CHAPTER 4

Permanent Runoff Control

Permanent runoff controls convey water in a manner that is stable and doesn't contribute sediment and additional pollutants to runoff. As land development occurs and portions of the natural drainage patterns are changed to manage runoff, permanent runoff control practices such as diversions, level spreaders, grassed swales and outlet protection are used to protect against erosion, safely route flows, dissipate high energy flows and in some cases provide water quality benefits. Generally permanent runoff controls must safely convey the community's prescribed design storm or at least a 10-year frequency storm.

Lands previously used for farming often have subsurface drainage systems, which must continue to serve upland areas. Construction in these areas is bound to uncover drainage systems and disrupting these can cause severe drainage problems to adjoining land. So every effort should be made to locate drainage lines prior to construction and to reroute them during construction. These systems should not be used as stormwater runoff outlets, since they were not designed to function as storm drains. Adding surface water will likely exceed the capacity of the tile system, cause it to fail and subsequently cause adjoining land to suffer drainage problems.

4.1 Grassed Swale

Description

Grassed swales are constructed channels shaped and established with suitable vegetation in order to convey stormwater runoff without allowing channel erosion.

Condition Where Practice Applies

This practice is applicable where added capacity and protection by vegetation are needed to control erosion from concentrated runoff, to improve drainage, or to convey stormwater.

This practice applies generally to small channels having flow only during storm events.

This practice is not applicable in larger ephemeral streams where grass cannot be established and maintained. Chapter 3 Stream Channel Rehabilitation or further channel restoration resources should be referenced for larger channels having seasonal low perennial flow.

Use caution when design flow for the swale is greater than 100 cubic feet per second (cfs) from a 10-yr.-frequency storm. Generally, grassed swales are suitable for drainage areas less than 100 acres in flat to gently rolling terrain. In steeper terrain, it may be more difficult even on smaller drainage areas to design a stable waterway.

Planning Considerations

Constructed Channels vs. Natural Drainageways

Discretion must be used when replacing natural channels with constructed channels. Natural drainage systems, even small intermittent and ephemeral drainageways, provide many hydraulic and environmental benefits not duplicated by constructed channels. See the introduction to Stream Practices for more discussion of natural channel design.

Permits

A construction permit may be required by the local government. Additionally, the U.S. Army Corps of Engineers and the Ohio Environmental Protection Agency, through Sections 404 and 401, respectively, of the Clean Water Act, may require a permit for grassed swales that are located adjacent to a stream. It is best to contact your local Soil and Water Conservation District (SWCD) office to determine what both agencies' permit requirements are for your project.

Water Quality

Grassed swales are designed to reduce erosion and therefore provide a limited water quality benefit. Swales may be modified to store a water quality volume by adding weirs or check dams in order to detain and treat runoff for a minimum of 24 hours.

Stable Outlet

The swale should not be constructed until a suitable stable outlet is in place, and upstream erosion control is in place.

Design Criteria

Grassed swales shall be planned, designed and constructed to comply with all Federal, State, and local laws and regulations.

Runoff

Runoff computation will be based upon the most severe soil and cover conditions that will exist in the area draining into the swale during the planned life of the structure. Use the NRCS Technical Release 55 (TR 55) or other suitable method shall be used to determine peak rate of runoff.

Capacity

The channel's capacity shall be adequate to carry the peak rate of runoff from a 10-yr. frequency storm prior to out of bank flow. Out of bank flows may be permitted in short sections of a reach to facilitate alignment or to minimize grade changes, as long as positive drainage to the swale is maintained, and flow will continue along the swale re-entering the swale prior to reaching the outlet. Where high-hazard conditions exist, higher frequency storms should be chosen to provide protection compatible with conditions. Grassed swales designed to protect residences and businesses, shall have out of bank capacity to carry the peak rate of runoff prior to flow inside adjacent planned residences or businesses.

Cross Section Shape

- *Parabolic channels* most closely approximate natural flow characteristics at low as well as high flows. Although generally preferred for esthetic reasons, design and construction procedures are more complex.
- *Trapezoidal channels* often are used where the quantity of water to be carried is large and velocities high. Channels constructed to treat stormwater runoff should be trapezoidal in shape to promote settling and infiltration. Side slopes that are 3 to 1 or flatter are recommended. Consider future maintenance when designing the shape of trapezoidal channels.

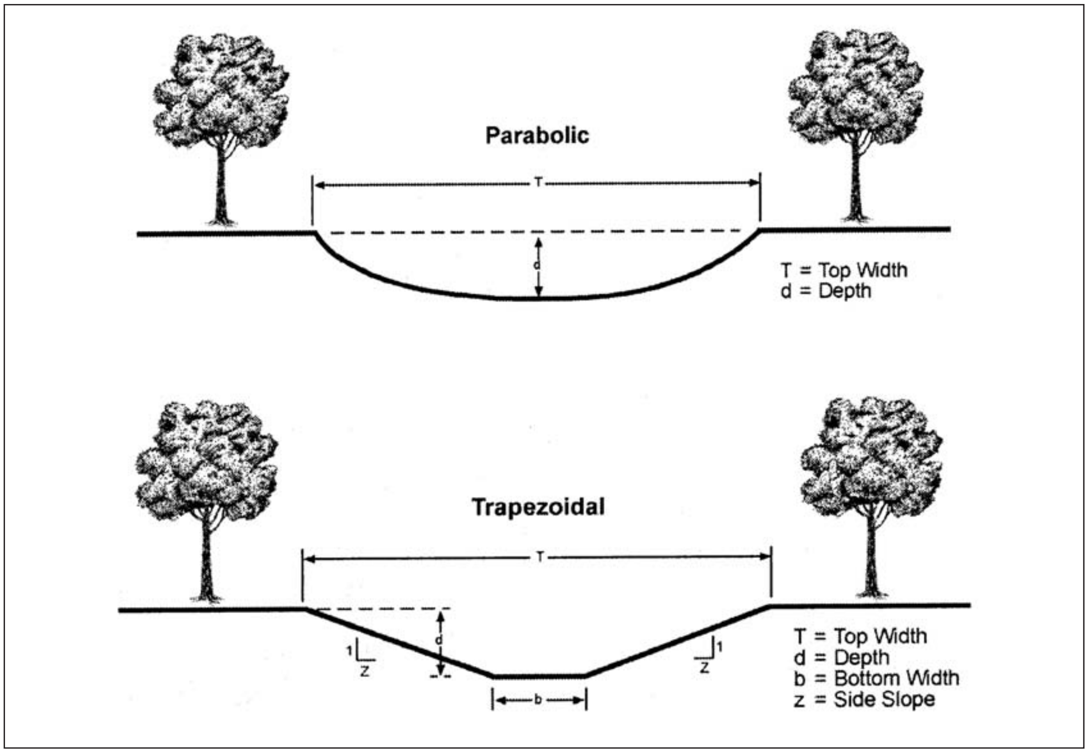


Figure 4.1.1

Special Considerations

Where out-of-bank flow would not cause erosion, property damage or flood damage, no minimum size channel is required. These conditions will most often occur in areas with little slope and established woody vegetation.

Design Velocity of Vegetative Lining:

Channels shall be designed so that the velocity of flow expected from a 10-year frequency storm does not exceed the permissible velocity for the type of lining used (see the table below). Manning's Equation or other suitable method should be used to determine design velocity.

Table 4.1.1 Grass Lining

Maximum Flow Velocity for a 10-Yr. Frequency Storm				
Soil		Maximum Velocity (fps)		
Texture	Type	Seed & mulch	Seed & Matting	Sod
Sand, Silt, Sandy Loam, Silt Loam	Sand	1.5	3.0	3.5
Silty Clay Loam, Sandy Clay Loam	Firm Loam	2.0	4.0	4.0
Clay	Clay	2.5	4.0	5.0
N/A	Gravel	3.5	5.0	6.0
N/A	Weathering Shale	4.5	5.0	N/A

Note: Generally soil texture can be determined from soil surveys. For channels on fill, soils should be tested.

Establishing Vegetation

All grassed swales shall be vegetated or otherwise stabilized, as soon as possible after construction. Stabilization should be done according to the appropriate Standards and Specifications for Vegetative Practices (e.g. Permanent Seeding, Mulching, Matting)

- *For design velocities of less than 3.5 fps,* seeding and mulching may be used for the establishment of the desired vegetation. Mulch netting should be used to protect the seeding during establishment. It is recommended that when conditions permit temporary diversion or other means be used to prevent water from entering the grassed swale during the establishment of vegetation.
- *For design velocities of more than 3.5 fps,* the grassed swale shall be stabilized with seeding protected by erosion control matting or blankets, or with sod. It is recommended that when conditions permit temporary diversion or other means be used to prevent water from entering the grassed swale during the establishment of vegetation.

Check Dams

Check dams may be incorporated to increase channel stability by decreasing flow velocities, and reducing erosion and headcutting. Check dams are grade control structures constructed out of durable material (i.e. rock riprap) across the swale cross section to prevent headcutting. Check dams should be used where they will not be considered a nuisance or create a high maintenance burden. See Chapter __ - Water Quality Swale for planning and design details that could be used to maximizing the detention time within the grassed swale to enhance water quality benefits.

Drainage

Designs for a site having prolonged flows, a high water table, or seepage problems shall include Subsurface Drains, Rock Lined Waterway, or other suitable measures to avoid saturated conditions. See Chapter 4, part 7 Subsurface Drains and Chapter 4, part 3 Rock Lined Channel, for planning and design details.

Offset subsurface drains at least _ of the designed top width from the centerline of the swale. The drain's flowline should be at least 1 foot below the centerline grade and maintain at least 2 feet of cover. Subsurface drains should be installed on both sides of the swale if a high water table or other site conditions will create wetness on both sides. Orifice plates or other acceptable means should be used to prevent pressure flow in the subsurface drain as necessary.

Outlets

All grassed swales shall have a stable outlet with adequate capacity to prevent ponding or flooding damages.

In cases where the grassed swale outlets into a larger ditch or stream with a continual or seasonal base flow, protection of that portion of the grassed waterway / conveyance channel / swale affected by this wet condition is necessary. This may be accomplished by installation of use of a rock lined outlet or grade stabilization structure (see rock channel protection).

Maintenance

A maintenance program shall be established to maintain capacity, vegetative cover, and associated structural components such as inlets, outlets, and tile lines. Items to consider in the maintenance program include:

- Determine responsible party to inspect and maintain the channel after construction
- Protect the channel from damage by equipment and traffic
- Fertilize annually to and maintain a vigorous stand of grass
- Mow the channel regularly to maintain a healthy and vigorous stand of grass
- Inspect grassed swales regularly, especially following heavy rains
- Repair damage to channels immediately. Damaged areas will be filled, compacted, and seeded immediately. All broken subsurface drains should be repaired
- Remove sediment deposits to maintain capacity of grassed swale. Seed and mulch any bare areas that develop. Note: excessive deposition or erosion of the swale may indicate the need to consider changes to the current design that will be appropriate to the water and sediment transport.
- Easements should be obtained to ensure the channel is maintained as constructed.

References

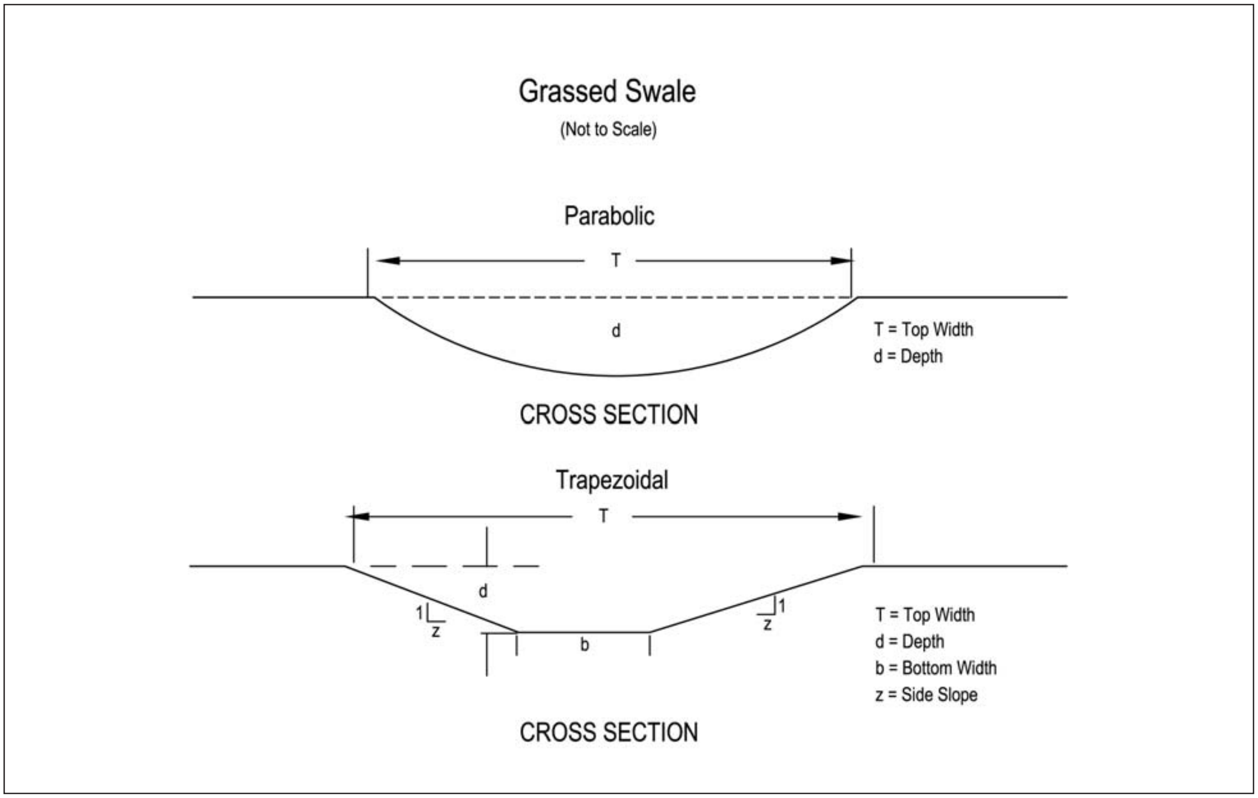
Additional guidance for evaluation, planning, and design of grassed swales is given in:

- NRCS Ohio Practice Standard 412, Grassed Waterway.
- NRCS Engineering Field Handbook (EFH) Part 650, Chapter 7 - Grassed Waterways.
- Agricultural Handbook 667, Stability Design of Grass-lined Open Channels.

Specifications

for

Grassed Swale



1. All trees, brush, stumps, and other unsuitable material shall be removed from the site.
2. The channel shall be excavated and shaped to the proper grade and cross section.
3. Fill material used in the construction of the channel shall be well compacted in uniform layers not exceeding 9 inches using the wheel treads or tracks of the construction equipment to prevent unequal settlement.
4. Excess earth shall be graded or disposed of so that it will not restrict flow to the channel or interfere with its functioning.
5. Stabilization shall be done according to the appropriate specifications for permanent seeding, vegetative practices, sodding and matting.
6. Construction shall be sequenced so that newly constructed channels are stabilized prior to becoming operational. To aid in the establishment of vegetation, surface water may be prevented from entering the newly constructed channel through the establishment period.
7. Gullies that may form in the channel or other erosion damage that occurs before the grass lining becomes established shall be repaired without delay.

4.2 Level Spreader

Description

A level spreader is a constructed weir that is shaped or graded flat perpendicular to the direction of flow. Level spreaders are used to convert concentrated flow to sheet flow over nearly level areas without causing erosion, formation or gullies, or flooding.

Condition Where Practice Applies

This practice applies to sites where:

1. Small concentrated flows, less than 30 cfs from a 10-yr. frequency storm, can be converted to sheet flow using a level spreader
2. The outlet area below the level spreader is stable with dense vegetation with a slope less than 10%. The soils are nonerosive and gully formation is not a concern.
3. A level spreader can convert runoff from an impervious surface (i.e. parking lot) or concentrated runoff from curb cuts or roof downspouts to shallow uniform sheet flow
4. Concentrated flows from storm drains, or diversions can be released onto a nearly flat natural densely vegetated area
5. The level lip of the spreader can be constructed in undisturbed soil
6. The level spreader is needed in conjunction with another measure (i.e. vegetated filter strip, detention pond, etc.)

Planning Considerations

The following benefits and impacts of level spreaders should be considered where they are planned:

- Level spreaders are relatively low cost structures that can uniformly disperse impervious surface runoff, roof downspout runoff, or other small volumes of concentrated flow.
- Runoff containing high sediment loads must be treated by a sediment trapping device prior to release into the level spreader
- Level spreaders must be placed where there would be no traffic over the spreader to assure that the level lip remains level and undisturbed
- Level spreaders can be used below pipe outlets where the flow can be converted to and continue as sheet flow. However, the pipe outlet must be stabilized with outlet protection prior to release of runoff into the level spreader.

Design Criteria

Capacity

The design capacity of the level spreader shall be estimated by determining the peak rate of runoff from a 10-yr. frequency storm. The design flow should not be greater than 30 cubic feet per second (cfs) from a 10-yr.-frequency storm.

Spreader Dimensions

Select the length and depth of the spreader from Table 4.2.1 below.

- The minimum width (W) is in the direction that is perpendicular to the flow.
- The minimum depth (D) of the level spreader shall be at least 0.5 feet measured down from the level lip. Depth may be greater to increase temporary storage capacity, improve trapping of debris, and enhance settling of any suspended solids based on erosion potential or other site conditions.

Table 4.2.1 Level Spreader Dimensions

Flow Rate (cfs)	Minimum Depth – D (ft)	Minimum Width – W (ft)
0 – 10	0.5	10
10 – 20	0.6	20
20 – 30	0.7	30

The level lip of the spreader must be constructed completely level (0% grade) to insure uniform spreading of the runoff over the entire length of the spreader.

Flows released from level spreaders must outlet onto undisturbed stable areas with a slope not exceeding 10%, where sheet flow are maintained and concentrated flow prevented.

When constructing a level spreader as an outlet for a diversion, the last 20 feet of the diversion should be used to smoothly transition the width of the diversion to the width of the spreader to ensure uniform outflow. The grade of the channel for the last 20 feet of the diversion entering the level spreader shall be 1.0% or less.

Side Slopes

The sides of the spreader shall be tied into higher ground to prevent flow around the spreader. Side slopes shall be 2 to 1 (horizontal to vertical) or flatter.

Weir Materials

- For design flows less than 4 cfs, the level spreader lip may be vegetated natural earth (not fill).

  The ***vegetated lip spreader*** shall be protected using an erosion control blanket (installed according to manufacturers recommendations) to prevent erosion and allow vegetation to become established. The blanket shall start a minimum of 4 feet above the lip and extend at least 1 foot downstream over the spreader lip secured with heavy-duty staples with the downstream and upstream ends buried at least 6 inches in a vertical trench.

- For design flows greater than 4 cfs, the level spreader lip must be constructed of rigid, durable, non-erodible material (i.e. riprap, concrete, or precast block or geosynthetic materials).

  The ***rigid lip spreader*** constructed of riprap shall meet ODOT Type D riprap and shall be carefully installed with a 2-foot wide level lip. An apron with existing vegetation shall extend downstream from the rigid lip at least 3 feet. The riprap shall be a minimum of 12 inches thick. Spread gravel or soil over top of the placed riprap surface to fill the voids and interlock the riprap together. A rigid lip spreader constructed from other durable, non-erodible material (ie –concrete curbing) shall be constructed of material that is anchored securely at least 4 inches below existing ground to prevent displacement. An apron of AASHTO No. 1 stone shall be placed adjacent to and downstream from the rigid lip at least 3 feet. The top of the stone shall be at the same elevation as the top of the lip.

Use with Pipe Outlet Protection

Level spreaders can be used below pipe outlets where the flow can be converted to and continue as sheet flow. However, the pipe outlet must be stabilized with outlet protection prior to release of runoff into the level spreader.

Establishing Vegetation

All level spreaders shall be vegetated or otherwise stabilized, as soon as possible after construction. Stabilization should be done according to the appropriate Standards and Specifications for Vegetative Practices (e.g. Permanent Seeding, Mulching, Matting).

Maintenance

A maintenance plan shall be established to maintain the level spreader, its capacity, vegetative cover, and other associated structural components such as outlets, headwalls or rock.

Items to consider in the maintenance program include:

- Determine responsible party to inspect and maintain the practice after construction
- Protect the practice from damage by equipment and traffic
- Fertilize the vegetated area annually to and maintain a vigorous stand of grass
- Mow the vegetated area to maintain a healthy and vigorous stand of grass.
- Check the level spreader periodically to verify that the spreader is distributing flow uniformly. If problems are noted, make repairs to ensure even flow over the level lip.
- Repair damage to the level spreader immediately. Missing materials should be replaced as soon as possible. Seed and mulch any bare areas that develop.
- Remove sediment and debris that have accumulated.

- Easements, or other means, should be obtained to ensure the level spreader is maintained as constructed.

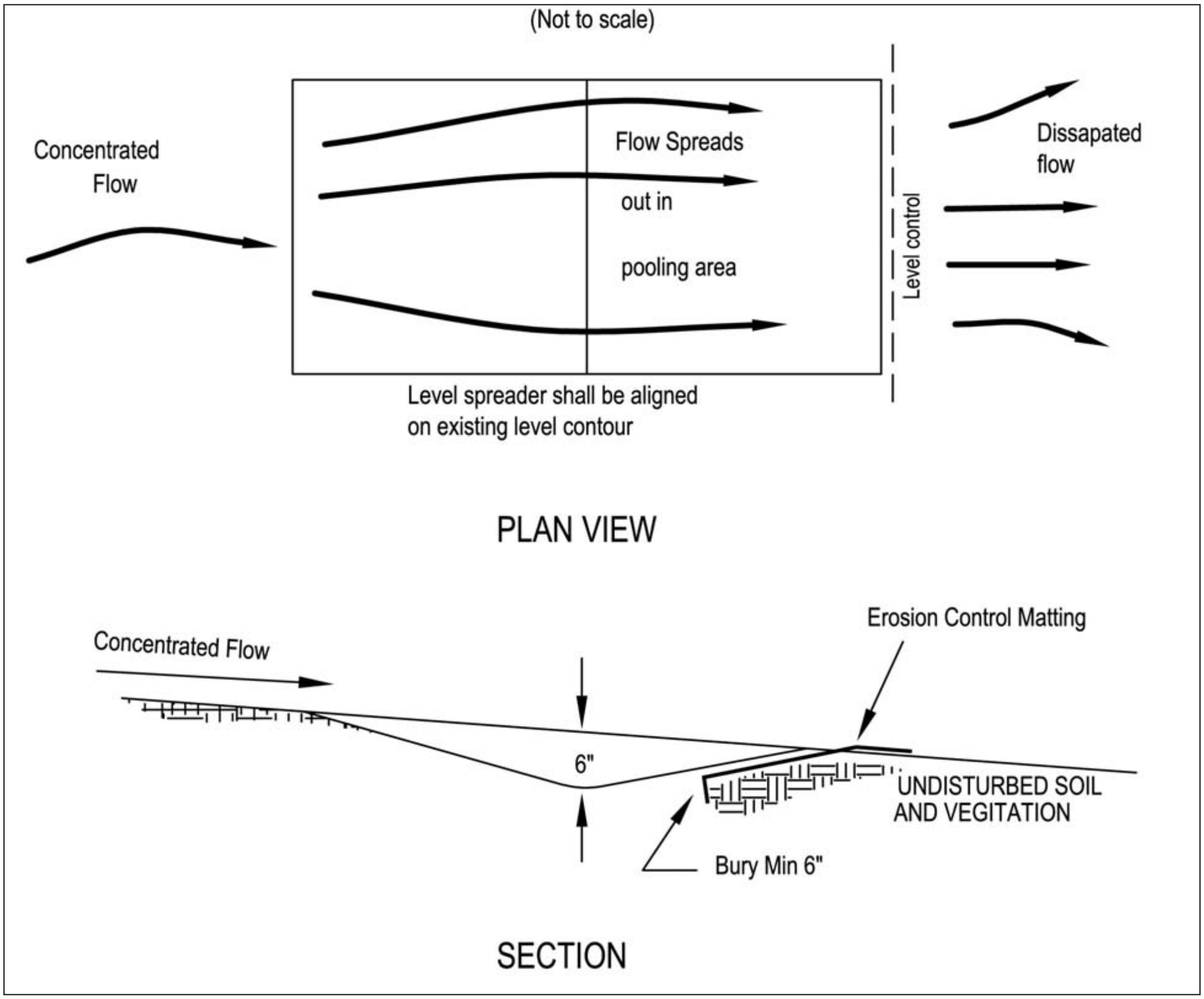
References

Additional guidance for evaluation, planning, and design of level spreaders is given in:

- Illinois Urban Manual: A Technical Manual Designed for Urban Ecosystem Protection and Enhancement, prepared for the Illinois EPA by Illinois NRCS
- Ohio Rainwater and Land Development Manual, Second Edition 1996
- NRCS Design Note 24, Guide for Use of Geotextiles

Specifications
for

Vegetated Level Spreader



1. Construct level spreader on a level grade to ensure uniform spreading of storm runoff.

2. Level spreaders must be constructed on undisturbed soil, NOT on fill.

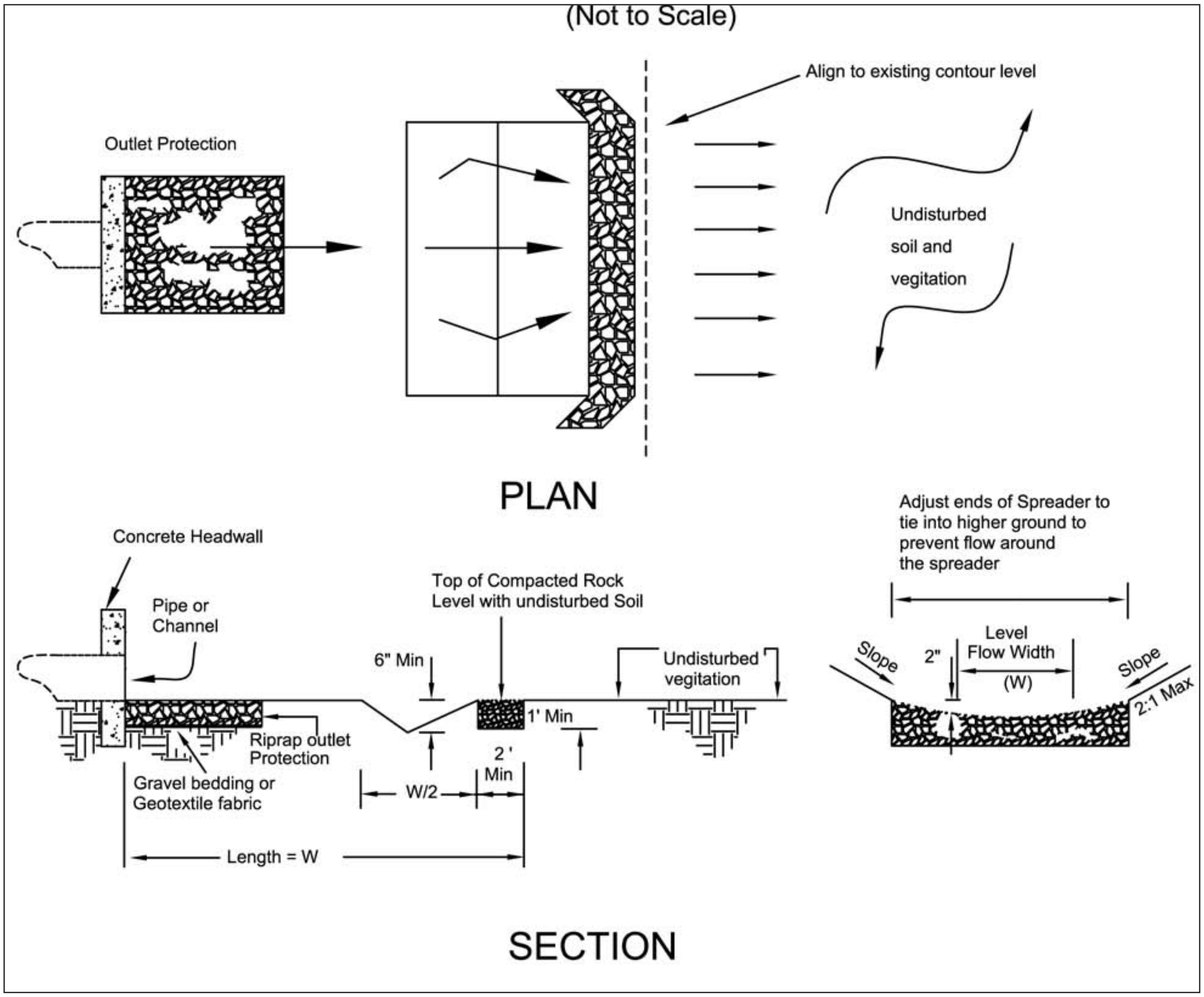
3. The level spreader must outlet to erosion-resistant areas with established existing vegetation.

4. Vegetated lip spreaders shall be protected using an erosion control blanket installed according to manufactures' recommendations. The blanket shall start a minimum of 4 feet above the lip and extend at least 1 foot downstream over the spreader lip, secured with heavy-duty staples and the downstream and upstream ends buried at least 6 inches in a vertical trench.

5. Fertilizing, seeding, and mulching shall conform to the recommendations in the applicable vegetative specification.

Specifications
for

Rigid Lip Level Spreader



1. Construct level spreader on a level grade to ensure uniform spreading of storm runoff.
2. Level spreaders must be constructed on undisturbed soil, NOT on fill.
3. The level spreader must outlet to erosion-resistant areas with established existing vegetation.
4. Rock shall be ODOT Type D where 50% of the material by weight is larger than 6 inches, and 85% of the material by weight is larger than 3 inches but less than 12 inches.
5. Rock in level spreader shall be compacted with at least two passes of heavy machinery to prevent further settling. Spread gravel or soil over top of the placed riprap surface to fill the voids and interlock the riprap together.
6. Fertilizing, seeding, and mulching shall conform to the recommendations in the applicable vegetative specification.

4.3 Rock Lined Channel

Description

A channel that is shaped or graded and protected with an erosion resistant rock riprap underlain with filter or bedding material used to convey stormwater runoff without allowing channel erosion. Rock channel protection provides for the safe conveyance of runoff from areas of concentrated flow without damage from erosion or flooding, where vegetated waterway / conveyance channel / swales would be inadequate. Rock lined channel may also be necessary to control seepage, piping, and sloughing or slides. The riprap section extends up the side slopes to designed depth. The earth above the rock should be vegetated or otherwise protected.

Conditions Where Practice Applies

This practice applies where the following conditions exist:

- Concentrated runoff will cause erosion unless a liner is provided
- Steep grades, wetness, seepage, prolonged base flow, or piping would cause erosion
- Damage by vehicles or animals will make the establishment or maintenance of vegetation difficult
- Soils are highly erosive or other soil or climatic conditions preclude the use of vegetation
- Velocities are expected that will erode the channel or outlet without protection

Caution should be used when design flow greater than 100 cubic feet per second (cfs) from a 10-yr.-frequency storm is expected. Chapter __ - Stream Channel Restoration, should be referenced for planning and design of larger channels.

Planning Considerations

Permits

A construction permit may be required by the local government. Additionally, the U.S. Army Corps of Engineers and the Ohio Environmental Protection Agency, through Sections 404 and 401, respectively, of the Clean Water Act, may require a permit for rock lined channel / outlet that are located adjacent to a stream. It is best to contact your local Soil and Water Conservation District (SWCD) office to determine what both agencies' permit requirements are for your project.

Water Quality

Rock lined channels and outlet protection provide water quality benefits by providing channel stability, prevention of excessive erosion, and limiting subsequent downstream sedimentation.

Design Criteria

Runoff

Runoff computation will be based upon the most severe soil and cover conditions that will exist in the area draining into the channel during the planned life of the structure. Use the NRCS Technical Release 55 (TR 55) or other suitable method shall be used to determine peak rate of runoff.

Capacity

The design capacity of the rock lined channel shall be adequate to carry the peak rate of runoff from a 10-yr. frequency storm. Where high-hazard conditions exist, higher frequency storms should be chosen to provide protection compatible with conditions. The rock-lined channel must have design capacity as required if it to be used as an outlet for a grassed waterway, diversion, terrace, or other measure. Capacity shall be computed using Manning's Equation with a coefficient of roughness "n" listed in the "rock size" table below.

Rock-lined channels / outlets shall be designed by accepted engineering methods such as the Federal Highway Administration Circular No. 15 or Figure 2-1 (Maximum depth of Flow for Riprap Lined Channels) that can be used to determine rock size using flow depth and velocity obtained from Manning's equation. Procedures are also available in the NRCS Engineering Field Handbook.

Velocity

Table 4.3.1 Maximum Design Velocity

Design Flow Depth	Maximum Velocity
0 - 0.5 ft	25 fps
0.5 – 1.0 ft	15 fps
> 1.0 ft	10 fps

Cross Section Shape

The cross sectional shape of rock lined waterway / outlets shall be parabolic, trapezoidal, or triangular.

- *Parabolic channels* most closely approximate natural flow characteristics at low as well as high flows. Although generally preferred for esthetic reasons, design and construction procedures are more complex.
- *Trapezoidal channels* often are used where the quantity of water to be carried is large and velocities high. The steepest permissible side slopes, horizontal to vertical, shall be 2 to 1.
- *Triangular shaped channels* generally is used where the quantity of water to be handled is relatively small, such as roadside ditches. The steepest permissible side slopes, horizontal to vertical, shall be 2 to 1.

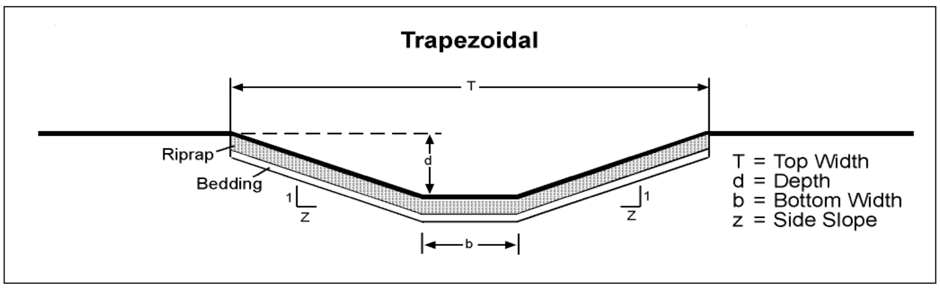


Figure 4.3.1

Rock Lining

The rock-lined channel shall consist of the rock riprap layer and an underlying filter or bedding. Minimum thickness of the rock riprap layer shall be the maximum stone size. Stone used for riprap shall be dense and hard enough to withstand exposure to air, water, freezing and thawing. Figure 4.3.2 gives the maximum depth of flow for riprap lined channels. Rock riprap must have a well-graded distribution and be placed in a to obtain a solid, compact layer of riprap. This may require some hand placing and tamping with construction equipment. Spreading gravel or soil over top of the placed riprap surface will fill the voids by interlocking the riprap together.

Filter or Granular Bedding

Filter or granular bedding must be placed beneath all riprap to prevent the underlying soil from eroding and undermining the riprap, and to collect seepage and base flow. Minimum bedding thickness shall be 4 inches. Use of large size riprap may necessitate the use of a thicker bedding layer or 2 differently sized bedding layers. Care should be taken to select a granular bedding that that is suitable with the subgrade material.

Table 4.3.2 Rock Riprap Size

Type of Rock or Riprap (ODOT)	“n” value	Size of Rock	
		50% by weight	85% by weight
Type D	.036	> 6 in.	3 - 12 in.
Type C	.04	> 12 in.	6 - 18 in.
Type B	.043	> 18 in.	12 - 24 in.
Type A	.045	> 24 in.	18 - 30 in.

Adjustments to Naturalize Rock Lining

In order to more closely reflect the nature of the bed of a natural channel, smaller size graded stone may be used to fill the voids left in typical riprap applications.

Besides channel shape and pattern, typical rock lined channels depart from the flow behavior of natural channels by having to much pore space in the rock. Therefore regular flow is often entirely below the surface. This will be improved by extending the gradation of stone down to the gravel-sized material. This addition will increase velocity and reduce capacity slightly; therefore corresponding adjustments should be made.

Geotextile

Geotextile may be used as a filter to be placed beneath the riprap to prevent piping of the soil where wetness, seepage, or prolonged base flow is the reason for lining the channel with riprap. If design of the rock lined channel results in high velocities and steep grades, granular bedding should be used instead of geotextile. Care should be taken to properly anchor the geotextile to prevent unraveling under flowing water. Geotextile shall be woven or nonwoven monofilament yarn and shall meet Class I criteria in the attached table "Requirements for Geotextile".

Maintenance

A maintenance program shall be established to maintain capacity, vegetative cover above the riprap, and associated structural components such as inlets, outlets, and tile lines. Items to consider in the maintenance program include:

- Determine responsible party to inspect and maintain the channel after construction
- Protect the channel from damage by equipment, traffic, or livestock
- Fertilize the vegetated area annually to and maintain a vigorous stand of grass
- Mow the vegetated area to maintain a healthy and vigorous stand of grass.
- Repair damage to channels immediately. Missing riprap should be replaced as soon as possible. All broken subsurface drains should be repaired. Seed and mulch any bare areas that develop.
- Remove sediment and debris that have accumulated.
- Easements, or other means, should be obtained to ensure the channel is maintained as constructed

References

Additional guidance for evaluation, planning, and design of rock lined channels is given in:

- National Cooperative Highway Research Program Report 108 – Tentative Design Procedure for Riprap – Lined Channels
- NRCS Ohio Practice Standard 468, Lined Waterway Or Outlet
- NRCS Engineering Field Handbook, Chapter 6 - Structures
- NRCS Design Note 24, Guide for Use of Geotextiles

Table 4.3.3 Requirements for Geotextiles

Property	Test method	Woven - Class I	Nonwoven - Class I
Tensile strength (pounds) 1/	ASTM D 4632 grab test	200 minimum in any principal direction	180 minimum
Elongation at failure (percent) 1/	ASTM D 4632 grab test	<50	≥ 50
Puncture (pounds) 1/	ASTM D 4833	90 minimum	80 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified, but no smaller than 0.212 mm (#70) 2/	As specified max. #40 2/
Percent open area (percent)	CWO-02215-86	4.0 minimum	---------------
Permitivity sec-1	ASTM D 4491	0.10 minimum	0.70 minimum

1/ Minimum average roll value (weakest principal direction).
2/ U.S. standard sieve size.
Note: CWO is a USACE reference.

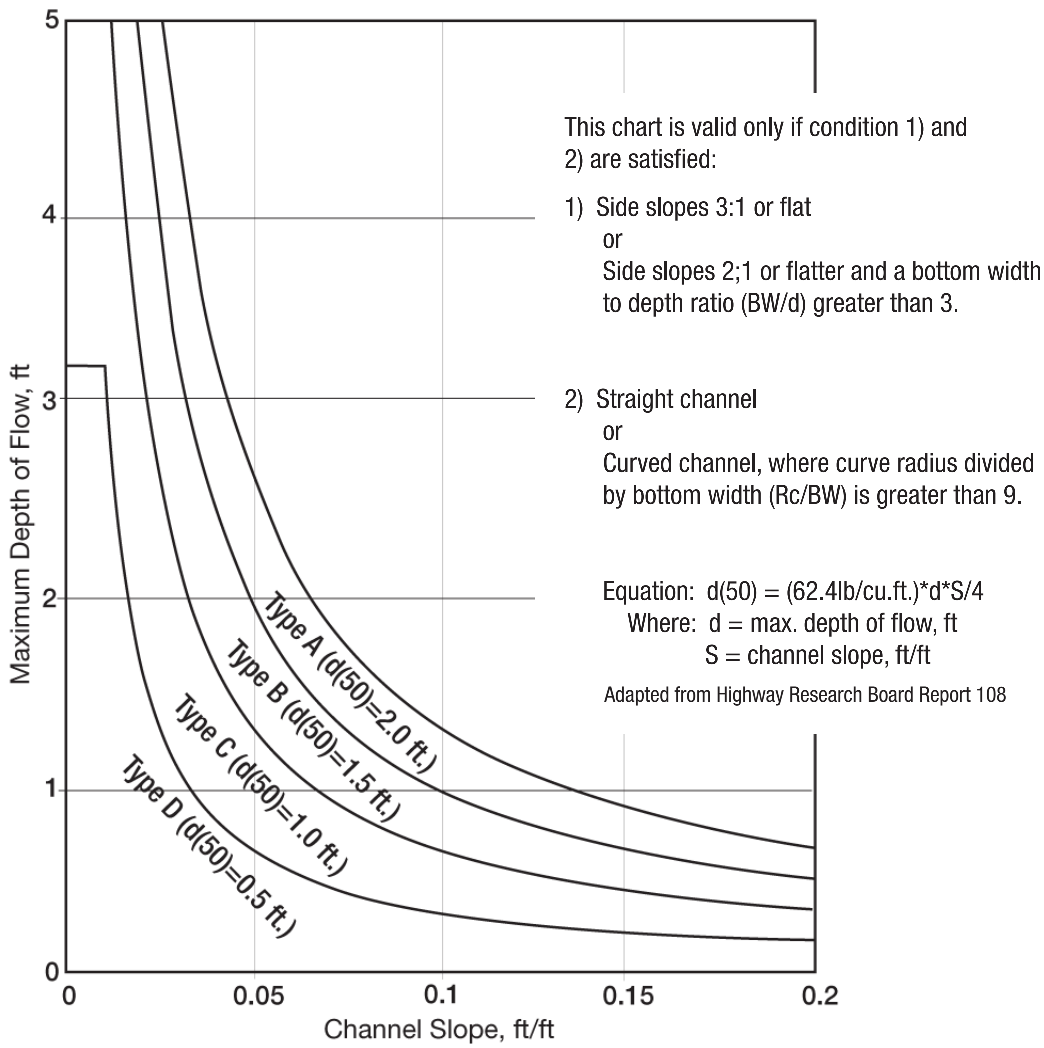
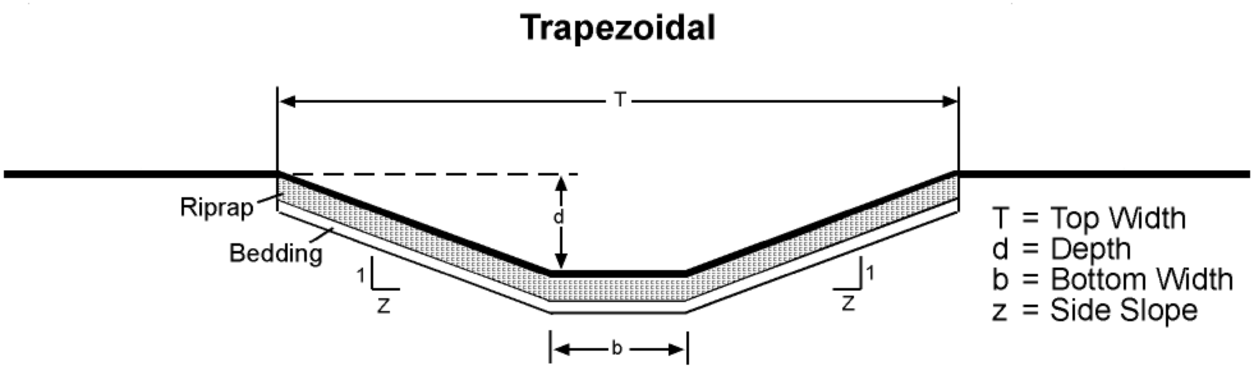


Figure 4.3.2 Maximum Depth of Flow for Riprap Lined Channels

Specifications
for
Rock Lined Channel



1. Subgrade for the filter and riprap shall be prepared to the required lines and grades as shown on the plan. The subgrade shall be cleared of all trees, stumps, roots, sod, loose rock, or other material.
2. Riprap shall conform to the grading limits as shown on the plan.
3. No abrupt deviations from the design grade or horizontal alignment shall be permitted.
4. Geotextile shall be securely anchored according to manufacturers recommendations.
5. Geotextile shall be laid with the long dimension parallel to the direction of flow and shall be laid loosely but without wrinkles and creases. Where joints are necessary, strips shall be placed to provide a 12-in. minimum overlap, with the upstream strip overlapping the downstream strip.
6. Gravel bedding shall be ODOT No. 67's or 57's unless shown differently on the drawings.
7. Riprap may be placed by equipment but shall be placed in a manner to prevent slippage or damage to the geotextile.
8. Riprap shall be placed by a method that does not cause segregation of sizes. Extensive pushing with a dozer causes segregation and shall be avoided by delivering riprap near its final location within the channel.
9. Construction shall be sequenced so that riprap channel protection is placed and functional without delays when the channel becomes operational.
10. All disturbed areas will be vegetated as soon as practical.

4.4 Rock Outlet Protection

Description

A rock or riprap apron typically needed at the outlet of storm drains, culverts, or open channels. Rock Outlet Protection provides an erosion resistant transition area where concentrated or high velocity flows enters less modified channels or natural streams.

Conditions Where Practice Applies

This practice applies where discharge velocities from channels, storm drains or culverts are high enough to erode receiving streams or areas. Suggested areas of application are:

- Outfalls of stormwater detention facilities or sediment traps or basins.
- Constructed channel outlets
- Culvert outlets

This practice is not intended for use on slopes greater than 10% or at the top of cut or fill slopes. Caution should be used when design flows exceed 100 cubic feet per second (cfs) from a 10-yr.-frequency storm..

Planning Considerations

Rock Outlet Protection may be used in conjunction with other practices, such as level spreaders. Rock Outlet Protection and Level Spreaders can both be used at the end of pipe outlets. This practice should be used alone where flow will continue as concentrated flow. Level Spreaders can be used with Rock Outlet Protection only when flow can be converted to and continue as sheet flow.

Permits

A construction permit may be required by the local government. Additionally, the U.S. Army Corps of Engineers and the Ohio Environmental Protection Agency, through Sections 404 and 401, respectively, of the Clean Water Act, may require a permit for an outlet protection that is located adjacent to a stream.

Water Quality

Rock outlet protection may also provide water quality benefits by providing for channel stability, prevention of excessive erosion, and limiting subsequent downstream sedimentation.

Design Criteria

Runoff

Runoff computation will be based upon the most severe soil and cover conditions that will exist in the area draining into the channel during the planned life of the structure. Use the NRCS Technical Release 55 (TR 55) or other suitable method shall be used to determine peak rate of runoff.

Velocity

Outlet protection shall be designed to be stable for discharge velocity expected from a 10-year frequency storm. Where high-hazard conditions exist, higher frequency storms should be chosen to provide protection compatible with conditions. Outlet protection shall meet the following criteria

Design Velocity

Outlet protection shall be designed to be stable for the velocity of flow expected from a 10-year frequency storm. Outlet protection shall be designed to meet the criteria below or by other accepted engineering methods.

Width

The width of the outlet protection shall be the width of the headwall or 4 feet wider than the pipe diameter (2 feet on each side of the pipe).

Bottom Grade

The outlet protection should be constructed with no slope along it length. The elevation on the downstream end of the outlet protection shall be equal to the elevation of the receiving stream or channel.

Length of Rock Outlet Protection and Rock Size

Use the velocity calculated at the pipe outlet, the pipe diameter, and Figure 4.4.1. Outlet Protection Length, to find the length of outlet protection needed and rock size to use.

Rock Lining

The outlet protection shall consist of the rock riprap layer and an underlying filter or bedding. Minimum thickness of the rock riprap layer shall be the maximum stone size. Stone used for riprap shall be dense and hard enough to withstand exposure to air, water, freezing and thawing. Rock riprap must have a well-graded distribution and be placed to obtain a solid, compact layer of riprap. This may require some hand placing and tamping with construction equipment. Spreading gravel or soil over top of the placed riprap surface will fill the voids by interlocking the riprap together.

Table 4.4.1 Rock Riprap Size

Type of Rock or Riprap (ODOT)	"n" value	Size of Rock	
		50% by weight	85% by weight
Type D	.036	> 6 in.	3 - 12 in.
Type C	.04	> 12 in.	6 - 18 in.
Type B	.043	> 18 in.	12 - 24 in.
Type A	.045	> 24 in.	18 - 30 in.

Filter or Granular Bedding

Filter or granular bedding must be placed beneath all riprap to prevent the underlying soil from eroding and undermining the riprap, and to collect seepage and base flow. Minimum bedding thickness shall be 4 inches. Use of large size riprap may necessitate the use of a thicker bedding layer or 2 differently sized bedding layers. Care should be taken to select granular bedding that that is suitable with the subgrade material.

Geotextile

Geotextile may be used as a filter to be placed beneath the riprap to prevent piping of the soil where wetness, seepage, or prolonged base flow is the reason for lining the channel with riprap. If design of the outlet protection results in high velocities and steep grades, granular bedding should be used instead of geotextile. Care should be taken to properly anchor the geotextile to prevent unraveling under flowing water. Geotextile shall be woven or nonwoven monofilament yarn and shall meet Class I criteria in the attached table "Requirements for Geotextile".

Maintenance

A maintenance program shall be established to maintain riprap, vegetative cover above the riprap, and associated structural components such as pipe outlets, and tile lines. Items to consider in the maintenance program include:

- Determine responsible party to inspect and maintain the outlet protection after construction
- Missing riprap should be replaced as soon as possible.
- Protect the outlet protection from damage by equipment and traffic
- Fertilize the vegetated area annually to and maintain a vigorous stand of grass
- Mow the vegetated area to maintain a healthy and vigorous stand of grass.
- Seed and mulch any bare areas that develop.
- Remove sediment and debris that have accumulated.
- Easements, or other means, should be obtained to ensure the channel is maintained as constructed

References

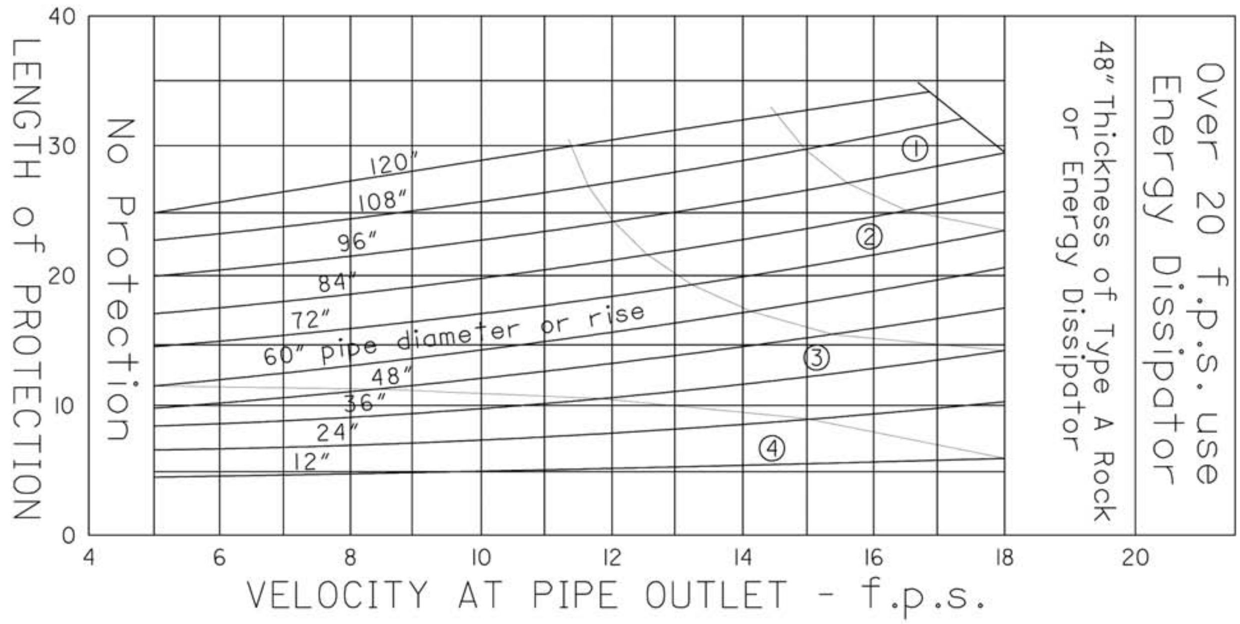
Additional guidance for evaluation, planning, and design of outlet protection is given in:

- NRCS Ohio Practice Standard 468, Lined Waterway Or Outlet
- NRCS Engineering Field Handbook, Chapter 6 - Structures
- NRCS Design Note 24, Guide for Use of Geotextiles
- ODOT Location and Design Manual, Rock Channel Protection at Culvert and Storm Sewer Outlets

Table 4.4.2 Requirements for Geotextiles

Property	Test method	Woven - Class I	Nonwoven - Class I
Tensile strength (pounds) 1/	ASTM D 4632 grab test	200 minimum in any principal direction	180 minimum
Elongation at failure (percent) 1/	ASTM D 4632 grab test	<50	≥ 50
Puncture (pounds) 1/	ASTM D 4833	90 minimum	80 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified, but no smaller than 0.212 mm (#70) 2/	As specified max. #40 2/
Percent open area (percent)	CWO-02215-86	4.0 minimum	---------------
Permitivity sec-1	ASTM D 4491	0.10 minimum	0.70 minimum

1/ Minimum average roll value (weakest principal direction).
2/ U.S. standard sieve size.
Note: CWO is a USACE reference.



NOTES

Rock size (6", 12", 18") indicates the square opening on which 85% of the material, by weight, will be retained.

The width of protection shall be the width of the headwall, with 4' being the minimum.

(Where a stream bed will withstand the calculated velocity without erosion, no rock channel protection will be required.)

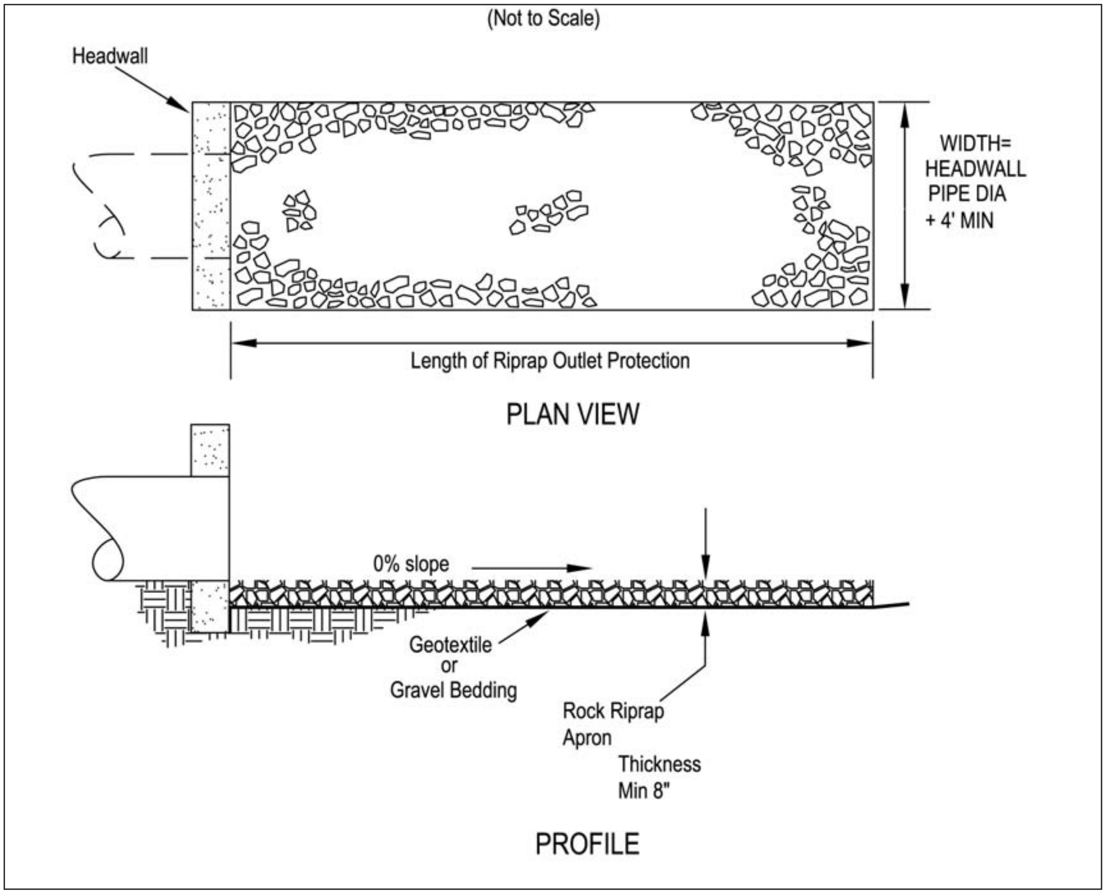
LEGEND	ROCK TYPE
① 48" of 18" rock	A
② 36" of 18" rock	A
③ 30" of 12" rock	B
④ 18" of 6" rock	C

Source: ODOT Location and Design Manual, Rock Channel Protection at Culvert and Storm Sewer Outlets

Figure 4.4.1 Length of Rock Outlet Protection and Rock Size

Specifications
for

Rock Outlet Protection



1. Subgrade for the filter or bedding and riprap shall be prepared to the required lines and grades as shown on the plan. The subgrade shall be cleared of all trees, stumps, roots, sod, loose rock, or other material.
2. Riprap shall conform to the grading limits as shown on the plan.
3. Geotextile shall be securely anchored according to manufacturers' recommendations.
4. Geotextile shall be laid with the long dimension parallel to the direction of flow and shall be laid loosely but without wrinkles and creases. Where joints are necessary, strips shall be placed to provide a 12-in. minimum overlap, with the upstream strip overlapping the downstream strip.
5. Gravel bedding shall be ODOT No. 67's or 57's unless shown differently on the drawings.
6. Riprap may be placed by equipment but shall be placed in a manner to prevent slippage or damage to the geotextile.
7. Riprap shall be placed by a method that does not cause segregation of sizes. Extensive pushing with a dozer causes segregation and shall be avoided by delivering riprap near its final location within the channel.
8. Construction shall be sequenced so that outlet protection is placed and functional when the storm drain, culvert, or open channel above it becomes operational.
9. All disturbed areas will be vegetated as soon as practical.

4.5 Diversion

Description

A permanent channel constructed across the slope with a supporting ridge on the lower side used to divert excess water from one area for use or safe disposal in other areas.

Conditions Where Practice Applies

This practice applies to sites where:

- A permanent diversion is required to control erosion and runoff on down slope developing areas and construction sites
- Runoff from higher areas is causing off site damage
- Surface and shallow subsurface flow is damaging sloping upland.
- A diversion is required as part of a pollution abatement system to protect off site sensitive areas
- Permanent diversions are suitable on flatter gradients. Steeper gradients may require a rock lining or other means of protection
- For a temporary diversion that is needed to divert excess runoff for a short period of time, see the design considerations for Temporary Diversion, Chapter 5.

Planning Considerations

Water Quality

Besides the primary design objective of providing a stable channel, water quality benefits may also be achieved. Diversions may promote settling and infiltration for small storm events, thereby treating runoff. To provide water quality treatment benefits, see Chapter __ - Water Quality Swale for planning and design details.

Location

Locations of diversions shall be determined by topography, outlet conditions, land use, soil type, and length of slope. When diversions are used to intercept subsurface flow or seepage, depth and location of seepage should be used to determine location and spacing of diversions.

A subsurface drain should be used as necessary to establish and maintain vegetative cover.

Design Criteria

Runoff

Runoff computation will be based upon the most severe soil and cover conditions that will exist in the area draining into the waterway during the planned life of the structure. Use the NRCS Technical Release 55 (TR 55) or other suitable method shall be used to determine peak rate of runoff.

Capacity

Diversions protecting undeveloped land shall have a capacity to carry the peak rate of runoff from a 10-yr. frequency storm. Where high-hazard conditions exist, higher frequency storms should be chosen to provide protection compatible with conditions. Diversions designed to protect urban areas, buildings and roads, shall have a capacity to carry the peak rate of runoff from a 25-yr. frequency storm with a freeboard of not less than 0.3 feet.

Cross Section

The diversion channel shall be parabolic or trapezoidal. The diversion shall be designed to have stable side slopes (3 horizontal to 1 vertical or flatter are recommended on both sides). The ridge height shall include a minimum of 0.3 ft of freeboard and a minimum settlement factor of 10% in addition to the design flow depth. The ridge shall have a minimum constructed top width of 4 feet at the design elevation. The minimum cross sectional area shall meet the specified dimensions. The top of the constructed ridge shall not be lower at any point than the design elevation plus the specified amount for settlement.

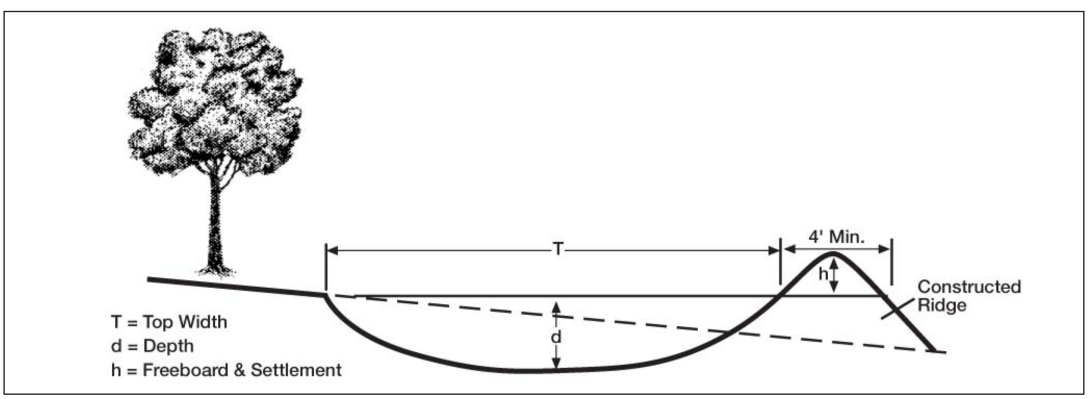


Figure 4.5.1

Grade and velocity

Channel grades shall be as uniform as possible. Special care should be taken in evaluating site conditions for diversions where the grade decreases toward the outlet because of potential sediment deposition problems.

Design Velocity of Vegetative Lining:

Diversions shall be designed so that the velocity of flow expected from a 10-year frequency storm does not exceed the permissible velocity for the type of lining used (see the table below). Manning's Equation or other suitable method should be used to determine design velocity.

Table 4.5.1 Grass Lining Maximum Flow Velocity for a 10-Yr. Frequency Storm

Soil		Maximum Velocity (fps)		
Texture	Type	Seed & Mulch	Seed & Matting	Sod
Sand, Silt, Sandy Loam, Silt Loam	Sand	1.5	3.0	3.5
Silty Clay Loam, Sandy Clay Loam	Firm Loam	2.0	4.0	4.0
Clay	Clay	2.5	40	5.0
N/A	Gravel	3.5	5.0	6.0
N/A	Weathering Shale	4.5	5.0	N/A

Note: Soil texture can be generally determined from the soil surveys. If the channel is on fill, the soil should be tested.

Establishing Vegetation

All diversions shall be vegetated or otherwise stabilized, as soon as possible after construction. Stabilization should be done according to the appropriate Standards and Specifications for Vegetative Practices (e.g. Permanent Seeding, Mulching, Matting).

- For design velocities of less than 3.5 fps, seeding and mulching may be used for the establishment of the desired vegetation. Mulch netting should be used to protect the seeding during establishment. It is recommended that when conditions permit, a temporary diversion or other means be used to prevent water from entering the diversion during the establishment of vegetation.
- For design velocities of more than 3.5 fps, the diversion shall be stabilized with seeding protected by erosion control matting or blankets, or with sod. It is recommended that when conditions permit, a temporary diversion or other means be used to prevent water from entering the diversion during the establishment of vegetation.

Sedimentation

Diversions should not be used below high sediment producing areas unless land treatment practices or structural measures that will prevent damage to the diversion are designed and installed prior to installation of the diversion. If some accumulation of sediment cannot be prevented, then the design shall include extra capacity for the sediment. Accumulation of sediment shall be considered in the maintenance plan for this practice.

Outlets

All diversions shall have a stable outlet with adequate capacity to prevent ponding or flooding damages. The outlet may be a grassed waterway / conveyance channel / swale, stable vegetated area, grade stabilization structure, rock lined waterway / outlet, or stable stream. The outlet must convey runoff to a point where outflow will not cause damage. The design elevation of the water surface in the diversion shall not be less than the water surface in the outlet at the junction when both are operating at design flow.

Maintenance

A maintenance program shall be established to maintain capacity, vegetative cover, and associated structural components such as inlets, outlets, and subsurface drains. Items to consider in the maintenance program include:

- Determine responsible party to inspect and maintain the diversion after construction
- Protect the diversion from damage by equipment, traffic, or livestock
- Fertilize annually to and maintain a vigorous stand of grass
- Mow the diversion regularly to maintain a healthy and vigorous stand of grass
- Inspect the diversion regularly, especially following heavy rains
- Repair damage to the diversion immediately. Damaged areas will be filled, compacted, and seeded immediately. All broken subsurface drains should be repaired
- Remove sediment deposits to maintain capacity of the diversion. Seed and mulch any bare areas that develop
- Easements should be obtained to ensure the diversion is maintained as constructed

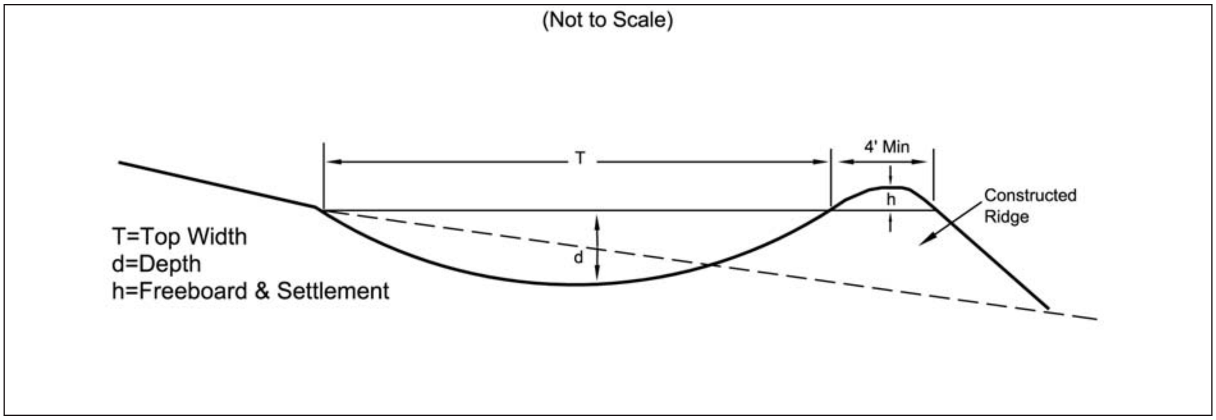
References

Additional guidance for evaluation, planning, and design of diversions is given in:

- NRCS Ohio Practice Standard 362, Diversion.
- NRCS Engineering Field Handbook (EFH) Part 650, Chapter 9 - Diversion
- Agricultural Handbook 667, Stability Design of Grass-lined Open Channels.

Specifications
for

Diversion



1. All trees, brush, stumps, and other unsuitable material shall be removed from the work site.
2. The diversion shall be excavated and shaped to the proper grade and cross section.
3. Fill material used in the construction of the channel shall be well compacted in uniform layers not exceeding 9 inches using the wheel treads or tracks of the construction equipment to prevent unequal settlement.
4. Excess earth shall be graded or disposed of so that it will not restrict flow to the channel or interfere with its functioning.
5. Fertilizing, seeding, and mulching shall conform to the recommendations in the applicable vegetative specifications.
6. Construction shall be sequenced so that the newly constructed channel is stabilized prior to becoming operational. To aid in the establishment of vegetation, surface water may be prevented from entering the newly constructed channel through the establishment period.
7. Gullies that may form in the channel or other erosion damage that occurs before the grass lining becomes established shall be repaired without delay.

4.6 Terrace

Description

A terrace is an earthen embankment, channel, or a combination ridge and channel constructed across the slope to:

- reduce slope length
- reduce erosion
- improve, intercept, and conduct surface runoff at a nonerosive velocity to a stable outlet
- reform the land surface
- prevent gully development
- reduce flooding

Conditions Where Practice Applies

This practice is applicable where:

- reduced slope length is needed to control erosion from concentrated runoff
- runoff and sediment can damage land or improvements downstream
- the soils and topography are such that terraces can be constructed with reasonable effort
- a suitable outlet can be provided

Planning Considerations

Terraces should generally fit the contour of the land. A system of terraces down the slope will work best if they are aligned parallel to each other. Land grading or benching between the terraces can enhance or improve the topography. On steeper slopes, by borrowing fill material above or below the terrace to construct the ridge, terraces can help to flatten the land between the terraces. Proper planning of the layout of a terrace system will aid in balancing cuts and fills.

Water Quality

Besides the primary design objective of reducing slope length and reduce erosion, water quality benefits may also be achieved. Terraces may promote settling and infiltration. Modifications may be made that store the water quality volume by adding weirs or check dams in order to detain and treat runoff for a minimum of 24 hours. See Water Quality Ponds for an explanation of the water quality volume.

Location

Locations of terraces shall be determined by topography, outlet conditions, land use, soil type, and length of slope. When terraces are used to intercept subsurface flow or seepage, depth and location of seepage should be used to determine location and spacing of terraces.

A subsurface drain should be used as necessary to establish and maintain vegetative cover.

Design Criteria

Runoff

Runoff computation will be based upon the most severe soil and cover conditions that will exist in the area draining into each terrace during the planned life of the structure. Use the NRCS Technical Release 55 (TR 55) or other suitable method shall be used to determine peak rate of runoff.

Capacity

Terraces shall have a capacity to carry the peak rate of runoff from a 10-yr. frequency storm for the area draining into each terrace. Where high-hazard conditions exist, higher frequency storms should be chosen to provide protection compatible with conditions. Terraces designed to protect urban areas, buildings and roads, shall have a capacity to carry the peak rate of runoff from a 25-yr. frequency storm with a freeboard of not less than 0.3 feet.

Types of Terraces

There are 2 types of terraces. Steep slope terraces are constructed with steeper ridges and are generally more suitable for steeper topography (See Figure 1). Broad based terraces are constructed with flatter ridges and are generally more suitable for flatter topography (See Figure 4.6.1).

Spacing

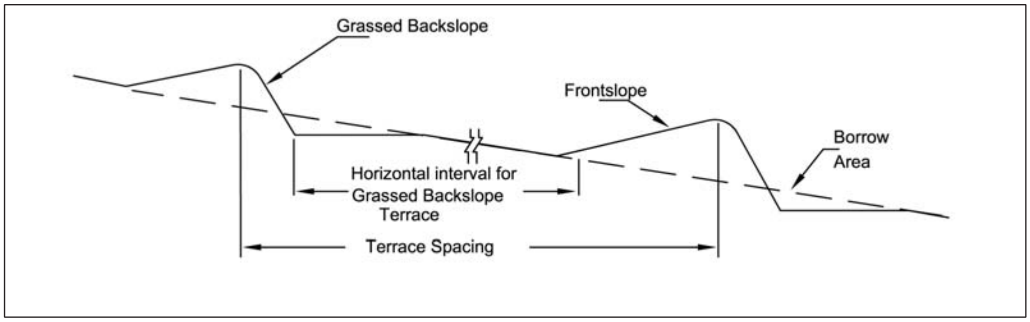
A system of terraces, whether steep sloped or broad based, shall be spaced not less than 90-ft. apart, or exceed the following:

Table 4.6.1

Land Slope-(Percent)	Terrace Spacing-(Feet)
0-2	500
2-4	400
4-6	400
6-9	300
9-12	250

Terraces

(Not to Scale)



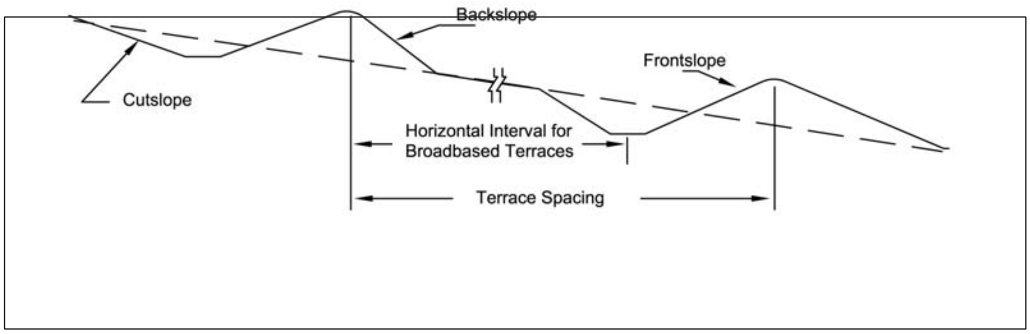


Figure 4.6.1

Cross Section

The channel shall be parabolic or trapezoidal. The terrace shall be designed to have stable side slopes. The maximum side slope shall be 2 horizontal to 1 vertical. The ridge height shall include a minimum of 0.3 ft of freeboard and a minimum settlement factor of 10% in addition to the design flow depth. The ridge shall have a minimum constructed top width of 4 feet at the design elevation. The minimum cross sectional area shall meet the specified dimensions. The top of the constructed ridge shall not be lower at any point than the design elevation plus the specified amount for settlement. Risers will be used on underground outlets (Figure 4.6.2). The riser will be placed in the lowest area so that all the water will drain from the terrace.

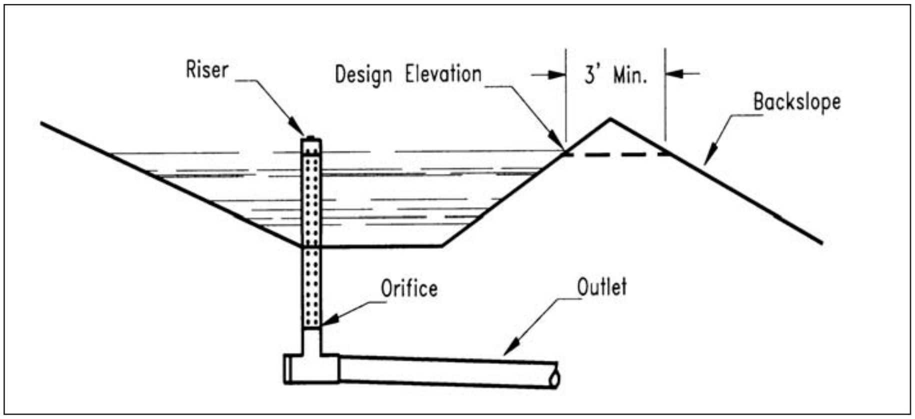


Figure 4.6.2 Riser utilized to drain terrace.

It is necessary to select the type of terrace before layout as the cross section affects terrace spacing. Cuts and fills should be made in such a manner that topography would be enhanced. Where deep cuts will expose unfavorable subsoil, the topsoil will be stripped, stockpiled and replaced. Terraces can be constructed having flatter broad base backslope or a steeper 2 horizontal to 1 vertical backslope.

The broad base terrace is constructed with flatter side slopes, and borrow is usually taken from the uphill side of the ridge. The broad base terrace is generally adapted to land slopes of less than 6 percent.

The steep slope terrace is constructed with steep side slopes (no steeper tan 2 to 1) that must be maintained in sod. Steep slope terraces are best adapted to field slopes to 6 percent or greater. Borrow is normally taken from the downhill side where the slope of the land between the terraces is reduced.

Grade

Channel grades are generally 2% or less to reduce velocities. Grade shall be as uniform as possible.

Design Velocity of Vegetative Lining:

Terraces shall be designed so that the velocity of flow expected from a 10-year frequency storm does not exceed the permissible velocity for the type of lining used (see the table below). Manning's Equation or other suitable method should be used to determine design velocity.

Table 4.6.2 Grass Lining Maximum Flow Velocity for a 10-Yr. Frequency Storm

Soil		Maximum Velocity (fps)		
Texture	Type	Seed & mulch	Seed & Matting	Sod
Sand, Silt, Sandy Loam, Silt Loam	Sand	1.5	3.0	3.5
Silty Clay Loam, Sandy Clay Loam	Firm Loam	2.0	4.0	4.0
Clay	Clay	2.5	40	5.0
N/A	Gravel	3.5	5.0	6.0
N/A	Weathering Shale	4.5	5.0	N/A

Note: Soil texture/type can be determined from the soil surveys. If the channel is on fill, the soil should be tested.

Outlets

All terraces shall have a stable outlet. Outlets for terraces may be surface outlets such as grassed waterways or rock lined channel, or an underground outlet such as pipe.

- *Surface outlet.* A grassed waterway or vegetated area. may be suitable as a terrace outlet if the waterway will convey runoff water to a point where the outflow will not cause damage. The outlet must be stable and vegetated prior to construction of the terrace. In cases where the terrace outlets into a larger ditch or stream with a continual or seasonal base flow, protection of that portion of the terrace affected by this wet condition is necessary. This may be accomplished by installation of use of a rock lined outlet or grade stabilization structure (see Rock Lined Channel / Rock Outlet Protection).
- *Underground outlet.* Underground outlets may be used on flat, or nearly flat, terraces. The outlet consists of an inlet or riser and underground conduit. An orifice plate, decrease in conduit size or other features shall be installed in each inlet as needed to control the release rate and prevent excessive pressure when more than one terrace discharges into the same conduit. The discharge, when combined with the storage within the terrace, is to be such that a 10-year frequency, 24-hour storm will not overtop the terrace. The release time shall not exceed 24 hours for the design storm.

Conduits must be installed deep enough to prevent damage from traffic on roads that cross the conduit. The inlet is to consist of a vertical perforated pipe of a material suitable for the intended purpose.

All risers (except the top one) shall be placed on a lateral leading to the main line so that in event the riser is damaged the main will not be disturbed and can continue to outlet other terraces.

A 6-in. diameter riser will have as minimum 4 rows of slots 0.75 in. x 4 in. in size or 24 holes of 0.75 in. diameter per lineal foot of riser. An 8-in. diameter riser should have 6 rows of slots. Care will be taken not to cut the seam in helical pipe, as this will allow it to unwind. The riser shall extend above the ground a minimum of 3 ft. for good visibility and within 6 in. of the terrace top of terraces have a fill height of 3.5 ft. or higher.

Establishing Vegetation

All terraces shall be vegetated or otherwise stabilized, as soon as possible after construction. Stabilization should be done according to the appropriate Standards and Specifications for Vegetative Practices (e.g. Permanent Seeding, Mulching, TRECP).

- *For design velocities of less than 3.5 fps,* seeding and mulching may be used for the establishment of the desired vegetation. Mulch netting should be used to protect the seeding during establishment. It is recommended that when conditions permit, a temporary diversion or other means be used to prevent water from entering the terrace during the establishment of vegetation.
- *For design velocities of more than 3.5 fps,* the terrace shall be stabilized with seeding protected by erosion control matting or blankets, or with sod. It is recommended that when conditions permit, a temporary diversion or other means be used to prevent water from entering the terrace during the establishment of vegetation.

Sedimentation

Terraces should not be used below high sediment producing areas unless land treatment practices or structural measures that will prevent damage to the terrace are designed and installed prior to installation of the terrace. If some accumulation of sediment cannot be prevented, then the design shall include extra capacity for the sediment. Accumulation of sediment shall be considered in the maintenance plan for this practice.

Maintenance

A maintenance program shall be established to maintain capacity, vegetative cover, and associated structural components such as inlets, outlets, and subsurface drains. Items to consider in the maintenance program include:

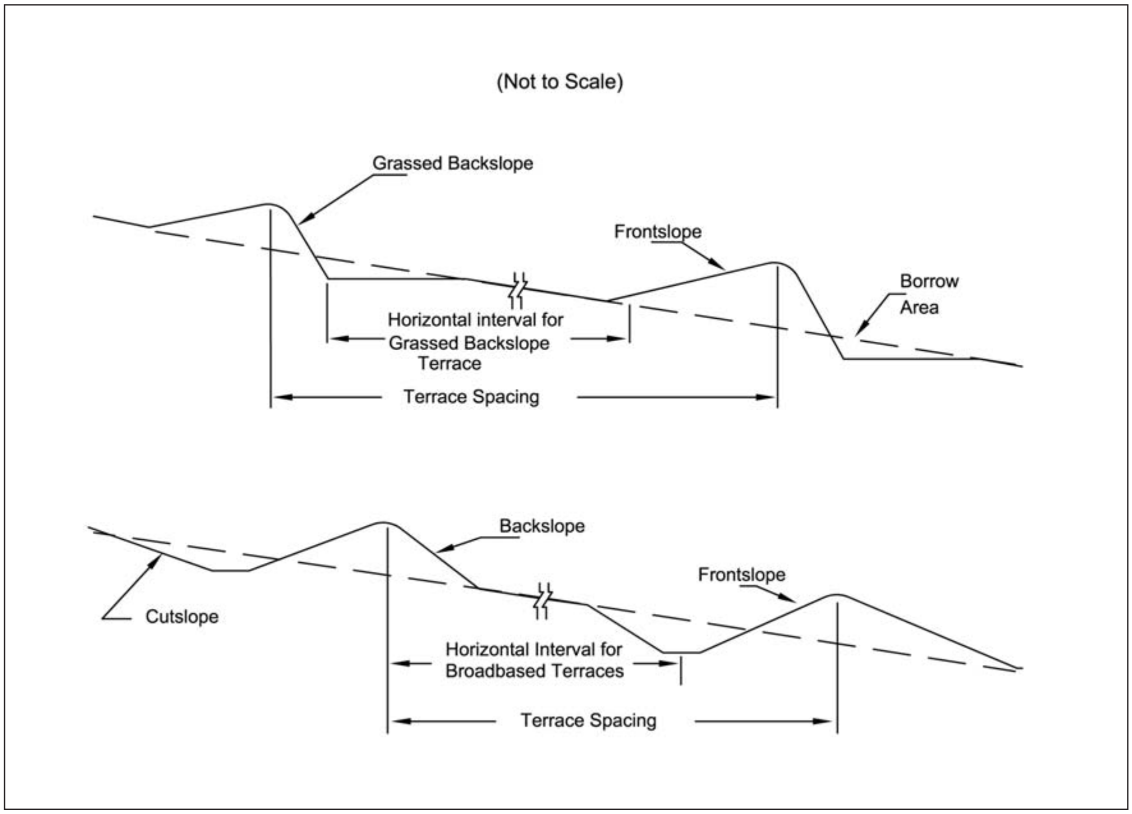
- Determine responsible party to inspect and maintain the terraces after construction
- Protect the terraces from damage by equipment and traffic
- Fertilize annually to and maintain a vigorous stand of grass
- Mow the terraces regularly to maintain a healthy and vigorous stand of grass
- Inspect terraces regularly, especially following heavy rains
- Repair damage to terraces immediately. Damaged areas will be filled, compacted, and seeded immediately. All broken subsurface drains should be repaired
- Remove sediment deposits to maintain capacity of terraces. Seed and mulch any bare areas that develop
- Easements should be obtained to ensure the terraces are maintained as constructed

References

Additional guidance for evaluation, planning, and design of terraces is given in:

- NRCS Ohio Practice Standard 600, Terrace.
- NRCS Engineering Field Handbook (EFH) Part 650, Chapter 8 - Terraces.

Specifications
for
Terraces



1. All ditches or gullies shall be filled before constructing the terrace or shall be part of the construction. All old terraces, fence rows, organic matter, hedgerows, trees, and other obstructions shall be removed, as necessary.
2. The terraces shall be constructed to planned alignment, grade, and cross section with the specified overfill for settlement, and the channel shall be graded to drain reasonably well.
3. Fill material shall be free of sod, roots, organic material, stones larger than 6 in. (.15 m) or other objectionable material.
4. Fill will be placed in approximately horizontal lifts no greater than 6-in thick prior to compaction. Each lift will be compacted using excavating equipment, or other equipment that will obtain equivalent compactive effort. At least two passes (tread tracks) of the compacting equipment will be required completely covering each lift. Fill material will have a moisture content that will allow a ball of soil to hold together when squeezed by hand.
5. Any ditch or depression at the bottom of the back slope shall be filled and smoothed so that drainage will be away from the terrace and not parallel to it.
6. Provisions must be made to prevent piping if underground conduits are located under terrace ridges. Mechanical compaction of trench backfill will be required for sections of underground outlet pipes located beneath terrace, channels, and ridges. The materials used for the inlet and conduit shall be as specified on the plan. Terrace ridges constructed across gullies or depressions shall be compacted by machinery travel or by other suitable means to ensure proper functioning of the terrace. The surface of the finished terrace shall be reasonably smooth and present a workmanlike finish.
7. When specified on the plan, topsoil shall be stockpiled and spread over excavations and other areas to facilitate restoration of productivity.
8. Fertilizing, seeding, and mulching shall conform to the recommendations in the applicable vegetative specification.

4.7 Subsurface Drain

Description

Subsurface drainage is the installation of a conduit, such as corrugated plastic tubing, tile, or pipe installed beneath the ground surface to collect and/or convey drainage water. The purpose of subsurface drainage is to:

- Provide internal drainage of slopes to improve slope stability and reduce erosion
- Intercept and reroute existing subsurface drains and drainage systems
- Regulate the water table and ground water flows, and relieve artesian pressures
- Intercept and preventing water movement into a wet area
- Remove surface runoff, or standing water
- Provide internal drainage behind bulkheads, retaining walls, etc
- Collect ground water for beneficial uses
- Remove water from heavy use areas, such as around buildings, roads, and other structures
- Regulate water to control health hazards caused by pests such as flies, or mosquitoes

Conditions Where Practice Applies

Subsurface drains are used in areas having a high water table where benefits of lowering or controlling ground water or surface runoff justify the installation of such a system. All lands to be drained shall be suitable for the intended use after installation of required drainage and other practices. The soil shall have enough depth and permeability to permit installation of an effective and economically feasible system.

An outlet for the drainage system shall be available, either by gravity flow or by pumping. The outlet shall be adequate for the quantity and quality of effluent to be disposed of with consideration of possible damages above or below the point of discharge that might involve legal actions. Ohio drainage and water laws shall be adhered to in the planning and installation of drains.

Design Criteria

Subsurface drainage shall be designed by acceptable engineering methods such as those outlined in Chapter 14 – Water Management (Drainage) of the NRCS Part 650 Engineering Field Handbook, or the following:

Required Capacity of Subsurface Drains

Where the land to be drained has adequate surface drainage, either natural or artificial, the spacing between drains and their capacity shall be based on minimum removal rates as follows:

Table 4.7.1

Soil	Inches to be Removed in 24 Hours
Mineral	1/2
Organic	3/4

Where it is necessary to admit surface water to the subsurface drain system through surface inlets:

Table 4.7.2

Soil	Inches to be Removed in 24 Hours	
	Blind/Inlets	Open Inlets
Mineral	3/4	1
Organic	1	1-1/2

Required Capacity of Interceptor Subsurface Drains

Where springs or seepage are to be intercepted, the subsurface drain size will be determined on the basis of the estimated flow, or computed as outlined in Chapter 14 – Water Management (Drainage) of the NRCS Part 650 Engineering Field Handbook or the following table.

Table 4.7.3

Interceptor, Random, and Single Drain Line Inflow Rates				
Soil Texture	Inflow Rate per 1,000 feet of line (cfs)			
	Land Slope			
	0-2%	2-5%	5-12%	> 12%
~~Coarse Sand and Gravel~~	~~1.0~~	~~1.1~~	~~1.2~~	~~1.3~~
Sand	0.50	0.55	0.60	0.65
Sandy Loam	0.25	0.28	0.30	0.33
Silt Loam	0.10	0.11	0.12	0.13
Clay and Clay Loam	0.20	0.22	0.24	0.26

Size of Subsurface Drain

The size of drains shall be computed by applying Manning's Formula. The size shall be based on the required capacity and computed using one of the following:

1. Hydraulic grade line parallel to the bottom grade of the subsurface drain with the conduit flowing full at design flow.
2. The conduit flowing part full where a steep grade or other condition requires excess capacity.
3. Conduit flowing under pressure with hydraulic grade line set by site conditions on a grade that differs from that of the subsurface drain. This procedure shall be used only where surface water inlets or nearness of the drain to outlets with fixed water elevations permit satisfactory estimates of hydraulic pressure and flows under design conditions.

The outlet pipe is part of the hydraulic system, and its grade and roughness characteristic ("n" value) must be considered in determining the required size of the outlet pipe.

All subsurface drains shall have a nominal diameter that equals or exceeds 3".

Existing Subsurface Drains and Drainage Systems

Care should be taken to thoroughly evaluate existing subsurface drains and drainage systems that might be impacted. This evaluation should be based on adequate surveys, field investigations, and a check of existing records, or as-builts, that might be available on the system. When adding on to an existing system, the capacity of the existing drain line must be known, or should be calculated, so as to not overload and damage the existing drain. The existing drain line must be in good condition before a decision is made to add more lines to it. When eliminating the downstream end of an existing drainage system, a new drain line must be provided as an outlet. This new re-routed drain line must have adequate capacity to handle all the remaining upstream drain lines.

Depth, Spacing, and Location

The depth, spacing and location of the subsurface drain shall be based on site conditions, including soils, topography, ground water conditions, land use, and outlets. In general, however, a depth of 3 feet and a spacing of 50 feet will be adequate.

The minimum depth of cover over subsurface drains in mineral soils shall be 2 ft, and may exclude sections of line near the outlet, or sections lain through minor depressions that will be filled as part of the installation. (After filling these minor depressions, the depth of cover over the drain will be at least 2 ft.

Minimum Velocity and Grade

In areas with no sedimentation hazard, the minimum grades shall be based on site conditions and a velocity of not less than 0.5 ft/s. Where it is determined that a sedimentation hazard exists, a velocity of not less than 1.4 ft./s shall be used to establish the minimum grades if site conditions permit. Otherwise, provisions shall be made for prevention of sedimentation by use of filters or collection and periodic removal of sediment by use of sediment traps or the periodic cleaning of the lines by high pressure jetting systems or cleaning solutions as specified in the plans.

Maximum Grade and Protection

On sites where topographic conditions require the use of subsurface drain lines on steep grades and design velocities will be greater than indicated in the following table, special measures shall be used to protect the conduit.

Table 4.7.4 Maximum Permissible Velocity in Drains Without Protective Measures

Soil Texture	Velocity (ft/s)
Sand and Sandy Loam	3.5
Silt and Silt Loam	5.0
Silty Clay Loam	6.0
Clay and Clay Loam	7.0
Coarse Sand or Gravel	9.0

Protective measures shall be specified for each job based on the particular conditions of the job site. These measures shall include one or more of the following:

1. Use only drains that are uniform in size and shape and with square ends to obtain tight fitting joints. Lay the drains so as to secure a tight fit with the inside diameter of one section matching that of the adjoining sections.
2. Wrap open joints with tar impregnated paper, burlap, or special fabric type filter material.
3. Place the conduit in a sand and gravel envelope or blinding with the least erodible soil available.
4. Seal joints or use a watertight pipe or nonperforated continuous tubing.
5. For continuous pipe or tubing with perforations, completely enclose the pipe with geotextile type filter material, or well-graded sand and gravel.
6. Install open risers for air release or entry.

Iron Ochre Considerations

If drains are to be installed in sites where iron ochre problems are likely to occur, provisions should be made to provide access for cleaning the lines. Each drain line should outlet directly into an open ditch and/or should have entry ports as needed to provide access for cleaning equipment. Drain cleaning provisions should be installed in such a way that the drains can be cleaned in an upstream or rising grade direction. If possible, drains in ochre-prone areas should be installed during the dry season when the water table is low and the iron is in its insoluble form.

Where possible, in areas where the potential for ochre problems is high, some protection against ochre development can be provided by designing an outlet facility to ensure permanent submergence of the drain line.

Protection Against Root Clogging

Problems may occur where it is necessary to place drains in close proximity to perennial vegetation. Roots of water-loving trees, such as willow, cottonwood, elm and soft maple, or some shrubs and grasses growing near subsurface drains may enter and obstruct the flow.

The first consideration is to use non-perforated tubing or closed joints through the root zone area. Where this is not possible, water-loving trees must be removed from a distance of at least 100 feet on each side of the drain. A distance of 50 feet must be maintained from other species of trees except for fruit trees. Drains located close to the fruit trees can often drain orchards.

Where grasses may cause trouble on drain lines, facilities may be installed to provide a means for submerging the line to terminate the root growth as desired or to maintain a water table above the drain lines to prevent growth into the system.

Materials

Subsurface drains include conduits of clay, concrete, metal, plastic, or other materials of acceptable quality. The conduit shall meet strength and durability requirements of the site. All conduits shall meet or exceed the minimum requirements specified in the Material Specification.

Foundation Requirements

When soft or yielding foundations are encountered, they shall be stabilized and the lines shall be protected from settlement by adding gravel or other suitable materials to the trench, by placing the conduit on treated plank that will not readily decompose, or other rigid supports, or by using long sections of perforated or watertight pipe with adequate strength to ensure satisfactory subsurface drain performance. The use of flat treated plank is not recommended for corrugated plastic tubing. If planking is used on CPT, it should be constructed with a "v" groove or other means to provide the required support to the side walls of the conduit.

Loading

The allowable loads on subsurface drain conduits shall be based on the bedding conditions and the crushing strength of the kind and class of drain specified for the job.

The design load on the conduit will be based on a combination of equipment loads and trench loads.

1. Equipment loads are based on the heaviest wheel loads of the construction equipment or other vehicles being used, or likely to be used, in the area where the subsurface drainage system will be installed, the maximum height of cover over the conduit, and the trench width. Equipment loads on the conduit decrease as the depth of cover increases and may be neglected when the depth of cover exceeds 6 feet.
2. Trench loads are based on the type of backfill, the height of backfill over the conduit, the width of trench, and the unit of weight of the backfill material. A factor of safety of not less than 1.5 shall be used in computing the design trench load.

Heavy-duty corrugated plastic drainage tubing shall be specified if the soil is rocky, if cover over the tubing is expected to exceed 10 ft., or trench widths are expected to exceed 2 ft. (This refers to trench widths in the area of the tubing and at least 1-foot above the top of the tubing.)

Filters and Filter Materials

Filters will be used around conduits, as needed, to prevent movement of the surrounding soil material into the conduit. The characteristics of the surrounding soil material, site conditions and the velocity of flow in the conduit will determine the need for a filter. A suitable filter should be specified if:

1. Local experience indicates a need,
2. Soil materials surrounding the conduit are dispersed clays, low plasticity silts, or fine sands (ML or SM with P.I. less than 7),
3. Where deep soil cracking is expected, or
4. Where the method of installation may result in voids between the conduit and backfill material.

If a sand-gravel filter is specified, it shall be clean, hard, durable material. The filter gradation will be based on the gradation of the base material surrounding the conduit within the following limits:

- D_{15} size smaller than 7 times d85 size but not smaller than 0.6 mm,
- D_{15} size larger than 4 times d_{15} size.
- Less than 5 percent passing No. 200 sieve,
- Maximum size smaller than 1.5 inches,

Where D represents the filter material and d represents the surrounding base material. The number following each letter is the percent of the sample, by weight that is finer than that size. For example, D15 size means that 15 percent of the filter material is finer than that size.

Specified filter material must completely encase the conduit so that all openings are covered with at least 3 inches of filter material.

Artificial fabric or mat-type filter materials may be used, provided that the effective opening size, strength, durability, and permeability are adequate to constantly filter the soil to protect subsurface drain operation throughout the expected life of the system. (These filters should not be used under submerged conditions or where sediment laden flows occur prior to backfill.) Artificial fabric or mat-type filters should not be used in silty soil conditions.

Envelopes and Envelope Material

Envelopes shall be used around subsurface drains where required for proper bedding of the conduit, or where necessary to improve the characteristics of flow of ground water into the conduit.

Envelope materials shall consist of sand-gravel material. Sand-gravel envelope materials shall all pass a 1.5 inch sieve; not more than 30 percent shall pass a No. 60 sieve; and not more than 5 percent shall pass the No. 200 sieve. ASTM-C-33 fine aggregate for concrete has been satisfactorily used and is readily available.

Placement and Bedding

The trench bottom shall be smooth and free of clods and loose or exposed rock. All subsurface drains, whether flexible conduit such as plastic, or rigid conduit such as clay and concrete, shall be laid to a neat line and grade. For trench installations of corrugated plastic tubing 8 inches or less in diameter, one of the following methods will be specified:

1. A shaped groove or 90 degree V-notch in the bottom of the trench for tubing support and alignment
2. A sand-gravel envelope, at least 3 inches thick, to provide support
3. Compacted soil bedding material beside and to 3 inches above the tubing

For trench installations of corrugated plastic tubing larger than 8 inches in diameter, the same bedding requirement will be met except that a semi-circular or trapezoidal groove shaped to fit the conduit will be used rather than the V-shaped groove.

Rigid drainage conduits, such as clay or concrete drain tile, do not need the 90 degree V-groove in the trench bottom, however, the trench bottom must be shaped so that good alignment in the center of the trench is assured.

Where the conduit will be bedded with fine-grained friable soil or a sand and gravel mixture, the minimum trench width will be at least 0.5 ft. greater than the outside diameter of the conduit. When the conduit is installed in conditions where cloddy material will likely be used for bedding, the trench width will be at least 1.0 ft. greater than the outside diameter of the conduit. In all cases the conduit will be laid in the center of the trench. When the conduit must be installed in rocky conditions, the trench must be over excavated and backfilled to grade with a suitable bedding materials.

All trench installations should be made when the soil profile is in its driest possible conditions in order to minimize problems of trench stability, conduit alignment, and soil movement into the drain.

For trench installations where a sand-gravel or compacted bedding is not specified, the conduit will be blinded with selected material containing no hard objects larger than 1.5 inches in diameter, and will be carried to a minimum of three inches above the conduit.

Conduit Perforations Special Requirements:

Where perforated conduit is required, the water inlet area shall be at least 1 inch2/ foot of conduit length. Round perforations shall not exceed 3/16-inch diameter except where filters, envelopes, or other protection is provided or for organic soils, where a maximum hole diameter of _ inch may be used. Slotted perforations shall not exceed 1/8 inch in width.

Outlets

Subsurface drain outlets shall be protected against erosion from undermining of the conduit, against entry of tree roots, against damaging periods of submergence, and against entry of rodents or other animals into the subsurface drain.

The vertical interval between the bottom of the outlet pipe and the ditch bottom shall be at least 1.0 ft. except that this vertical interval may be reduced to 0.5 ft. if (1) the outlet ditch is not subject to any significant deposition of sediment, or if (2) there is an effective maintenance program on the outlet ditch. In all cases, the subsurface drain shall outlet above the normal low flow elevation in the outlet ditch. Where the subsurface drain outlets into Lake Erie or its backwater, the invert of the conduit shall be no lower than 573.0 MSL.

When discharging a subsurface drainage system into a pond or lake, the minimum elevation of the outlet pipe invert shall be at the normal level of the pond or lake. When the outlet is located near an area of sediment deposition along the shoreline, the minimum elevation of the invert shall be at least 1.0 foot above the normal water elevation.

Where no surface water enters the ditch at the location of the subsurface drain outlet, a continuous section of pipe without joints or perforations shall be used. The outlet pipe and its installation shall conform to the following requirements:

1. Due to the hazard from burning of vegetation on the ditch bank the material from which the outlet pipe is fabricated shall be fire resistant. Where the hazard of burning is high, the outlet pipe shall be fireproof. PVC pipe is fire resistant, and pipe meeting ASTM-D 2241, ASTM-D-3034, or better have adequate strength to be used for outlet pipes.
2. At least two-thirds of the pipe shall be buried in the ditch bank and cantilevered section shall extend to or beyond the toe of the ditch side slope, or the side slope shall be protected from erosion. The minimum length of pipe shall be 8 ft. for diameters 8” or less; 12 ft. for 10” and 12” diameters; 16’ for 15” and 18” diameters, and 20 ft. for diameters larger than 18”.

3. Where ice or floating debris may damage the outlet pipe, the outlet shall be recessed to the extent that the cantilevered portion of the pipe will be protected from the current in the ditch.
4. Headwalls, which are used for subsurface drain outlets, shall be adequate in strength and design to avoid washouts and other failures.
5. Adverse visual impact of projecting outlets will be minimized.

Where surface water enters the ditch at the location on the drain outlet a grade stabilization structure shall be used.

Auxiliary Structures and Protection

Watertight conduits strong enough to withstand the expected loads shall be used where subsurface drains cross under irrigation canals, grassed waterways, or other ditches. Conduits under roadways shall be designed to withstand the expected loads. Shallow drains through depression areas and near outlets shall be protected against hazards of vehicular equipment, and freezing and thawing.

Structures installed in drain lines must not unduly impede the flow of water in the system. Their capacity shall be no less than that of the line or lines feeding into or through them. The use of internal couplers for corrugated plastic tubing will be allowed.

If the drain system is to carry surface water flow, surface water inlets shall have a capacity of no greater than that required providing the maximum design flow in the drain line or lines.

Junction boxes, manholes, catch basins, and sand traps shall be accessible for maintenance. A clear opening of not less than 2 ft. shall be provided in either circular or rectangular structures.

The size of breathers and relief wells is generally based on the available materials rather than on hydraulic considerations, and shall not be less than 4 inches in diameter.

The drain system shall be protected against velocities exceeding those provided under "Maximum Permissible Velocity without Protective Measures" and against turbulence created near outlets, surface inlets, or similar structures. Continuous or closed-joint pipe, or non-perforated tubing shall be used in drain lines adjoining the structures where excessive velocities will occur.

Junction boxes shall be installed if more than three main drains join or if two main drains join at different elevations. In some cases it may be possible to bury junction boxes. Then a solid, durable cover will be used and there must be at least 18 inches of natural soil cover over the cover.

If surface water is to be admitted to subsurface drains, inlets shall be designed to exclude debris and prevent sediment from entering the conduit. Surface water inlets will be offset from main lines unless located at the upper end of the line.

Lines flowing under pressure shall be designed to withstand the resulting pressures and velocity of flow. Auxiliary surface waterways shall be used where feasible.

If not connected to a structure, the upper end of each subsurface drain line shall be capped with a tight-fitting cap of the same material as the conduit or other durable materials.

Early Use Damage

Newly installed drains at shallow depths (less than 3') and without a gravel envelope may be crushed, especially after a heavy rain, by heavy equipment traveling over the freshly backfilled trenches. Heavy equipment should avoid crossing drain lines, especially mains and sub-mains.

Operation and Maintenance

A properly designed and installed subsurface drain requires little maintenance. However, inlets, outlets, and drain lines should be periodically inspected. A maintenance plan should include the following items:

- Determine responsible party to inspect and maintain the practice after construction
- Protect the drain from damage by equipment, traffic, or livestock
- Check the drains periodically to verify that the drains are operating properly.
- Investigate wet areas along the drain line for blockage by roots, drain separation, or other problems. Repair damage promptly.
- Keep the outlet free of sediment and debris
- Keep the animal guard in place and functional

References

Additional guidance for evaluation, planning, and design of subsurface drainage is given in:

- NRCS Ohio Practice Standard 606, Subsurface Drain.
- NRCS Engineering Field Handbook (EFH) Part 650, Chapter 14 - Water Management (Drainage)
- Illinois Urban Manual: A Technical Manual Designed for Urban Ecosystem Protection and Enhancement, prepared for the Illinois EPA by Illinois NRCS

Materials for Subsurface Drains

The following specifications pertain to products currently acceptable for use as subsurface drains. These specifications are also to be applied in determining the quality of materials referenced by other standards:

Table 4.7.5 Subsurface Drain Materials

Type	Specification
Plastic	
Corrugated polyethylene (PE) tubing and fittings 3-6 in.	ASTM-F-405[1]
Corrugated polyethylene (PE) tubing and fittings 8-24 in.	ASTM-F-667[1]
Corrugated polyvinyl chloride (PVC) tubing and Compatible fittings	ASTM-F-800[1]
Polyvinyl chloride (PVC) corrugated sewer pipe with a smooth Interior and fittings 4-8 in.	ASTM-F-949[1] or D-3034 type
Polyvinyl chloride (PVC) pipe	PSM or PSP
Clay	
Clay drain tile	ASTM-C-4[1]
Clay drain tile, perforated	ASTM-C-498[1]
Clay pipe, perforated, standard and extra strength	ASTM-C-700[1]
Clay pipe, testing	ASTM-C-301[1]
Concrete	
Concrete drain tile	ASTM-C-412[1]
Concrete pipe for irrigation or drainage	ASTM-C-118[1]
Concrete pipe or tile, determining physical properties of	ASTM-C-497[1]
Concrete sewer, storm drain, and culvert pipe	ASTM-C-14[1]
Reinforced concrete culvert, storm drain, and sewer pipe	ASTM-C-76[1]
Perforated concrete pipe	ASTM-C-444[1]
Portland cement	ASTM-C-150[1]
Other	
Styrene rubber plastic drain pipe and fittings	ASTM-D-2852[1]
Pipe, corrugated (aluminum alloy)	Federal Spec. (WW-P-4022)
Pipe, corrugated (aluminum alloy)	Federal Spec. (WW-P-4052)

[1] Specifications can be obtained from the American Society for Testing and Materials, 1016 Race Street, Philadelphia, PA 19103

[2] Specifications can be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

Specifications
for
Subsurface Drain

1. Safety – All operations shall be carried out in a safe manner and meet applicable health and safety regulations. Workers should not enter a vertical trench deeper than 5 feet unless the trench walls are supported by shoring or by a trench shield. In lieu of shoring on trenches greater than 5 feet in depth, the walls above the 5 foot level may be sloped to a stable slope, no steeper than 1-1/2:1

2. Trenching – Trenching width shall be adequate for proper installation of the conduit; must allow proper joining of sections; and must allow proper placement of filter, envelope, or blinding materials. The trench bottom shall be constructed to proper grade and shape before placement of the conduit.

- For clay and concrete tile, the trench width will be a minimum of 3 to 6 inches on both sides of tubing. A groove must be formed in the bottom of the trench that is adequate to hold the tile in alignment during placement and backfilling.

- Where rock is encountered the trench will be over excavated a minimum of 6 inches and refilled to proper grade with a suitable bedding material.

- Where rock is encountered the trench will be over excavated a minimum of 6 inches and refilled to proper grade with a suitable bedding material.

3. Bedding – The trench bottom shall be smooth and free of clods or loose and exposed rock. Where a gravel envelop is not specified, the bottom of the trench shall be shaped to conform to the pipe. If unstable soils are encountered, the trench bottom must be stabilized before placement of conduit. Where necessary, the unstable material will be removed and replaced with sand-gravel or similar suitable stabilizing material of sufficient thickness and gradation to prevent soil movement into the tile.

4. Backfilling – Place backfill material so that displacement or deflection of the conduit will not occur. This is preferably on an angle, so the material flows down the front slope. Avoid large stones, frozen material, and dry clods that cause concentrated point loads on the tubing or damage the conduit. The trench should be backfilled as soon as practical. When installing the tubing on a hot day, backfilling should be delayed until tubing temperature cools to the soil temperature.

5. Inspecting and Handling Materials – Material for subsurface drains shall be carefully inspected before the drains are installed. Plastic pipe and tubing shall be protected from hazard causing deformation or warping. Plastic pipe and tubing with physical imperfections shall not be installed. A damaged section shall be removed and a suitable joint made connecting the retained sections. Clay and concrete tile shall be checked for damage from freezing and thawing before it is installed. All material shall be satisfactory for its intended use and shall meet applicable specifications and requirements.

SPECIFICATIONS FOR FLEXIBLE CONDUIT

General Requirements

All conduits shall be laid to line and grade in such a way that the side walls are continuously and uniformly supported with suitable bedding material. Such material shall be properly placed and compacted to provide lateral restraint against deflection and to protect the conduit against collapse during backfilling.

Plow Installation

Plow installation has been satisfactorily used in many situations. Special care needs to be exercised relative to grade control and bedding conditions.

Placement

Flexible conduit will be placed in such a way that maximum stretch does not exceed 5 percent.

Fittings shall be installed in accordance with instructions furnished by the manufacturers. Couplers are required at all joints and fittings, at all changes in direction (where the center-line radius is less than three times tubing diameter), at changes in diameter, and a junction with another line.

Caps are needed at the ends of lines. All fittings shall be compatible with the tubing. Place selected bedding material, containing no hard objects larger than 11/2 inches in diameter in the trench to a minimum depth of 6 inches over the conduit. The conduit will be held in place mechanically until secured by blinding.

SPECIFICATIONS FOR CLAY AND CONCRETE TILE

The use of concrete tile in acid and sulfate soils shall be in accordance with the following limitations:

Table 4.7.6 Limitations of acid and sulfate soils.

Acid Soils:

Class of Tile		Lower Permissible Limits of pH Values: Organic and Sandy Soils	Lower Permissible Limits of pH Values: Medium and Heavy-Textured Soils
ASTM-C-412			
	Standard quality	6.5	6.0
	Extra quality	6.0	5.5
	Heavy duty extra quality	6.0	5.5
	Special quality	5.5	5.0
ASTM-C-14			
	C-118, C-444	5.5	5.0

Note: Figures represent the lowest reading of pH values for soil or soil water at subsurface drain depth.

Sulfate Soils:

Type of Tile and Cement (minimum)		Permissible Maximum limit of sulfates singly or in combination (p/m)
Tile:	ASTM-C-412	
	Special quality	7,000
	C-14, C-118, C-444	
Cement:	ASTM-C-150, Type V	
Tile:	ASTM-C-412	
	Extra quality	3,000
	Heavy-duty extra quality	
	C-14, C-118, C-444	
Cement:	ASTM-C-150, Type II or V	
Tile:	ASTM-C-412	
	Standard quality	1,000
	C-14, C-118, C-444	
Cement:	ASTM-C-150, any type	

Note: Figures represent the highest reading of sulfates for soil or soil water at subsurface drain depth.

Bell and spigot, tongue and groove, and other types of tile that meet the strength, absorption, and other requirements of clay or concrete tile as specified in the preceding paragraphs, except for minor imperfections in the bell, the spigot tongue or the groove, and ordinarily classes by the industry as "seconds," may be used for drainage conduits, provided that the pipe is otherwise adequate for the job.

Placement

All conduits shall be laid to line and grade and covered with the specified blinding, envelope, or filter material to a depth of not less than 3 inches around the drain. Blinding material shall contain no hard objects larger than 1-_ inches in diameter.

When a sand-gravel filter is specified, all openings in the conduit must be covered with at least 3 inches of filter material except that the top of the conduit and the side filter material may be covered with a sheet of plastic or similar impervious material. The impervious sheet will be covered with at least 3 inches of blinding material.

Joints between the drain tile shall not exceed 1/8 inch, except in organic soils where some of the more fibrous types make it desirable to increase slightly the space between the file. In sandy soils the closest possible fit must be obtained to prevent flow of soil material into the tile.