Dec. 1, 1992

Grade Stabilization Structures

Description

Grade stabilization structures (GSSs) are permanent structures which stabilize grades in natural or artificial channels by carrying runoff from one grade to another. These structures include vertical drop structures, chutes, pipe drop structures and downdrains. They may be made of rock riprap, concrete, metal, wood and/or heavy plastic. Note that Riprap is a separate BMP.

Note that GSSs located in or adjacent to streams or other water courses will need a permit from the MDNR.

In natural stream, every effort should be made to reduce stormwater inputs which may increase stream velocities.

Other Terms Used to Describe

Chute
Downdrain
Drop Box
Drop Control Structure
Drop Inlet Spillway
Drop Pipe
Earth Embankment Structure
Enclosed Side Drain
Flume
Spillway
Straight-pipe
Toewall

Pollutants Controlled and Impacts

Grade stabilization structures are designed to prevent banks from slumping, reduce the velocity with which water runs off the land, and prevent erosion of a channel that results from excessive grade in the channel bed. Proper grade stabilization, combined with adequately protected outlet structures, can reduce the likelihood that soil will be detached and transported to surface water.

Application

Land Use
This practice is applicable to all land uses, but is most often used in agricultural, urban/urbanizing and transportation areas.

Soil/Topography/Climate
The foundation material at the site should be stable, relatively homogeneous, mineral soil with sufficient strength to support the structure without uneven settling. The soils should have low piping potential.

When to Apply
Implementation of this practice should occur early in the construction sequence. Use the Staging and Scheduling BMP to help coordinate its implementation with other BMPs.

Where to Apply
Applications include areas where the concentration and velocity of water are such that head cutting or gully erosion is occurring, where beds of intersecting channels are at different elevations, and where a flatter grade is needed for stability in a proposed channel.

Relationship With Other BMPs

Check Dams, Diversions and other BMPs may be required upstream of GSSs to reduce the velocity of incoming runoff, and to prevent undercutting, piping or scouring. Grassed Waterways are often used in conjunction with a GSS to control erosion in unstable areas. The outlets for GSSs should be stable and included in the design.

Specifications

Planning Considerations:
An on-site evaluation should be done to ensure that the channel upstream and downstream from the structure will be stable for the design flow conditions. A site evaluation should include:

1. An evaluation of the entire drainage area, including the size of the drainage area. GSSs are often built in conjunction with other BMPs, some of which also control drainage. By looking at the entire drainage area, the appropriate type and design of all BMPs needed in the drainage area can be determined.

2. Determine soil textures. Use soil surveys, where available. Soils should be stable and able to support the planned structure, with no piping.

3. The drainage area above the structure should be protected against erosion.

4. For most structures, the channel below the selected site must be stable for the design flow.

5. Consideration should be given in the planning phases as to how water will be diverted if Dewatering will be done.

6. Selection of the appropriate type of grade stabilization structure should be based on actual site conditions. Exhibits 1-3 show some of the more commonly used GSSs.

The design criteria which follows applies to most grade stabilization structures. The actual design should be based on sound engineering principles.

Design Considerations:

Note: The design of a GSS should be done by a registered professional engineer.

The information provided below consists of guidelines which will help in deciding if the site is appropriate for consideration of a GSS, and what things need to be considered in the design and construction of a GSS.

1. Design considerations should include the following:

   -the differences in channel depths and widths

   -the effect on the water table

   -the need for an emergency bypass and the effect the bypassed water may have on the areas downstream

   -the stability of side slopes

   -outlet velocities and the need for a stabilized outlet below the GSS.

In general, shallow channels stabilized with riprap are preferred to deeper earth channels that require GSSs.

2. Grassed Waterways are often used in conjunction with GSSs and should be designed in conjunction with the GSS.

3. When GSSs are designed to stabilize head cutting in an existing channel, make sure that the channel upstream and downstream of the proposed structure will be stable for the design flow conditions. Make the stability evaluation based on clean water flow, since another head cut may begin below the structure once sediment sources are controlled. Side slopes on the site should also be stable.

4. Structures which include an emergency bypass/spillway should be designed so that the overflow enters the channel below the grade stabilization structure. The emergency bypass should be designed to prevent structural failure from larger storms, based on the expected structure life and frequency of failure.

5. Consideration should also be given to incorporating some type of foundation drainage to reduce hydrostatic loads on drop spillway structures.

6. All grade stabilization structures should complement their surroundings, both visually and functionally. Excavated material and cut slopes should be shaped to blend with the natural topography, or excess material removed from the site.

Grade Elevation:

The crest of the structure's inlet should be set at an elevation that will stabilize the grade of the upstream channel. To assure stability, set the outlet at an elevation that will provide a stable grade downstream.

Capacity:
The hydraulic capacity of all structures should be adequate to pass the frequency of storm determined based on the type of structure selected. At a minimum, structures other than "island type structures," defined below, should pass the peak runoff from the 24-hour design storm shown in Table 1, below.

Table 1

Drainage Area Acres	Design Storm Frequency - Years Principal Spillway	Principal Spillway + Emergency Spillway
< 20	2[1]	10
20-100	5	25
>100	10	25

[1]At the designer's option, a 10-inch minimum diameter pipe with at least 1.5 feet stage may be used in lieu of designing for the 2-year frequency design storm.

Source: USDA, Soil Conservation Service, Technical Guide, #410

Box inlets on road structures should meet the above hydraulic capacity requirements and should not have less capacity than 1.25 times the road structure capacity.

"Island type structures" consist of a drop spillway in the channel with auxiliary earth spillways for carrying excess flows around the structure. Either the straight drop spillway or the box inlet drop spillway can be used. This type of structure can only be used where there is a sufficient area of nearly level land on either side of the dam, for use as an earth spillway. Its use in urban areas is primarily limited to recreation areas and other open spaces. The minimum hydraulic capacity of these structures should be equal to or greater than the capacity of the downstream channel at bank full stage.

Earth Embankment:
The minimum top width of the embankment should be 6 feet if the total height of the embankment is 10 feet or less, and 8 feet if the total height of the embankment is 11-15 feet. The maximum effective height of the embankment should be 15 feet.

When the embankment top is to be used as a public road, guardrails or other approved safety devices should be used following the guidelines of the local transportation authority.

Emergency Bypass/Spillway:
Locate the emergency bypass/spillway so flood flows in excess of the spillway capacity enters the channel below the structure without serious erosion or damage to the structure.

Embankment Side Slopes:
The sum of the upstream and downstream side slopes of the settled embankment should not be less

than five horizontal to one vertical, with neither slope steeper than 2:1. Slopes must be designed to be stable in all cases, even if flatter side slopes are required.

Freeboard:
The minimum elevation of the top of the settled embankment should be 1.0 feet above the water surface with the emergency spillway flowing at design depth. The minimum difference in elevation between the crest of the emergency spillway and the settled top of the dam should be 2.0 feet. For surface water inlet pipe structures, the above dimensions may be reduced to 0.5 and 1.0 feet respectively.

Settlement:
The design height of the dam should be increased by the amount needed to insure that after all settlement has taken place the height of the dam will equal or exceed the design height. This increase shall not be less than five percent.

Foundation Drainage:
Foundation drainage may be needed on drop spillways and similar structures to reduce hydrostatic pressure.

Pipe Conduits:

1. In most cases, the diameter of the pipe should not be less than 6 inches.

2. The following pipe materials may be used: cast-iron, steel, corrugated steel or aluminum, plastic, or reinforced concrete. Plastic pipe that will be exposed to direct sunlight must be made of ultraviolet resistant materials or protected by coating or shielding.

3. Pipe appurtenances. Inlets and outlets should be structurally sound and made from materials compatible with the pipe. All pipe joints are to be made watertight in accordance with the manufacturer's specifications.

4. Pipe strength should not be less than that of the grades indicated in Table 2, below, for plastic pipe and Table 3, below, for corrugated aluminum and galvanized steel, or in accordance with other industry-accepted standards.

Concrete Chutes or Flumes:
Concrete chutes or flumes should be trapezoidal or rectangular in shape, with a minimum thickness of 4 inches. A well-graded aggregate gravel at least 6 inches thick can be used for the base material.

Table 2

Acceptable PVC* Pipe for use in Grade Stabilization Structures

Nominal Pipe Size	Schedule or Standard Dimension Ratio (SDR)	Maximum Depth of Fill Over Pipe (Feet)
8, 10, 12	Schedule 40	10
	Schedule 80	15
	SDR 26	10

* Polyvinyl chloride pipe, PVC 1120 or PVC 1220, conforming to ASTM D 1785 or ASTM D 2241

Source: USDA, Soil Conservation Service, Technical Guide, #410

Table 3

Gage or Thickness Required: Corrugated Metal Pipe for Fill
Heights Above Pipe not to exceed 15 feet

Pipe Diameter Inches	Steel [1]/ Minimum Gage	Aluminum [2]/ Minimum Thickness (Inches)
21 & less	16	0.06
24	16	0.06
30	16	0.075
36	14	0.075
42	12	XXX
48	10	XXX

[1]/ For steel CMP, maximum allowed pipe diameter is 48 inches.

[2]/ For aluminum CMP:

a. Pipe may be riveted or helical fabrication.
b. Pipe shall not be placed in soils having a pH less than 4 nor greater than 9.
c. Maximum allowed pipe diameter is 36 inches.

Source: USDA, Soil Conservation Service, Technical Guide, #410

Concrete used should be plastic enough for thorough consolidation and stiff enough to stay in place on side slopes. It should have a minimum strength of at least 3,000 lbs./square inch. Cement can be Portland Types I or II, or if required, Types IV or V. Aggregate used should have a minimum size of 1.5 inches.

If contraction joints are necessary, they should be formed transversely to a depth of about 1/3 the thickness of the cement at a uniform spacing of 10-15 feet. Uniform support should be provided to the joint to prevent unequal settlement.

Antivortex Devices:
Closed conduit spillways designed for pressure flow are to have adequate antivortex devices.

Emergency Spillways or Bypass Channel:
An emergency spillway must be constructed for all closed conduit structures. Other structures such as chute or drop spillway structures do not require an emergency spillway if the principal spillway has sufficient capacity to pass the emergency spillway design storm discharge.

Dimensions:
The **cross section** of the emergency spillway should be trapezoidal and located in undisturbed or compacted earth. The side slopes should be 2.5:1 or flatter. The emergency spillway should have a bottom width of not less than 8 feet.

The breadth of **earth** emergency spillways should be a minimum of 20 feet. The inlet channel may be curved to fit existing topography. The grade of the exit channel of a constructed spillway must fall within the range established by discharge requirements, existing topography and soil erodibility conditions. The exit channel should provide for passage of the design flow at a safe velocity to a point downstream of where the embankment will not be endangered.

Inlets:

1. To minimize future maintenance, field stone or riprap should be placed around the crest of drop inlet structures. Riprap should be placed 1 foot deep and extend 2 feet upstream from the inlet structure.

2. Where it is necessary to prevent clogging of the conduit, an appropriate **trash guard** should be installed at the inlet or riser. Trash guards are especially important in urban areas. Install trash guards immediately after the pipes are in place.

3. **Seepage Control** along a pipe conduit spillway should be provided if either of the following conditions exist:

   -the conduit is of smooth pipe larger than 8 inches in diameter, or
   -the conduit is of corrugated pipe larger than 12 inches in diameter.

   Seepage along pipes extending through the embankment should be controlled by use of a **filter or drainage diaphragm**, unless it is determined that antiseep collars will adequately serve the purpose.

The drainage diaphragm should consist of sand, meeting fine concrete aggregate requirements (at least 15% passing the No. 40 sieve but no more than 10% passing the No. 100 sieve). If unusual soil conditions exist, a special design analysis should be made.

The drainage diaphragm should be a minimum of 2 feet thick and extend vertically upward and horizontally at least three times the pipe diameter, and vertically downward at least 18 inches beneath the conduit invert. The drainage diaphragm should be located immediately downstream of the cutoff trench, approximately parallel to the centerline of the dam.

The drainage diaphragm should be outletted at the embankment downstream toe, preferably using a drain backfill envelope continuously along the pipe to where it exits the embankment. Protecting drain fill from surface erosion will be necessary.

When **antiseep collars** are used in lieu of a drainage diaphragm, they should have a watertight connection to the pipe. Maximum spacing should be approximately 14 times the minimum projection of the collar measured perpendicular to the pipe. Collar material should be compatible with pipe materials. The antiseep collar(s) should increase by 15% the seepage path along the pipe.

Outlets:

1. Where possible, grade stabilization structures should not outlet directly into a watercourse, but should be placed at a distance allowing for dissipation of water velocity.

2. The velocity of flow at the outlet should be within the permissible velocity for the receiving stream.

3. Outlet structures should be part of the design and should be stable. See the Stabilized Outlets BMP for some potential options.

Construction Considerations:

1. Divert all surface runoff around the structure during construction so that the site can be properly dewatered for foundation preparation, construction of headwalls, apron drains, and other structures. Follow specifications in the Dewatering BMP.

2. Ensure that the concrete is stable. To be stable, concrete should conform to Michigan Department of Transportation standards, ASCI or other appropriate standards for reinforced structural concrete.

3. Hand-compact backfill in 4-inch layers around the structure to a density consistent with the design.

4. If riprap is used to stabilize outlets, it should be underlain by geotextile filter fabric. Make the end of the riprap section as wide as the receiving channel, and make sure the transition section of the riprap between the structure end sill and the channel is smooth. Ensure that there is no overfall from the end sill along the surface of the riprap to the existing channel bottom, unless it is part of the design. Follow Riprap specifications.

5. Stabilize all disturbed areas following specifications in the Seeding and Mulching or Sodding BMPs.

Maintenance

Because grade stabilization structures are subject to high flow conditions, periodic inspections should be performed to ensure that erosion is not occurring, and that vegetation is adequately established. These structures should also be inspected after storm events which exceed the design storm. The discharge point should be investigated to ensure that the concentrated flows are not causing erosion downstream. Check the emergency bypass/spillway for erosion. Check the structure itself for cracked concrete, uneven or excessive settling, piping and proper drain functioning. Repair or replace failing structures immediately. Address vegetation and erosion problems as soon as weather permits.

Additional Considerations

Open structures should be signed or marked to alert people in the vicinity about potential dangers.

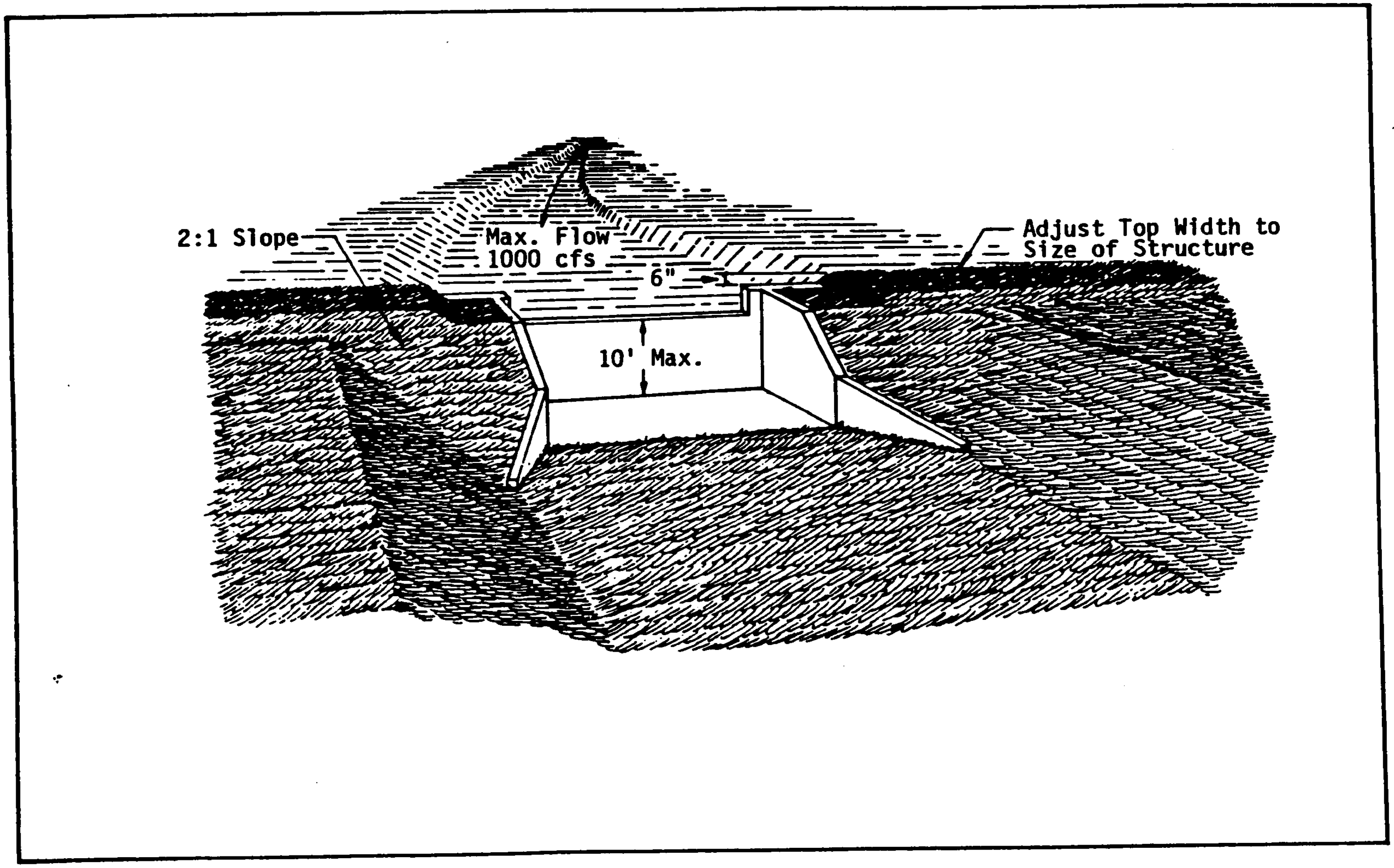
Exhibits

Exhibit 1: Waterway Drop Structure. USDA, Soil Conservation Service. 1980.

Exhibit 2: Rock Chute. USDA, Soil Conservation Service. 1983.

Exhibit 3: Earth Emergency Spillway. USDA, Soil Conservation Service.

Exhibit 1
Grade Stabilization Structure:
Waterway Drop Structure



Source: USDA-Soil Conservation Service

Exhibit 2 - - Grade Stabilization Structure: Rock Chute

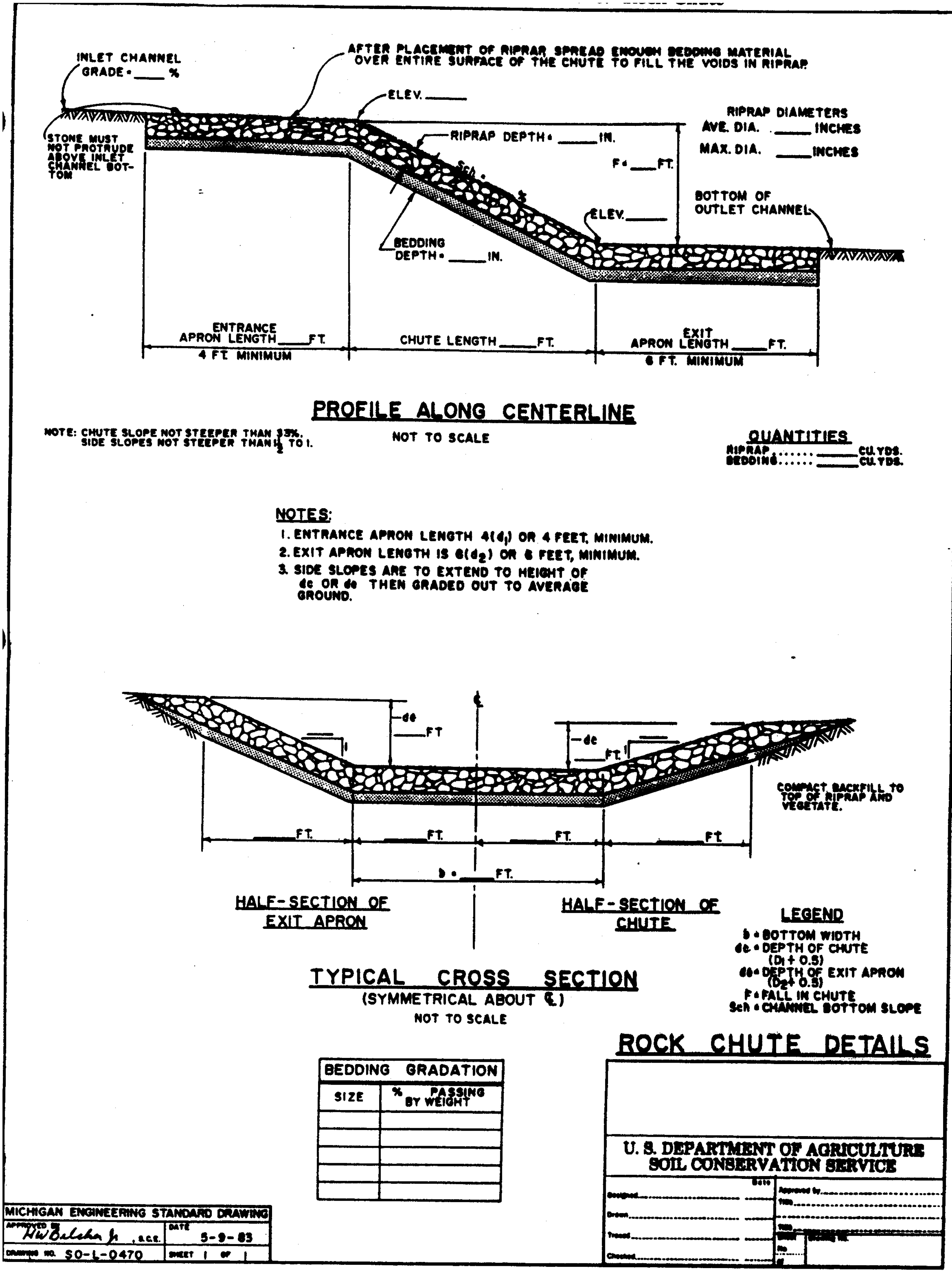
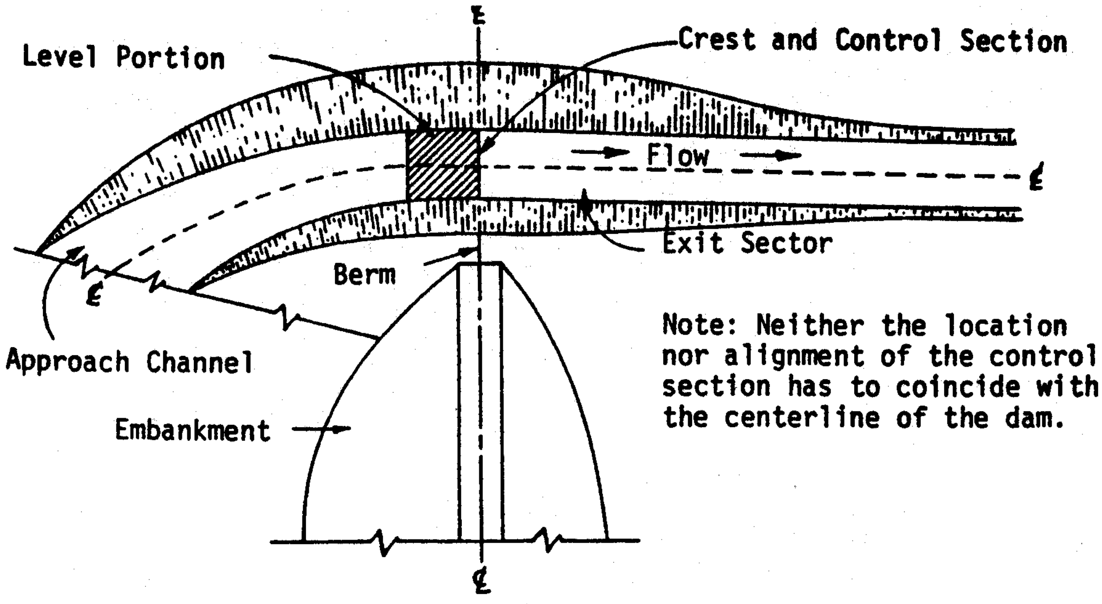
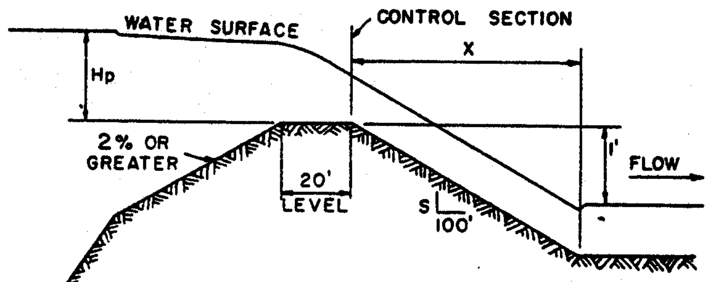


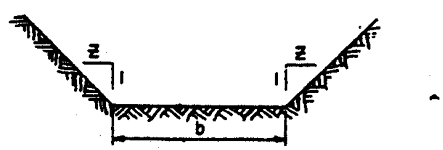
Exhibit 3
Grade Stabilization Structure:
Earth Emergency Spillway (showing level section and control section)



Plan



PROFILE ALONG ℄ OF EARTH SPILLWAY



CROSS SECTION OF EARTH SPILLWAY AT CONTROL SECTION

LEGEND

n	Manning's Coefficient of Roughness.
Hp	Difference in Elevation between Crest of Earth Spillway at the Control Section and Water Surface in Reservoir, in Feet.
b	Bottom Width of Earth Spillway at the Control Section, in Feet.
Q	Total Discharge, in cfs.
V	Velocity, in Feet Per Second, that will exist in Channel below Control Section, at Design Q, if Constructed to Slope (S) that is shown.
S	Flattest Slope (S), in %, allowable for Channel below Control Section.
X	Minimum Length of Channel below Control Section, in Feet.
z	Side Slope Ratio

Source: USDA, Soil Conservation Service