporary construction related easements versus permanent ownership.

Enhanced drain – a drainage mitigation method that uses a combination of perforated pipes to collect seepage and sub-surface water, and solid-wall pipes to convey the collected seepage away. The perforated pipe segments are typically limited to 50-100 foot lengths, and surrounded by free-draining gravel or sand with geotextile filter fabric; the conveyance pipes can be backfilled with native soils, and typically have an erosion pad at the discharge.

Erosion – grain-by-grain movement of soil and/or rock resulting from gravity or flowing water.

French drain – a drainage mitigation method that uses a perforated pipe surrounded by free-draining gravel or sand with geotextile filter fabric to capture and convey seepage originating typically in shallow depth subsurface applications.

Geology – the science that deals with the dynamics and physical history of the Earth's materials, and the processes that act on it, and that change it.

Geodetic Monitoring – Survey points at identified locations, typically completed over a period of time to track and monitor changes in position of that point; installed at landslide sites to track changes in ground position and/or elevation.

Geotechnical Engineering – the science and engineering addressing the Earth's materials with a focus on geotechnics, soil and rock mechanics, slope stability, subsurface conditions, soil interactions, etc.

Grading – the process of providing a smooth and even work area to facilitate the movement of equipment onto and along the ROW; entails cutting and filling of native ground to achieve a temporary ROW surface.

Hazard – in the context of this document; includes geologic, geotechnical, or hydrotechnical processes and conditions that can threaten the pipeline or ROW.

Hydrotechnical Engineering – the science and engineering addressing the earth's materials with a focus on hydrotechnics, hydrology, hydraulics, fluvial geomorphology, erosion, scour, surface and near sub-surface water, soil and water interactions, etc.

Inclinometer – a monitoring instrument used to measure and monitor changes in horizontal displacements along a borehole resulting from subsurface ground movement, particularly associated with landslide activity.

Land movement – generally describes horizontal and/or vertical changes in ground conditions resulting from landslide and/or erosion processes.

Landslide – mass movement of soil and/or rock down a slope from the effects of gravity.

Mitigation – in the context of this document; the planning, design, engineering, or construction efforts that are implemented or intended to reduce risk associated with an identified hazard.

Normal – orientation of a pipeline alignment that generally follows sidehill with the contours and perpendicular (i.e. normal) to the fall-line (i.e. alignment straight down) of the slope.

Oblique – orientation of a pipeline alignment at an angle to the fall-line (i.e. the alignment that goes straight down the slope) as it traverses down (on planar) or along (sidehill) slopes.

Padding – screened or sifted soils placed in a trench to prevent the pipeline from damage caused by rocky or coarse grained trench backfill,

Piezometer – a monitoring instrument installed in a well or casing to track and monitor subsurface ground water levels.

Pipeline – a system of connected lengths of pipe, usually buried, that is used for transporting liquid or gaseous products. The pipeline can be used as a conveyor or a temporary storage container.

Planar slopes – construction of pipeline alignment and/or ROW in sloping terrain that is generally flat (i.e. planar) when facing down the slope; there may be some vertical variation in the planar slope, transitioning through localized changes in flatter or steeper planar segments as the alignment traverses up/down a slope. The catchment area (i.e. the basin area that can capture rainfall) that drains to the disturbed ROW in this scenario is generally limited to the actual disturbed ROW itself, and may increase if the pipeline ROW is oblique to the fall-line of the slope as it traverses down the planar slope.

Ridge top – construction of pipeline ROW along the highest elevation ground that follows ridges; this scenario minimizes the catchment area (i.e. the basin area that can capture rainfall) that drains to the disturbed ROW. Steeper grades of ridge top areas are referred to as ‘inclined ridge tops’.

Right-of-Way (ROW) – the legal right of passage over public land and privately owned property; also the way or area over which the right exists. The width of the ROW varies according to contract specification and individual easements, but is generally between 50-150 feet.

Routing – the planning and decision making process for selecting a pipeline alignment.

ROW Restoration – in pipeline construction, the process of returning the ROW to its original condition, or better, after the pipeline has been installed in the trench. ROW restoration may depend on legal stipulation in the contract with the pipeline owner, and in agreements with individual land owners.

Sack-crete – individual sacks filled with concrete (in total) or mixed with fine grained soils, and used to build breakers or other slope stabilization structures in the trench or ROW. Typically used in steep slope, or rock conditions. Allows for constructing complex structures that conform to irregular ground surfaces, but requires directed manual labor to place each individual unit. Where concrete is mixed into sack fill, the sacks will be soft and flexible at initial placement, and then eventually set and harden as they become hydrated, resulting in a rigid structure over time.

Shear trench – placement of select (e.g. loose, granular, sand materials) backfill in targeted locations with the intent of creating a zone that will intentionally fail (i.e. shear) in response to land movement.

Side slope (a.k.a. side hill) – construction of pipeline alignment and/or ROW that follows with the contours (i.e. parallel), or follows at an angle (i.e. oblique) to the contours; essentially running along planar sloping ground, such that there is sloping ground coming to the pipeline ROW from the up-hill side, and sloping ground running away from the ROW to the down-hill side; this scenario maximizes the catchment area (i.e. the basin area that can capture rainfall) that drains to the disturbed ROW.

Slope breaker (a.k.a. water bar) – installed on disturbed ROW areas to intercept and manage surface runoff flows, typically functions like a water bar, and constructed using local materials in typical ROW construction and soil conditions; except in special conditions where slope geometry or limited availability requires constructing them using imported, engineered, or other specialized materials and/or configurations (e.g. in very steep or rock conditions). Slope breakers reduce concentration of surface runoff along disturbed ROW areas, by intercepting and diverting runoff to stable discharge areas along the ROW edge. Slope breaker spacing is typically coordinated with trench breakers, such that trench seepage is temporarily intercepted by trench breakers and directed to the ground surface (i.e. seepage builds up behind the trench breaker over a short period of time until it 'daylights' at the ground surface), where slope breakers placed just downslope divert the water to the side of the ROW. Slope breakers should be coordinated with permanent and temporary access roads, to avoid aggregated (i.e. multiple) discharges of water in the same concentrated ROW locations.

SME – Subject Matter Expert (SME), and professional expert in a targeted geologic, engineering, environmental, scientific, construction, or other field of expertise.

Spoil – excavated soils that are temporarily placed along the constructed ROW, or in some situations moved away from the site where they were excavated to a separate location.

Spread – the necessary equipment and crew needed to build a pipeline, or to build a targeted segment of a pipeline. Modern spreads, which are like moving assembly lines made up of teams of crews focused on individual specialties of pipeline construction, can consist of hundreds of pieces of equipment and supporting operators and other resources.

Strain gauge – a strain monitoring instrument attached directly to the pipeline that measures longitudinal strain changes and accumulated strain in the pipeline.

Stress relief excavation – removal of the trench backfill and surrounding soil within a landslide mass that displace (horizontally and/or vertically) the pipeline. This is to remove the landslide stresses, and mitigate the accumulated strain in the pipeline caused by the landslide stresses. The resulting excavation actions allow the pipeline to physically rebound to a pre-displacement geometry in the trench that eliminates, or significantly reduces, the accumulated strain in the pipeline. Note there may be more complex interactions of the soil mass within and outside the landslide mass that result in combinations of horizontal and vertical displacements. These complex relationships of ground movement need to be assessed and determined on a case-by-case basis, specific to the site conditions. These interactions are addressed in simple terms herein, for the purpose of describing the concept of this mitigation option, and recognizing that additional planning and design is needed to implement this type of mitigation action.

Targeted drain – a drainage mitigation method that uses a combination of perforated pipes to collect seepage and sub-surface water, solid-wall pipes to convey the collected seepage away, sandbags (or similar functioning units), filter fabric, and grading to manage targeted shallow subsurface seep and spring sources of water. The configuration of a targeted drain often addresses a water source on the upslope (i.e. inboard) side of the temporary ROW surface relative to the pipeline trench, and then must convey flows to the outboard side of the ROW. The geometry, configuration, materials, and construction can vary.

Trench – the excavated trench in which a pipeline is installed, not necessarily including the additional excavations for constructing the ROW.

Trench breaker - installed in pipeline trench to intercept and manage seepage flows along the trench, in order to restore the general seepage characteristics of the trench backfill to be as similar as possible to the adjacent in-situ native materials; typically constructed using sandbags filled with permeable sand/soil mix, sack-crete (in steep and rock conditions) with cement mixed in to form solid placements over time, or foam materials. Drainage pipe is sometimes added to the breakers to collect and convey seepage flows past individual breakers, and/or to the ground surface. Trench breakers are typically installed at spacing and dimensions that fit slope conditions, where steeper slopes require tighter spacing, and vice versa for flatter slopes. Technical guidance on the specific placement and spacing of trench breakers is lacking, leaving much to the discretion of the designer, and relying on experience. Trench breakers are typically coordinated with slope breakers, such that trench seepage is temporarily intercepted by the trench breakers and directed to the ground surface (i.e. seepage builds up behind the trench breaker over a short period of time, until it 'daylights' at the ground surface), where slope breakers placed just downslope divert the water to the side of the ROW into stable and/or erosion protected areas.

Valley Bottom - construction of pipeline alignment and/or ROW in generally flat ground following along valley bottom areas.

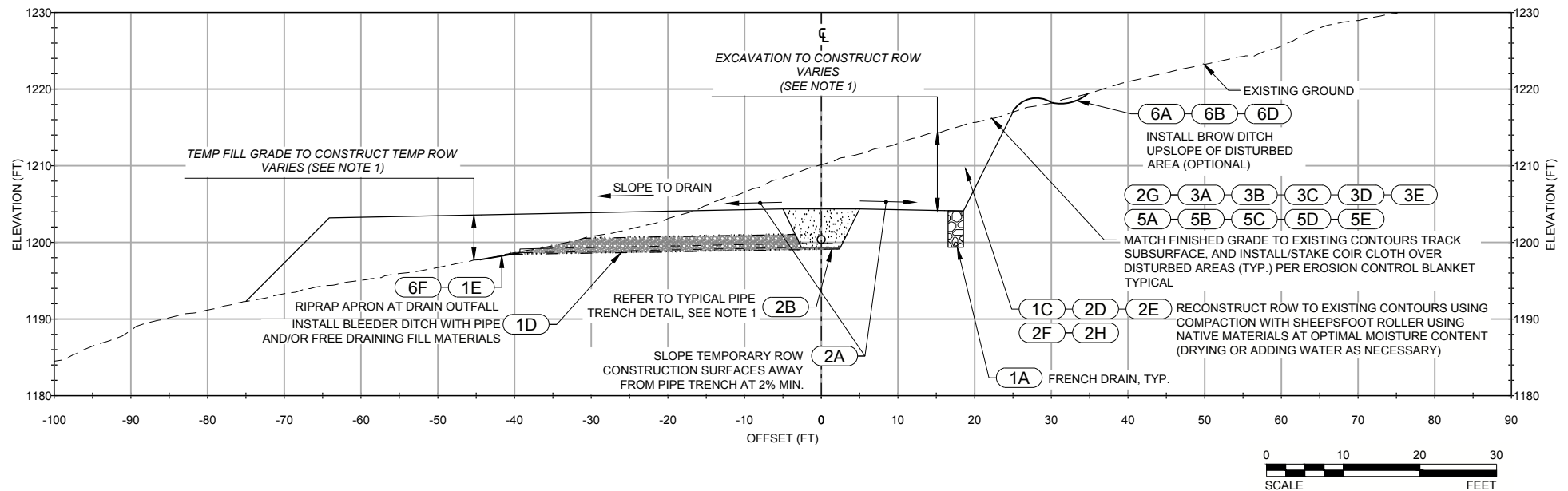
APPENDIX A-1
Typical Scenarios (14 Sheets)

WILLIAMS OHIO VALLEY MIDSTREAM (OVM)

TYPICAL RIGHT-OF-WAY RESTORATION SCENARIOS

TYPICAL SCENARIOS			
SHEET NO.	TITLE	REV.	DATE
1000	COVER SHEET	0	2/28/2014
1110	SIDE SLOPE (NORMAL)	1	8/11/2014
1120	SIDE SLOPE (OBLIQUE)	1	8/11/2014
1130	RIDGE TOP	1	8/11/2014
1140	INCLINED RIDGE	1	8/11/2014
1150	PLANAR SLOPE (STANDARD)	1	8/11/2014
1160	PLANAR SLOPE (EXCAVATION)	1	8/11/2014
1170	CONVERGENT TOPOGRAPHY	1	8/11/2014
1500	POTENTIAL SHALLOW BEDROCK	1	8/11/2014
1600	AREAS OF FILL GEOTECHNICAL CONCERN	0	2/28/2014
1710	LANDSLIDES - SIDE SLOPE WITH STABLE TRENCH	1	8/11/2014
1720	LANDSLIDES - SIDESLOPE WITH UNSTABLE TRENCH	1	8/11/2014
1730	LANDSLIDES - PLANAR SLOPE WITH STABLE TRENCH	1	8/11/2014
1740	LANDSLIDES - PLANAR SLOPE WITH UNSTABLE TRENCH	1	8/11/2014

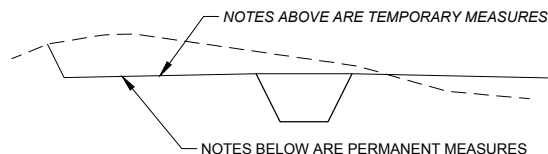
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		CADD	BJV	2014-02-28	SHEET	
		CHECK	AGM	2014-02-28	1000	
		REVIEW	AQK	2014-02-28		



SUPPORTING TYPICAL DETAILS

- | | | |
|---|---|---|
| 1A FRENCH DRAIN (SIMPLE), SEE NOTE 3 | 2E REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, SEE NOTE 1 | 5D ACCESS ROADS, SEE NOTE 1 |
| 1C TARGETED SEEP DRAINS, SEE NOTE 1 | 2F ROCK BACKFILL (WITH DRAIN), SEE NOTE 1 | 5E TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED |
| 1D BLEEDER DRAIN, SEE NOTE 1 | 2G GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1 | 6A COIR-LINED VEGETATED DIVERSION CHANNEL, SEE NOTE 1 |
| 1E DRAIN PIPE OUTFALL RIPRAP APRON, SEE NOTE 1 | 2H GRADING TO MINIMIZE BACKFILL OVER LANDSLIDE, SEE NOTE 1 | 6B BROW DITCH, SEE NOTE 1 |
| 1F ARMORED CHANNEL WITH DRAIN PIPE, SEE NOTE 1 | 3A TRACK DISTURBED SLOPES, SEE NOTE 1 | 6D ARMORED CHANNEL, AS NEEDED |
| 1H STEEP CONVEYANCE CHANNEL, AS NEEDED | 3B RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1 | 6F RIPRAP GRADATIONS, AS NEEDED |
| 1I CHANGED SEEP CHARACTERISTICS, AS NEEDED | 3C COIR CLOTH ON DISTURBED SLOPES, AS NEEDED | |
| 1J SINGLE TARGETED SEEP COLLECTOR, AS NEEDED | 3D ROCK ARMORING ON DISTURBED SLOPES, AS NEEDED | |
| 1K ENERGY DISSIPATION BASIN, AS NEEDED | 3E COIR LOGS ON DISTURBED SLOPES, AS NEEDED | |
| 2A GRADING TEMPORARY ROW SURFACE, SEE NOTE 1 | 4G SACK-CRETE ARMOR WITH BREAKERS, AS NEEDED | |
| 2B GRADING TRENCH WITH OUTBOARD WEDGE, SEE NOTE 1 | 5A SLOPE BREAKERS (TEMP AND PERMANENT), AS NEEDED | |
| 2C COMPACT BACKFILL, SEE NOTE 1 | 5B SLOPE BREAKER ARMORED OUTLET, AS NEEDED | |
| 2D DRY SOILS AND BACKFILL, SEE NOTE 1 | 5C SLOPE BREAKERS WITH DIVERSION CHANNELS, AS NEEDED | |

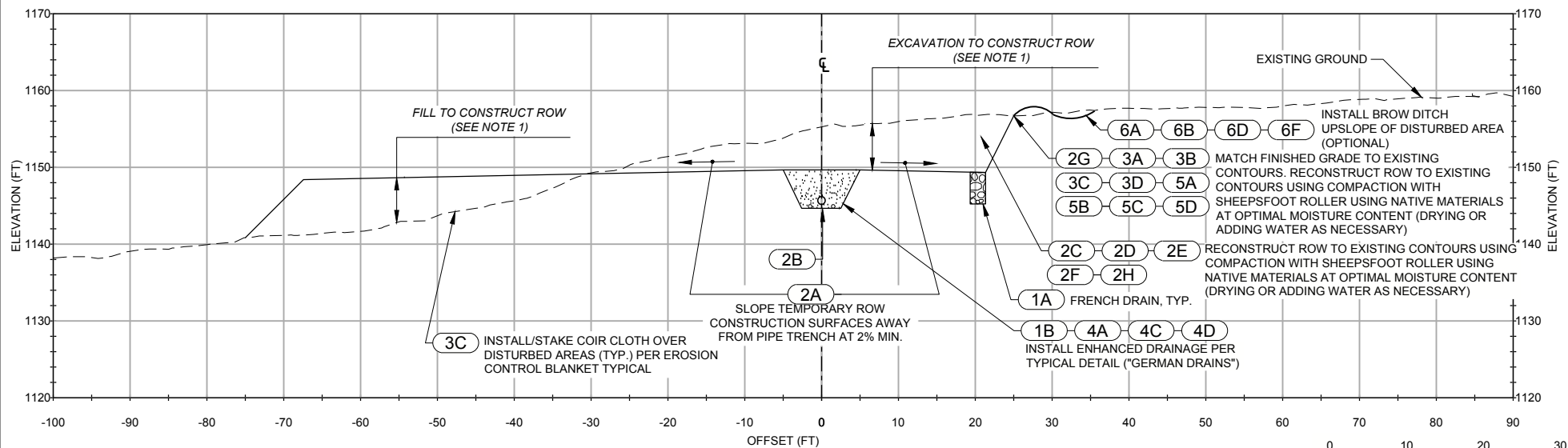
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NOTES

1. 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.
2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
3. TYPICAL SECTION SHOWS SCENARIO WITH VARIED CUT/FILL IN GENERALLY PLANAR GEOMETRY. EXTENT OF CUT/FILL MAY VARY.
4. WHERE THE TEMP ROW SURFACE GRADING DRAINS TO AN IN-BOARD CUT SLOPE, THEN FRENCH DRAINS, OR SHALLOW ARMORED DITCH WITH DRAIN, OR AN ARMORED CHANNEL CONNECTED TO SLOPE BREAKERS IS NEEDED.

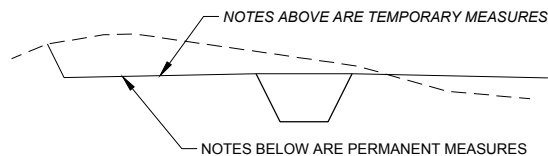
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Golder Associates						1110



SUPPORTING TYPICAL DETAILS

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|--|---|--|
| 1A FRENCH DRAIN (SIMPLE), SEE NOTE 3 | 2E REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, SEE NOTE 1 | 5A SLOPE BREAKERS (TEMP AND PERMANENT), AS NEEDED |
| 1B ENHANCED DRAIN (GERMAN DRAIN), SEE NOTE 1 | 2F ROCK BACKFILL (WITH DRAIN), SEE NOTE 1 | 5B SLOPE BREAKER ARMORED OUTLET, AS NEEDED |
| 1C TARGETED SEEP DRAINS, SEE NOTE 1 | 2G GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1 | 5C SLOPE BREAKERS WITH DIVERSION CHANNELS, AS NEEDED |
| 1D BLEEDER DRAIN, SEE NOTE 1 | 2H GRADING TO MINIMIZE BACKFILL OVER LANDSLIDE, SEE NOTE 1 | 5D ACCESS ROADS, SEE NOTE 1 |
| 1E DRAIN PIPE OUTFALL RIPRAP APRON, SEE NOTE 1 | 3A TRACK DISTURBED SLOPES, SEE NOTE 1 | 5E TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED |
| 1F ARMORED CHANNEL WITH DRAIN PIPE, SEE NOTE 1 | 3B RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1 | 6A COIR-LINED VEGETATED DIVERSION CHANNEL, SEE NOTE 1 |
| 1H STEEP CONVEYANCE CHANNEL, AS NEEDED | 3C COIR CLOTH ON DISTURBED SLOPES, AS NEEDED | 6B BROW DITCH, SEE NOTE 1 |
| 1I CHANGED SEEP CHARACTERISTICS, AS NEEDED | 3D ROCK ARMORING ON DISTURBED SLOPES, AS NEEDED | 6D ARMORED CHANNEL, AS NEEDED |
| 1J SINGLE TARGETED SEEP COLLECTOR, AS NEEDED | 3E COIR LOGS ON DISTURBED SLOPES, AS NEEDED | 6F RIPRAP GRADATIONS, AS NEEDED |
| 1K ENERGY DISSIPATION BASIN, AS NEEDED | 4A TRENCH BREAKERS (FOAM AND SANDBAGS), SEE NOTE 1 | |
| 2A GRADING TEMPORARY ROW SURFACE, SEE NOTE 1 | 4C SACK-CRETE BREAKERS (STRUCTURAL BREAKER), AS NEEDED | |
| 2B GRADING TRENCH WITH OUTBOARD WEDGE, SEE NOTE 1 | 4D SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER, SEE NOTE 1 | |
| 2C COMPACT BACKFILL, SEE NOTE 1 | 4F TRENCH BREAKER WITH DRAINAGE | |
| 2D DRY SOILS AND BACKFILL, SEE NOTE 1 | | |

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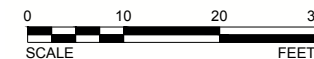
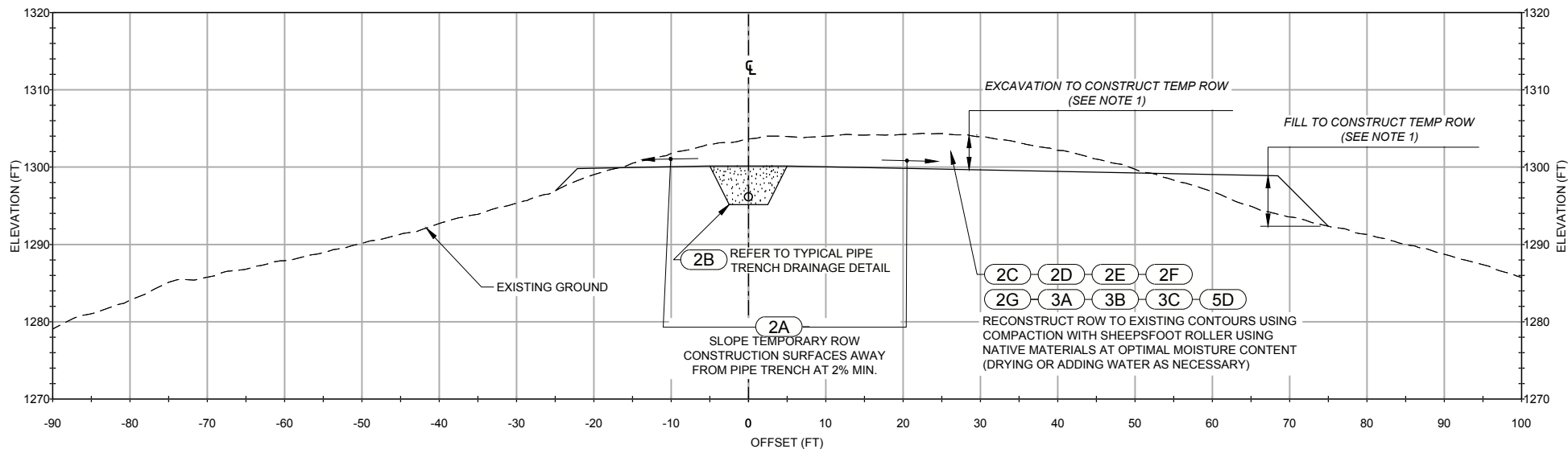


NOTES

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2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
3. TYPICAL SECTION SHOWS SCENARIO WITH VARIED CUT/FILL IN GENERALLY PLANAR GEOMETRY. EXTENT OF CUT/FILL MAY VARY.
4. WHERE THE TEMP ROW SURFACE GRADING DRAINS TO AN IN-BOARD CUT SLOPE, THEN FRENCH DRAINS, OR SHALLOW ARMORED DITCH WITH DRAIN, OR AN ARMORED CHANNEL CONNECTED TO SLOPE BREAKERS IS NEEDED.

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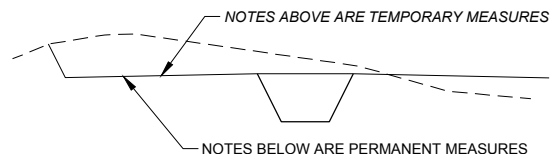
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- 2A** GRADING TEMPORARY ROW SURFACE, SEE NOTE 1
- 2B** GRADING TRENCH WITH OUTBOARD WEDGE, SEE NOTE 1
- 2C** COMPACT BACKFILL, SEE NOTE 1
- 2D** DRY SOILS AND BACKFILL, SEE NOTE 1
- 2E** REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, SEE NOTE 1
- 2F** ROCK BACKFILL (WITH DRAIN), SEE NOTE 1
- 2G** GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1
- 3A** TRACK DISTURBED SLOPES, SEE NOTE 1
- 3B** RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1
- 3C** COIR CLOTH ON DISTURBED SLOPES, SEE NOTE 1
- 5D** ACCESS ROADS, SEE NOTE 1

NOTES

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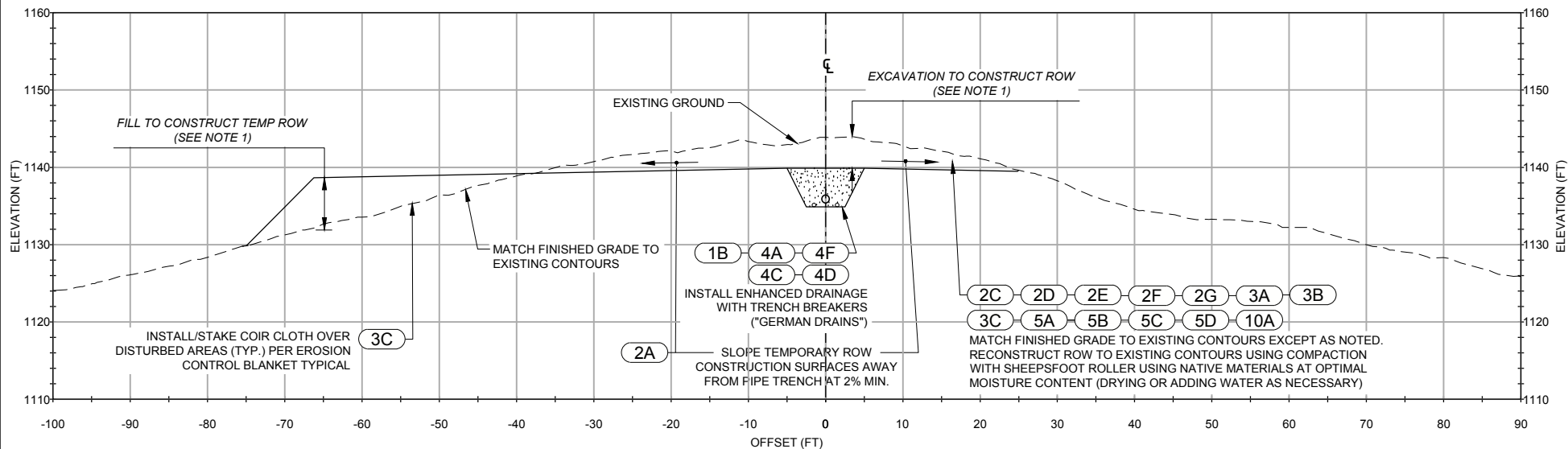
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SUPPORTING TYPICAL DETAILS

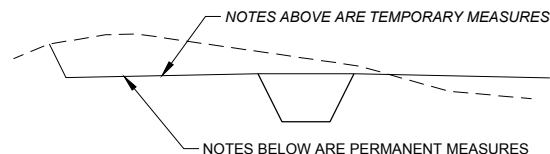
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- (1E) DRAIN PIPE OUTFALL RIPRAP APRON, SEE NOTE 1
- (2A) GRADING TEMPORARY ROW SURFACE, SEE NOTE 1
- (2B) GRADING TRENCH WITH OUTBOARD WEDGE, SEE NOTE 1
- (2C) COMPACT BACKFILL, SEE NOTE 1
- (2D) DRY SOILS AND BACKFILL, SEE NOTE 1
- (2E) REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, SEE NOTE 1
- (2F) ROCK BACKFILL (WITH DRAIN), SEE NOTE 1
- (2G) GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1
- (3A) TRACK DISTURBED SLOPES, SEE NOTE 1
- (3B) RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1
- (3C) COIR CLOTH ON DISTURBED SLOPES, AS NEEDED
- (4A) TRENCH BREAKERS (FOAM AND SANDBAGS), SEE NOTE 1
- (4C) SACK-CRETE BREAKERS (STRUCTURAL BREAKER), AS NEEDED
- (4D) SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER, SEE NOTE 1
- (4F) TRENCH BREAKER WITH DRAINAGE, SEE NOTE 1
- (5A) SLOPE BREAKERS (TEMP AND PERMANENT), SEE NOTE 1
- (5B) SLOPE BREAKER ARMORED OUTLET, SEE NOTE 1
- (5C) SLOPE BREAKERS WITH DIVERSION CHANNELS, SEE NOTE 1
- (5D) ACCESS ROADS, SEE NOTE 1
- (5E) TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED
- (10A) BENCHES RE-CONSTRUCTION THROUGH NATURAL STEPS, SEE NOTE 1

NOTES

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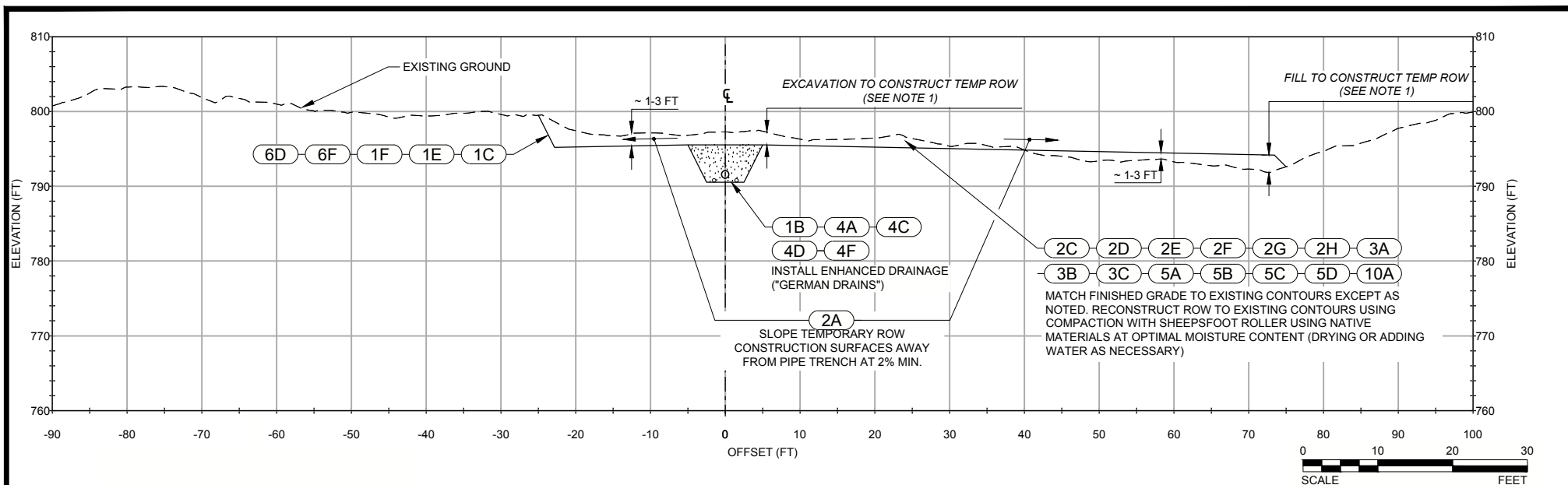


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REVIEW	AQK	2014-08-11				

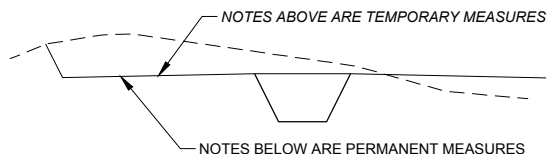




SUPPORTING TYPICAL DETAILS

- | | | |
|---|--|---|
| 1B ENHANCED DRAIN (GERMAN DRAIN), IN PIPELINE TRENCH, SEE NOTE 1 | 2G GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1 | 5C SLOPE BREAKERS WITH DIVERSION CHANNELS, SEE NOTE 1 AND 4 |
| 1C TARGETED SEEP DRAINS, AT INTERSEPTED SEEPS, AS NEEDED | 3A TRACK DISTURBED SLOPES, SEE NOTE 1 | 5D ACCESS ROADS, SEE NOTE 1 |
| 1E DRAIN PIPE OUTFALL RIPRAP APRON, AS NEEDED | 3B RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1 | 5E TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED |
| 1F ARMORED CHANNEL WITH DRAIN PIPE, AS NEEDED | 3C COIR CLOTH ON DISTURBED SLOPES, SEE NOTE 1 | 6D ARMORED CHANNEL, SEE NOTE 4 |
| 1H STEEP CONVEYANCE CHANNEL, AS NEEDED | 3D ROCK ARMORING ON DISTURBED SLOPES, AS NEEDED | 6F RIPRAP GRADATIONS, AS NEEDED |
| 1I CHANGED SEEP CHARACTERISTICS, AS NEEDED | 3E COIR LOGS ON DISTURBED SLOPES, AS NEEDED | 10A BENCHES RE-CONSTRUCTION THROUGH NATURAL STEPS, AS NEEDED |
| 1J SINGLE TARGETED SEEP COLLECTOR, AS NEEDED | 4A TRENCH BREAKERS (FOAM AND SANDBAGS), SEE NOTE 1 | |
| 1K ENERGY DISSIPATION BASIN, AS NEEDED | 4C SACK-CRETE BREAKERS (STRUCTURAL BREAKER), SEE NOTE 1 FOR UNSTABLE FILL | |
| 2C COMPACT BACKFILL, AS NEEDED | 4D SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER, SEE NOTE 1 | |
| 2A GRADING TEMPORARY ROW SURFACE, SEE NOTE 1 | 4F TRENCH BREAKER WITH DRAINAGE, SEE NOTE 1 | |
| 2D DRY SOILS AND BACKFILL, AS NEEDED | 4G SACK-CRETE ARMOR WITH BREAKERS, AS NEEDED | |
| 2E REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, AS NEEDED | 5A SLOPE BREAKERS (TEMP AND PERMANENT), SEE NOTE 1 | |
| 2F ROCK BACKFILL (WITH DRAIN), AS NEEDED | 5B SLOPE BREAKER ARMORED OUTLET, SEE NOTE 1 | |

LEGEND

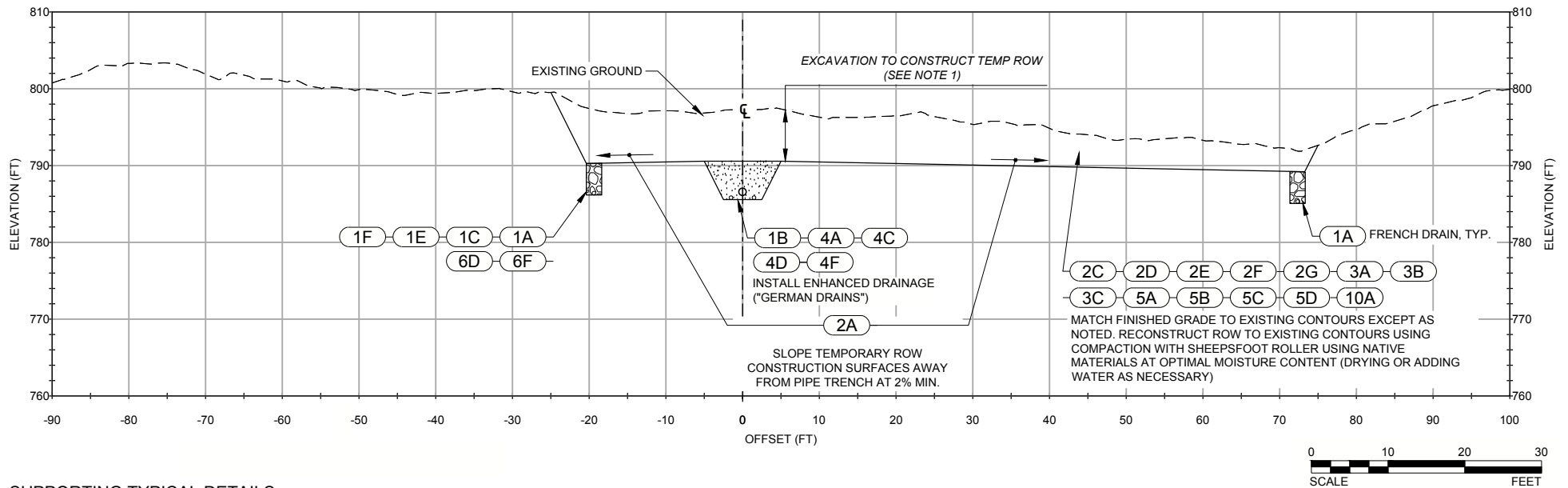


NOTES

1. 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.
2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
3. TYPICAL SECTION SHOWS SCENARIO WITH VARIED CUT/FILL IN GENERALLY PLANAR GEOMETRY. EXTENT OF CUT/FILL MAY VARY.
4. WHERE THE TEMP ROW SURFACE GRADING DRAINS TO AN IN-BOARD CUT SLOPE, THEN FRENCH DRAINS, OR SHALLOW ARMORED DITCH WITH DRAIN, OR AN ARMORED CHANNEL CONNECTED TO SLOPE BREAKERS IS NEEDED.

REV		DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
NOTES							
PROJECT							
WILLIAMS OVM							
TITLE							
TYPICAL ROW RESTORATION SCENARIO PLANAR SLOPE (STANDARD)							
PROJECT No.				SCALE			
DESIGN	BJV	2014-08-11		AS SHOWN			
CADD	BJV	2014-08-11		SHEET			
CHECK	AGM	2014-08-11					
REVIEW	AQK	2014-08-11					

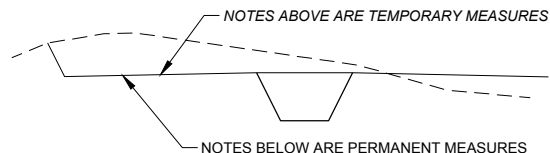




SUPPORTING TYPICAL DETAILS

- | | | |
|---|--|--|
| 1A FRENCH DRAIN (SIMPLE), SEE NOTE 4 | 2F ROCK BACKFILL (WITH DRAIN), AS NEEDED | 5A SLOPE BREAKERS (TEMP AND PERMANENT), SEE NOTE 1 |
| 1B ENHANCED DRAIN (GERMAN DRAIN), IN PIPELINE TRENCH, SEE NOTE 1 | 2G GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1 | 5B SLOPE BREAKER ARMORED OUTLET, SEE NOTE 1 |
| 1C TARGETED SEEP DRAINS, AT INTERSEPTED SEEPS, AS NEEDED | 3A TRACK DISTURBED SLOPES, SEE NOTE 1 | 5C SLOPE BREAKERS WITH DIVERSION CHANNELS, SEE NOTE 1 AND 4 |
| 1E DRAIN PIPE OUTFALL RIPRAP APRON, AS NEEDED | 3B RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1 | 5D ACCESS ROADS, SEE NOTE 1 |
| 1F ARMORED CHANNEL WITH DRAIN PIPE, AS NEEDED | 3C COIR CLOTH ON DISTURBED SLOPES, SEE NOTE 1 | 5E TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED |
| 1H STEEP CONVEYANCE CHANNEL, AS NEEDED | 3D ROCK ARMORING ON DISTURBED SLOPES, AS NEEDED | 6D ARMORED CHANNEL, SEE NOTE 4 |
| 1I CHANGED SEEP CHARACTERISTICS, AS NEEDED | 3E COIR LOGS ON DISTURBED SLOPES, AS NEEDED | 6F RIPRAP GRADATIONS AS NEEDED |
| 1J SINGLE TARGETED SEEP COLLECTOR, AS NEEDED | 4A TRENCH BREAKERS (FOAM AND SANDBAGS), SEE NOTE 1 | 10A BENCHES RE-CONSTRUCTION THROUGH NATURAL STEPS, SEE NOTE 1 |
| 1K ENERGY DISSIPATION BASIN, AS NEEDED | 4C SACK-CRETE BREAKERS (STRUCTURAL BREAKER), SEE NOTE 1 FOR UNSTABLE FILL | |
| 2A GRADING TEMPORARY ROW SURFACE, SEE NOTE 1 | 4D SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER, SEE NOTE 1 | |
| 2C COMPACT BACKFILL, AS NEEDED | 4F TRENCH BREAKER WITH DRAINAGE, SEE NOTE 1 | |
| 2D DRY SOILS AND BACKFILL, AS NEEDED | 4G SACK-CRETE ARMOR WITH BREAKERS, AS NEEDED | |
| 2E REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, AS NEEDED | | |

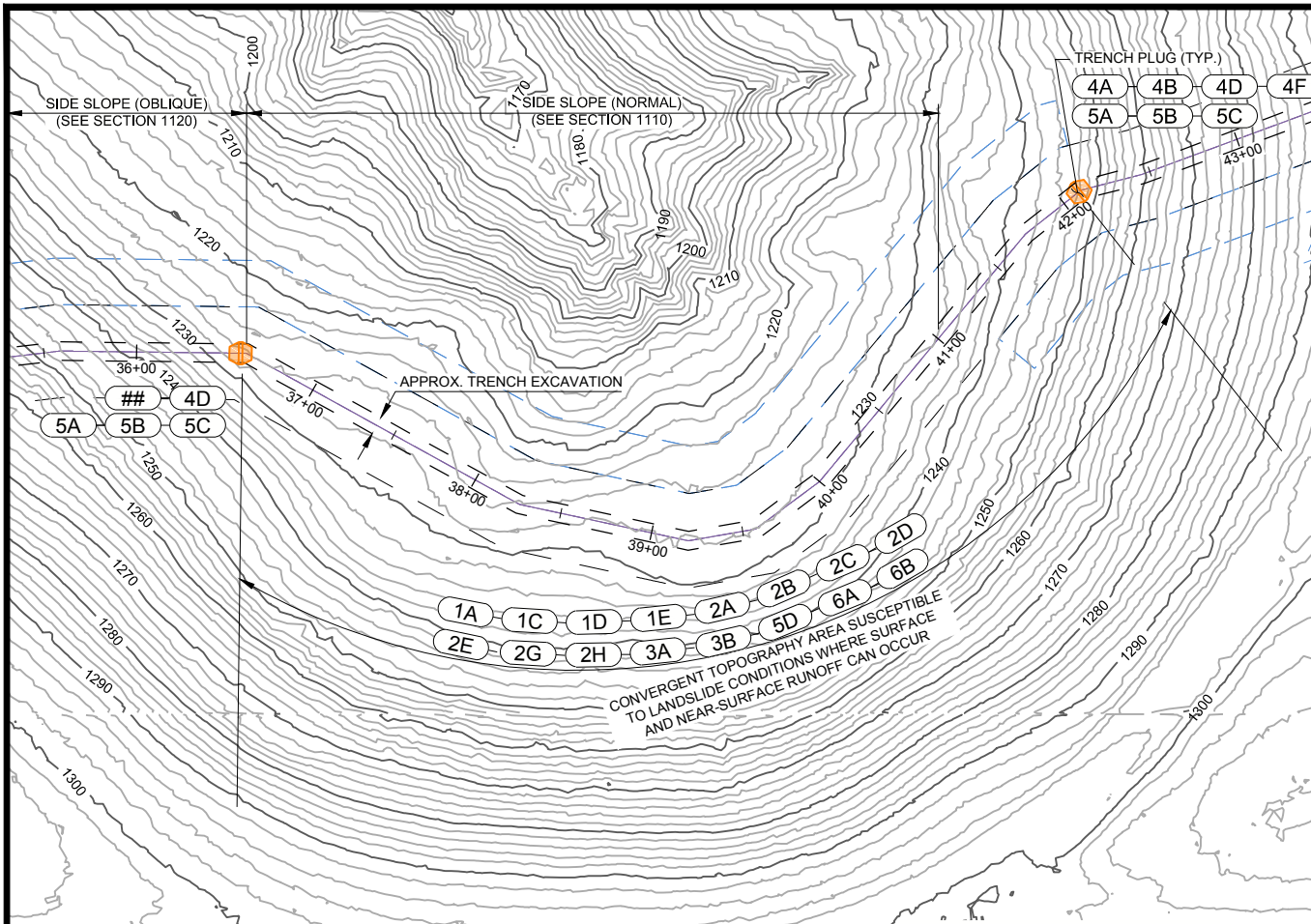
LEGEND



NOTES

1. 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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3. TYPICAL SECTION SHOWS SCENARIO WITH VARIED CUT/FILL IN GENERALLY PLANAR GEOMETRY. EXTENT OF CUT/FILL MAY VARY.
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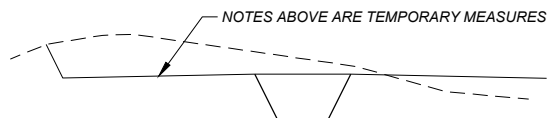
REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RWW
NOTES						
PROJECT WILLIAMS OVM						
TITLE						
TYPICAL ROW RESTORATION SCENARIO PLANAR SLOPE (DEEP EXCAVATION)						
PROJECT No.			SCALE AS SHOWN			
DESIGN	BJV	2014-08-11	CADD	BJV	2014-08-11	SHEET
CHECK	AGM	2014-08-11	REVIEW	AQK	2014-08-11	
Golder Associates						1160



SUPPORTING TYPICAL DETAILS, CONTINUED

- 5A** SLOPE BREAKERS (TEMP AND PERMANENT), SEE NOTES 1 AND 5
- 5B** SLOPE BREAKER ARMORED OUTLET, SEE NOTE 1
- 5C** SLOPE BREAKERS WITH DIVERSION CHANNELS, AS NEEDED
- 5D** ACCESS ROADS, SEE NOTE 1
- 6A** COIR-LINED VEGETATED DIVERSION CHANNEL, AS NEEDED
- 6B** BROW DITCH, AS NEEDED

LEGEND



NOTES

1. 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.
2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
3. TYPICAL SECTION SHOWS SCENARIO WITH VARIED CUT/FILL IN GENERALLY PLANAR GEOMETRY. EXTENT OF CUT/FILL MAY VARY.
4. WHERE THE TEMP ROW SURFACE GRADING DRAINS TO AN IN-BOARD CUT SLOPE, THEN FRENCH DRAINS, OR SHALLOW ARMORED DITCH WITH DRAIN, OR AN ARMORED CHANNEL CONNECTED TO SLOPE BREAKERS IS NEEDED.
5. INTERCEPT SEEPAGE FLOWS ALONG TRENCH IN SLOPED TERRAIN APPROACHING AND DEPARTING CONVERGENT AREA. COORDINATE WITH ## AND 5A.
6. FOR AREAS WHERE R.O.W. FOLLOW SLOPE (I.E. CONTOURS WITH SLOPE), AND AT IDENTIFIED SEEP LOCATIONS.

TYPICAL SUPPORTING DETAILS

REFER TO SCENARIO SHEETS FOR SIDE SLOPES AND PLANAR SLOPES:

- 1A** FRENCH DRAIN (SIMPLE), SEE NOTES 1 AND 5
- 1C** TARGETED SEEP DRAINS, SEE NOTES 1 AND 6
- 1D** BLEEDER DRAIN, SEE NOTE 1
- 1E** DRAIN PIPE OUTFALL RIPRAP APRON, SEE NOTE 1
- 1H** STEEP CONVEYANCE CHANNEL, AS NEEDED
- 1I** CHANGED SEEP CHARACTERISTICS, AS NEEDED
- 1J** SINGLE TARGETED SEEP COLLECTOR, AS NEEDED
- 1K** ENERGY DISSIPATION BASIN, AS NEEDED
- 2A** GRADING TEMPORARY ROW SURFACE, SEE NOTE 1
- 2B** GRADING TRENCH WITH OUTBOARD WEDGE, SEE NOTE 1
- 2C** COMPACT BACKFILL, SEE NOTE 1
- 2D** DRY SOILS AND BACKFILL, SEE NOTE 1
- 2E** REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, SEE NOTE 1
- 2G** GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1
- 2H** GRADING TO MINIMIZE BACKFILL OVER LANDSLIDE, SEE NOTE 1
- 3A** TRACK DISTURBED SLOPES, SEE NOTE 1
- 3B** RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1
- 3C** COIR CLOTH ON DISTURBED SLOPES, SEE NOTE 1
- 3D** ROCK ARMORING ON DISTURBED SLOPES, AS NEEDED
- 3E** COIR LOGS ON DISTURBED SLOPES, AS NEEDED
- 4A** TRENCH BREAKERS (FOAM AND SANDBAGS), SEE NOTE 1
- 4B** TRENCH DAMS (FOAM BAGS OR FINE GRAINED SOILS), SEE NOTE 1
- 4D** SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER, SEE NOTE 1
- 4F** TRENCH BREAKER WITH DRAINAGE, SEE NOTE 1
- 4G** SACK-CRETE ARMOR WITH BREAKERS, AS NEEDED

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RWW
NOTES						
PROJECT WILLIAMS OVM						
TITLE						
TYPICAL ROW RESTORATION SCENARIO CONVERGENT TOPOGRAPHY						
PROJECT No.			SCALE AS SHOWN			
DESIGN	BJV	2014-08-11	CADD	BJV	2014-08-11	SHEET
CHECK	AGM	2014-08-11	REVIEW	AQK	2014-08-11	
Golder Associates						1170

SUPPORTING TYPICAL DETAILS

- 1A FRENCH DRAIN (SIMPLE), SEE NOTE 1 AND 5
- 1B ENHANCED DRAIN (GERMAN DRAIN), SEE NOTE 1 AND 5
- 1C TARGETED SEEP DRAINS, SEE NOTE 1
- 1D BLEEDER DRAIN, SEE NOTE 1
- 1E DRAIN PIPE OUTFALL RIPRAP APRON, SEE NOTE 1
- 1F ARMORED CHANNEL WITH DRAIN PIPE, SEE NOTE 1
- 1H STEEP CONVEYANCE CHANNEL, AS NEEDED
- 1I CHANGED SEEP CHARACTERISTICS, SEE NOTE 1
- 1J SINGLE TARGETED SEEP COLLECTOR, AS NEEDED
- 1K ENERGY DISSIPATION BASIN, AS NEEDED
- 2C COMPACT BACKFILL, SEE NOTE 1
- 2D DRY SOILS AND BACKFILL, SEE NOTE 1
- 2E REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, AS NEEDED
- 4A TRENCH BREAKERS (FOAM AND SANDBAGS), SEE NOTES 1 AND 3
- 4C SACK-CRETE BREAKERS (STRUCTURAL BREAKER), SEE NOTE 1 AND 3
- 4D SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER, AS NEEDED
- 4F TRENCH BREAKER WITH DRAINAGE, SEE NOTE 1 AND 3
- 4G SACK-CRETE ARMOR WITH BREAKERS, SEE NOTE 1 AND 3
- 5D ACCESS ROADS, SEE NOTE 1
- 8A ROCK GUARD ON PIPELINE, SEE NOTE 1
- 10A BENCHES RE-CONSTRUCTION THROUGH NATURAL STEPS, SEE NOTE 1

NOTES

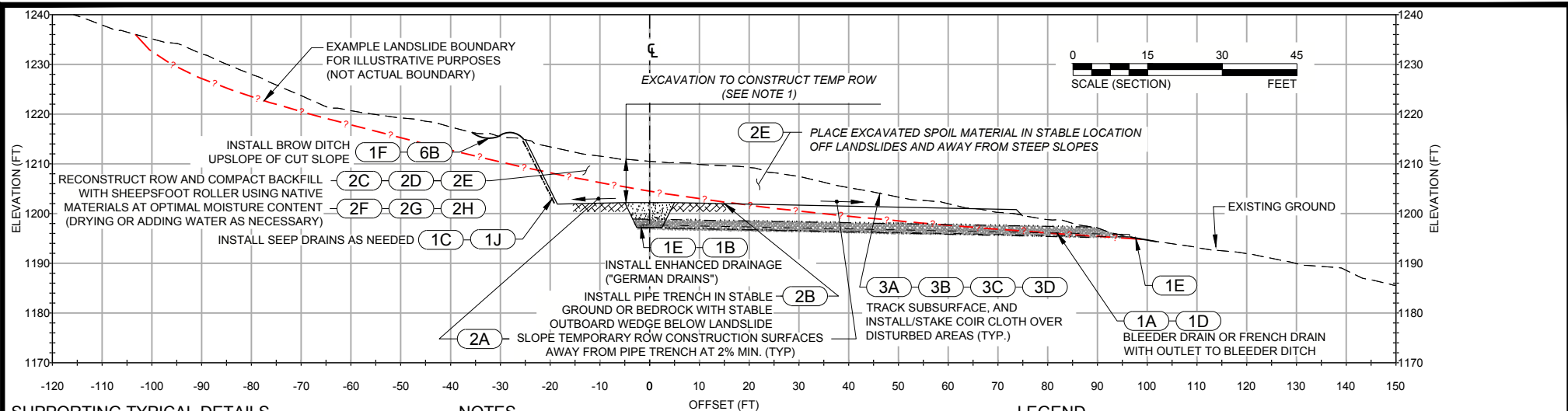
1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
3. TRENCH EXCAVATIONS INTO BEDROCK IN SLOPED TERRAIN (PLANAR SLOPES, INCLINED RIDGES, AND SIDESLOPE (OBLIQUE)) WILL REQUIRE TRENCH BREAKERS WITH SUFFICIENT MASS AND GEOTECHNICAL PROPERTIES TO RETAIN BACKFILL SOILS AND/OR ROCK MATERIALS. USE OF FOAM BREAKERS IS NOT RECOMMENDED. SANDBAG OR SACK-CRETE BREAKERS ARE RECOMMENDED.
4. ALTERNATING LAYERS OR WEAKER BEDROCK AND STRONGER BEDROCK MATERIALS OFTEN CREATES A "BENCHED" OR "STAIR-STEPPED" APPEARANCE TO EXISTING HILL SLOPES. MINIMIZE BACKFILL IN THESE SITUATIONS, AND TRANSITION THE SLOPES AT THE ROW BOUNDARIES TO MEET TO EXISTING TERRAIN, BUT MAINTAIN A MORE UNIFORM, POSITIVELY DRAINING SLOPE ACROSS THE ROW. INCORPORATE DRAINAGE MITIGATION WHERE NEEDED SEE NOTE 5. BUILDING BENCHES ALTERNATING WITH FILL ACROSS THE ROW TO MATCH THE EXISTING TOPOGRAPHY IS NOT RECOMMENDED.
5. DRAINAGE IMPROVEMENTS NEEDED TO MITIGATE FOR POSSIBLE SEEPAGE ACCUMULATIONS, OR TO ADDRESS SEEPAGE SCOURS.

REV	DATE	REVISION DESCRIPTION				DES	CADD	CHK	RVW
NOTES									
PROJECT									
WILLIAMS OVM									
TITLE									
TYPICAL ROW RESTORATION SCENARIO POTENTIAL SHALLOW BEDROCK									
		PROJECT No.			SCALE AS SHOWN 1500				
		DESIGN	BJV	2014-08-11					
		CADD	BJV	2014-08-11					
		CHECK	AGM	2014-08-11					
		REVIEW	AQK	2014-08-11					

NOTES

- 1. 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.
- 2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
- 3. GEOTECHNICAL STUDY MAY BE REQUIRED TO ADDRESS SITE-SPECIFIC CONDITIONS

								
REV	DATE	REVISION DESCRIPTION			DES	CADD	CHK	RVW
NOTES								
PROJECT WILLIAMS OVM								
TITLE TYPICAL ROW RESTORATION SCENARIO AREAS OF FILL								
		PROJECT No.			SCALE AS SHOWN			
		DESIGN	BJV	2014-02-28	1600			
		CADD	BJV	2014-02-28				
		CHECK	AGM	2014-02-28				
		REVIEW	AQK	2014-02-28				



SUPPORTING TYPICAL DETAILS

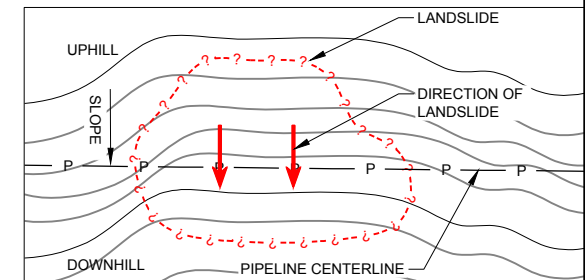
- 1A** FRENCH DRAIN (SIMPLE), SEE NOTES 1 AND 5
- 1B** ENHANCED DRAIN (GERMAN DRAIN), SEE NOTES 1 AND 2
- 1C** TARGETED SEEP DRAINS, SEE NOTES 1 AND 5
- 1D** BLEEDER DRAIN, SEE NOTE 1
- 1E** DRAIN PIPE OUTFALL RIPRAP APRON, SEE NOTE 1
- 1F** ARMORED CHANNEL WITH DRAIN PIPE, SEE NOTE 1
- 1H** STEEP CONVEYANCE CHANNEL, AS NEEDED
- 1I** CHANGED SEEP CHARACTERISTICS, AS NEEDED
- 1J** SINGLE TARGETED SEEP COLLECTOR, SEE NOTE 1 AND 6
- 1K** ENERGY DISSIPATION BASIN, AS NEEDED
- 2A** GRADING TEMPORARY ROW SURFACE, SEE NOTE 1
- 2B** GRADING TRENCH WITH OUTBOARD WEDGE, SEE NOTE 1
- 2C** COMPACT BACKFILL, SEE NOTE 1
- 2D** DRY SOILS AND BACKFILL, SEE NOTE 1
- 2E** REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, AS NEEDED
- 2F** ROCK BACKFILL (WITH DRAIN), AS NEEDED
- 2G** GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1
- 2H** GRADING TO MINIMIZE BACKFILL OVER LANDSLIDE, SEE NOTE 1
- 3A** TRACK DISTURBED SLOPES, SEE NOTE 1
- 3B** RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1
- 3C** COIR CLOTH ON DISTURBED SLOPES, AS NEEDED
- 3D** ROCK ARMORING ON DISTURBED SLOPES, AS NEEDED
- 3E** COIR LOGS ON DISTURBED SLOPES, AS NEEDED
- 4A** TRENCH BREAKERS (FOAM AND SANDBAGS), SEE NOTE 6
- 4B** TRENCH DAMS (FOAM BAGS OR FINE GRAINED SOILS), SEE NOTE 6
- 4G** SACK-CRETE ARMOR WITH BREAKERS, AS NEEDED
- 5D** ACCESS ROADS, SEE NOTE 1
- 5E** TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED
- 5F** SACK-CRETE WEDGE, AS NEEDED
- 6A** COIR-LINED VEGETATED DIVERSION CHANNEL, SEE NOTE 1
- 6B** BROW DITCH, SEE NOTE 1

NOTES

1. 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.
2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
3. LANDSLIDES ("SLIPS") ARE TO BE IDENTIFIED AND EVALUATED ON A CASE-BY-CASE BASIS FOR FOR EACH SITE. MITIGATION RECOMMENDATIONS SPECIFIC TO EACH LANDSLIDE SITE IDENTIFIED SHOULD BE OBTAIN BASED ON SITE-SPECIFIC REVIEW, MAPPING, CHARACTERIZATION, AND DELINEATION OF LANDSLIDE FEATURES.
4. MITIGATION RECOMMENDATIONS MAY CONTAIN THE FOLLOWING IN ADDITION TO OTHER SITE-SPECIFIC RECOMMENDATIONS:
 - A. IF POSSIBLE, REROUTE THE PIPELINE AROUND LANDSLIDE.
 - B. IF NOT POSSIBLE, TEST PIT TO DETERMINE EXTENT OF STABLE/UNSTABLE SOILS. IF POSSIBLE INSTALL PIPELINE TRENCH BENEATH THE LANDSLIDE INTO STABLE MATERIALS, PREFERABLY WITH TRENCH INTO BEDROCK.
 - C. IF PIPE IS NOT IN STABLE GROUND, THEN, INSTALL DEFORMABLE BACKFILL (SAND) WITHIN THE TRENCH AND INSTALL STRAIN GAUGES ON THE PIPE TO MONITOR LONG-TERM STRAIN ACCUMULATION.
 - D. IF POSSIBLE, HAUL EXCESS BACKFILL MATERIALS OFFSITE OR TO ANOTHER STABLE LOCATION AND MINIMIZE BACKFILL OVER THE TRENCH.
 - E. PROVIDE ADDITIONAL AND/OR ENHANCED TRENCH DRAINAGE MEASURES IN TRENCH. DISCHARGE POINTS MUST DRAIN AWAY FROM THE LANDSLIDES ONTO STABLE GROUND.
 - F. SURFACE WATER FLOWS SHOULD BE DIRECTED AWAY FROM LANDSLIDES. INSTALL SLOPE BREAKERS, BROW DITCHES, DIVERSION CHANNELS, DRAINS, ACCESS/ATV ROAD DRAINAGE MEASURES, ETC. AS NEEDED TO DIVERT CONCENTRATED FLOWS OFF THE ROW AND TO NOT POND OR SATURATE SOILS AT LANDSLIDES.
 - G. VERIFY BACKFILL MATERIALS ARE SUITABLE AND COMPACTED AT OPTIMUM MOISTURE CONTENT. ADD WATER OR DRY FILL MATERIALS AS NECESSARY AND, IF NECESSARY, ADD LIME-KILN DUST OR CEMENT-KILN DUST. REPLACE BACKFILL MATERIALS WITH FREE-DRAINING ROCKFILL IF LOCAL SOILS ARE NOT SUITABLE.
 - H. IF NECESSARY, INSTALL TRENCH BREAKERS OR TRENCH DAMS TO INTERRUPT AND BLOCK SEEPAGE FLOWS ALONG THE TRENCH THAT MAY ENTER THE LANDSLIDE AREAS.
 - I. IF NECESSARY, INSTALL SHEAR TRENCH AT ROW BOUNDARY.
 - J. INSTALL GEODETIC MONITORING POINTS (SURVEY BENCHMARKS) AND/OR STAKES.
5. INSTALL DRAINS AT IDENTIFIED SEEPS AND SOURCES OF WATER.
6. TRENCH BREAKERS OR TRENCH DAMS MAY BE REQUIRED AT AREAS JUST OUTSIDE OF LANDSLIDE LIMITS AS WELL AS AT TRANSITIONS FROM SLOPING GROUND TO FLAT GROUND. TRENCH BREAKERS AND TRENCH DAMS ARE USUALLY NOT NEEDED WITHIN LANDSLIDES ON SIDESLOPE - NORMAL.
7. TO-BE-DETERMINED BASED ON THE RECOMMENDATIONS FROM A SITE-SPECIFIC STUDY.

LEGEND

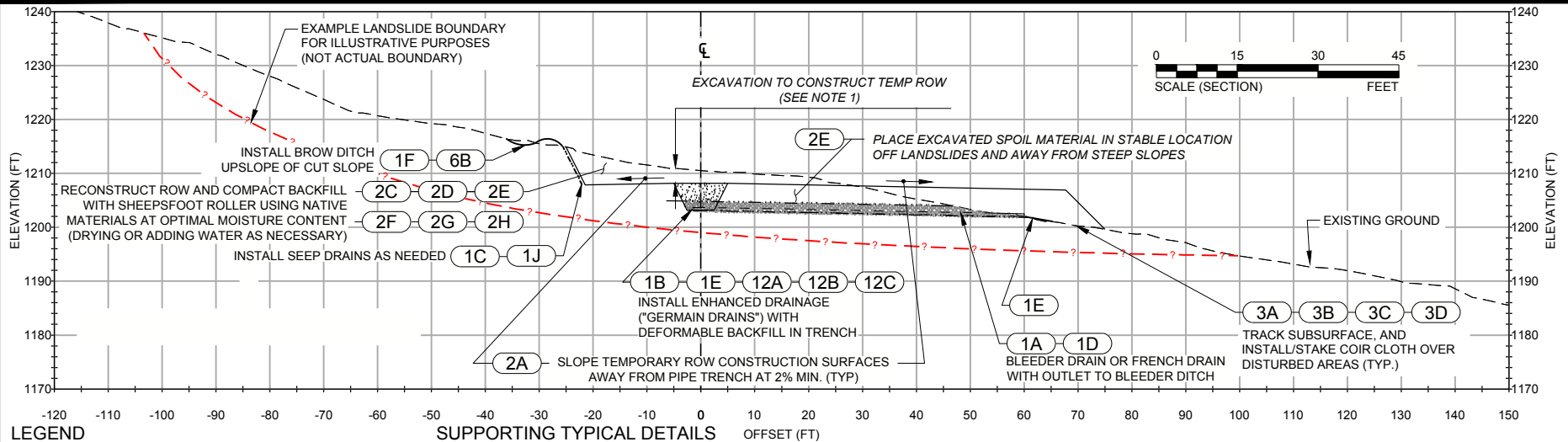
- NOTES ABOVE ARE TEMPORARY MEASURES
- NOTES BELOW ARE PERMANENT MEASURES



SIDESLOPE ORIENTATION (N.T.S.)

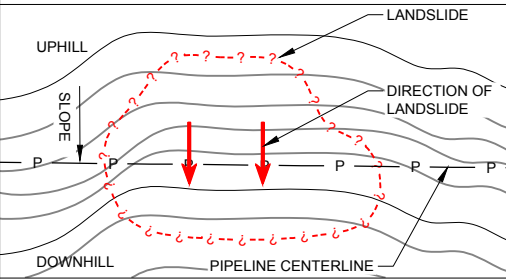
REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RWW
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PROJECT						
WILLIAMS OVM						
TITLE						
TYPICAL ROW RESTORATION SCENARIO LANDSLIDES SIDE SLOPE WITH STABLE TRENCH						
PROJECT No.						
DESIGN	BJV	2014-08-11	SCALE			
CADD	BJV	2014-08-11	SHEET			
CHECK	AGM	2014-08-11				
REVIEW	AQK	2014-08-11				





LEGEND

NOTES ABOVE ARE TEMPORARY MEASURES
NOTES BELOW ARE PERMANENT MEASURES



SIDESLOPE ORIENTATION (N.T.S.)

NOTES

- 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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- LANDSLIDES ("SLIPS") ARE TO BE IDENTIFIED AND EVALUATED ON A CASE-BY-CASE BASIS FOR EACH SITE. MITIGATION RECOMMENDATIONS SPECIFIC TO EACH LANDSLIDE SITE IDENTIFIED SHOULD BE OBTAIN BASED ON SITE-SPECIFIC REVIEW, MAPPING, CHARACTERIZATION, AND DELINEATION OF LANDSLIDE FEATURES.
- MITIGATION RECOMMENDATIONS MAY CONTAIN THE FOLLOWING IN ADDITION TO OTHER SITE-SPECIFIC RECOMMENDATIONS:
 - IF POSSIBLE, REROUTE THE PIPELINE AROUND LANDSLIDE.
 - IF NOT POSSIBLE, TEST PIT TO DETERMINE EXTENT OF STABLE/UNSTABLE SOILS. IF POSSIBLE INSTALL PIPELINE TRENCH BENEATH THE LANDSLIDE INTO STABLE MATERIALS, PREFERABLY WITH TRENCH INTO BEDROCK.
 - IF PIPE IS NOT IN STABLE GROUND, THEN, INSTALL DEFORMABLE BACKFILL (SAND) WITHIN THE TRENCH AND INSTALL STRAIN GAUGES ON THE PIPE TO MONITOR LONG-TERM STRAIN ACCUMULATION.
 - IF POSSIBLE, HAUL EXCESS BACKFILL MATERIALS OFFSITE OR TO ANOTHER STABLE LOCATION AND MINIMIZE BACKFILL OVER THE TRENCH.
 - PROVIDE ADDITIONAL AND/OR ENHANCED TRENCH DRAINAGE MEASURES IN TRENCH. DISCHARGE POINTS MUST DRAIN AWAY FROM THE

SUPPORTING TYPICAL DETAILS

- | | | |
|---|--|---|
| 1A FRENCH DRAIN (SIMPLE), SEE NOTES 1 AND 5 | 2E REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, AS NEEDED | 5E TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED |
| 1B ENHANCED DRAIN (GERMAN DRAIN), SEE NOTES 1 AND 2 | 2F ROCK BACKFILL (WITH DRAIN), AS NEEDED | 5F SACK-CRETE WEDGE, AS NEEDED |
| 1C TARGETED SEEP DRAINS, SEE NOTES 1 AND 5 | 2G GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1 | 6A COIR-LINED VEGETATED DIVERSION CHANNEL, SEE NOTE 1 |
| 1D BLEEDER DRAIN, SEE NOTE 1 | 2H GRADING TO MINIMIZE BACKFILL OVER LANDSLIDE, SEE NOTE 1 | 6B BROW DITCH, SEE NOTE 1 |
| 1E DRAIN PIPE OUTFALL RIPRAP APRON, SEE NOTE 1 | 3A TRACK DISTURBED SLOPES, SEE NOTE 1 | 11A GEODETIC MONITORING, SEE NOTE 7 |
| 1F ARMORED CHANNEL WITH DRAIN PIPE, SEE NOTE 1 | 3B RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1 | 11B STRAIN GAUGE MONITORING, SEE NOTE 7 |
| 1H STEEP CONVEYANCE CHANNEL, AS NEEDED | 3C COIR CLOTH ON DISTURBED SLOPES, AS NEEDED | 11C SLOPE INCLINOMETER MONITORING, SEE NOTE 7 |
| 1I CHANGED SEEP CHARACTERISTICS, AS NEEDED | 3D ROCK ARMORING ON DISTURBED SLOPES, AS NEEDED | 11D SLOPE INCLINOMETER CASING, SEE NOTE 7 |
| 1J SINGLE TARGETED SEEP COLLECTOR, SEE NOTE 1 AND 6 | 3E COIR LOGS ON DISTURBED SLOPES, AS NEEDED | 11E STANDPIPE PIEZOMETER MONITORING, SEE NOTE 7 |
| 1K ENERGY DISSIPATION BASIN, AS NEEDED | 4A TRENCH BREAKERS (FOAM AND SANDBAGS), | 12A STRESS RELIEF EXCAVATIONS, SEE NOTE 1 |
| 2A GRADING TEMPORARY ROW SURFACE, SEE NOTE 1 | 4B TRENCH DAMS (FOAM BAGS OR FINE GRAINED SOILS), SEE NOTE 6 | 12B SELECT (DEFORMABLE) TRENCH BACKFILL, SEE NOTE 1 |
| 2B GRADING TRENCH WITH OUTBOARD WEDGE, SEE NOTE 1 | 4G SACK-CRETE ARMOR WITH BREAKERS, AS NEEDED | 12C SHEAR TRENCH, SEE NOTES 1 AND 7 |
| 2C COMPACT BACKFILL, SEE NOTE 1 | 5D ACCESS ROADS, SEE NOTE 1 | |
| 2D DRY SOILS AND BACKFILL, SEE NOTE 1 | | |

LANDSLIDES ONTO STABLE GROUND.

- SURFACE WATER FLOWS SHOULD BE DIRECTED AWAY FROM LANDSLIDES. INSTALL SLOPE BREAKERS, BROW DITCHES, DIVERSION CHANNELS, DRAINS, ACCESS/ATV ROAD DRAINAGE MEASURES, ETC. AS NEEDED TO DIVERT CONCENTRATED FLOWS OFF THE ROW AND TO NOT POND OR SATURATE SOILS AT LANDSLIDES.
- VERIFY BACKFILL MATERIALS ARE SUITABLE AND COMPACTED AT OPTIMUM MOISTURE CONTENT. ADD WATER OR DRY FILL MATERIALS AS NECESSARY AND, IF NECESSARY, ADD LIME-KILN DUST OR CEMENT-KILN DUST. REPLACE BACKFILL MATERIALS WITH FREE-DRAINING ROCKFILL IF LOCAL SOILS ARE NOT SUITABLE.
- IF NECESSARY, INSTALL TRENCH BREAKERS OR TRENCH DAMS TO INTERRUPT AND BLOCK SEEPAGE FLOWS ALONG THE TRENCH THAT MAY ENTER THE LANDSLIDE AREAS.
- IF NECESSARY, INSTALL SHEAR TRENCH AT ROW BOUNDARY.
- INSTALL GEODETIC MONITORING POINTS (SURVEY BENCHMARKS) AND/OR STAKES.
- INSTALL DRAINS AT IDENTIFIED SEEPS AND SOURCES OF WATER.
- TRENCH BREAKERS OR TRENCH DAMS MAY BE REQUIRED AT AREAS JUST OUTSIDE OF LANDSLIDE LIMITS AS WELL AS AT TRANSITIONS FROM SLOPING GROUND TO FLAT GROUND. TRENCH BREAKERS AND TRENCH DAMS ARE USUALLY NOT NEEDED WITHIN LANDSLIDES ON SIDESLOPE - NORMAL.
- TO-BE-DETERMINED BASED ON THE RECOMMENDATIONS FROM A SITE-SPECIFIC STUDY.

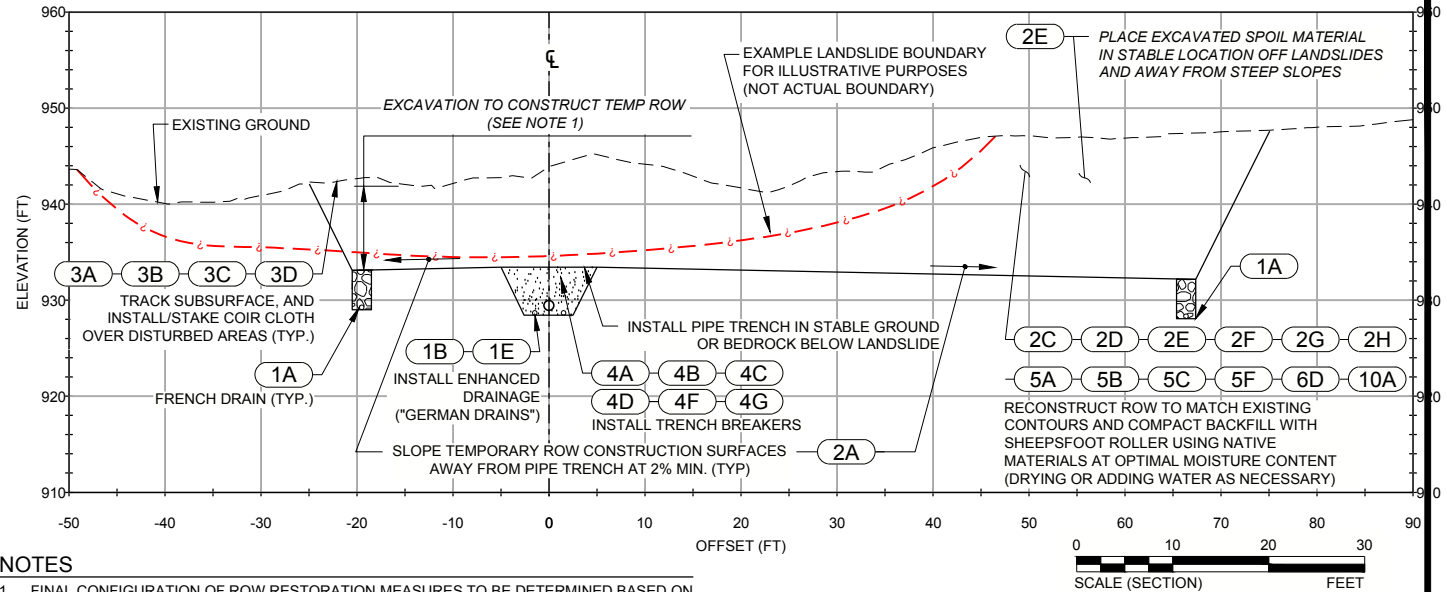
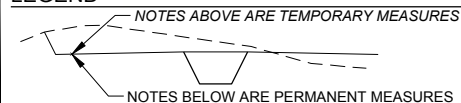
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PROJECT WILLIAMS OVM						
TITLE TYPICAL ROW RESTORATION SCENARIO LANDSLIDES SIDESLOPE WITH UNSTABLE TRENCH						
PROJECT No.			SCALE AS SHOWN			
DESIGN	BJV	2014-08-11	SHEET			
CADD	BJV	2014-08-11				
CHECK	AGM	2014-08-11				
REVIEW	AQK	2014-08-11				



SUPPORTING TYPICAL DETAILS

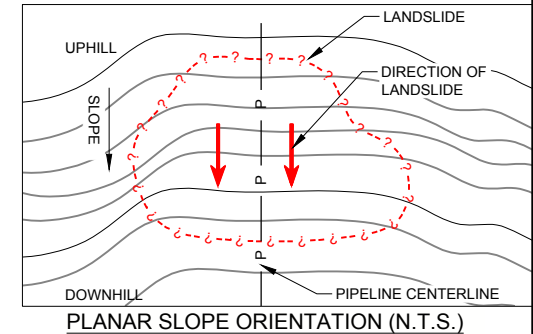
- (1A) FRENCH DRAIN (SIMPLE), SEE NOTES 1 AND 5
- (1B) ENHANCED DRAIN (GERMAN DRAIN), SEE NOTE 1
- (1C) TARGETED SEEP DRAINS, SEE NOTES 1 AND 5
- (1E) DRAIN PIPE OUTFALL RIPRAP APRON, SEE NOTE 1
- (1F) ARMORED CHANNEL WITH DRAIN PIPE, SEE NOTE 1
- (1H) STEEP CONVEYANCE CHANNEL, AS NEEDED
- (1I) CHANGED SEEP CHARACTERISTICS, AS NEEDED
- (1J) SINGLE TARGETED SEEP COLLECTOR, SEE NOTE 1 AND 6
- (1K) ENERGY DISSIPATION BASIN, AS NEEDED
- (2A) GRADING TEMPORARY ROW SURFACE, SEE NOTE 1
- (2C) COMPACT BACKFILL, SEE NOTE 1
- (2D) DRY SOILS AND BACKFILL, SEE NOTE 1
- (2E) REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, AS NEEDED
- (2F) ROCK BACKFILL (WITH DRAIN), AS NEEDED
- (2G) GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1
- (2H) GRADING TO MINIMIZE BACKFILL OVER LANDSLIDE, SEE NOTE 1
- (3A) TRACK DISTURBED SLOPES, SEE NOTE 1
- (3B) RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1
- (3C) COIR CLOTH ON DISTURBED SLOPES, SEE NOTE 1
- (3D) ROCK ARMORING ON DISTURBED SLOPES, AS NEEDED
- (3E) COIR LOGS ON DISTURBED SLOPES, AS NEEDED
- (4B) TRENCH BREAKERS (FOAM AND SANDBAGS), SEE NOTE 6
- (4B) TRENCH DAMS (FOAM BAGS OR FINE GRAINED SOILS), AS NEEDED
- (4C) SACK-CRETE BREAKERS (STRUCTURAL BREAKER), SEE NOTE 1
- (4D) SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER, SEE NOTE 1
- (4F) TRENCH BREAKER WITH DRAINAGE, SEE NOTE 6
- (4G) SACK-CRETE ARMOR WITH BREAKERS, AS NEEDED
- (5A) SLOPE BREAKERS (TEMP AND PERMANENT), SEE NOTE 1
- (5B) SLOPE BREAKER ARMORED OUTLET, SEE NOTE 1
- (5C) SLOPE BREAKERS WITH DIVERSION CHANNELS, SEE NOTE 1
- (5D) ACCESS ROADS, SEE NOTE 1
- (5E) TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED
- (5F) SACK-CRETE WEDGE, AS NEEDED
- (6D) ARMORED CHANNEL, AS NEEDED
- (10A) BENCHES RE-CONSTRUCTION THROUGH NATURAL STEPS, SEE NOTE 1

LEGEND



NOTES

1. 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.
2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
3. LANDSLIDES ("SLIPS") ARE TO BE IDENTIFIED AND EVALUATED ON A CASE-BY-CASE BASIS FOR EACH SITE. MITIGATION RECOMMENDATIONS SPECIFIC TO EACH LANDSLIDE SITE IDENTIFIED SHOULD BE OBTAINED BASED ON SITE-SPECIFIC REVIEW, MAPPING, CHARACTERIZATION, AND DELINEATION OF LANDSLIDE FEATURES.
4. MITIGATION RECOMMENDATIONS MAY CONTAIN THE FOLLOWING IN ADDITION TO OTHER SITE-SPECIFIC RECOMMENDATIONS:
 - A. IF POSSIBLE, REROUTE THE PIPELINE AROUND LANDSLIDE.
 - B. IF NOT POSSIBLE, TEST PIT TO DETERMINE EXTENT OF STABLE/UNSTABLE SOILS. IF POSSIBLE INSTALL PIPELINE TRENCH BENEATH THE LANDSLIDE INTO STABLE MATERIALS, PREFERABLY WITH TRENCH INTO BEDROCK.
 - C. IF PIPE IS NOT IN STABLE GROUND, THEN, INSTALL DEFORMABLE BACKFILL (SAND) WITHIN THE TRENCH AND INSTALL STRAIN GAUGES ON THE PIPE TO MONITOR LONG-TERM STRAIN ACCUMULATION.
 - D. IF POSSIBLE, HAUL EXCESS BACKFILL MATERIALS OFFSITE OR TO ANOTHER STABLE LOCATION AND MINIMIZE BACKFILL OVER THE TRENCH.
 - E. PROVIDE ADDITIONAL AND/OR ENHANCED TRENCH DRAINAGE MEASURES IN TRENCH. DISCHARGE POINTS MUST DRAIN AWAY FROM THE LANDSLIDES ONTO STABLE GROUND.
 - F. SURFACE WATER FLOWS SHOULD BE DIRECTED AWAY FROM LANDSLIDES. INSTALL SLOPE BREAKERS, BROW DITCHES, DIVERSION CHANNELS, DRAINS, ACCESS/ATV ROAD DRAINAGE MEASURES, ETC. AS NEEDED TO DIVERT CONCENTRATED FLOWS OFF THE ROW AND TO NOT POND OR SATURATE SOILS AT LANDSLIDES.
 - G. VERIFY BACKFILL MATERIALS ARE SUITABLE AND COMPACTED AT OPTIMUM MOISTURE CONTENT. ADD WATER OR DRY FILL MATERIALS AS NECESSARY AND, IF NECESSARY, ADD LIME-KILN DUST OR CEMENT-KILN DUST. REPLACE BACKFILL MATERIALS WITH FREE-DRAINING ROCKFILL IF LOCAL SOILS ARE NOT SUITABLE.
 - H. IF NECESSARY, INSTALL TRENCH BREAKERS OR TRENCH DAMS TO INTERRUPT AND BLOCK SEEPAGE FLOWS ALONG THE TRENCH THAT MAY ENTER THE LANDSLIDE AREAS.
 - I. IF NECESSARY, INSTALL SHEAR TRENCH AT ROW BOUNDARY.
 - J. INSTALL GEODETIC MONITORING POINTS (SURVEY BENCHMARKS) AND/OR STAKES.
5. INSTALL DRAINS AT IDENTIFIED SEEPS AND SOURCES OF WATER.
6. TRENCH BREAKERS OR TRENCH DAMS MAY BE REQUIRED JUST OUTSIDE OF LANDSLIDE LIMITS, AT TRANSITIONS, AND WITHIN LANDSLIDES AS NEEDED BASED ON SITE-SPECIFIC RECOMMENDATIONS.
7. TO-BE-DETERMINED BASED ON THE RECOMMENDATIONS FROM A SITE-SPECIFIC STUDY.



	2014-08-11	ISSUED FOR CONSTRUCTION	BJV	BJV	AGM	AQK
REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RWV

NOTES

PROJECT

WILLIAMS OVM

TITLE

TYPICAL ROW RESTORATION SCENARIO LANDSLIDES PLANAR SLOPE WITH STABLE TRENCH



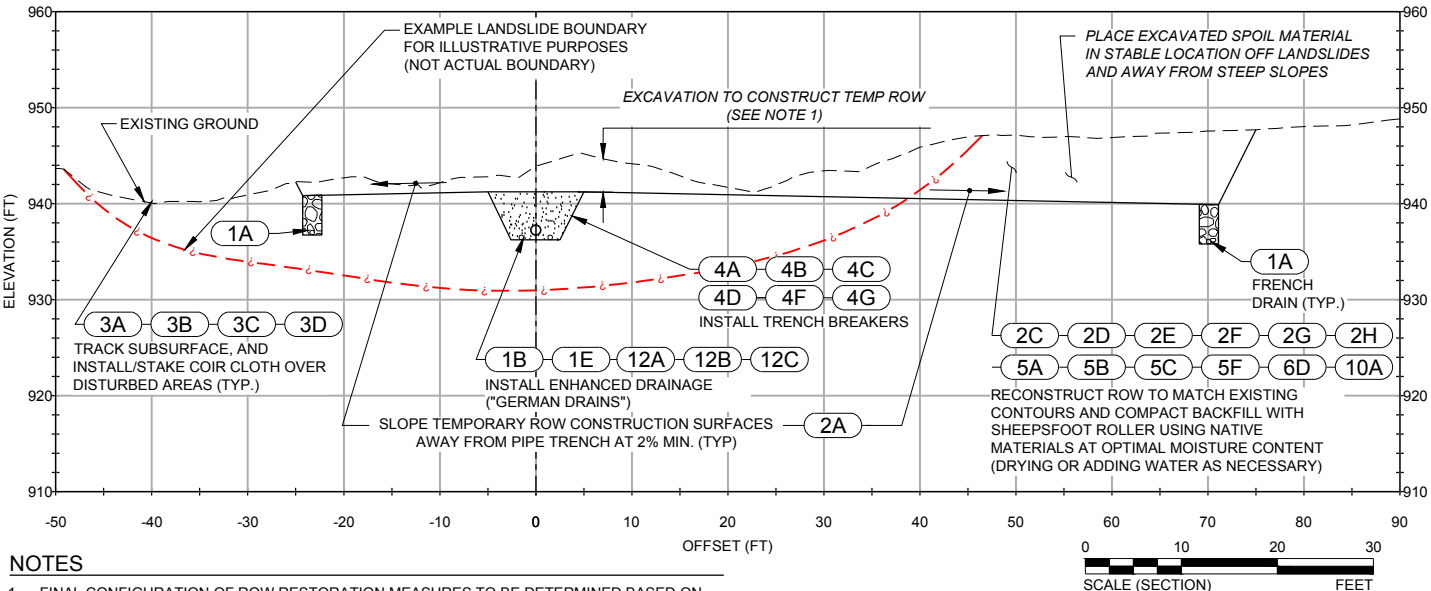
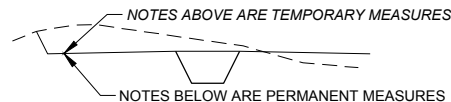
PROJECT No.				SCALE		AS SHOWN
DESIGN	BJV	2014-08-11		SHEET		
CADD	BJV	2014-08-11				
CHECK	AGM	2014-08-11				
REVIEW	AQK	2014-08-11				

1730

SUPPORTING TYPICAL DETAILS

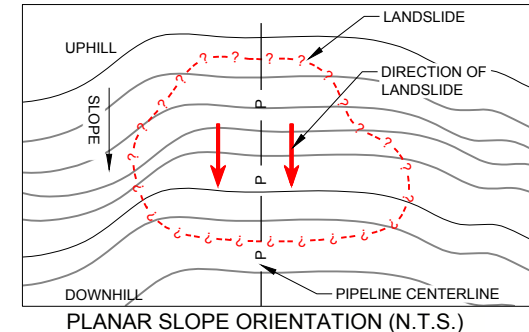
- 1A FRENCH DRAIN (SIMPLE), SEE NOTES 1 AND 5
1B ENHANCED DRAIN (GERMAN DRAIN), SEE NOTE 1
1C TARGETED SEEP DRAINS, SEE NOTES 1 AND 5
1E DRAIN PIPE OUTFALL RIPRAP APRON, SEE NOTE 1
1F ARMORED CHANNEL WITH DRAIN PIPE, SEE NOTE 1
1H STEEP CONVEYANCE CHANNEL, AS NEEDED
1I CHANGED SEEP CHARACTERISTICS, AS NEEDED
1J SINGLE TARGETED SEEP COLLECTOR, SEE NOTE 1 AND 6
1K ENERGY DISSIPATION BASIN, AS NEEDED
2A GRADING TEMPORARY ROW SURFACE, SEE NOTE 1
2C COMPACT BACKFILL, SEE NOTE 1
2D DRY SOILS AND BACKFILL, SEE NOTE 1
2E REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, AS NEEDED
2F ROCK BACKFILL (WITH DRAIN), AS NEEDED
2G GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1
2H GRADING TO MINIMIZE BACKFILL OVER LANDSLIDE, SEE NOTE 1
3A TRACK DISTURBED SLOPES, SEE NOTE 1
3B RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1
3C COIR CLOTH ON DISTURBED SLOPES, SEE NOTE 1
3D ROCK ARMORING ON DISTURBED SLOPES, AS NEEDED
3E COIR LOGS ON DISTURBED SLOPES, AS NEEDED
4A TRENCH BREAKERS (FOAM AND SANDBAGS), SEE NOTE 6
4B TRENCH DAMS (FOAM BAGS OR FINE GRAINED SOILS), AS NEEDED
4C SACK-CRETE BREAKERS (STRUCTURAL BREAKER), SEE NOTE 1
4D SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER, SEE NOTE 1
4F TRENCH BREAKER WITH DRAINAGE, SEE NOTE 6
4G SACK-CRETE ARMOR WITH BREAKERS, AS NEEDED
5A SLOPE BREAKERS (TEMP AND PERMANENT), SEE NOTE 1
5B SLOPE BREAKER ARMORED OUTLET, SEE NOTE 1
5C SLOPE BREAKERS WITH DIVERSION CHANNELS, SEE NOTE 1
5D ACCESS ROADS, SEE NOTE 1
5E TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED
5F SACK-CRETE WEDGE, AS NEEDED
6D ARMORED CHANNEL, AS NEEDED
10A BENCHES RE-CONSTRUCTION THROUGH NATURAL STEPS, SEE NOTE 1
11A GEODETIC MONITORING, SEE NOTE 7
11B STRAIN GAUGE MONITORING, SEE NOTE 7
11C SLOPE INCLINOMETER MONITORING, SEE NOTE 7
11D SLOPE INCLINOMETER CASING, SEE NOTE 7
11E STANDPIPE PIEZOMETER MONITORING, SEE NOTE 7
12A STRESS RELIEF EXCAVATIONS, SEE NOTE 1
12B SELECT (DEFORMABLE) TRENCH BACKFILL, SEE NOTE 1
12C SHEAR TRENCH, SEE NOTE 1

LEGEND



NOTES

- 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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- MITIGATION RECOMMENDATIONS MAY CONTAIN THE FOLLOWING IN ADDITION TO OTHER SITE-SPECIFIC RECOMMENDATIONS:
 - IF POSSIBLE, REROUTE THE PIPELINE AROUND LANDSLIDE.
 - IF NOT POSSIBLE, TEST PIT TO DETERMINE EXTENT OF STABLE/UNSTABLE SOILS. IF POSSIBLE INSTALL PIPELINE TRENCH BENEATH THE LANDSLIDE INTO STABLE MATERIALS, PREFERABLY WITH TRENCH INTO BEDROCK.
 - IF PIPE IS NOT IN STABLE GROUND, THEN, INSTALL DEFORMABLE BACKFILL (SAND) WITHIN THE TRENCH AND INSTALL STRAIN GAUGES ON THE PIPE TO MONITOR LONG-TERM STRAIN ACCUMULATION.
 - IF POSSIBLE, HAUL EXCESS BACKFILL MATERIALS OFFSITE OR TO ANOTHER STABLE LOCATION AND MINIMIZE BACKFILL OVER THE TRENCH.
 - PROVIDE ADDITIONAL AND/OR ENHANCED TRENCH DRAINAGE MEASURES IN TRENCH. DISCHARGE POINTS MUST DRAIN AWAY FROM THE LANDSLIDES ONTO STABLE GROUND.
 - SURFACE WATER FLOWS SHOULD BE DIRECTED AWAY FROM LANDSLIDES. INSTALL SLOPE BREAKERS, BROW DITCHES, DIVERSION CHANNELS, DRAINS, ACCESS/ATV ROAD DRAINAGE MEASURES, ETC. AS NEEDED TO DIVERT CONCENTRATED FLOWS OFF THE ROW AND TO NOT POND OR SATURATE SOILS AT LANDSLIDES.
 - VERIFY BACKFILL MATERIALS ARE SUITABLE AND COMPACTED AT OPTIMUM MOISTURE CONTENT. ADD WATER OR DRY FILL MATERIALS AS NECESSARY AND, IF NECESSARY, ADD LIME-KILN DUST OR CEMENT-KILN DUST. REPLACE BACKFILL MATERIALS WITH FREE-DRAINING ROCKFILL IF LOCAL SOILS ARE NOT SUITABLE.
 - IF NECESSARY, INSTALL TRENCH BREAKERS OR TRENCH DAMS TO INTERRUPT AND BLOCK SEEPAGE FLOWS ALONG THE TRENCH THAT MAY ENTER THE LANDSLIDE AREAS.
 - IF NECESSARY, INSTALL SHEAR TRENCH AT ROW BOUNDARY.
 - INSTALL GEODETIC MONITORING POINTS (SURVEY BENCHMARKS) AND/OR STAKES.
- INSTALL DRAINS AT IDENTIFIED SEEPS AND SOURCES OF WATER.
- TRENCH BREAKERS OR TRENCH DAMS MAY BE REQUIRED JUST OUTSIDE OF LANDSLIDE LIMITS, AT TRANSITIONS, AND WITHIN LANDSLIDES AS NEEDED BASED ON SITE-SPECIFIC RECOMMENDATIONS.
- TO-BE-DETERMINED BASED ON THE RECOMMENDATIONS FROM A SITE-SPECIFIC STUDY.



 2014-08-11		ISSUED FOR CONSTRUCTION		BJV	BJV	AGM	AQK	
REV	DATE	REVISION DESCRIPTION			DES	CADD	CHK	RWV
NOTES								
PROJECT WILLIAMS OVM								
TITLE TYPICAL ROW RESTORATION SCENARIO LANDSLIDES PLANAR SLOPE WITH UNSTABLE TRENCH								
				PROJECT No.				
				DESIGN	BJV	2014-08-11	SCALE	AS SHOWN
				CADD	BJV	2014-08-11	SHEET	
				CHECK	AGM	2014-08-11	1740	
				REVIEW	AQK	2014-08-11		



APPENDIX A-2
Typical Details (42 Sheets)

WILLIAMS OHIO VALLEY MIDSTREAM (OVM)

TYPICAL DETAILS

SHEET NO.	TITLE	REV.	DATE
0	COVER SHEET	1	2014-08-07
1A	FRENCH DRAIN (SIMPLE)	0	2014-02-28
1B	ENHANCED DRAIN (GERMAN DRAIN)	0	2014-02-28
1C	TARGETED SEEP DRAINS	1	2014-05-30
1D	BLEEDER DRAIN	0	2014-02-28
1E	DRAIN PIPE OUTFALL RIPRAP APRON	0	2014-02-28
1F	ARMORED CHANNEL WITH DRAIN PIPE	1	2014-05-30
1H	STEEP CONVEYANCE CHANNEL	0	2014-05-30
2A	GRADING TEMPORARY ROW SURFACE	1	2014-05-30
2B	GRADING TRENCH WITH OUTBOARD WEDGE	0	2014-02-28
2C	COMPACT BACKFILL	0	2014-02-28
2D	DRY SOILS AND BACKFILL	0	2014-02-28
2E	REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL	0	2014-02-28
2F	ROCK BACKFILL (WITH DRAIN)	1	2014-05-30
2G	GRADING TO MATCH EXISTING CONTOURS	0	2014-02-28
2H	GRADING TO MINIMIZE BACKFILL OVER LANDSLIDE	0	2014-02-28
3A	TRACK DISTURBED SLOPES	0	2014-02-28
3B	RE-VEGETATE DISTURBED SLOPES	0	2014-02-28
3C	COIR CLOTH ON DISTRUBED SLOPES	0	2014-02-28
3D	ROCK ARMORING ON DISTRUBED SLOPES	0	2014-02-28
4A	TRENCH BREAKERS (FOAM AND SANDBAGS)	0	2014-02-28
4B	TRENCH DAMS (FOAM, BAGS, OR FINE GRAINED SOILS)	0	2014-02-28
4C	SACK-CRETE BREAKERS (STRUCTURAL BREAKER)	1	2014-05-30
4D	SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER	1	2014-05-30
5A	SLOPE BREAKERS (TEMP AND PERMANENT)	0	2014-02-28
5B	SLOPE BREAKER ARMORED OUTLET	0	2014-02-28
5C	SLOPE BREAKERS WITH DIVERSION CHANNELS	0	2014-02-28
5D	ACCESS ROADS	0	2014-02-28
6B	BROW DITCH	0	2014-02-28
6D	ARMORED CHANNEL	0	2014-02-28
8A	ROCK GUARD ON PIPELINE	0	2014-02-28
10A	BENCH RE-CONSTRUCTION THROUGH NATURAL STEPS	0	2014-02-28
11A	GEODETIC MONITORING	0	2014-02-28
11B	STRAIN GAUGE MONITORING	0	2014-02-28
11C	SLOPE INCLINOMETER MONITORING	0	2014-02-28
11D	SLOPE INCLINOMETER CASING	0	2014-02-28

CLIENT
WILLIAMS OVM

CONSULTANT



YYYY-MM-DD	2014-08-07
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TYPICAL DETAILS

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PROJECT

TYPICAL DETAILS

TITLE
COVER SHEET

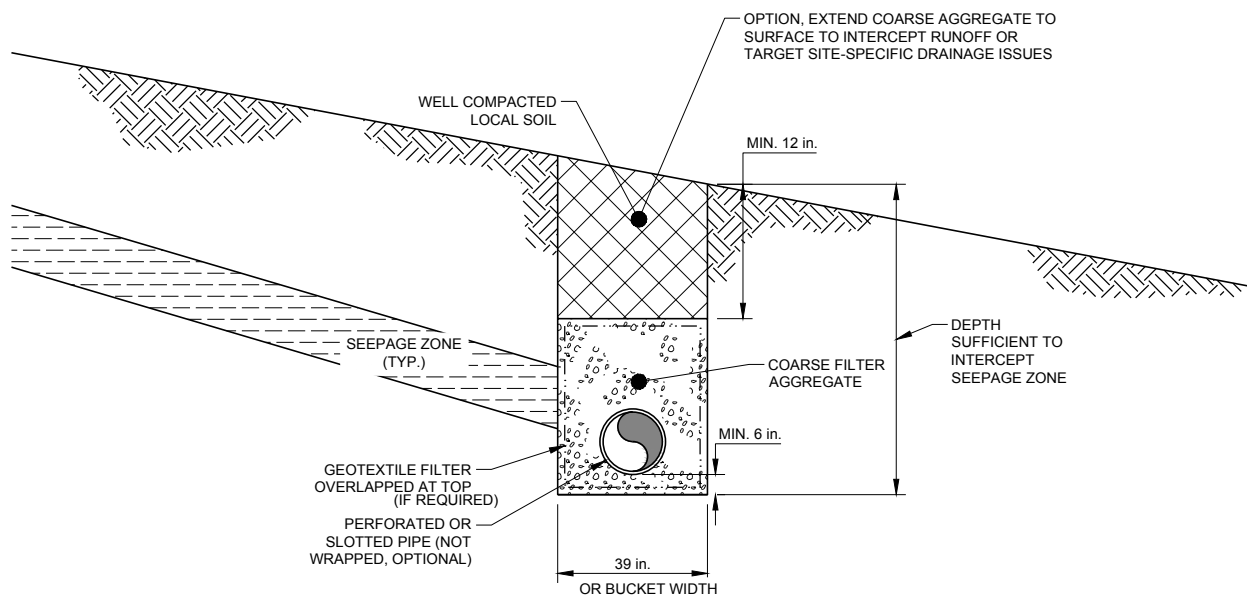
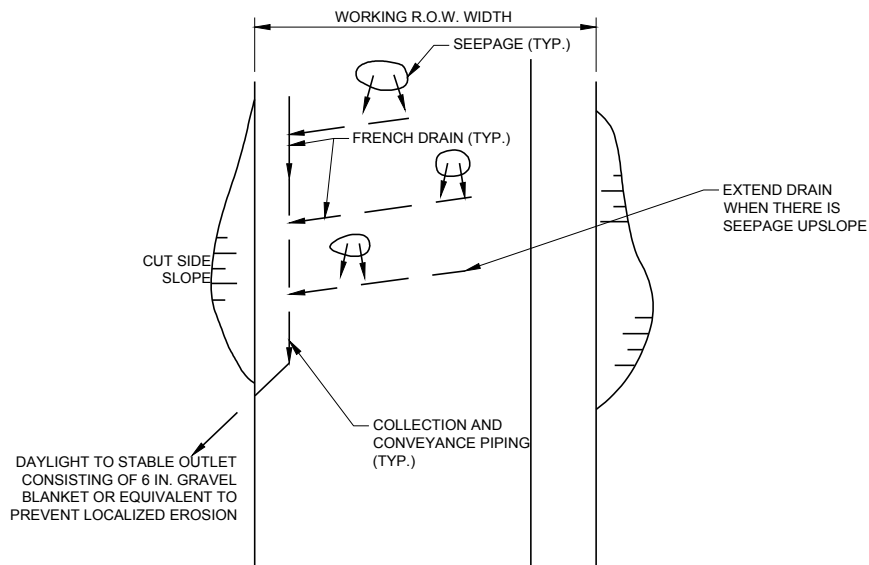
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ISSUED FOR
CONSTRUCTION

Rev.
1

SHEET
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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A



NOTES:

1. 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.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE
FRENCH DRAIN (SIMPLE)

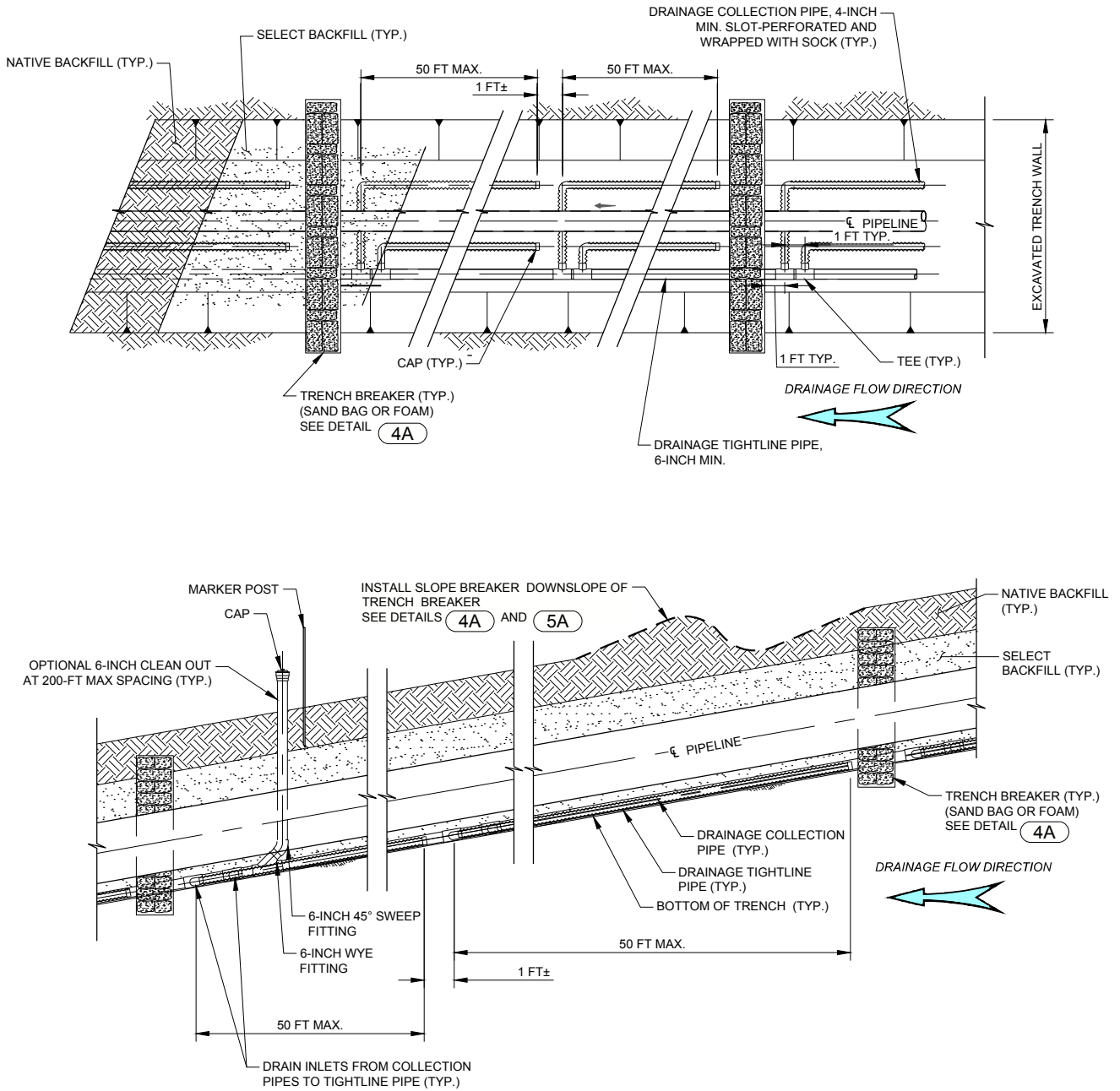
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ISSUED FOR
CONSTRUCTION

Rev.
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CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT

YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK



TITLE
ENHANCED DRAIN (GERMAN DRAIN)

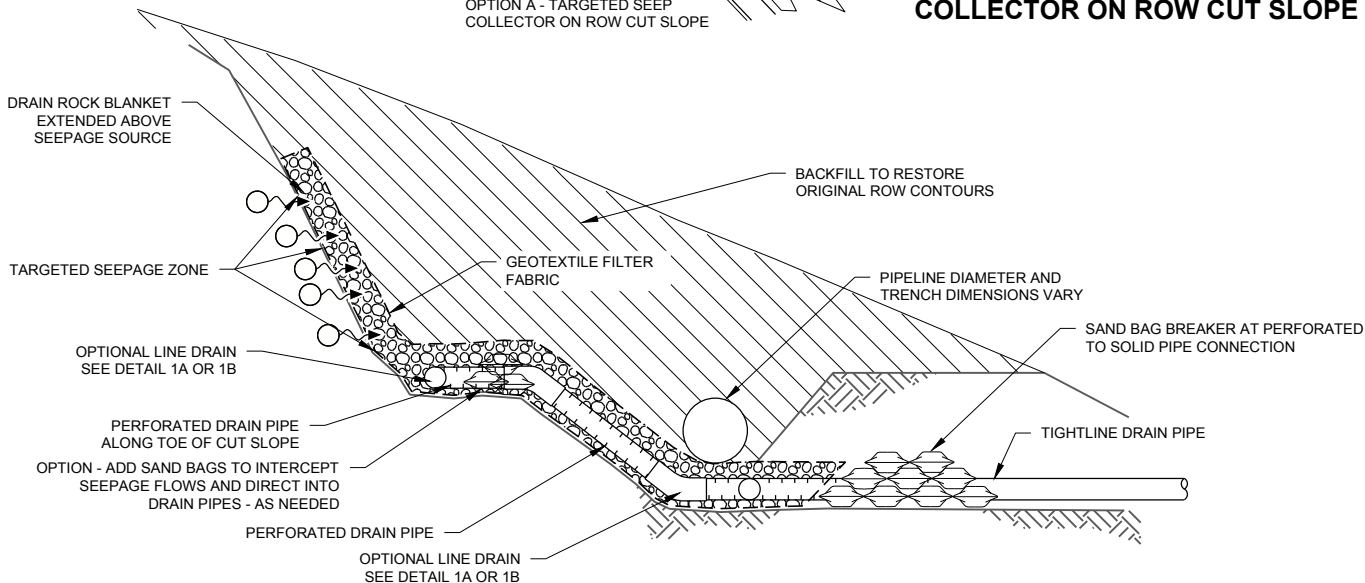
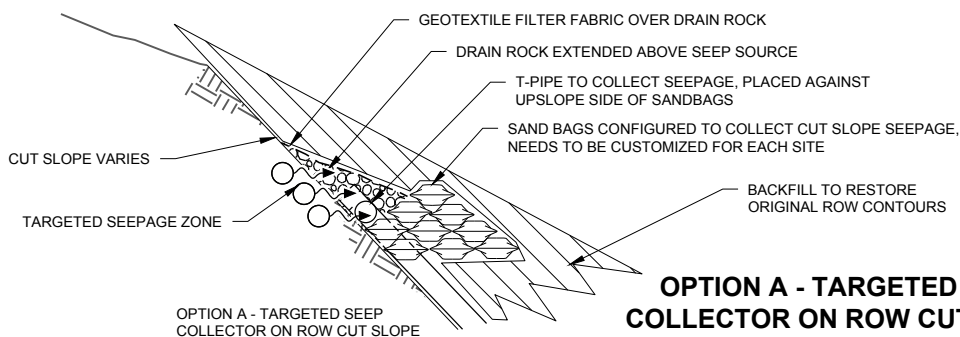
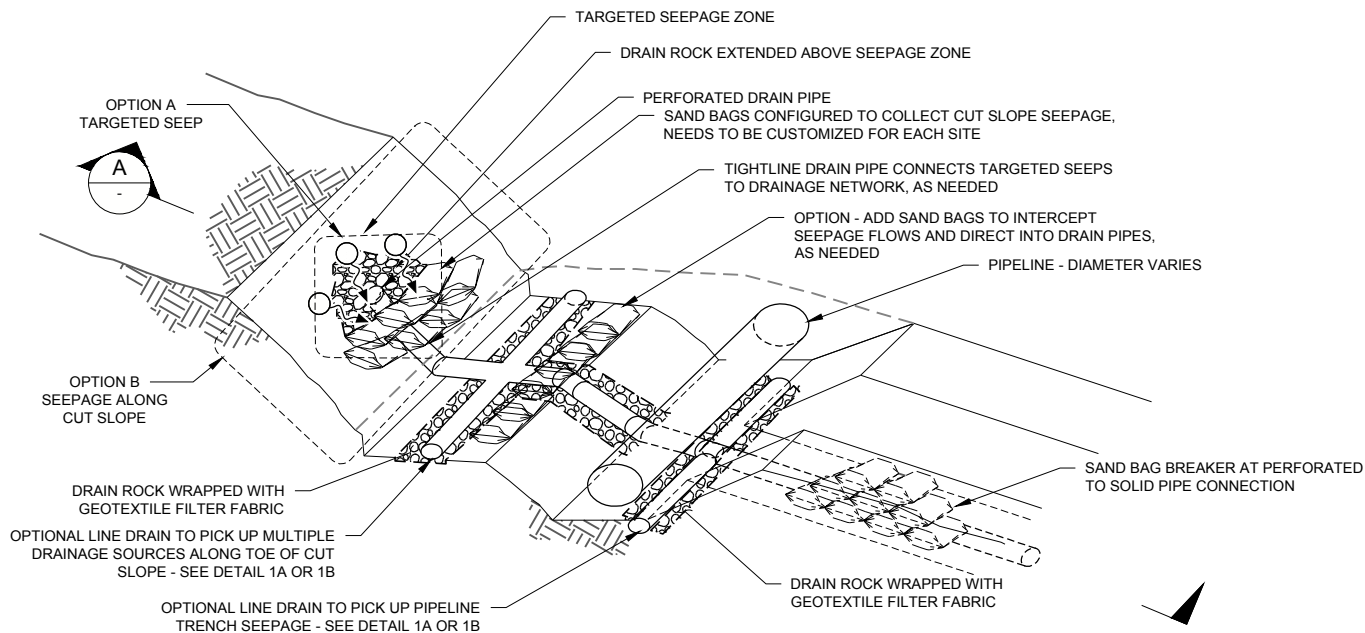
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ISSUED FOR
CONSTRUCTION

Rev. 0

SHEET
1B

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OPTION B - TARGETED SEEP COLLECTOR ON ROW CUT SLOPE

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT

YYYY-MM-DD 2014-05-30

TITLE

TARGETED SEEP DRAINS



PREPARED ACF

DESIGN BJV

REVIEW AGM

APPROVED AQK

PROJECT No.

ISSUED FOR
CONSTRUCTION

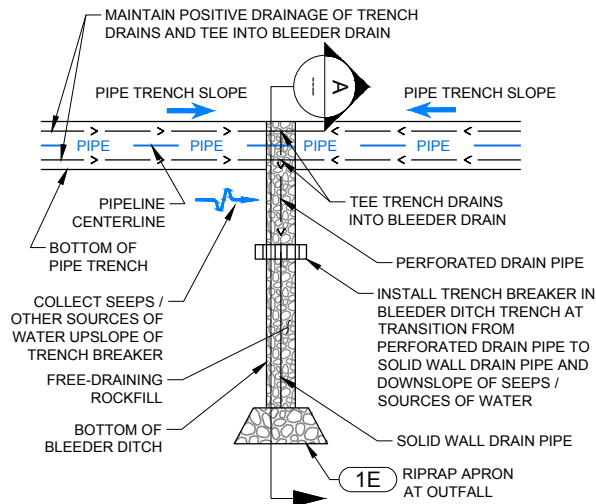
Rev.

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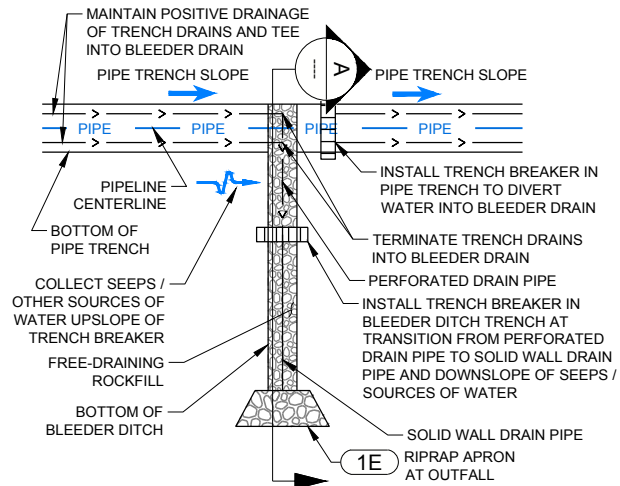
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1C

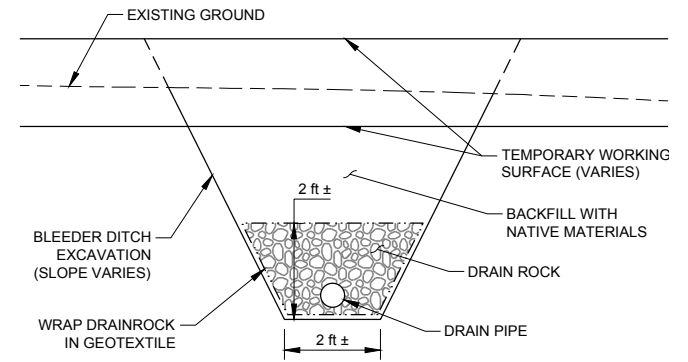
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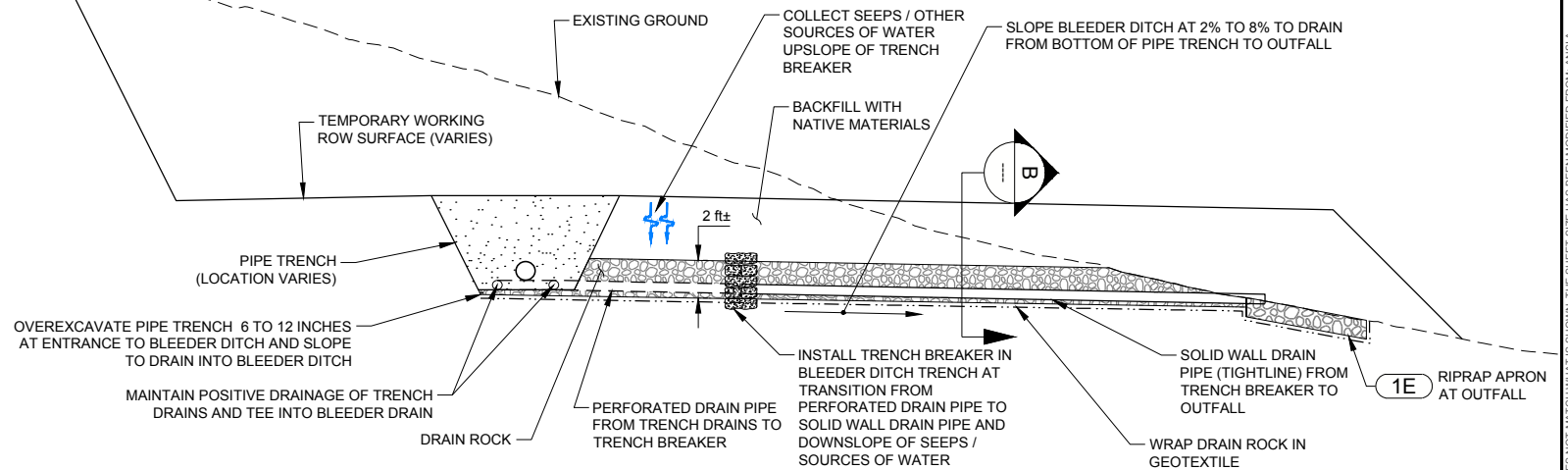
BLEEDER DRAIN WITH FLAT PIPE TRENCH



BLEEDER DRAIN WITH SLOPED PIPE TRENCH



B BLEEDER DRAIN DITCH SECTION



A BLEEDER DRAIN PROFILE

NOTES:

1. 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.
2. 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.
3. NATIVE MATERIALS MAY BE USED DOWNSLOPE OF BLEEDER DITCH TRENCH BREAKER 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.
4. LENGTH OF BLEEDER DRAIN WILL VARY AS NEEDED TO MAINTAIN POSITIVE DRAINAGE IN DITCH TO OUTFALL.

CLIENT
WILLIAMS OVM

CONSULTANT



PROJECT
TYPICAL DETAILS

YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

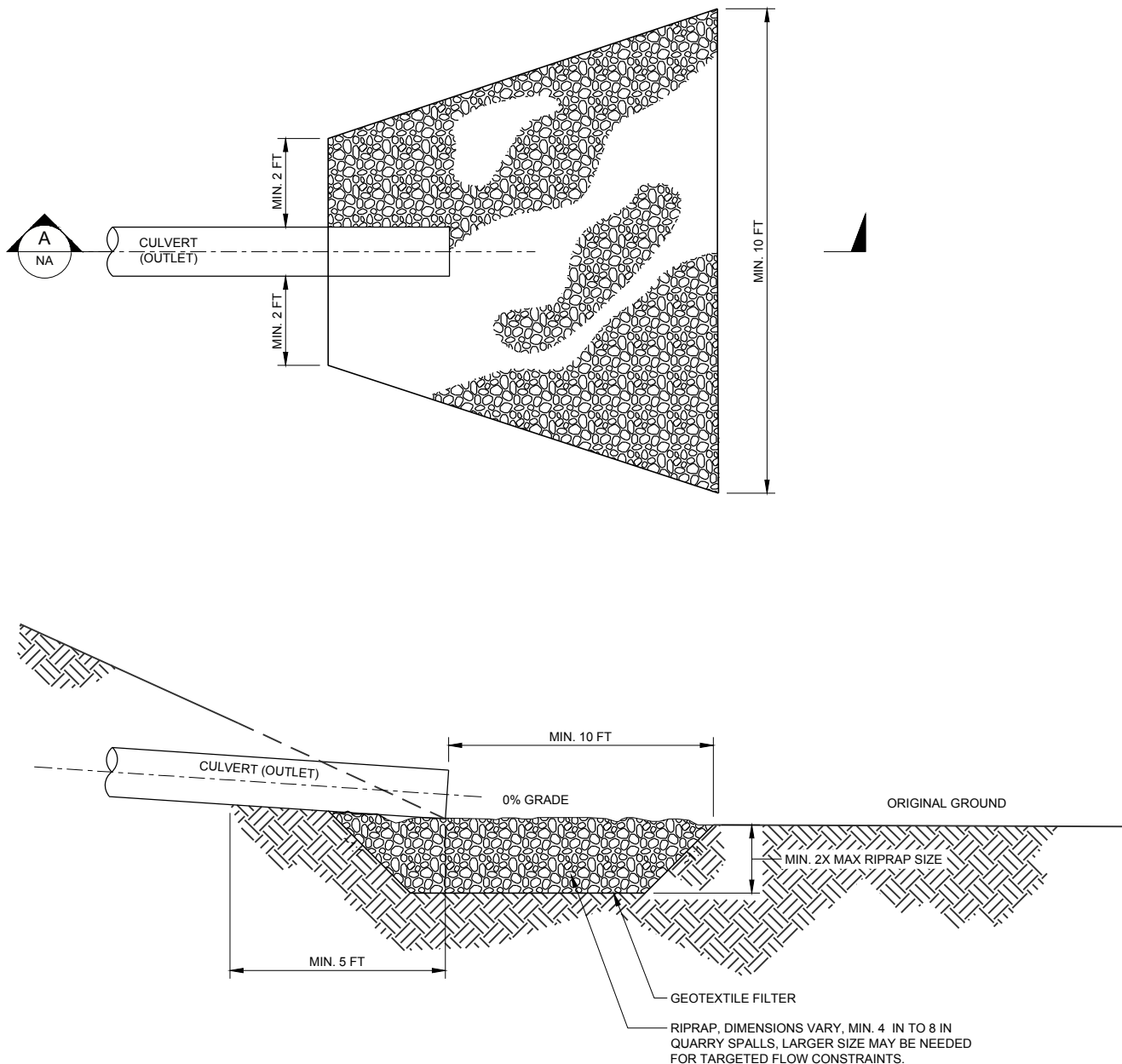
TITLE
BLEEDER DRAIN

PROJECT No.

ISSUED FOR
CONSTRUCTION

Rev.
0

SHEET
1D



NOTES

1. 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.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

DRAIN PIPE OUTFALL RIPRAP APRON

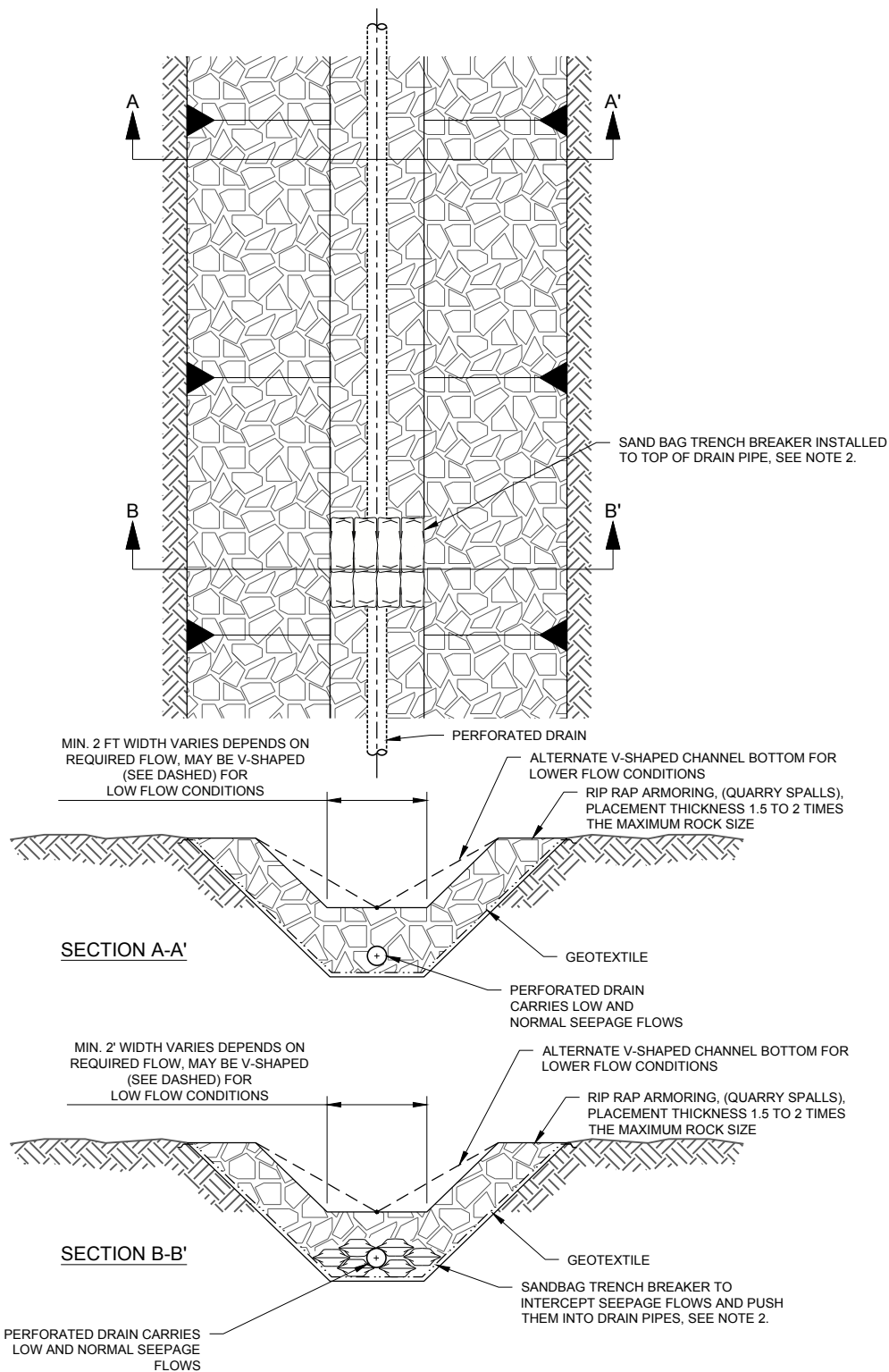
PROJECT No.

ISSUED FOR
CONSTRUCTION

Rev.
0

SHEET
1E

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



NOTES:

1. 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.
2. 100-FT MAX SPACING FOR BREAKERS.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-05-30

PREPARED ACF

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

ARMORED CHANNEL WITH DRAIN PIPE

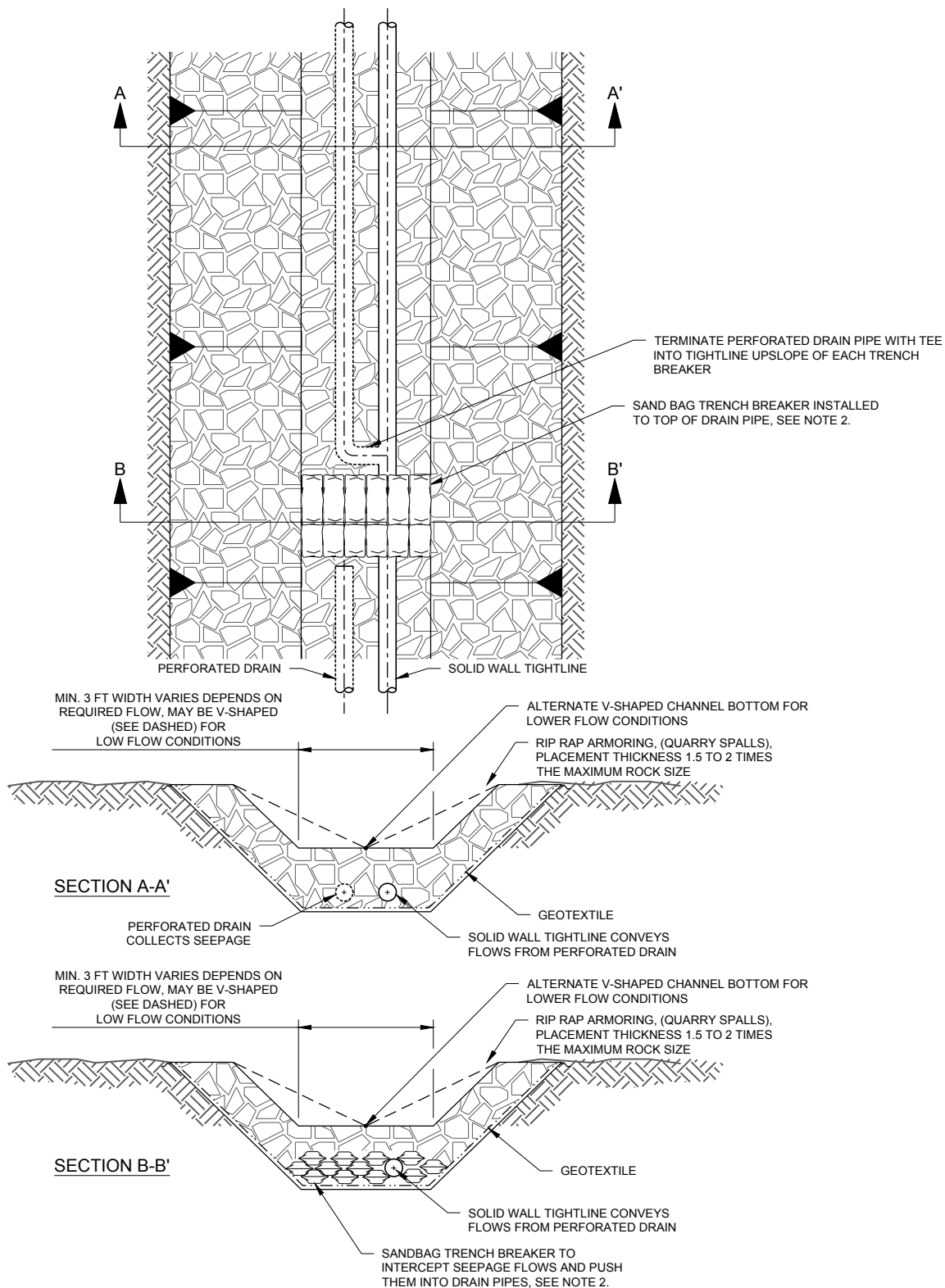
PROJECT No.

ISSUED FOR
CONSTRUCTION

Rev.
1

SHEET
1F

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
11in



NOTES:

1. 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.
2. 100-FT MAX SPACING FOR BREAKERS.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-05-30

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

STEEP CONVEYANCE CHANNEL

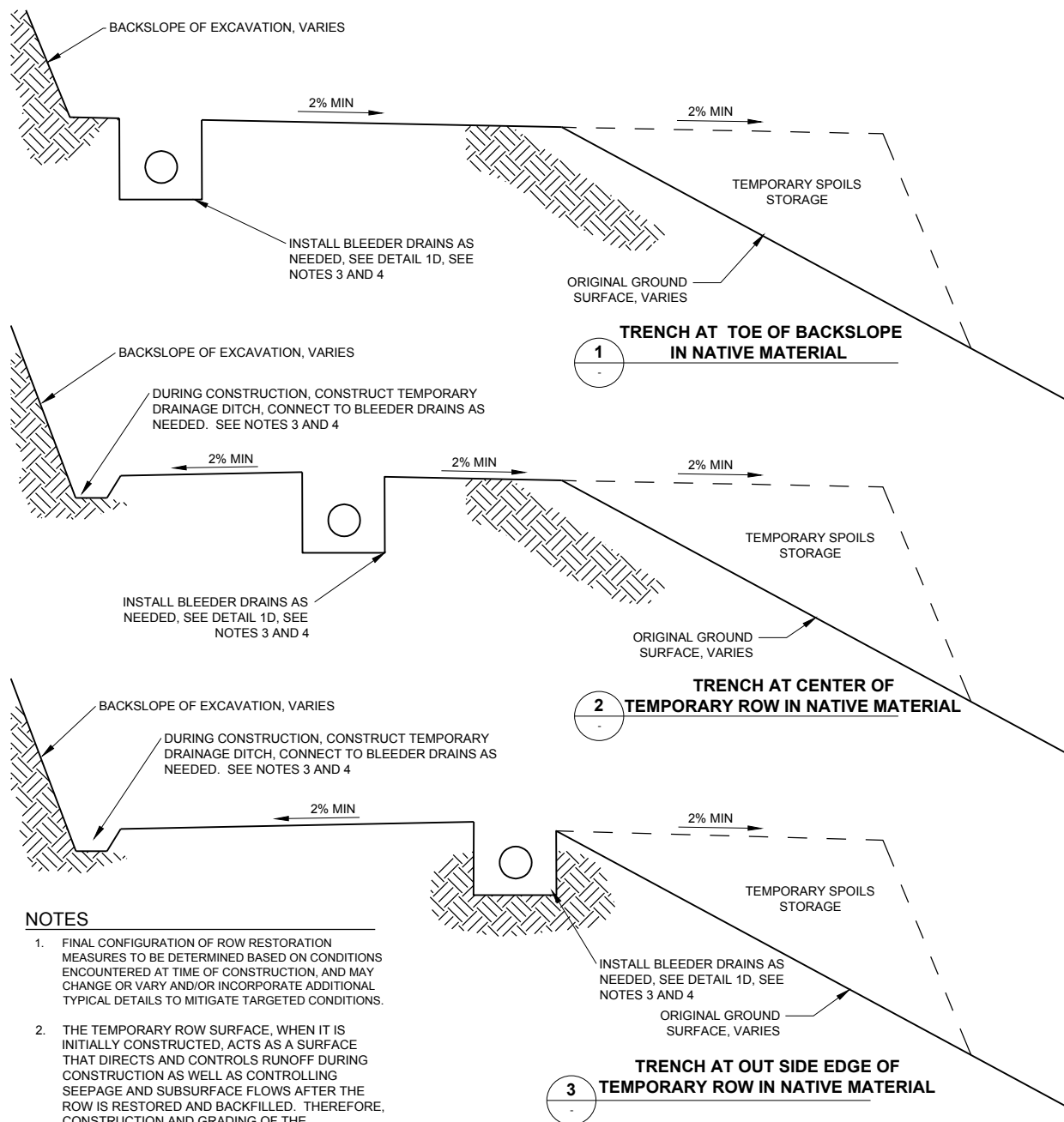
PROJECT No.

ISSUED FOR
CONSTRUCTION

Rev.
0

SHEET
1H

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



NOTES

1. 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.
2. THE TEMPORARY ROW SURFACE, WHEN IT IS INITIALLY CONSTRUCTED, ACTS AS A SURFACE THAT DIRECTS AND CONTROLS RUNOFF DURING CONSTRUCTION AS WELL AS CONTROLLING SEEPAGE AND SUBSURFACE FLOWS AFTER THE ROW IS RESTORED AND BACKFILLED. THEREFORE, CONSTRUCTION AND GRADING OF THE TEMPORARY ROW SURFACE SHOULD BE COMPLETED TO SO AS TO MAINTAIN POSITIVE DRAINAGE (I.E. APPROXIMATELY 2% SLOPE) AWAY FROM THE PIPELINE TRENCH, AND TO OUTBOARD SIDES OF THE ROW THAT DISCHARGE ONTO NATURAL SLOPES DIRECTED AWAY FROM THE ROW, SO THAT RUNOFF ON THE TEMPORARY ROW SURFACE DOES NOT ACCUMULATE OR POND.
3. FOR TEMPORARY CONSTRUCTION WORK PERIOD, WHERE THE TEMPORARY ROW SURFACE MUST SLOPE TO AN INSIDE AREA, WHERE ACCUMULATED RUNOFF CAN POND, THEN DRAINAGE MEASURES SHOULD BE IMPLEMENTED THAT COLLECT AND EVACUATE THE PONDED WATER DURING TEMPORARY CONSTRUCTION PERIODS AND FOR PERMANENT RESTORATION.
4. FOR PERMANENT RESTORATION, CONVERT TEMPORARY DRAINAGE DITCH TO FRENCH DRAINS AND/OR TARGETED SEEP COLLECTORS, AS NEEDED. SEE DETAILS 1A, 1C, 1D AND 1E.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT

YYYY-MM-DD 2014-05-30

PREPARED ACF

DESIGN BJV

REVIEW AGM

APPROVED AQK



TITLE

GRADING TEMPORARY ROW SURFACE

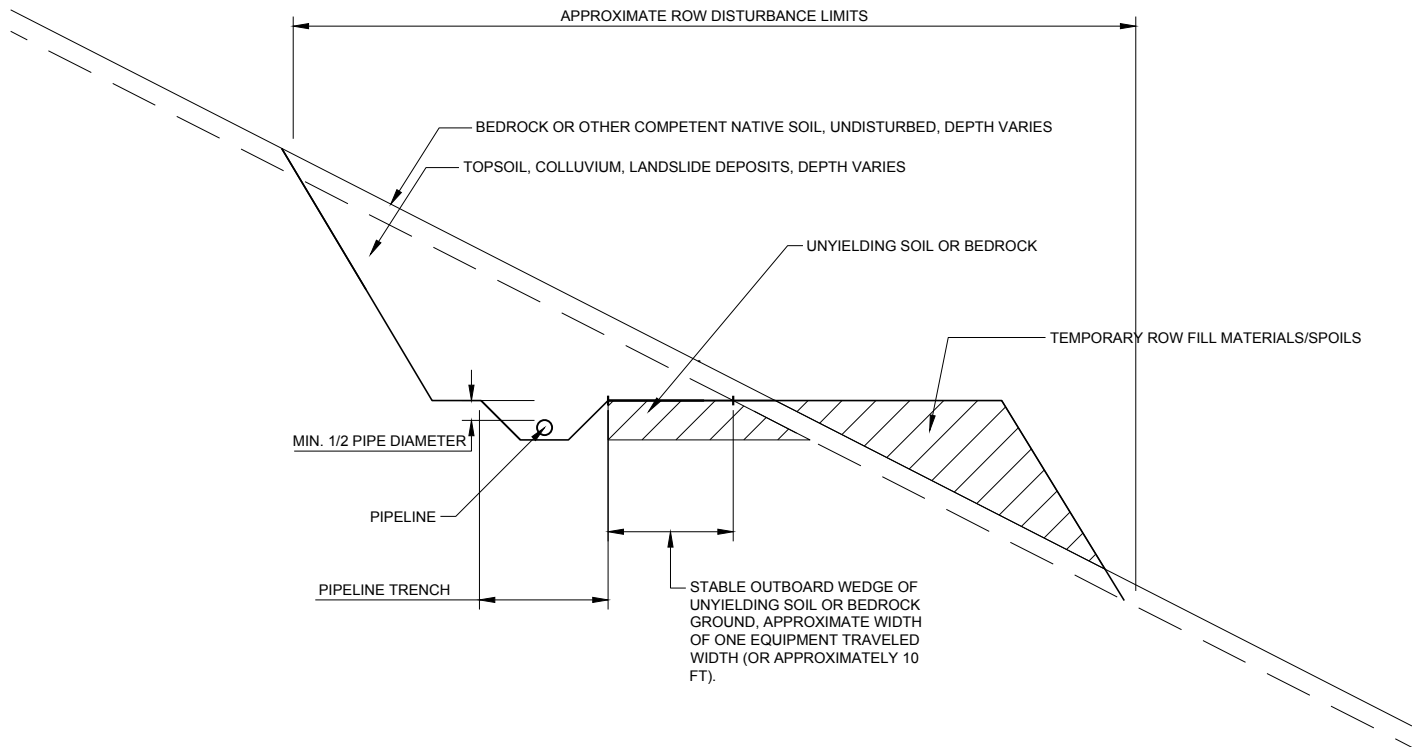
PROJECT No.

ISSUED FOR
CONSTRUCTION

Rev.
1

SHEET
2A

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



NOTE

BASED ON INFORMATION FROM WILLIAMS

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.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

GRADING TRENCH WITH STABLE OUTBOARD WEDGE

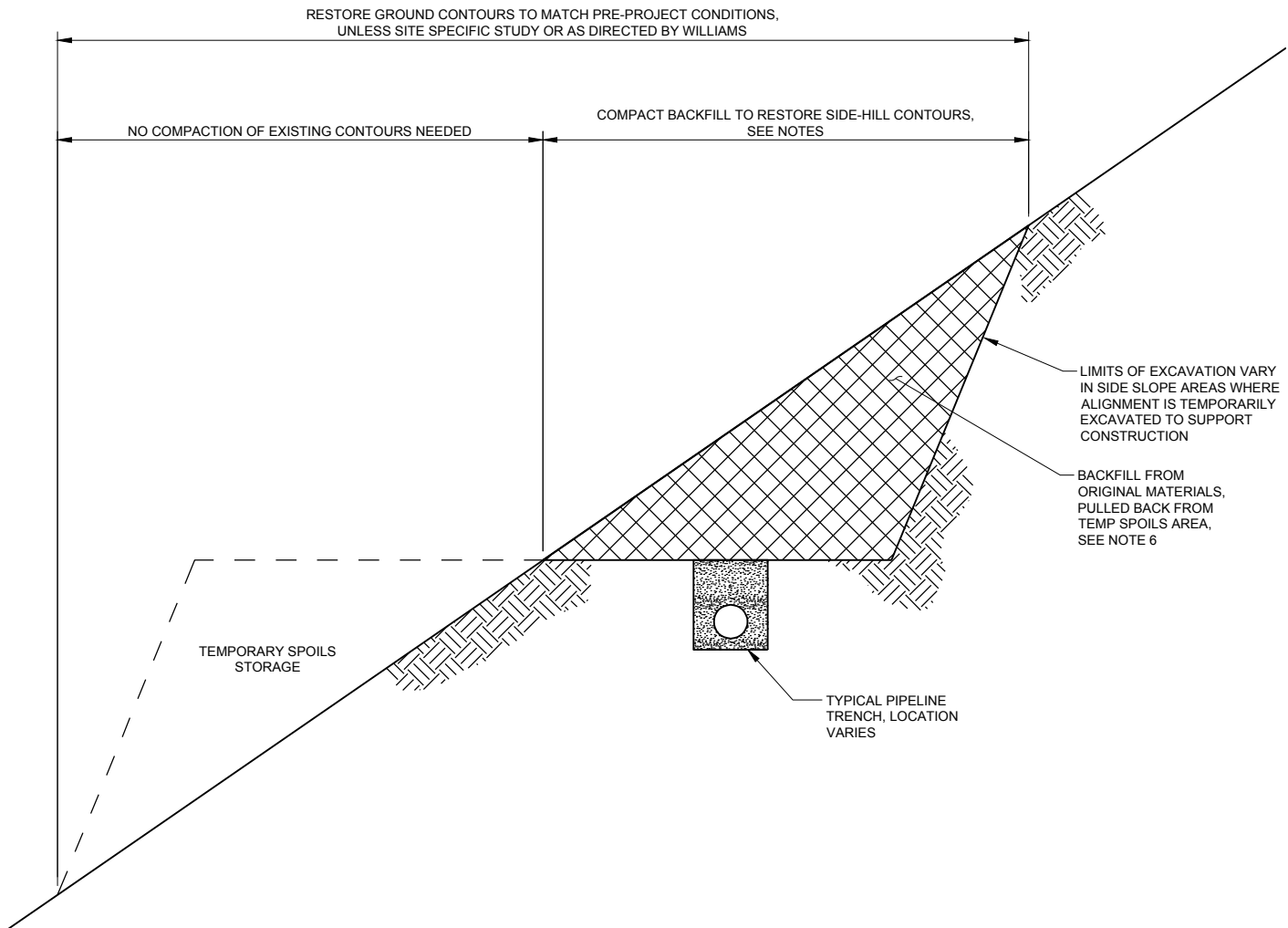
PROJECT No.

ISSUED FOR
CONSTRUCTION

Rev.
0

SHEET
2B

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



NOTES:

1. 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.
2. RECOMMEND COMPACTING SIDE SLOPE AREAS USING "SHEEP'S FOOT" COMPACTION EQUIPMENT IN HORIZONTAL LAYERS.
3. BACKFILL MATERIALS SHOULD BE AT OR NEAR OPTIMUM MOISTURE CONTENT (DRYING SOILS OR ADDING WATER AS NECESSARY), VISUALLY DETERMINED BY A COMPETENT ON-SITE REPRESENTATIVE. SEE TYPICAL DETAIL 2D FOR DRYING BACKFILL.
4. SOILS COMPACTION SHOULD BE COMPLETED IN LIFTS SUCH THAT BACKFILL MATERIALS ARE STABLE, SHED WATER AND DO NOT EASILY BECOME SATURATED, AND ARE AT APPROXIMATELY THE MAXIMUM DRY DENSITY, VISUALLY DETERMINED BY A COMPETENT ON-SITE REPRESENTATIVE.
5. ADDITIONAL COMPACTION REQUIREMENTS MAY APPLY AT ROAD CROSSINGS, AREAS IDENTIFIED BY WILLIAMS, OR AT OTHER LOCATIONS AS MAY BE REQUIRED BY LAWS AND REGULATIONS. SEE TYPICAL DETAIL 2I FOR COMPACTION REQUIREMENTS ACROSS ROADS.
6. BACKFILL CONFIGURATION MAY VARY TO FIT SITE CONDITIONS, AND MAY BE USED IN OTHER ROW CROSS-SECTION BACKFILL GEOMETRIES, AS DIRECTED BY WILLIAMS.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE
COMPACT BACKFILL

PROJECT No.

ISSUED FOR
CONSTRUCTION

Rev.
0

SHEET
2C

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

1 in

NOTES

1. 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.
2. SATURATED ON-SITE SOILS MAY NEED TO BE DRIED BEFORE RE-USE AND PLACEMENT AS BACKFILL. DRYING MAY INCLUDE WIND-ROWING AND TURNING OVER IN FURROWS TO ALLOW FOR AIR EXCHANGE AND EVAPORATION TO DRY THE MATERIALS, OR ADDITION OF ADD-MIXTURES TO DRY THE SOILS.
3. THE USE OF ADD-MIXTURES TO SATURATED SOILS SHOULD BE REVIEWED AND APPROVED BY WILLIAMS PRIOR TO USE.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

DRY SOILS AND BACKFILL

PROJECT No.

ISSUED FOR
CONSTRUCTION

Rev.
0

SHEET
2D

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

1in

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NOTES

1. 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.
2. WHERE THE PLACEMENT OF SPOILS ON THE SITE MAY INITIATE OR EXACERBATE LANDSLIDES OR RESULT IN SLOPE INSTABILITY, THE MATERIALS SHOULD BE REMOVED FROM THE SITE AND SPOILED AT A SAFE AND OFF-SITE LOCATION.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL

PROJECT No.

ISSUED FOR
CONSTRUCTION

Rev.
0

SHEET
2E

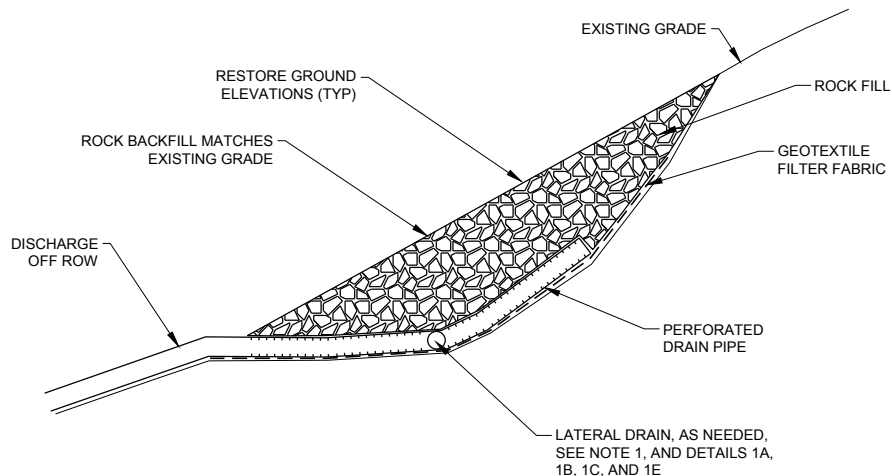
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

1in

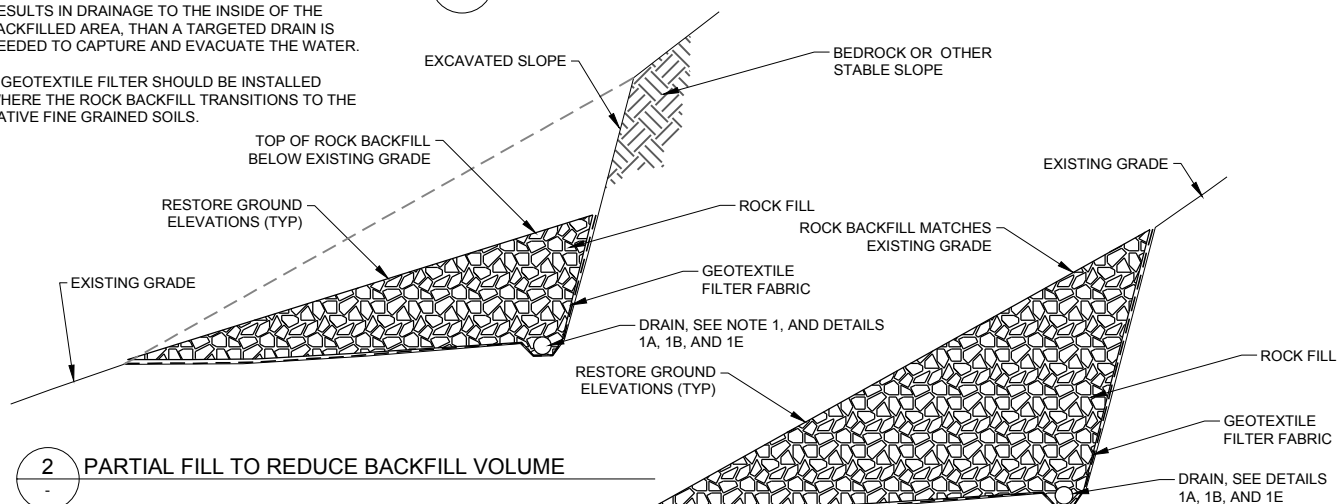
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NOTES

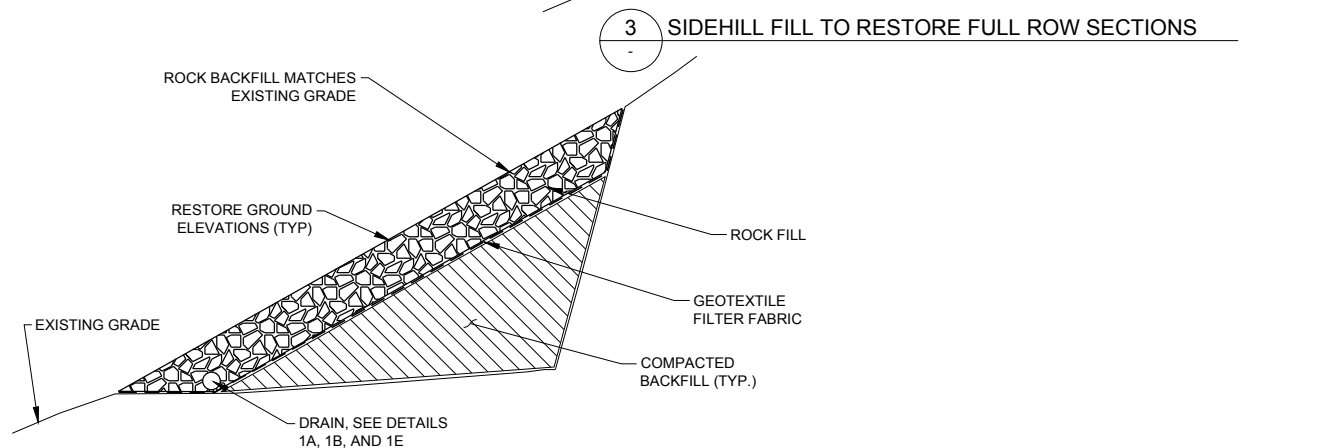
1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. WHERE LOCAL SOILS ARE NOT SUITABLE FOR BACKFILL DUE TO SATURATED CONDITIONS OR OTHER NON-COMPLIANT CONDITIONS (I.E. ORGANICS, DEBRIS, ETC.), AND BACKFILL IS NEEDED TO RESTORE GROUND CONTOURS, THEN USE OF SMALL DIAMETER ANGULAR ROCK FILL IS RECOMMENDED.
3. ROCK BACKFILL SHOULD BE UNIFORMLY GRADED (I.E. GENERALLY THE SAME SIZE), SMALL IN SIZE (APPROXIMATELY 4-8 INCH DIAMETER), AND FREE OF FINES OR OTHER NON-COMPLIANT MATERIALS.
4. INSTALL A DRAIN AT THE INSIDE CATCH OF THE EXCAVATED SLOPE WHERE ROCK FILL IS INSTALLED.
5. GRADE THE BOTTOM OF THE BACKFILLED AREA TO PROVIDE POSITIVE DRAINAGE TO THE OUTBOARD SIDE (I.E. AWAY FROM THE INSIDE CUT BANK) OF THE BACKFILLED AREA. THE INTENT IS TO NOT ACCUMULATE SEEPAGE OR DRAINAGE ON ANY INSIDE EXCAVATED SURFACES. WHERE GRADING RESULTS IN DRAINAGE TO THE INSIDE OF THE BACKFILLED AREA, THEN A TARGETED DRAIN IS NEEDED TO CAPTURE AND EVACUATE THE WATER.
6. A GEOTEXTILE FILTER SHOULD BE INSTALLED WHERE THE ROCK BACKFILL TRANSITIONS TO THE NATIVE FINE GRAINED SOILS.



1 RESTORE SLUMP OR SMALL SLIPS



2 PARTIAL FILL TO REDUCE BACKFILL VOLUME



3 SIDEHILL FILL TO RESTORE FULL ROW SECTIONS



4 SLIVER FILL TO PROVIDE ARMOR ON BACKFILL AND/OR RESTORE CONTOURS

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT

YYYY-MM-DD 2014-05-30

PREPARED ACF

DESIGN BJV

REVIEW AGM

APPROVED AQK



TITLE

ROCK BACKFILL (WITH DRAIN)

PROJECT No.

ISSUED FOR
CONSTRUCTION

Rev.
1

SHEET
2F

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

NOTES

1. 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.
2. RESTORATION OF ROW SURFACES SHOULD GENERALLY RE-CONSTRUCT THE GROUND SURFACE TO MATCH THE PRE-PROJECT CONTOURS.
3. CHANGES IN THE FINAL GRADING MAY BE NEEDED TO ADDRESS SPECIFIC TARGETED GEOTECHNICAL OR HYDROTECHNICAL OR GEOLOGIC ENGINEERING ISSUES (I.E. CORRECT DRAINAGE PROBLEMS, MINIMIZE DELIVERY OF WATER TO LANDSLIDE SITES, ETC.).
4. FINAL GRADING TO BE REVIEWED AND APPROVED BY WILLIAMS PRIOR TO COMPLETION.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

GRADING TO MATCH EXISTING CONTOURS

PROJECT No.

ISSUED FOR
CONSTRUCTION

Rev.
0

SHEET
2G

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

1in

NOTES

1. 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.
2. MINIMIZE THE PLACEMENT OF BACKFILL MATERIALS WHEN RESTORING AND RE-CONSTRUCTING LANDSLIDE SITES, IN ORDER TO REDUCE THE IMPOSED LOAD ON LANDSLIDE SITES.
3. MINIMIZE THE PLACEMENT OF SPOILS FROM GRADING WORK IN OTHER AREAS ALONG THE ROW THAT MAY OVERLAP OTHER LANDSLIDES, IN ORDER TO REDUCE THE POTENTIAL FOR INITIATING NEW LANDSLIDES.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

GRADING TO MINIMIZE BACKFILL OVER LANDSLIDE

PROJECT No.

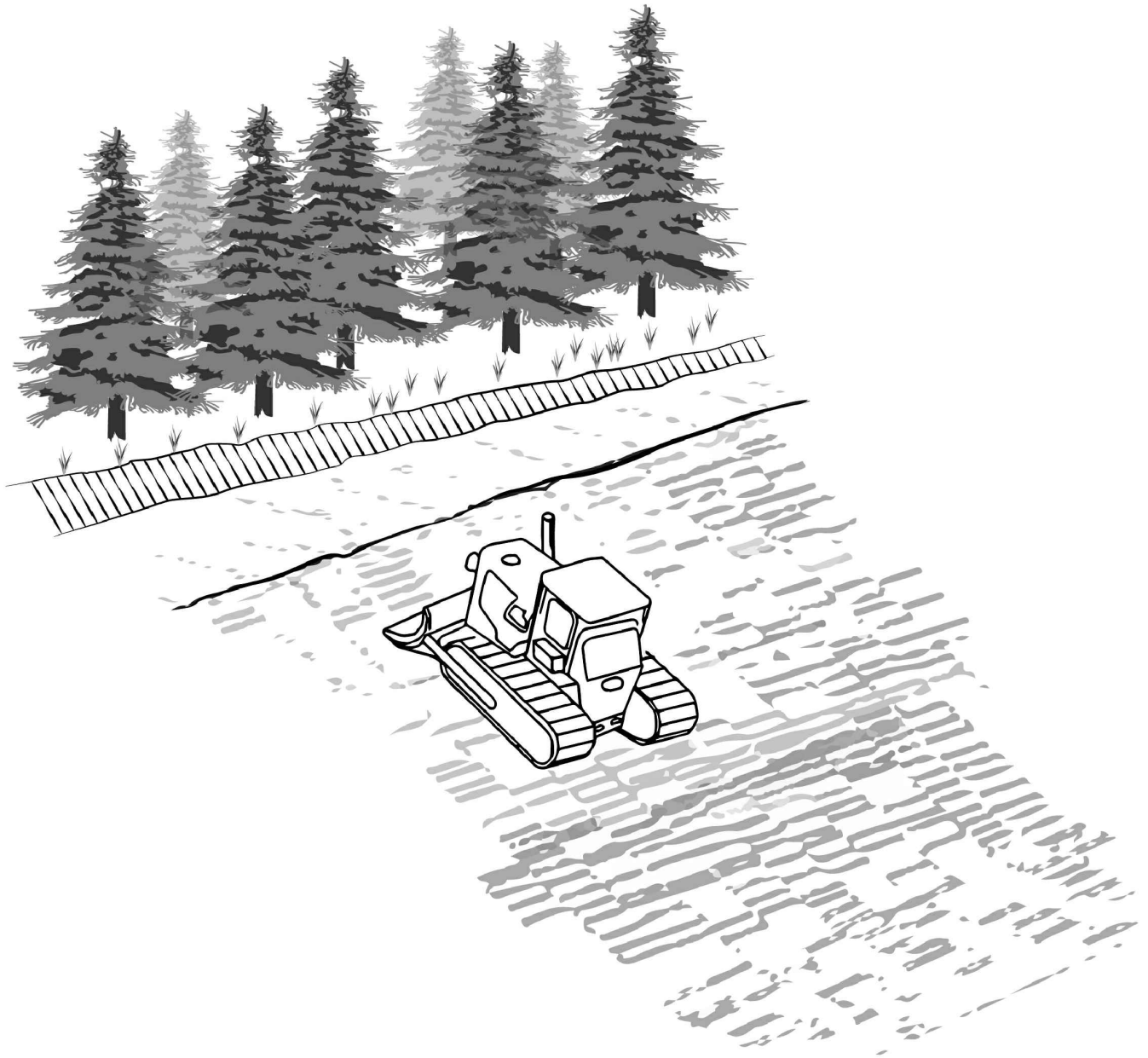
ISSUED FOR
CONSTRUCTION

Rev.
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SHEET
2H

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

1in



NOTES

1. 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.
2. INFORMATION FOR DETAIL PROVIDED BY WILLIAMS.
3. TRACKING SLOPES IS DONE BY RUNNING TRACKED MACHINERY UP AND DOWN THE SLOPE, LEAVING TREAD MARKS PERPENDICULAR TO THE SLOPE.
4. IF A BULLDOZER IS USED, THE BLADE MUST BE UP.
5. CARE SHOULD BE EXERCISED ON SOILS HAVING HIGH CLAY CONTENT TO AVOID OVER COMPACTION.

NOT TO SCALE

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

TRACK DISTURBED SLOPES

PROJECT No.

ISSUED FOR
CONSTRUCTION

Rev.
0

SHEET
3A

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

NOTES

1. 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.
2. RE-VEGETATE DISTURBED SLOPES WITH NATIVE GRASS SEED MIX PER REGULATORY AND PERMIT REQUIREMENTS.
3. FINAL SEED MIX TO BE REVIEWED AND APPROVED BY WILLIAMS PRIOR TO INSTALLATION.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

RE-VEGETATE DISTURBED SLOPES

PROJECT No.

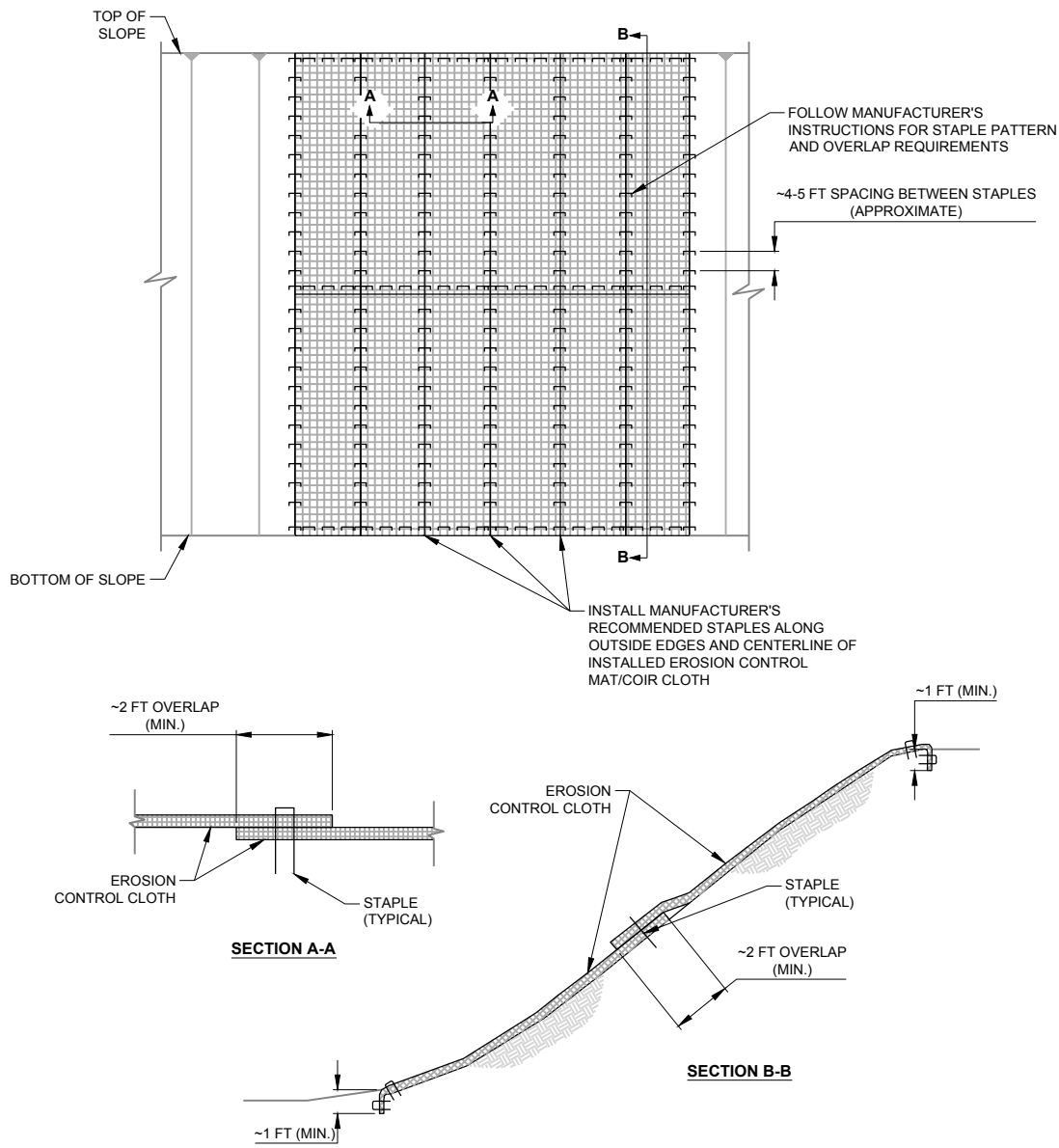
ISSUED FOR
CONSTRUCTION

Rev.
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SHEET
3B

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

1 in



NOTES

1. 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.
2. INSTALL BLANKETS IN ACCORDANCE WITH MANUFACTURER'S INSTRUCTIONS.
3. PREPARE SOIL BEFORE INSTALLING BLANKETS, INCLUDING GRADING REMOVAL OF LARGE ROCKS AND DEBRIS, AND THE APPLICATION OF SEED AND FERTILIZER IF NOT USING PRE-SEEDED BLANKET.
4. EROSION CONTROL BLANKETS SHALL EXTEND COMPLETELY ACROSS DISTURBED AREAS TO PROTECT ERODIBLE SURFACES.
5. BEGIN AT THE TOP OF THE SLOPE BY ANCHORING THE BLANKET IN A MIN. 12- INCH WIDE AND 312-INCH DEEP TRENCH. BACKFILL AND COMPACT THE TRENCH AFTER STAPLING.
6. ROLL THE BLANKETS DOWN THE SLOPE IN THE DIRECTION OF THE WATER FLOW.
7. AS AN ALTERNATIVE TO STAPLES, WOODEN STAKES CAN BE USED IN ACCORDANCE WITH MANUFACTURER'S INSTRUCTIONS.
8. ENSURE COMPLETE CONTACT BETWEEN THE BLANKETS AND THE SLOPE FACE.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE
COIR CLOTH ON DISTRUBED SLOPES

PROJECT No.

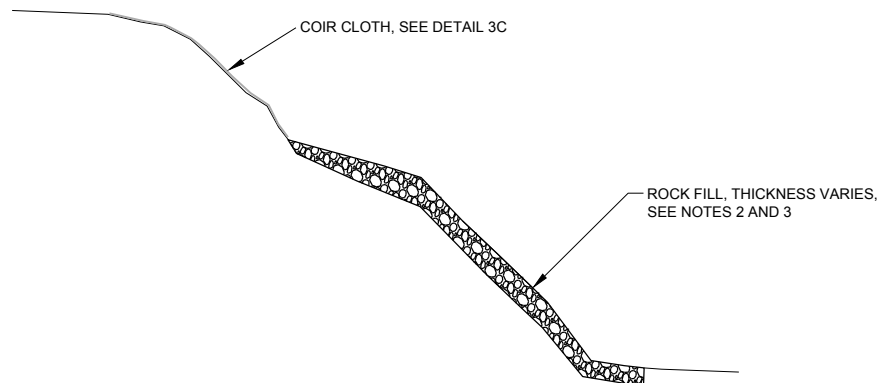
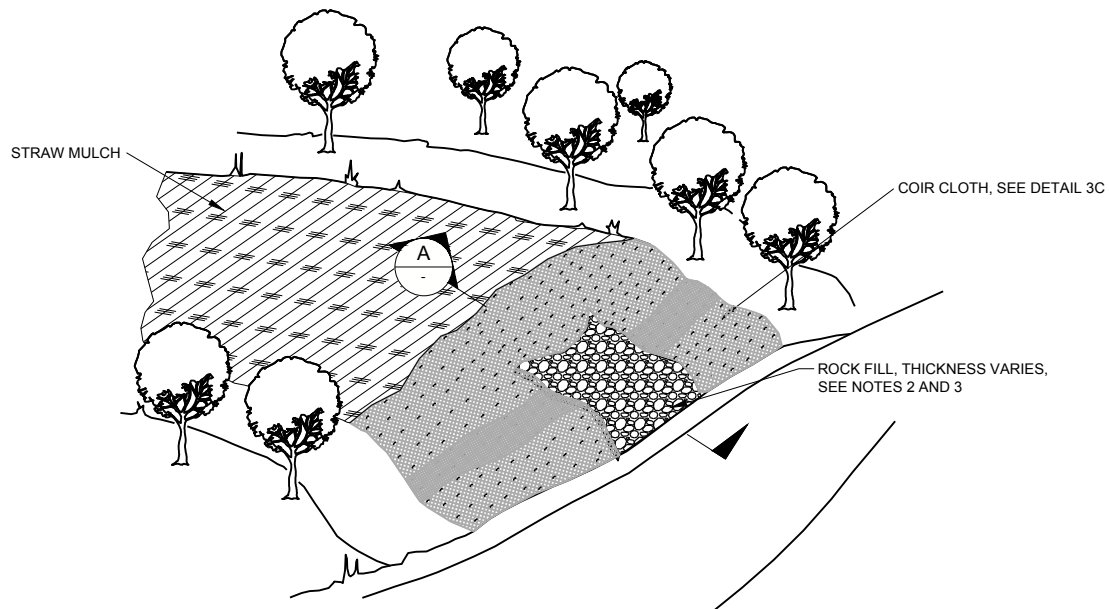
ISSUED FOR
CONSTRUCTION

Rev.
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SHEET
3C

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NOTES



A ROCK ARMORING ON DISTURBED SLOPE

1. 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.
2. USE OF RIPRAP ARMORING ON SLOPES MAY BE REQUIRED FROM GRADES ARE STEEP OR SURFACE RUN-OFF IS PRESENT AND MAY RESULT IN SURFACE EROSION. DO NOT USE GEOTEXTILE FABRIC UNDER RIPRAP.
3. REFER TO 6F FOR RIPRAP MATERIAL GRADATIONS.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

ROCK ARMORING ON DISTURBED SLOPES

PROJECT No.

ISSUED FOR
CONSTRUCTION

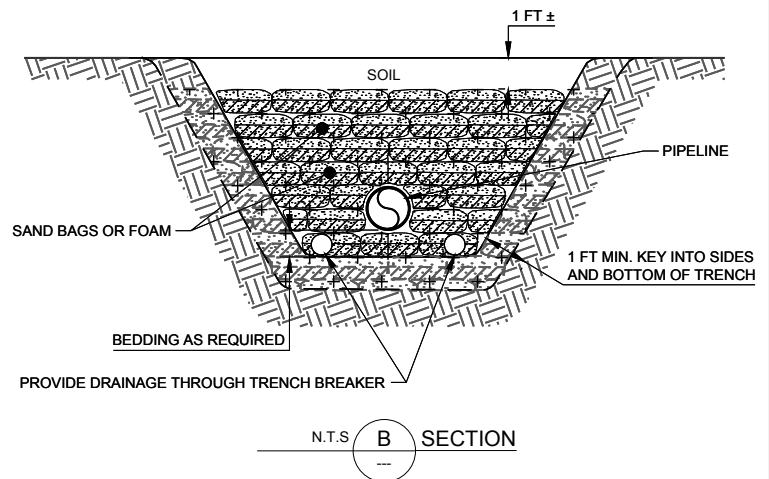
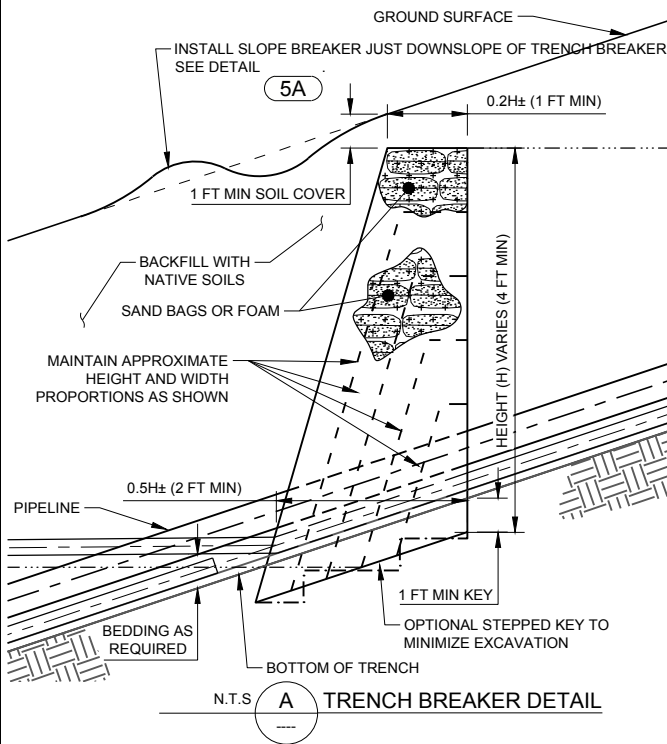
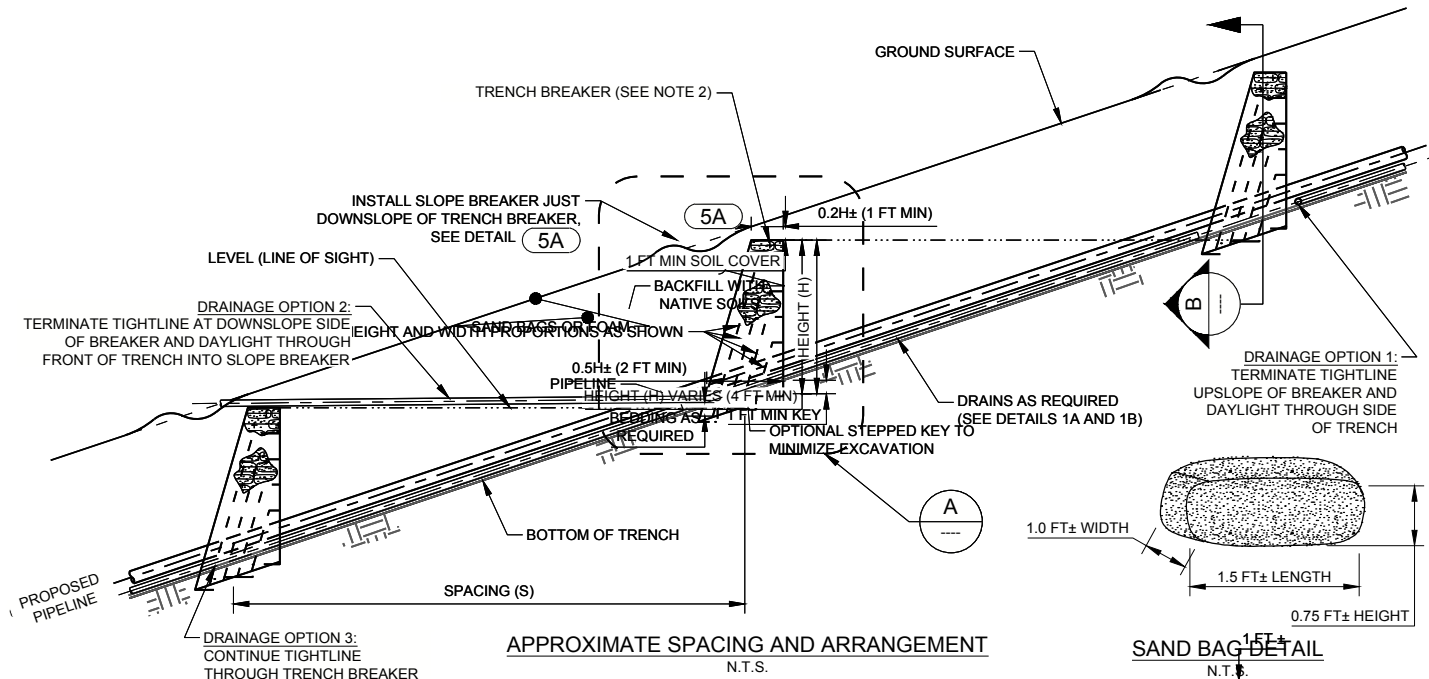
Rev.

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SHEET

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NOTES

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2. THE PURPOSE AND INTENT OF TRENCH BREAKERS IS TO SLOW THE FLOW OF WATER IN THE TRENCH AND TO DIVERT WATER INTO DRAINS AS NECESSARY.
3. TOPSOIL SHALL NOT BE USED TO CONSTRUCT TRENCH PLUGS/BREAKERS.
4. SPACING OF BREAKERS SHALL BE AS SHOWN OR LOCATED AS DIRECTED BY COMPANY REPRESENTATIVE TO MEET FIELD CONDITIONS.
5. AT LOCATIONS WHERE BREAKERS ARE SPECIFIED ON DETAILS, PLANS OR AS DIRECTED BY COMPANY REPRESENTATIVE, SOFT PLUGS (UNEXCAVATED SECTIONS ALONG TRENCH-LINE) MAY BE LEFT IN PLACE TO PERFORM FUNCTION OF PERMANENT BREAKERS PRIOR TO PIPE PLACEMENT.
6. THE TRENCH SHALL BE DEWATERED THROUGH A SEDIMENT TRAP, FILTER BAG, OR DEWATERING STRUCTURE.
7. PERMANENT TRENCH BREAKERS SHALL BE INSTALLED BEFORE THE TRENCH IS BACKFILLED.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT

YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK



TITLE

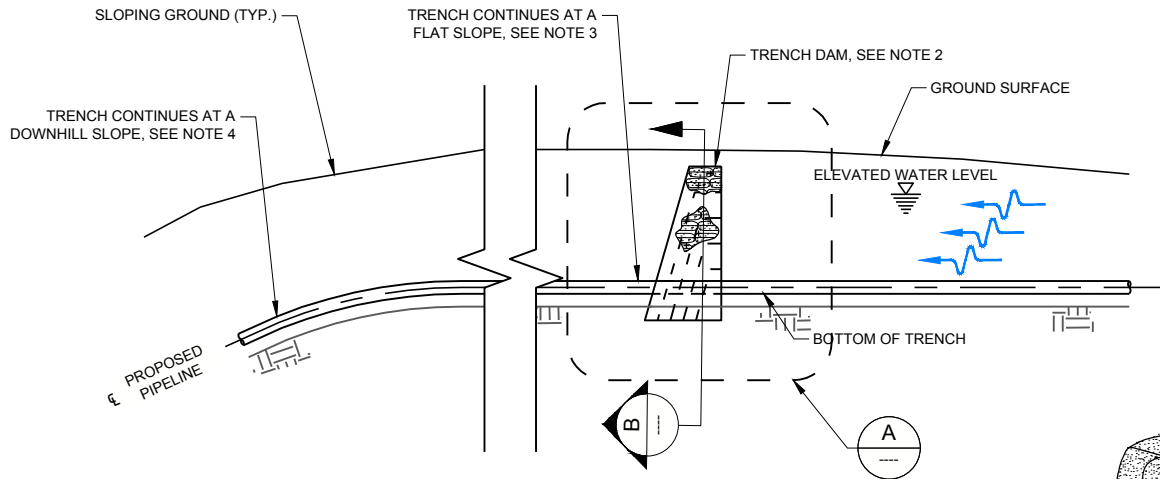
TRENCH BREAKERS (FOAM AND SANDBAGS)

PROJECT No.

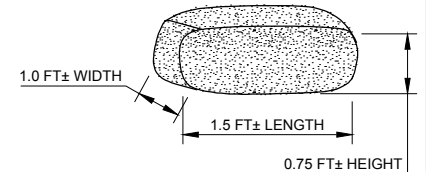
ISSUED FOR
CONSTRUCTION

Rev.
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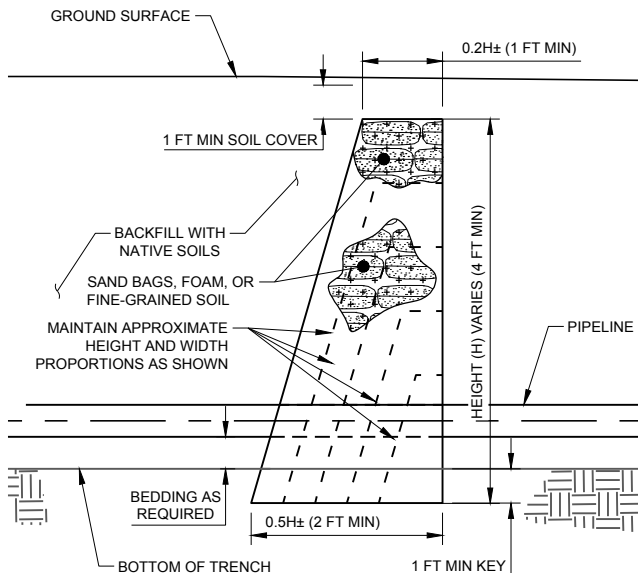
SHEET
4A



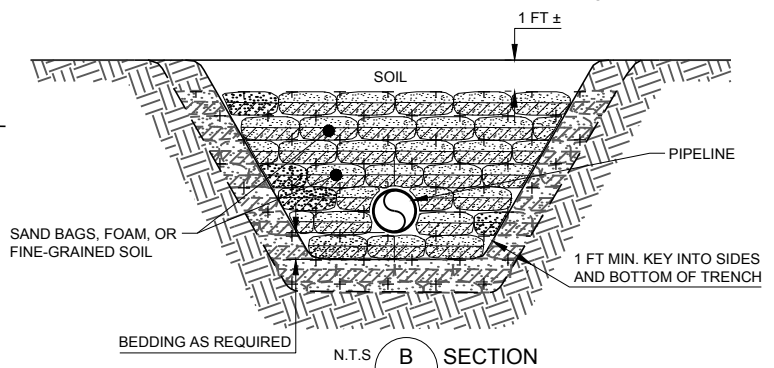
TRENCH DAM CONFIGURATION
N.T.S.



SAND BAG DETAIL
N.T.S.



N.T.S. A TRENCH DAM DETAIL



N.T.S. B SECTION

NOTES

1. 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.
2. THE PURPOSE AND INTENT OF TRENCH DAMS IS TO STOP THE FLOW OF WATER IN THE TRENCH WHERE ELEVATED WATER SURFACES MAY EXIST (SUCH AS STREAM CROSSINGS OR PONDED AREAS).
3. INSTALL TRENCH DAM IN LOW / FLAT TERRAIN AREAS THAT MAY HAVE ELEVATED WATER LEVELS. THE PURPOSE OF THE TRENCH DAM IS TO STOP FLOW OF WATER FROM RUNNING DOWN THE FLAT TRENCH.
4. INSTALL TRENCH DAM AT THE TOP OF SLOPES AT AREAS THAT MAY HAVE ELEVATED WATER LEVELS. THE PURPOSE OF THE TRENCH DAM IS TO STOP FLOW OF WATER FROM RUNNING DOWN THE TRENCH ON THE HILL SLOPE.
5. AT LOCATIONS WHERE DAMS ARE SPECIFIED ON DETAILS, PLANS OR AS DIRECTED BY COMPANY REPRESENTATIVE, SOFT PLUGS (UNEXCAVATED SECTIONS ALONG TRENCH-LINE) MAY BE LEFT IN PLACE TO PERFORM FUNCTION OF PERMANENT DAMS PRIOR TO PIPE PLACEMENT.
6. THE TRENCH SHALL BE DEWATERED THROUGH A SEDIMENT TRAP, FILTER BAG, OR DEWATERING STRUCTURE.
7. PERMANENT TRENCH DAMS SHALL BE INSTALLED BEFORE THE TRENCH IS BACKFILLED.
8. TRENCH PLUGS SHALL BE INSTALLED AT THE BANKS OF ALL PERENNIAL STREAM CROSSINGS IMMEDIATELY AFTER TRENCH EXCAVATION. THE PLUGS MAY BE TEMPORARILY REMOVED DURING PIPE PLACEMENT, BUT THEN REPLACED.
9. THE TRENCH SHALL BE DEWATERED THROUGH A SEDIMENT TRAP, FILTER BAG, OR DEWATERING STRUCTURE REFER TO TRENCH DEWATERING DETAIL (TWD).
10. PERMANENT TRENCH DAMS SHALL BE INSTALLED BEFORE THE TRENCH IS BACKFILLED.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

TRENCH DAMS (FOAM, BAGS, OR FINE GRAINED SOILS)

PROJECT No.

ISSUED FOR
CONSTRUCTION

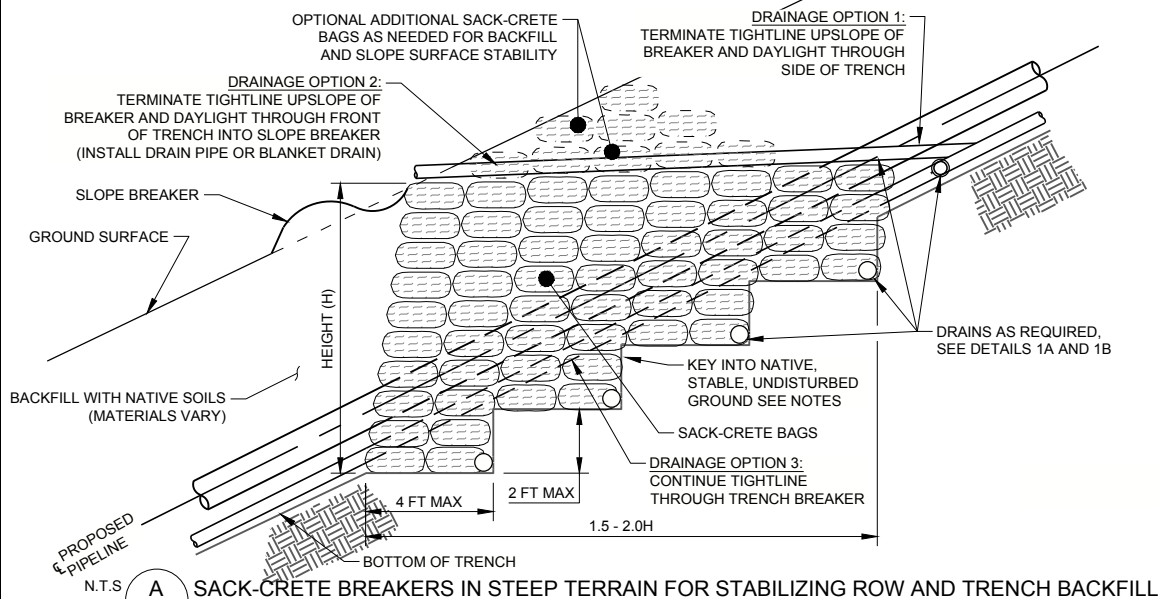
Rev.

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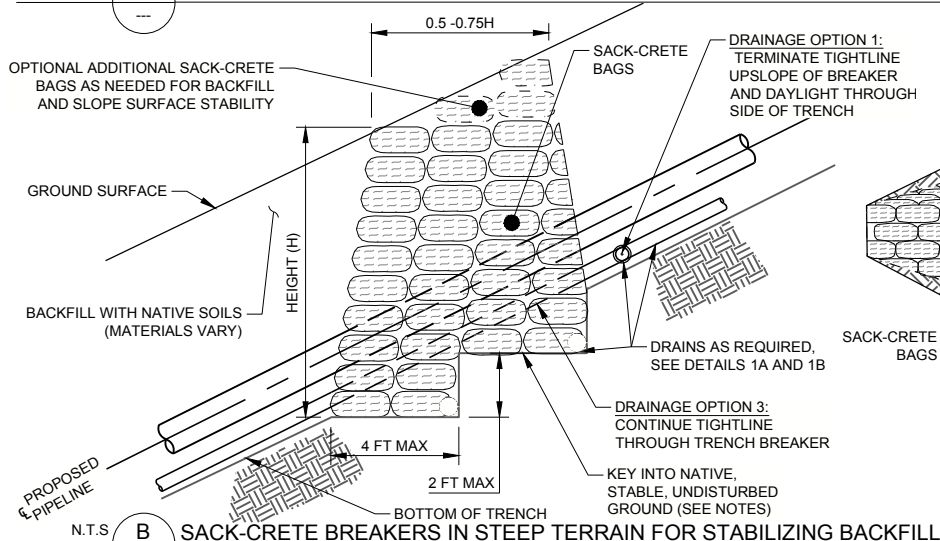
SHEET

4B

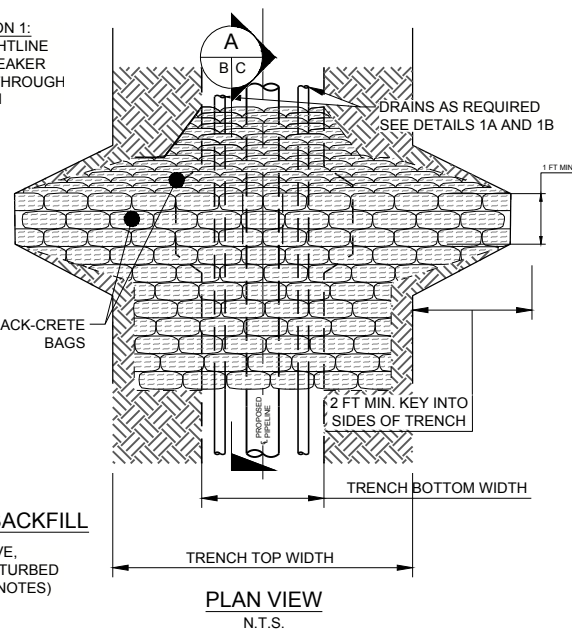
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



A SACK-CRETE BREAKERS IN STEEP TERRAIN FOR STABILIZING ROW AND TRENCH BACKFILL



B SACK-CRETE BREAKERS IN STEEP TERRAIN FOR STABILIZING BACKFILL



C SACK-CRETE KEYWAY FOR ROCK BACKFILL IN STEEP TERRAIN

PLAN VIEW
N.T.S.

NOTES

1. 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.
2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
3. ADD OR EXTEND KEYS OR PLACE ADDITIONAL SACK-CRETE BAGS AS NECESSARY TO MAINTAIN STABILITY.
4. DRAINAGE OPTION TO BE SELECTED AT THE TIME OF CONSTRUCTION BASED ON CONDITIONS ENCOUNTERED.
5. EXCAVATE KEY WITH OUTBOARD SLOPE, AND INCLUDE DRAINAGE MEASURES THAT EVACUATE ACCUMULATED SEEPAGE.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-05-30

PREPARED ACF

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

SACK-CRETE BREAKERS (STRUCTURAL BREAKER)

PROJECT No.

ISSUED FOR
CONSTRUCTION

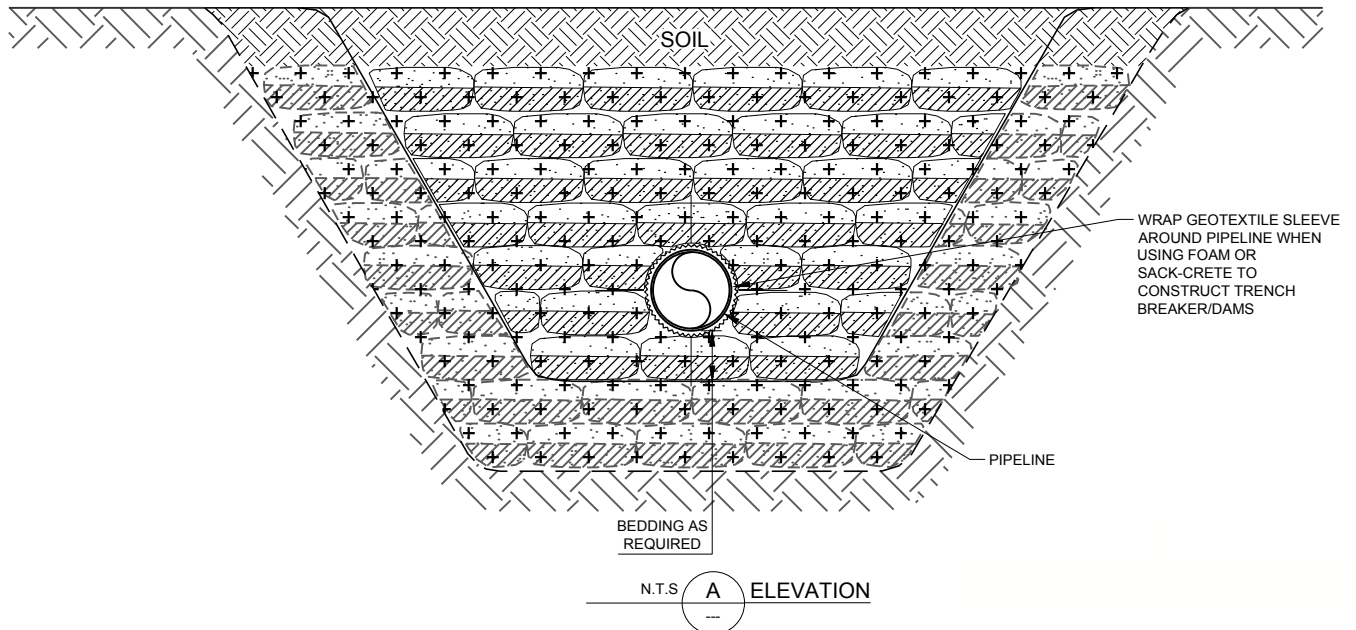
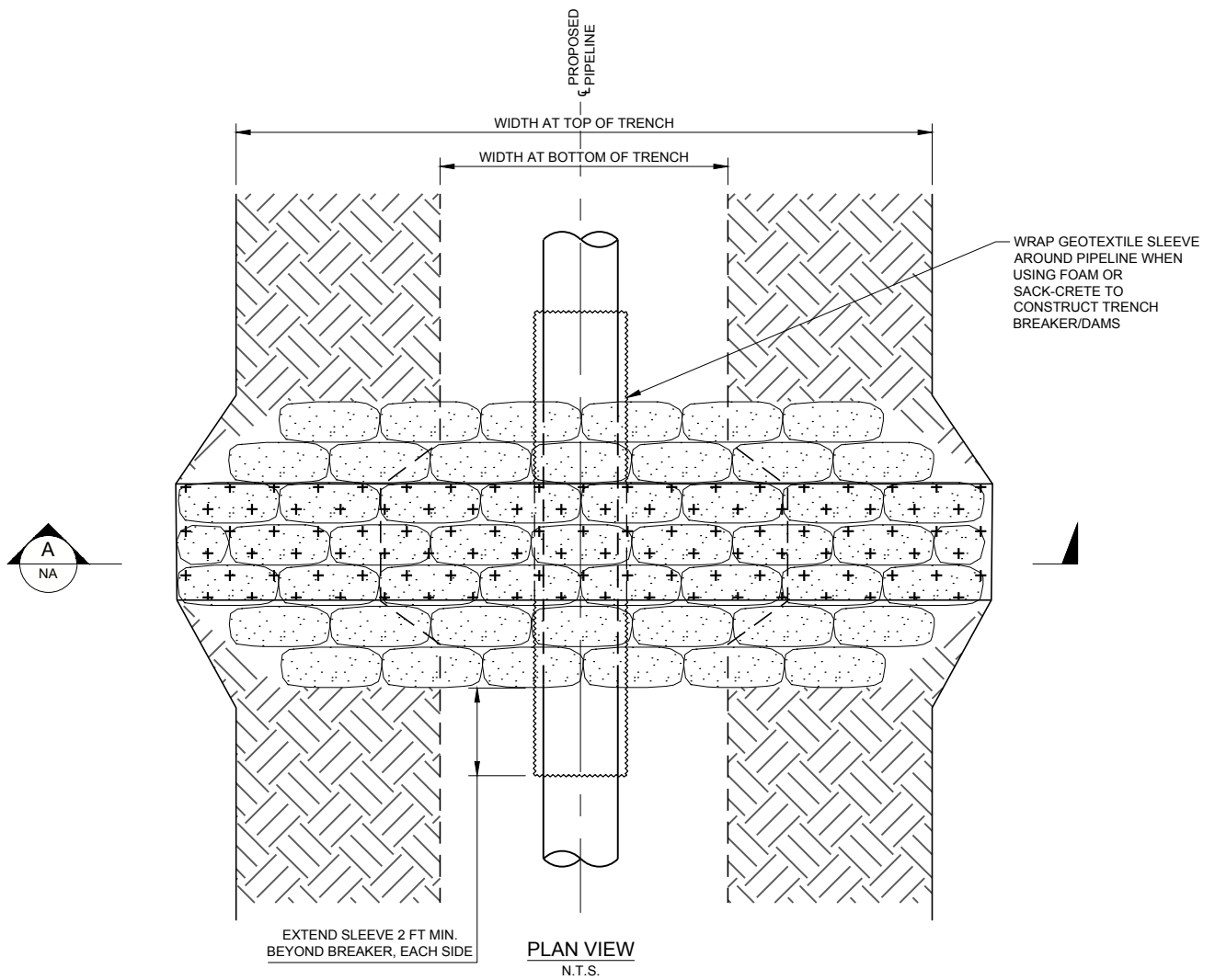
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SHEET

4C

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT

YYYY-MM-DD 2014-05-30

PREPARED ACF

DESIGN BJV

REVIEW AGM

APPROVED AQK



TITLE

SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER

PROJECT No.

ISSUED FOR
CONSTRUCTION

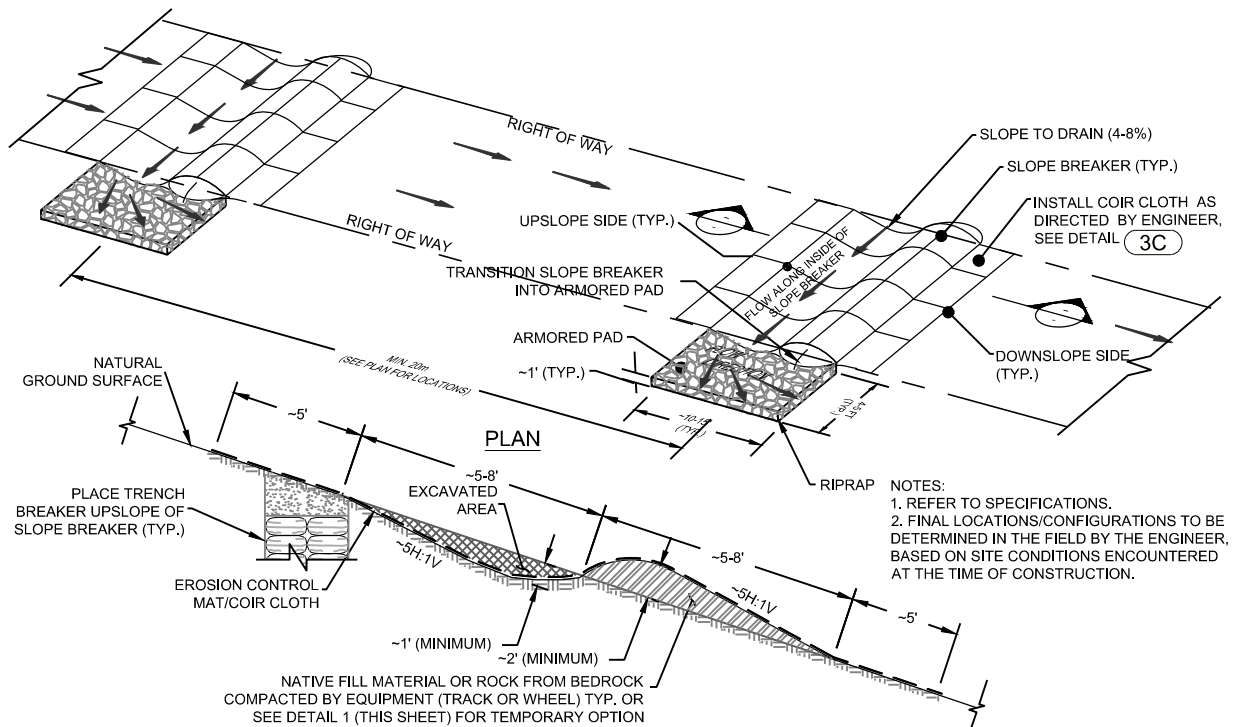
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SHEET

4D

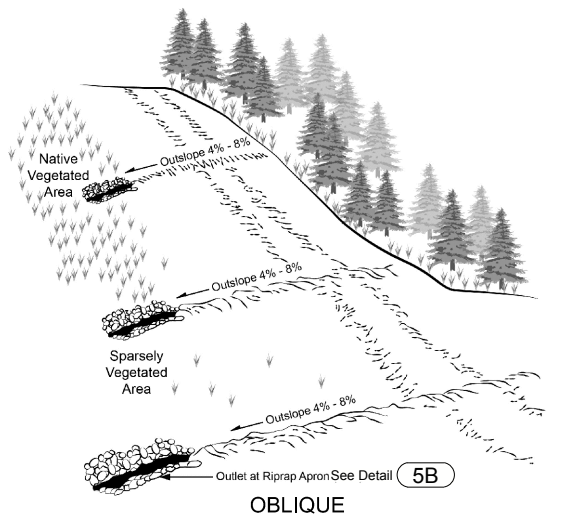
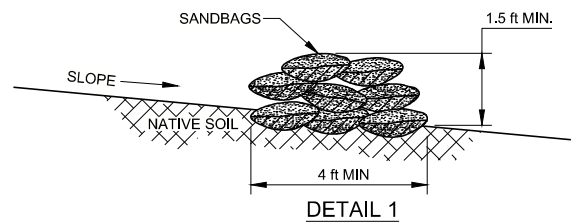
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



- NOTES:
1. REFER TO SPECIFICATIONS.
 2. FINAL LOCATIONS/CONFIGURATIONS TO BE DETERMINED IN THE FIELD BY THE ENGINEER, BASED ON SITE CONDITIONS ENCOUNTERED AT THE TIME OF CONSTRUCTION.

NOTES

1. 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.
2. TEMPORARY SLOPE BREAKERS WILL BE INSTALLED DURING CONSTRUCTION AS NECESSARY TO PREVENT EXCESSIVE EROSION; PERMANENT SLOPE BREAKERS WILL BE INSTALLED FOLLOWING BACKFILLING AND REGRADING. INSTALL SLOPE BREAKER ON MODERATE AND STEEP SLOPES TO DIVERT SURFACE WATER OFF RIGHT-OF-WAY. ALSO INSTALL SLOPE BREAKER IMMEDIATELY DOWNSLOPE OF TRENCH BREAKERS TO COLLECT SEEPAGE FORCED TO SURFACE.
3. INSTALL DIVERSION BERM AND CROSS DITCH OR MODERATE AND STEEP SLOPES TO DIVERT SURFACE WATER OF RIGHT-OF-WAY. ALSO INSTALL BERMS IMMEDIATELY DOWNSLOPE OF TRENCH BREAKERS TO COLLECT SEEPAGE FORCED TO THE SURFACE.
4. SKEW BERM ACROSS THE RIGHT-OF-WAY AT A DOWNHILL GRADIENT OF 4% TO 8%.
5. CONSTRUCT DIVERSION BERM OF COMPACTED NATIVE SUBSOILS WHERE EXTENSIVE DISTURBANCE OF THE SOD LAYER HAS OCCURRED. AVOID USE OF ORGANIC MATERIAL WHERE NATIVE MATERIAL IS HIGHLY ERODIBLE. PROTECT UPSLOPE OF BERM AND BASE OF CROSS DITCH BY BURYING A GEOTEXTILE LINER 6 TO 8 INCHES BELOW THE SURFACE OR ARMOUR UPSLOPE FACE OF BERM WITH EARTH FILLED SAND BAGS.
6. NOTE THAT TYPICAL DIVERSION BERM HEIGHT AND WIDTHS ARE APPROXIMATELY 12 INCHES. BERMS SHALL BE INSPECTED AFTER HEAVY RAINS AND THE FIRST SPRING FOLLOWING CONSTRUCTION; CONTRACTOR SHALL REPLACE OR RESTORE BERMS, IF WARRANTED.
7. LEAVE A BREAK IN TRENCH CROWN IMMEDIATELY UPSLOPE OF DIAGONAL BERM AND CROSS DITCH TO ALLOW PASSAGE OF WATER ACROSS THE RIGHT-OF-WAY.
8. USE DIAGONAL BERMS WHERE DIRECTION OF SLOPE AND SURFACE WATER MOVEMENT IS OBLIQUE TO PIPELINE RIGHT-OF-WAY.
9. USE HERRINGBONE BERM AND CROSS DITCH WHERE DIRECTION OF SLOPE AND SURFACE WATER MOVEMENT IS PARALLEL TO RIGHT-OF-WAY SO RUNOFF DOES NOT CROSS DITCHLINE.
10. DETERMINE LOCATION AND DIRECTION OF BERM BASED ON LOCAL TOPOGRAPHY AND DRAINAGE PATTERNS. ALSO INSTALL BERMS IMMEDIATELY DOWNSLOPE OF TRENCH BREAKERS. SKEW BERMS WITH DOWNHILL GRADIENT OF 4% TO 8%.
11. REFER TO TABLE FOR TYPICAL DIVERSION BERM SPACING.
12. TEMPORARY SLOPE BREAKERS AND/OR SEDIMENT LOGS SHALL BE INSTALLED AT THE BASE OF SLOPES GREATER THAN 5 PERCENT THAT ARE LESS THAN 50 FEET FROM A WATERBODY, WETLAND, OR ROAD CROSSING.
13. WILLIAMS OVM TO DETERMINE LOCATION, DIRECTION AND SPACING OF SLOPE BREAKERS AND NECESSITY FOR ENERGY DISSIPATORS BASED ON LOCAL TOPOGRAPHY, DRAINAGE PATTERNS AND EXISTING SLOPE BREAKERS PRESENT ADJACENT TO THE RIGHT-OF-WAY. SLOPE BREAKER BERM (NOT TROUGH) SHALL EXTEND ALONG BASE OF ENERGY DISSIPATORS FOR APPROXIMATE THREE TO FIVE FEET TO PREVENT WATER FROM FLOWING BACK ON PROJECT DISTURBANCE BELOW THE SLOPE BREAKER.



TYPICAL SPACING	
SLOPE GRADIENT	SPACING (FEET)
0-15	300, OR AS DIRECTED BY WILLIAMS
>15-30	200
>30	100

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

SLOPE BREAKERS (TEMP AND PERMANENT)

PROJECT No.

ISSUED FOR
CONSTRUCTION

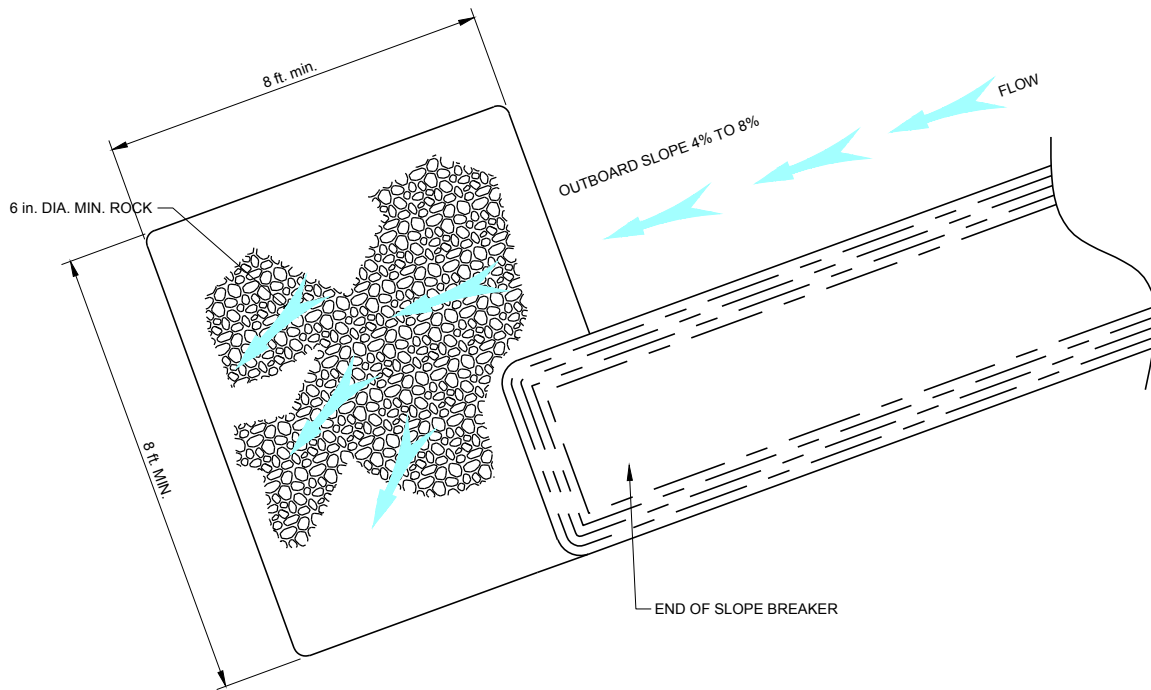
Rev.

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SHEET

5A

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



NOTES

1. 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.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

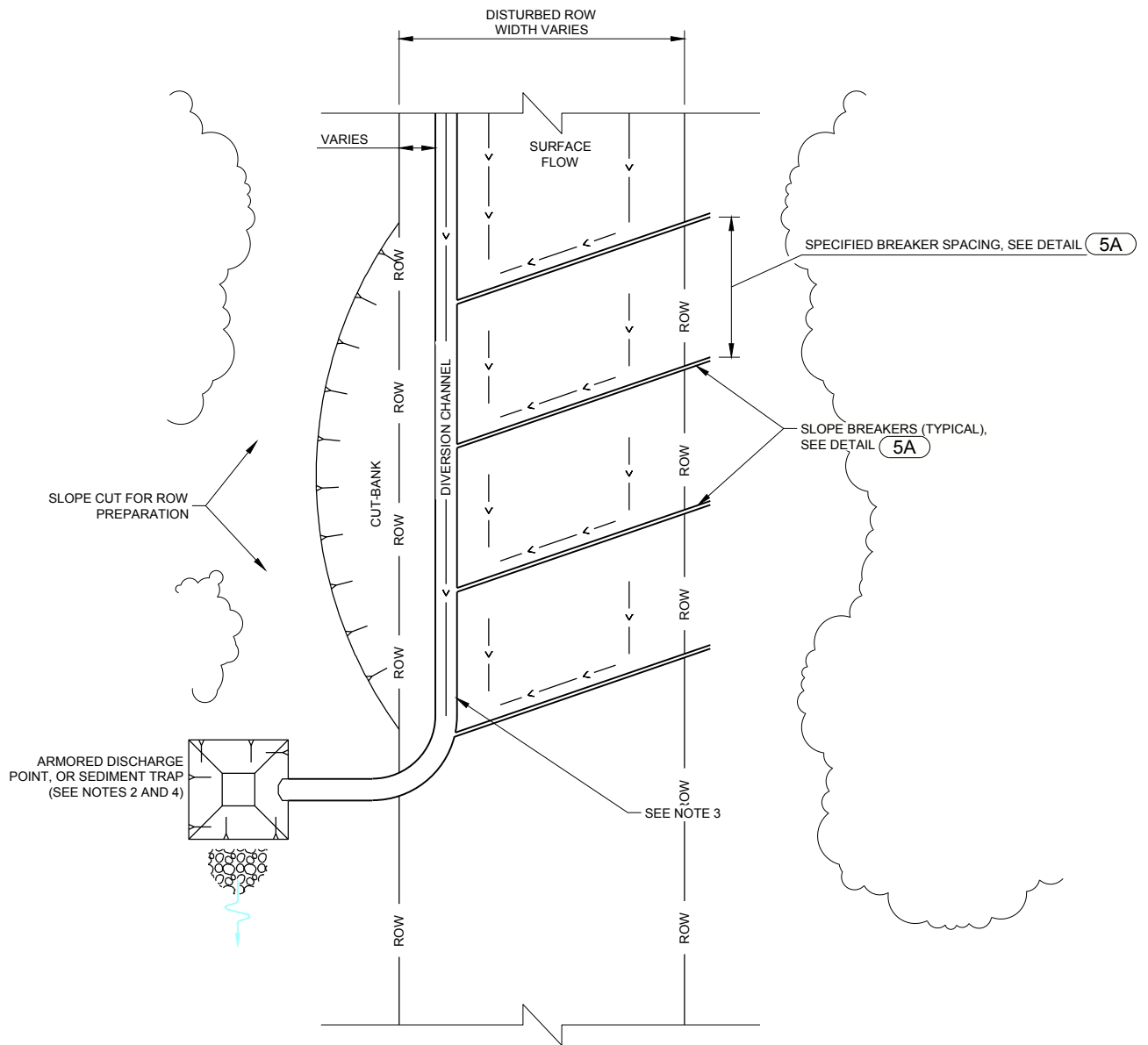
SLOPE BREAKER ARMORED OUTLET

PROJECT No.

ISSUED FOR
CONSTRUCTION

Rev.
0

SHEET
5B



NOTES:

1. 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.
2. DIVERSION CHANNEL MAY REQUIRE SITE SPECIFIC DESIGN WITH REGARD FOR SLOPE, DRAINAGE AREA, EROSION PROTECTION, DISCHARGE ARMORED PAD, CHECK DAMS, ETC.
3. DIVERSION CHANNEL MUST BE SUITABLY LINED TO PREVENT EROSION FOR INSTANCE: GEOTEXTILE EROSION CONTROL BLANKET, PLASTIC SHEETING (FOR TEMPORARY MEASURE), OR GEOTEXTILE WITH RIPRAP ARMOR (FOR PERMANENT MEASURES).
4. SEDIMENT TRAP REQUIRED WHERE SUFFICIENT BUFFER IS NOT AVAILABLE SITE SPECIFIC DESIGN OF SEDIMENT TRAP MAY BE REQUIRED, AS DIRECTED BY WILLIAMS

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

SLOPE BREAKERS WITH DIVERSION CHANNELS

PROJECT No.

ISSUED FOR
CONSTRUCTION

Rev.

0

SHEET

5C

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

NOTES:

1. 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.
2. SPECIAL CARE AND CONSIDERATION IS REQUIRED TO CONSTRUCT DRAINAGE MEASURES FOR EXISTING, PERMANENT, AND TEMPORARY ACCESS ROADS ON A SITE-SPECIFIC BASIS. ACCESS ROADS MAY COLLECT RUNOFF FROM UPSLOPE AREAS AND DELIVER WATER TO THE ROW, PIPE TRENCH, OR TO OTHER GEOTECHNICAL, GEOLOGIC, OR HYDROTECHNICAL AREAS OF CONCERN. RECOMMENDED DRAINAGE MEASURES FOR ACCESS ROADS INCLUDE THE FOLLOWING:
 - A. DRAINAGE MEASURE MAY REQUIRE SITE SPECIFIC DESIGN WITH REGARD FOR SLOPE, DRAINAGE AREA, EROSION PROTECTION , DISCHARGE ARMORED PAD, CHECK DAMS, ETC.
 - B. INSTALL WATER BARS (I.E. SLOPE BREAKERS) EVERY 100-200 FEET ALONG THE ACCESS ROAD, PROVIDED THAT WATER IS NOT DISCHARGED ONTO OR ABOVE GEOTECHNICALLY SENSITIVE AREAS (LANDSLIDES, AREAS OF FILL, POTENTIALLY UNSTABLE SLOPES, ETC.) OR THE ROW.
 - C. INSTALL INBOARD SLOPES WITH BAR DITCH (LINED OR ARMORED AS NECESSARY) UPSLOPE OF GEOTECHNICALLY SENSITIVE AREAS AND/OR THE ROW TO CONVEY WATER TO A STABLE DISCHARGE POINT.
 - D. INSTALL FRENCH DRAINS AS NEEDED TO COLLECT WATER IN AREAS WHERE WATER BARS AND BAR DITCHES CAN NOT BE USED OR WOULD RESULT IN DIRECTING WATER INTO THE ROW OR PIPE TRENCH. FRENCH DRAINS SHOULD CONVEY COLLECTED WATER IN A TIGHTLINE (SOLID WALL PIPE) TO A STABLE DISCHARGE POINT.
 - E. INSTALL EROSION PROTECTION FOR CONCENTRATED FLOWS AND DISCHARGE POINTS/OUTLETS AS NECESSARY (I.E. CHANNEL LINING, RIPRAP APRON, ETC.).
 - F. DO NOT ALLOW WATER DELIVERED FROM ACCESS ROADS TO CROSS OR ENTER THE PIPE TRENCH.
 - G. SPECIAL STUDY MAY BE REQUIRED FOR COMPLEX SITES OR AREAS OF CONCERN.
3. CHANGES IN THE FINAL GRADING MAY BE NEEDED TO ADDRESS SPECIFIC TARGETED GEOTECHNICAL OR HYDROTECHNICAL OR GEOLOGIC ENGINEERING ISSUES (I.E. CORRECT DRAINAGE PROBLEMS, MINIMIZE DELIVERY OF WATER TO LANDSLIDE SITES, ETC.)
4. FINAL GRADING TO BE REVIEWED AND APPROVED BY WILLIAMS PRIOR TO COMPLETION.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

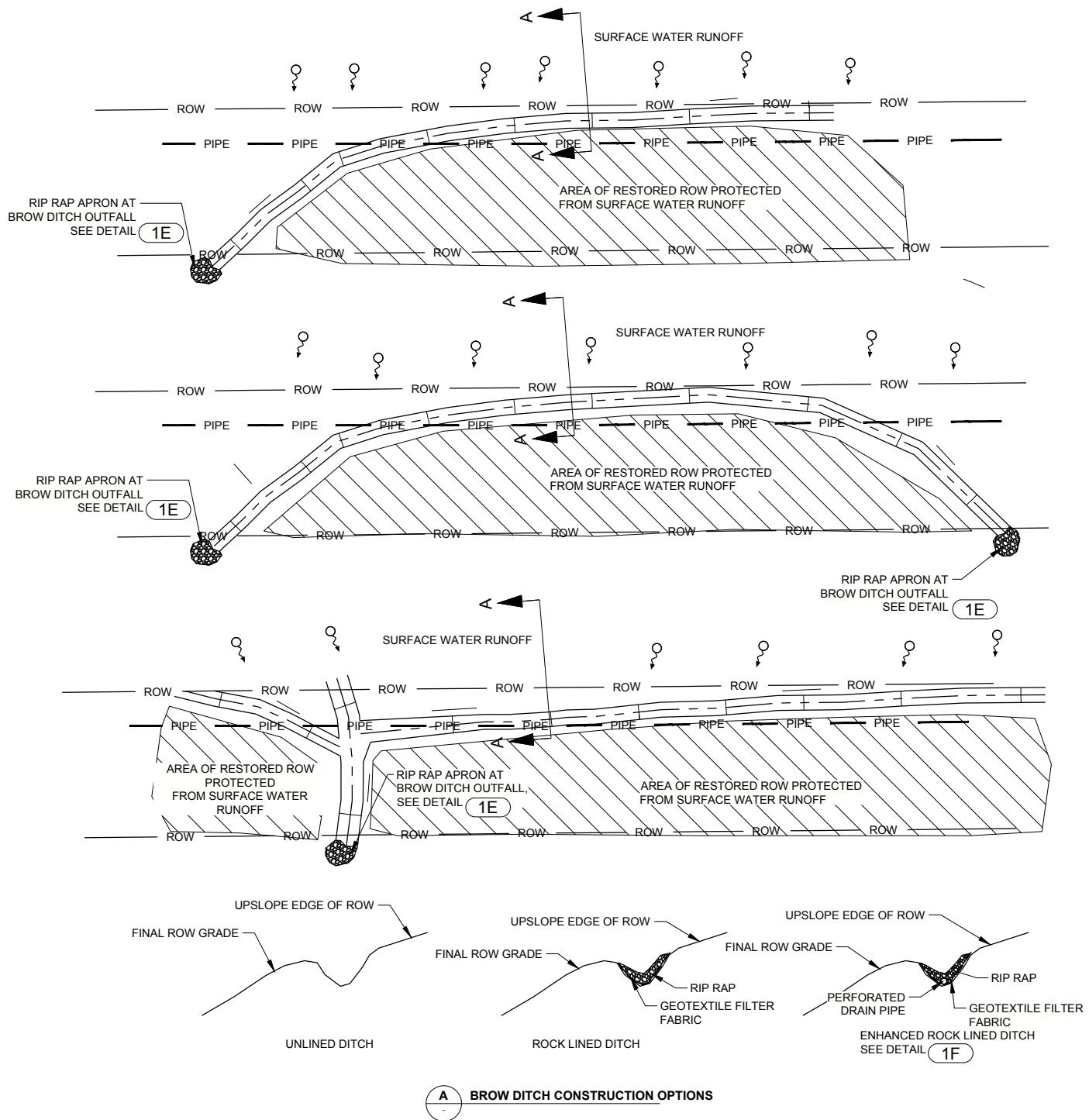
TITLE
ACCESS ROADS

PROJECT No. ISSUED FOR
CONSTRUCTION

Rev.
0

SHEET
5D

1" IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT

YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK



TITLE
BROW DITCH

PROJECT No.

ISSUED FOR
CONSTRUCTION

Rev.

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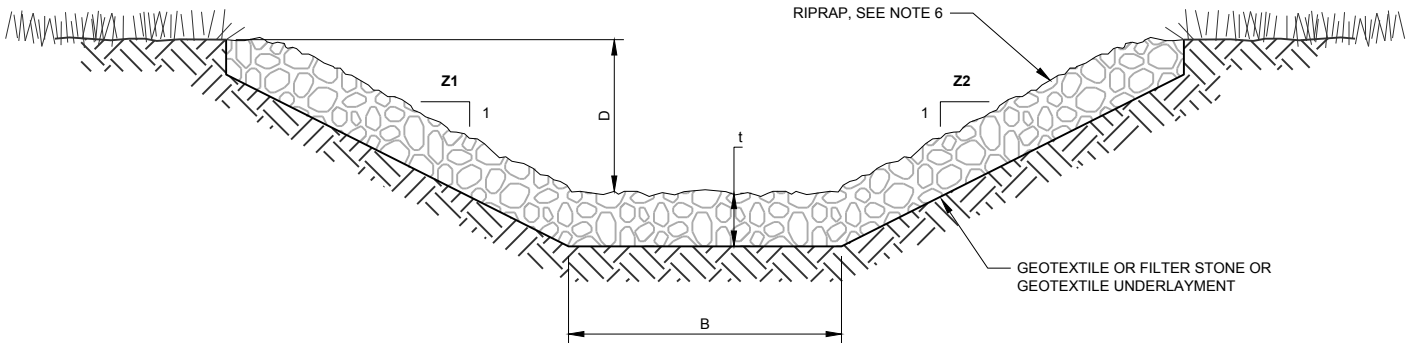
SHEET

6B

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RIPRAP CHANNEL	Stations	B	D	Z1	Z2	Riprap Gradation			t
						D _{max}	D ₅₀	D _{min}	
Channel Identification	__+__-__+__	MIN. 2 FT	MIN. 3 FT	2H	2H	SEE NOTE 6			1.5 - 2 TIMES THE MAXIMUM ROCK SIZE

SEE NOTE 5



NOTES

1. 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.
2. USE GEOTEXTILE OR FILTERSTONE UNDERLAYMENT FOR CHANNEL GRADIENTS OF > 0.10 FT/FT.
3. CHANNEL DIMENSIONS ARE FOR COMPLETED CHANNEL (AFTER ROCK PLACEMENT). CHANNEL MUST BE OVER EXCAVATED A SUFFICIENT AMOUNT TO ALLOW FOR THE VOLUME OF ROCK PLACED WITH THE CHANNEL WHILE PROVIDING THE SPECIFIED FINISHED DIMENSIONS.
4. THE MINIMUM ROCK THICKNESS (t) IS 1.5-2.0 TIMES THE MAXIMUM ROCK SIZE.
5. CHANNEL DIMENSIONS MAY VARY DEPENDING ON SITE CONDITIONS AND AS DIRECTED BY WILLIAMS.
6. REFER TO DETAIL 6F FOR RIPRAP GRADATIONS.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE
ARMORED CHANNEL

PROJECT No.

ISSUED FOR
CONSTRUCTION

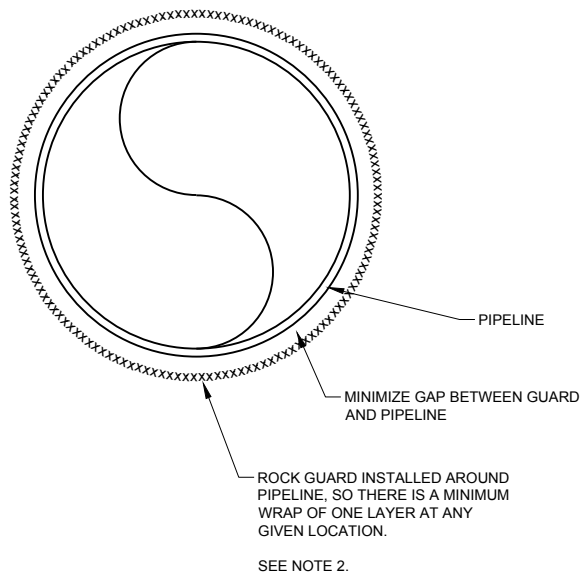
Rev.

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SHEET

6D

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



NOTES

1. 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.
2. SECURE ROCK GUARD PER MANUFACTURER SPECIFICATIONS , OR AS DIRECTED BY WILLIAMS.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

ROCK GUARD ON PIPELINE

PROJECT No.

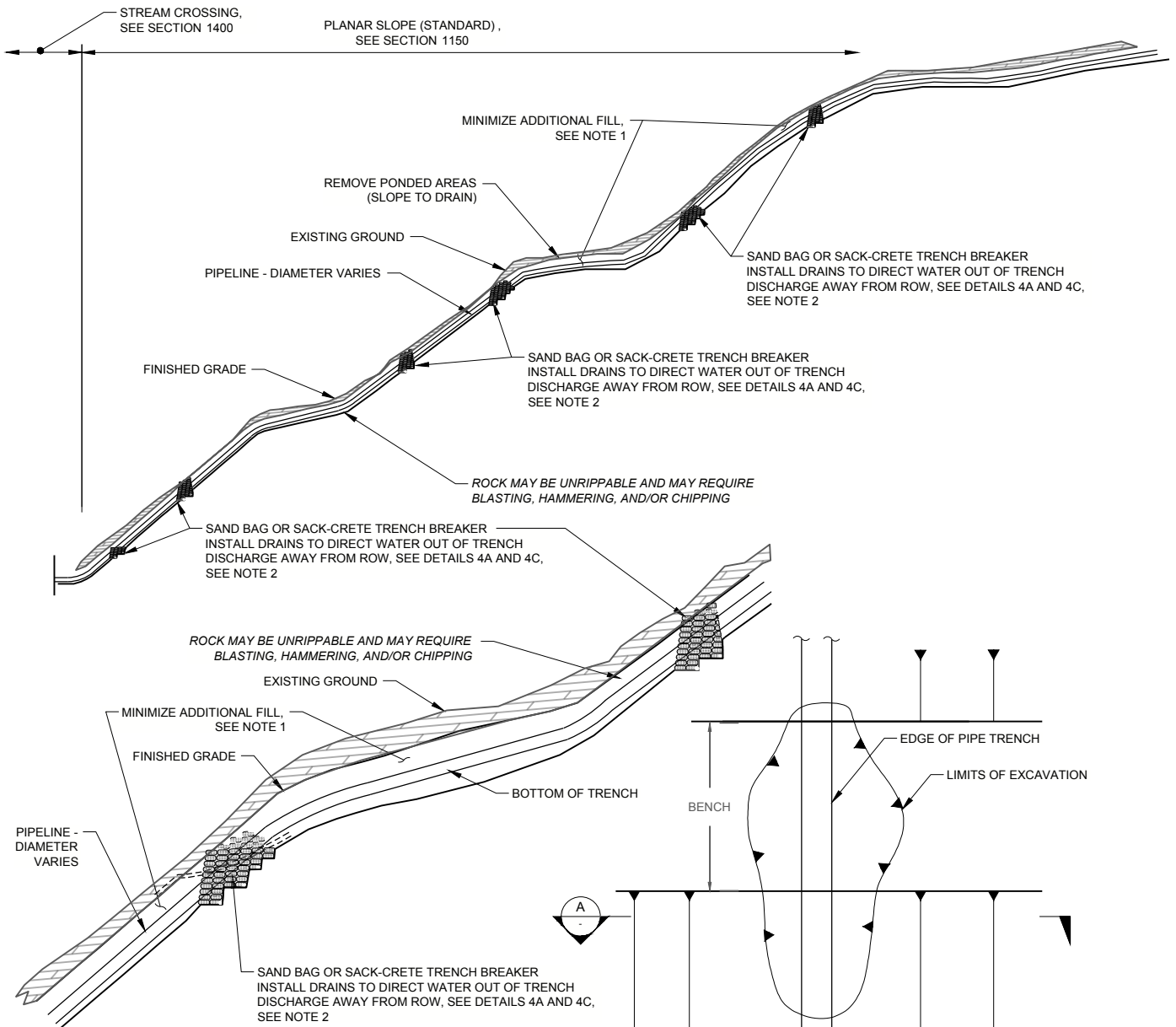
ISSUED FOR
CONSTRUCTION

Rev.
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SHEET
8A

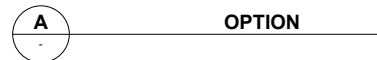
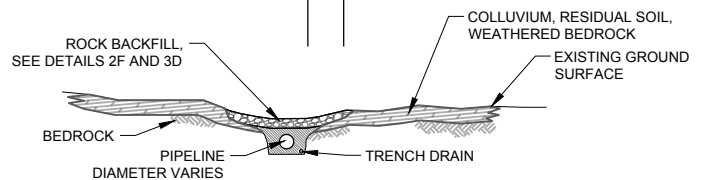
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

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NOTES

1. TRENCH EXCAVATIONS INTO BEDROCK IN AREAS MAY RESULT IN INSUFFICIENT AMOUNTS OF BACKFILL AND PADDING/BEDDING DUE TO LARGER, ANGULAR SPOIL MATERIAL. ROCK GUARD MATERIALS MAY BE REQUIRED TO PROTECT THE PIPELINE.
2. TRENCH EXCAVATIONS INTO BEDROCK IN SLOPED TERRAIN (PLANAR SLOPES & INCLINED RIDGES) WILL REQUIRE TRENCH BREAKERS WITH SUFFICIENT MASS AND GEOTECHNICAL PROPERTIES TO RETAIN BACKFILL SOILS AND/OR ROCK MATERIALS. USE OF FOAM BREAKERS IS NOT RECOMMENDED. SANDBAG OR SACK-CRETE BREAKERS ARE RECOMMENDED.
3. ALTERNATING LAYERS OF WEAKER BEDROCK AND STRONGER BEDROCK MATERIALS OFTEN CREATES A "BENCHED" OR "STAIR-STEPPED" APPEARANCE TO EXISTING HILL SLOPES, ILLUSTRATED IN THE FIGURE SHOWN ON THIS SHEET. MINIMIZE BACKFILL IN THESE SITUATIONS, AND WARP THE SLOPES AT THE ROW BOUNDARIES TO MEET TO EXISTING TERRAIN, BUT MAINTAIN A MORE UNIFORM, POSITELY DRAINING SLOPE ACROSS THE ROW. BUILDING BENCHES ALTERNATING WITH FILL ACROSS THE ROW TO MATCH THE EXISTING TOPOGRAPHY IS NOT RECOMMENDED.



CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT

YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK



TITLE

BENCH RE-CONSTRUCTION THROUGH NATURAL STEPS

PROJECT No.

ISSUED FOR
CONSTRUCTION

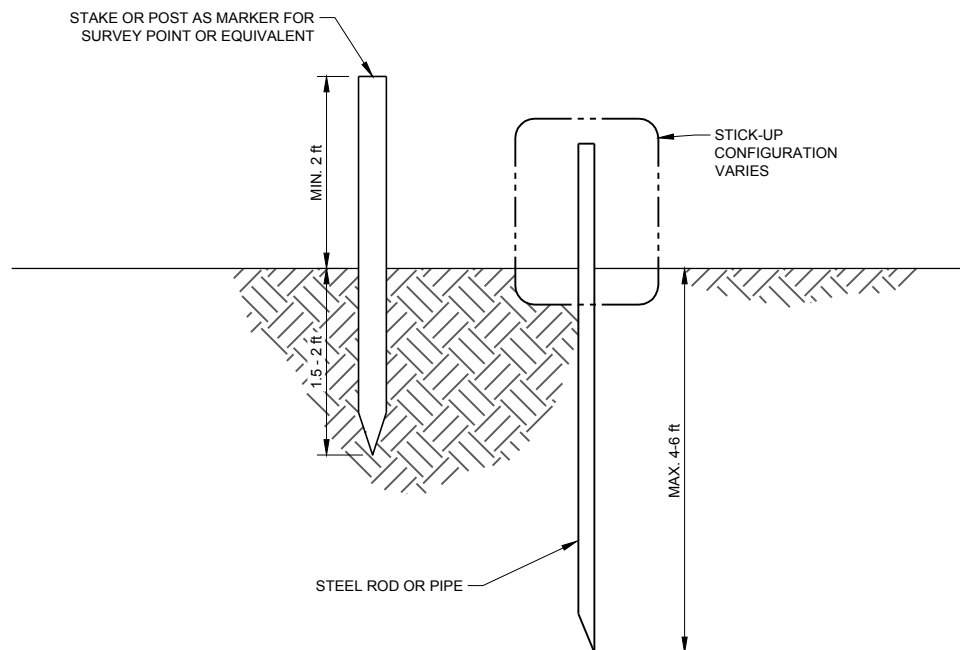
Rev.

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SHEET

10A

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



NOTES

1. 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.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE
GEODETIC MONITORING

PROJECT No.

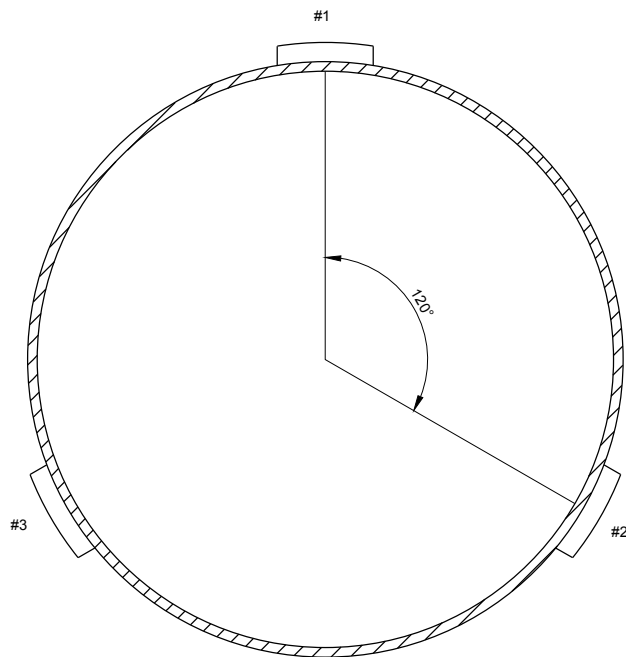
ISSUED FOR
CONSTRUCTION

Rev.
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SHEET
11A

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

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NOTES

1. 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.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

STRAIN GAUGE MONITORING

PROJECT No.

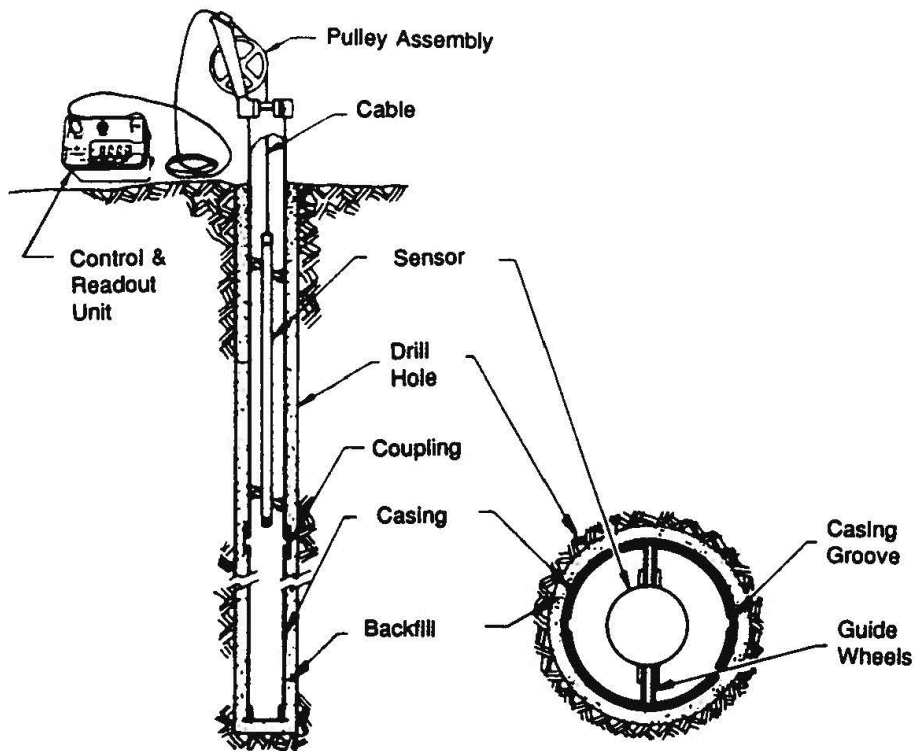
ISSUED FOR
CONSTRUCTION

Rev.
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SHEET
11B

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NOTES

1. 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.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



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PREPARED BJV

DESIGN BJV

REVIEW AGM

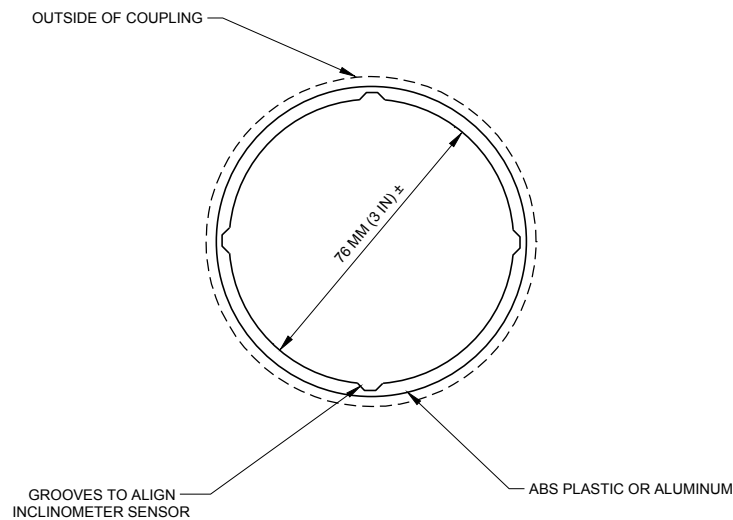
APPROVED AQK

TITLE
SLOPE INCLINOMETER MONITORING

PROJECT No. ISSUED FOR
CONSTRUCTION

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SHEET
11C



NOTES

1. 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.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

SLOPE INCLINOMETER CASING

PROJECT No.

ISSUED FOR
CONSTRUCTION

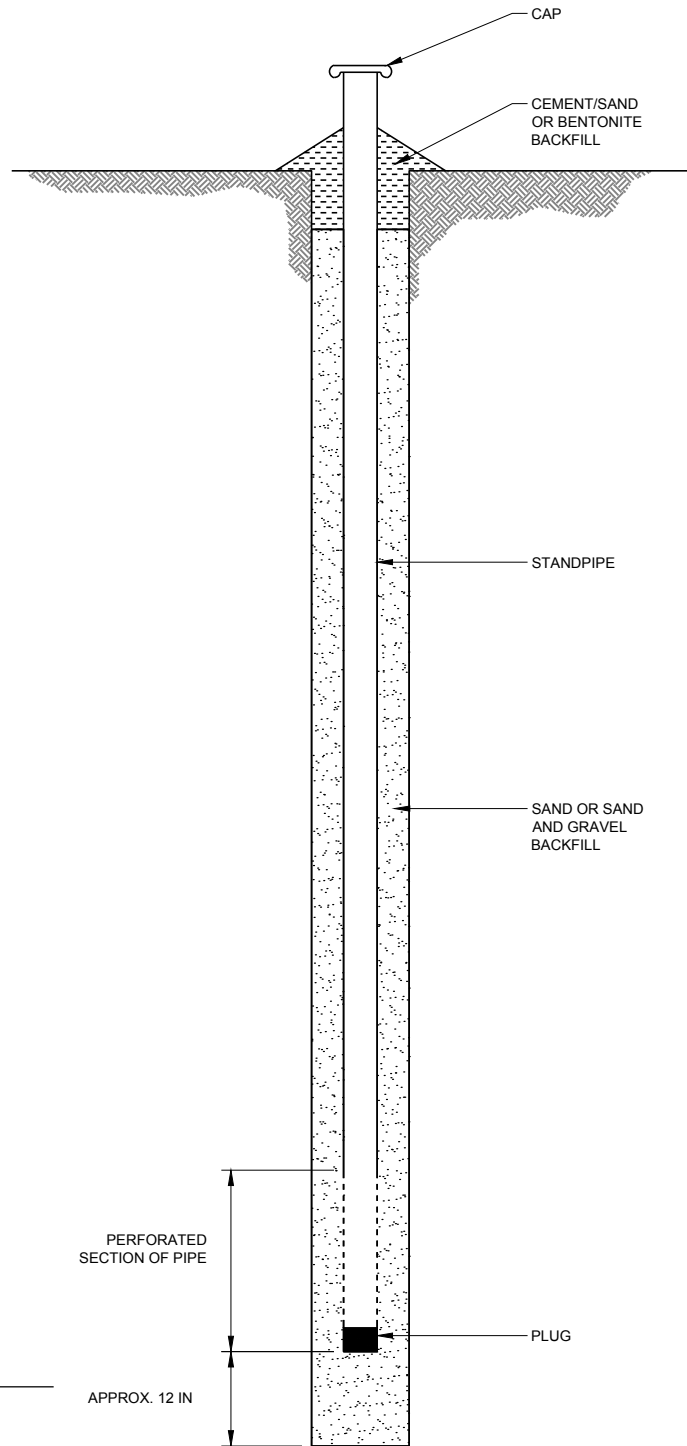
Rev.
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SHEET
11D

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

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NOTES

1. 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.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

STANDPIPE PIEZOMETER MONITORING

PROJECT No.

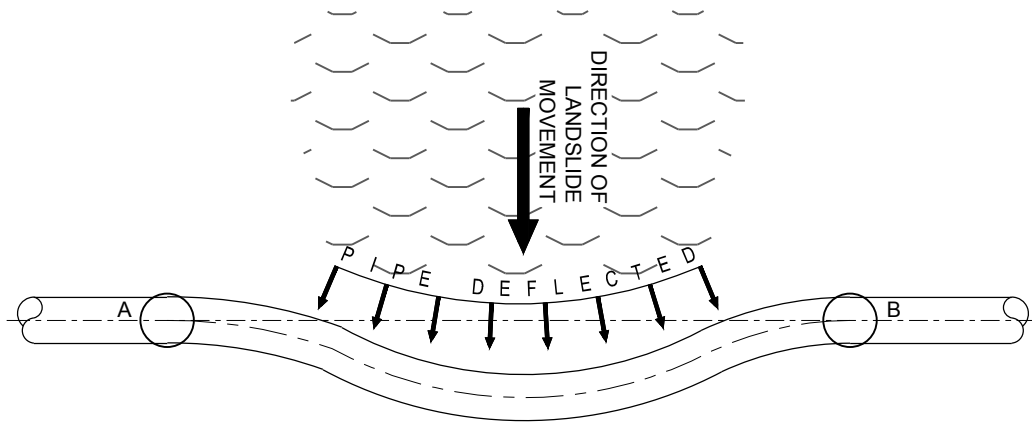
ISSUED FOR
CONSTRUCTION

Rev.
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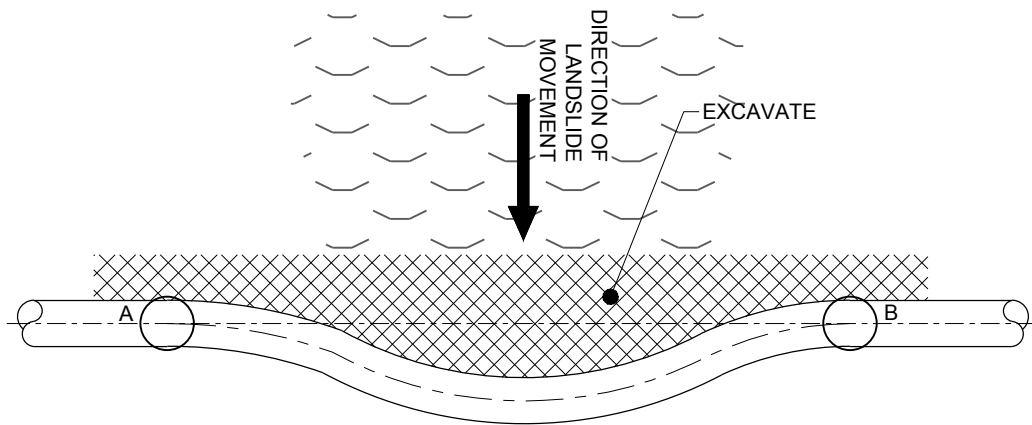
SHEET
11E

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

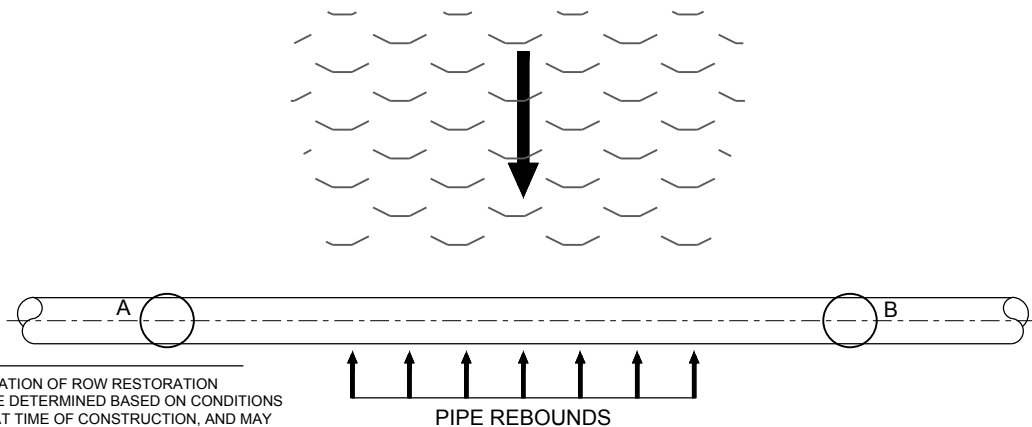
BEFORE STRAIN RELIEF EXCAVATION



DURING STRAIN RELIEF EXCAVATION



AFTER STRAIN RELIEF EXCAVATION



NOTES

1. 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.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

STRESS RELIEF EXCAVATIONS

PROJECT No.

ISSUED FOR
CONSTRUCTION

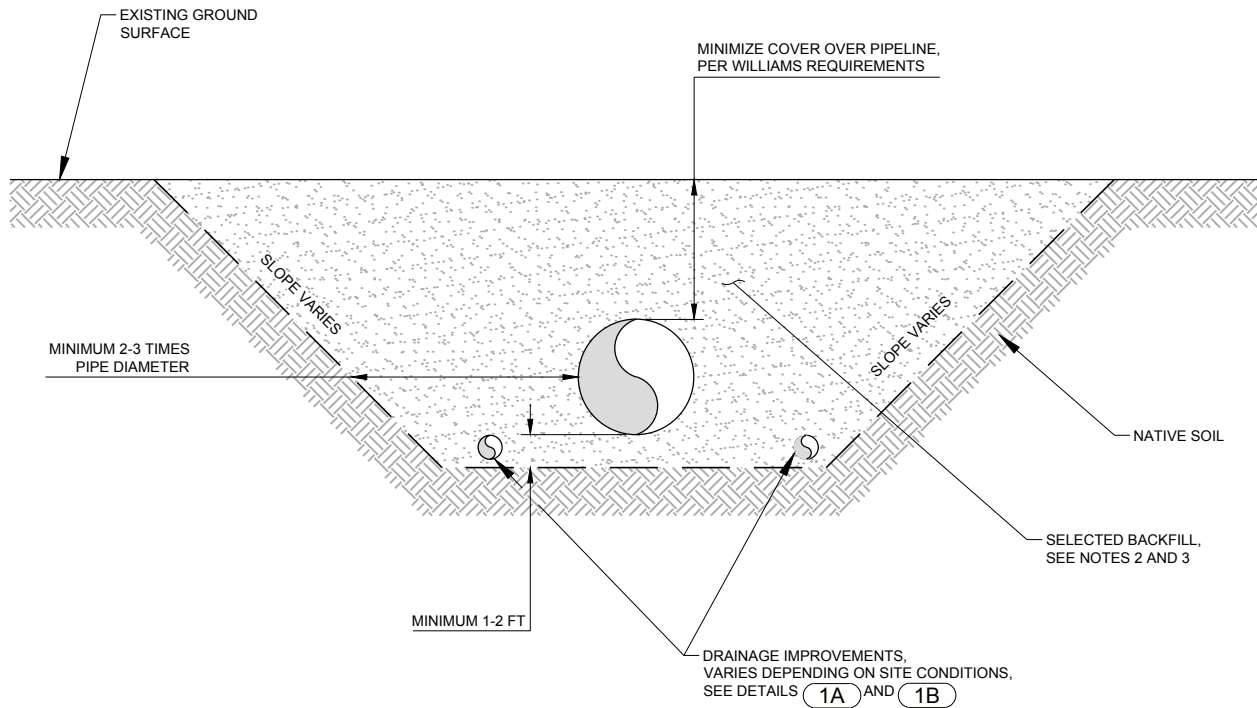
Rev.

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SHEET

12A

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



NOTES:

1. 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.
2. SELECT BACKFILL SHALL CONSIST OF SANDY, INVERT GRANULAR MATERIAL, EITHER NATURALLY OCCURRING OR PROCESSED. IT SHALL BE FREE FROM ORGANICS, SILT CLAY, SWELLING SOILS, GARBAGE, WOOD, OR OTHER EXTRANEOUS OR OBJECTIONABLE MATERIAL.
3. SAND SHALL BE WELL GRADED FROM COARSE TO FINE. THE GRAIN SIZE DISTRIBUTION SHALL CONFORM TO THE FOLLOWING.

GRAIN SIZE TABLE

PERCENT PASSING	MINIMUM
3/8" INCH	100
U.S. NO. 4	96
8	78
16	60
30	34
50	14
100	2
200	0

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE

SELECT (DEFORMABLE) BACKFILL AROUND PIPELINE IN LANDSLIDE

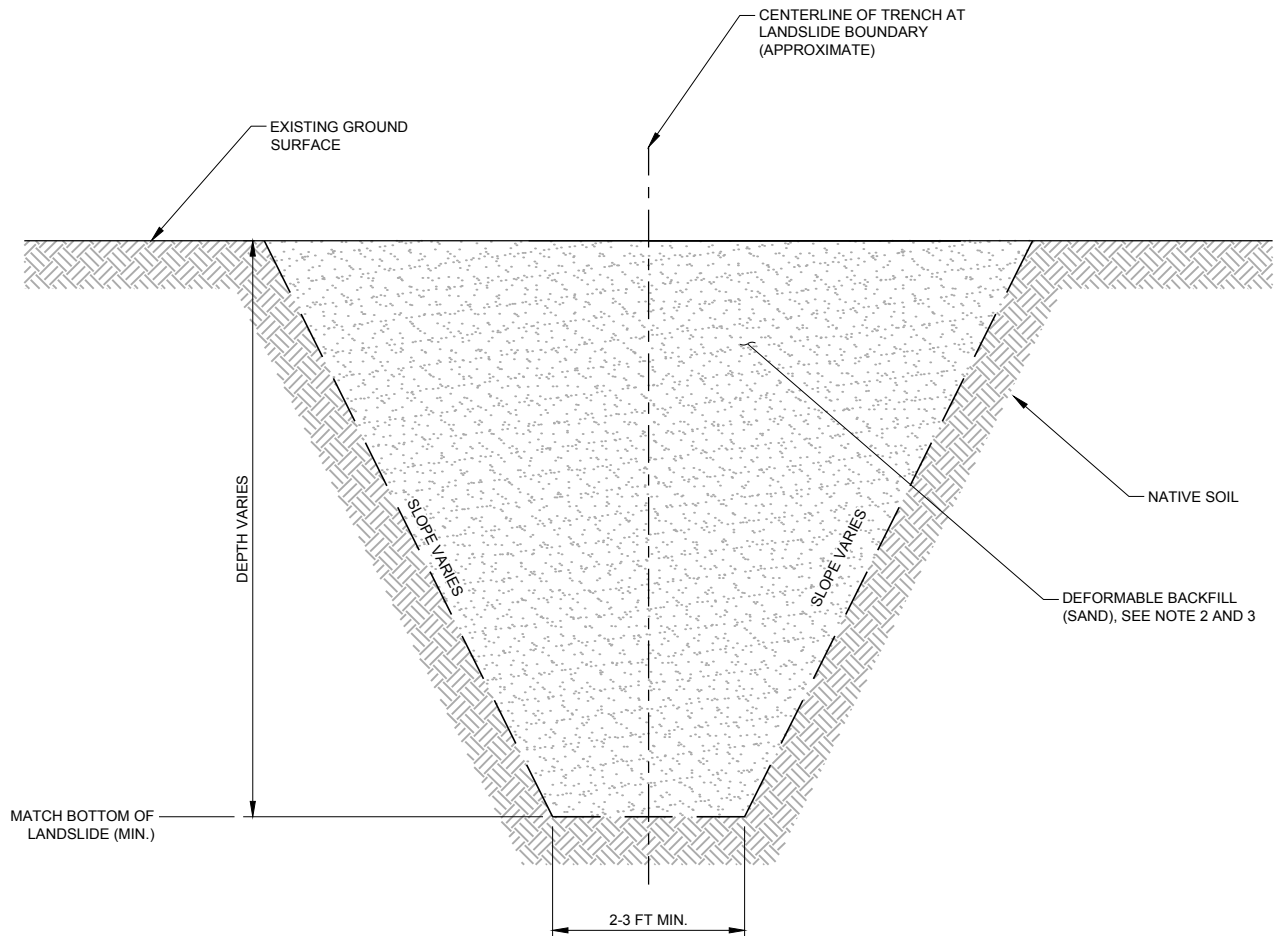
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ISSUED FOR
CONSTRUCTION

Rev.
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SHEET
12B

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



NOTES:

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U.S. NO. 4	96
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100	2
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CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-02-28

PREPARED BJV

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE
SHEAR TRENCH

PROJECT No. ISSUED FOR
CONSTRUCTION

Rev.
0

SHEET
12C

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

NOTES

1. 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.
2. ADJUST ROUTING AND/OR ROW EASEMENTS, AND/OR PROPOSED REMEDIATION MEASURES AS NECESSARY TO AVOID POTENTIAL HAZARDS WHERE POSSIBLE.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-05-30

PREPARED ACF

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE
AVOIDANCE

PROJECT No. ISSUED FOR
CONSTRUCTION

Rev.
1

SHEET
15A

1m IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

NOTES

1. 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.
2. SITE INVESTIGATIONS NEEDED TO CONFIRM LATERAL AND VERTICAL EXTENT OF IDENTIFIED LANDSLIDE OR OTHER UNSTABLE SLOPE CONDITIONS.
3. INVESTIGATION MAY INCLUDE PROBES, TEST PITS, EXCAVATIONS ALONG PIPELINE TRENCH, GEOPHYSICAL METHODS (I.E. NON-INTRUSIVE GPR, SEISMIC OR ELECTRICAL METHODS), OR MAY REQUIRE DEEPER SUBSURFACE DRILLING METHODS. FINAL INVESTIGATION METHONGS(S) TO BE DETERMINED BASED ON SITE CONDITIONS AND REQUIREMENTS OF SITE WORK.
4. EXCAVATIONS TO REMOVE IDENTIFIED LANDSLIDE OR OTHER UNSTABLE SLOPE CONDITIONS SHOULD BE COMPLETED FOR THE FULL EXTENT OF CHARACTERIZED HAZARD AREA, AT A MINIMUM MATCHING OR EXCEEDING THE UNDERLYING AND/OR LATERAL BOUNDING FAILURE SURFACE AND/OR SLIP PLANE. THE GOAL AND INTENT OF THIS MITIGATION APPROACH IS TO ESSENTIALLY REMOVE THE SLOPE HAZARD FROM THE SITE BY DIGGING OUT THE LIMITS OF THE IDENTIFIED HAZARD.
5. REMOVAL OF TARGETED LANDSLIDE AND/OR UNSTABLE SLOPE MATERIALS MAY REQUIRE SPECIAL CONSIDERATIONS FOR OTHER DIRECTLY OR INDIRECTLY RELATED OR CONNECTED SITE MITIGATION MEASURES AND/OR SITE ACTIVITIES TO ADDRESS SAFETY, SLOPE STABILITY, ACCESS, CONSTRUCTION FEASIBILITY, ETC, THEREFORE, PLANNING FOR IMPLEMENTATION OF THIS OPTION SHOULD INCLUDE A COMPREHENSIVE REVIEW OF EXISTING PROPOSED WORK AT THE SITE.
6. EXCAVATED MATERIALS SHOULD BE SPOILED IN LOCATION(S) THAT DO NOT ACCELERATE OR EXACERBATE THE TARGETED LANDSLIDE OR UNSTABLE SLOPE AREA, OR IMPACT OTHER NEIGHBORING LANDSLIDES OR UNSTABLE SLOPE AREAS.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT



YYYY-MM-DD 2014-05-30

PREPARED ACF

DESIGN BJV

REVIEW AGM

APPROVED AQK

TITLE
EXCAVATION REMOVAL OF HAZARD

PROJECT No. ISSUED FOR
CONSTRUCTION

Rev.
0

SHEET
15B

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