Water Resources Division

Upland Grade Stabilization Structure

Definition

Upland grade stabilization structures (UGSS) are permanent practices used to maintain channel stability in flow paths and channels by safely carrying concentrated overland flow or runoff over grade elevation changes without causing erosion. These structures include vertical drop structures, chutes, pipe drop structures and downdrains. They can be made of rock Riprap, concrete, metal, wood, geosynthetic materials or heavy plastic.

For the purpose of this practice, UGSS are differentiated from **in-stream structures**, which are located in natural streams or drainage channels. Some types of in-stream structures include: **constructed riffles, cross vanes**, **'J' hooks**, **step pools**, and **'W' weirs**. In-stream structures must be designed using natural channel design techniques described in the 'Fluvial Geomorphology' section of the introduction to this manual, and in greater detail elsewhere. Both UGSS and in-stream structures located in or adjacent to streams or other water courses typically require an MDEQ permit prior to construction.

Common applications of UGSS as described in this practice include: side channel inlets from farm fields to constructed drains, outlets of grassed waterways, outlets from ponds, and other water control structures and gully stabilizations.

Pollutant Removal

UGSS are soil erosion control structures which are designed to prevent banks from slumping, reduce the velocity of channelized runoff, and prevent channel erosion or gully formation that results from water directed over excessive grade. Proper grade stabilization, combined with adequately protected outlet structures, can reduce the likelihood that soil will be detached and transported to surface water.

Location

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

Select sites where the foundation material is stable, relatively homogeneous, mineral soil, with sufficient strength to support the structure without uneven settling, and where the soil has low piping potential.

When to Apply

When used as part of a larger site development implement this practice 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 or could occur or where beds of intersecting channels are at different elevations. As mentioned above, UGSS as defined here are not recommended for use in natural waterways. Grade control in natural channels should be done consistent with natural channel design techniques described in the fluvial geomorphology section of the introduction to this manual, and described in detail in BMPs intended specifically for that purpose.

Companion & Alternate Practices

Check Dams, Diversions, Riprap, and other BMPs might be required upstream of UGSS to reduce the velocity of incoming runoff, and to prevent undercutting, piping, or scouring. UGSS are often used in conjunction with Grassed Waterways. UGSS outlets must be stable, and included in the design. Riprap is often used to construct UGSS.

Planning

Conduct an on-site evaluation to ensure that the channel upstream and downstream of the structure will be stable for the design flow conditions. Include the following in the site evaluation:

1. An evaluation of the entire drainage area, including the size of the drainage area. UGSS 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. Onsite evaluation of soils is recommended. Use of soil surveys, where available, is acceptable. Soils must be stable, and able to support the planned structure, with no piping;

3. Protect the drainage area above the structure against erosion;

4. Confirm that the receiving channel below the selected site is stable for the expected design flow. A UGSS and its receiving channel must be stable at the chosen design flow.

5. Consider how water will be diverted if Dewatering will be done;

6. Base the selection of the appropriate type of UGSS on actual site conditions. There are many types of UGSS. Figures 1 through 3 show some of the more commonly used UGSS.

General Design Considerations

The following design criteria apply to most UGSS. Base the actual design on sound engineering principles.

Note: It is recommended that all structural best management practices be designed 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 UGSS, and what factors need to be considered in the design and construction of a UGSS.

1. Include the following design considerations:

    - The differences in upper and lower channel depths and widths;

    - The effect on the water table;

    - The need for an emergency bypass and the effect any bypassed water will have on the areas downstream;

    - The stability of side slopes;

    - Outlet velocities and the need for a Stabilized Outlet below the UGSS;

    - Sediment movement through the structure. Placement of the structure should not cause downstream sediment deposition; and

    - In general, shallow channels which can be stabilized without the need for a UGSS are preferred to deeper earth channels that require UGSS.

2. Grassed Waterways are often used in conjunction with UGSS. Design them in conjunction with the UGSS.

3. When UGSS 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. Site side slopes must be stable.

4. Use materials that provide the needed resistance to the force of the water through the grade change.

5. Design structures that include emergency bypasses/spillways so that the overflow enters the channel below the UGSS, and so that the emergency bypass prevents structural failure from larger storms, based on the expected structure life and frequency of failure.

6. Consider incorporating some type of foundation drainage to reduce hydrostatic loads on drop spillway structures.

7. Have all UGSS complement their surroundings, both visually and functionally. Shape excavated material and cut slopes to blend with the natural topography. Otherwise, remove all excess material from the site.

Grade Elevation

Set the crest of the structure's inlet at an elevation that will maintain a stable grade of the upstream channel. Similarly, set the outlet at an elevation consistent with a stable grade of the downstream channel.

Capacity

Make the hydraulic capacity of all structures adequate to pass the frequency of storm determined based on the type of structure selected.

Design all structures to, at a minimum, pass the peak runoff from the design storm frequencies shown in Table 1. The duration for all these design storms is 24 hours.

Table 1. Capacity Criteria: Minimum Frequency of 24-Hour Duration Design Storm

Maximum Drainage Area (ac)	Maximum Vertical Drop (ft)	Frequency for Principal Spillway Capacity (yrs)	Frequency for Total Capacity (yrs)
20	All	2	10
100	All	5	25
450	5	5	10
900	10	10	25

Source: NRCS, 2008

Notes: 1. If site conditions exceed those shown, the minimum 24-hour design storm frequencies are 25 years for the principal spillway capacity and 100 years for the total capacity.

2. For geosynthetic chutes with a maximum 10-year, 24-hour frequency design of 80 cubic feet per second and a maximum drop of 15 feet, the minimum design for total capacity shall be for a 10-year frequency, 24-hour duration storm.

Design box inlets on road structures to meet the hydraulic capacity requirements above, and with no less than 1.25 times the road structure capacity.

Foundation Drainage

Drop spillways and similar structures might need foundation drainage to reduce hydrostatic pressure.

Anti-Vortex Devices

Provide closed-conduit spillways designed for pressure flow with adequate anti-vortex protection, by using of plates, baffles, or other devices placed near outlets. These will ensure that adequate flow is maintained, while preventing damage to the system through the formation of vortexes from water draining out of the system, which might otherwise form in the absence of such devices.

Emergency Spillways or Bypass Channels

Construct an emergency spillway for all closed-conduit structures. Other structures, such as chute or drop spillways, do not require emergency spillways if the principal spillway has sufficient capacity to pass the design storm discharge that would otherwise be carried by an emergency spillway.

Locate the emergency bypass/spillway required for any earth embankments such that flood flows in excess of the primary spillway capacity enter the channel below the structure without serious erosion or damage to the structure, embankments, or the receiving channel.

Dimensions

Make the cross section of the emergency spillway trapezoidal, and locate it in undisturbed or compacted earth. Set the side slopes to 2.5H:1V (where H:V represents the relative relationship of the horizontal to vertical measurements of the slope) or flatter. Make the emergency spillway bottom width at least eight (8) feet.

Set the breadth of earth emergency spillways to at least 20 feet. The inlet channel can 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. Design the exit channel to provide for passage of the design flow at a safe velocity to a point downstream so that the embankment will not be endangered.

Specific Design Considerations

Concrete Chutes or Flumes

Make concrete chutes or flumes trapezoidal or rectangular in cross section, with a minimum thickness of four (4) inches. A well-graded aggregate gravel layer at least six (6) inches thick is recommended for the base material.

Use concrete that is plastic enough for thorough consolidation, stiff enough to stay in place on side slopes, and with a strength of at least 3,000 pounds per square inch. Cement can be Portland Types I or II, or if required, Types IV or V. Use aggregate with a minimum size of 1.5 inches.

If contraction joints are necessary, form them transversely to a depth of about one-third (1/3) the thickness of the cement at a uniform spacing of 10 to 15 feet. Provide uniform support to the joint to prevent unequal settlement.

Earth Embankments

Earth embankments can be used to direct overland runoff into the structure, detain and release runoff from large events or maintain permanent pools of water for other purposes.

In general, embankments shall be constructed such that:

- The sum of the upstream and downstream side slopes is at least 5H:1V, with neither slope steeper than 2H:1V. Design slopes to be stable in all cases, even if flatter side slopes are required; and
- Fill is increased by a minimum of 5% for mineral foundation soil, and 33% for organic foundation soil, to maintain the design elevation with settlement.

The minimum top width requirements for embankments are shown in Table 2 below.

Table 2. Minimum Top Width Requirements for Embankments

Fill Height (ft)	Effective Top Width (ft)
0-5	3
5-10	6
10-15	8

Source: NRCS, 2008.

Earth embankment dams are defined as fills greater than three (3) feet in height that have a permanent pool, or which are designed to pass the design storm peak inflow through the principal and auxiliary spillways with reduction for storage. The following additional criteria apply to such embankments where UGSS are used:

Embankment Side Slopes

Design embankments so that the sum of the upstream and downstream side slopes is at least 5H:1V, with neither slope steeper than 2H:1V. Design slopes to be stable in all cases, even if flatter side slopes are required.

Emergency Spillway Elevation

Set the elevation of the crest of the emergency spillway so that:

- It is two (2) feet or more below the top of the embankment, after it has completely settled; and
- When flowing at its maximum design, the water surface elevation is one (1) foot or more below the top of the embankment, after it has completely settled.

For surface water inlet pipe structures, the above minimum dimensions can be reduced to one (1) foot and one-half (0.5) foot, respectively.

Pipe Conduits

1. In general, use pipe with a minimum diameter of eight (8) inches;
2. The following pipe materials can be used: cast-iron, steel, corrugated steel or aluminum, plastic, concrete, 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. Inlet and outlet pipe appurtenances must be structurally sound, and made from materials compatible with the pipe. Make all pipe joints watertight, in accordance with the manufacturer's specifications;
4. To ensure adequate pipe strength, follow the recommendations indicated in Table 3 for plastic pipe, and Table 4 for corrugated aluminum and galvanized steel, or in accordance with other industry-accepted standards.

Inlets

1. To minimize future maintenance requirements, place field stone or Riprap around the crest of drop inlet structures, to a depth of at least one (1) foot, and extending at least two (2) feet upstream of the structure.
2. Where it is necessary to prevent clogging of the conduit, install an appropriate trash guard at the inlet or riser. Trash guards are especially important in urban areas. Install trash guards immediately after the pipes are in place.

Outlets

1. Do not outlet UGSS directly into watercourses. Rather, site them at a distance allowing for dissipation of water velocity.
2. Ensure that the velocity of flow at the outlet is within the permissible velocity for the receiving stream.
3. Include outlet structures as part of the design, and ensure that they are stable. See the Stabilized Outlets BMP for some potential options.

Table 3. Acceptable PVC and PE Pipe for Use in UGSS

Nominal Pipe Size (in)	Material and Schedule or Wall Type	Maximum Depth of Fill Over Pipe (ft)
8-12	PVC 40	10
8-12	PVC 80	15
8-24	PE single	20
8-60	PE double	20

Source: NRCS, 2008.

Notes: 1. Polyvinyl chloride (PVC) pipe, PVC 1120 or PVC 1220, conforming to ASTM D 1785;

2. Polyethylene (PE) pipe will conform to one or more of the following standards: ASTM F 405, ASTM F 665, AASHTO M 252, or AASHTO M 294.

Seepage Control

Provide seepage control along a pipe conduit spillway if the conduit is either of the following:

- Smooth pipe eight (8) inches or larger in diameter; or

- Corrugated pipe 12 inches or larger in diameter.

Control seepage along pipes extending through embankments by using either filters or drainage diaphragms, unless it is determined that anti-seep collars will adequately protect from seepage along the pipe.

Construct the drainage diaphragm of sand meeting fine concrete aggregate requirements, which is at least 15% passing the No. 40 sieve, and no more than 10% passing the No. 100 sieve. If unusual soil conditions exist, conduct a special design analysis.

Make the drainage diaphragm at least two (2) feet thick, and extend it vertically and horizontally at least three times the pipe diameter, and vertically downward at least 18 inches beneath the conduit invert. Locate the drainage diaphragm immediately downstream of the cutoff trench, approximately parallel to the centerline of the dam.

Design the drainage diaphragm to discharge at the toe of the embankment, preferably using a continuous drain backfill envelope along the pipe, to where it exits the embankment. Protect drain fill from surface erosion.

Table 4. Required Gage or Thickness of Corrugated Metal Pipe for Fill Heights Not to Exceed 15 Feet above Pipe

Pipe Diameter (in)	Minimum Steel Gage[1]	Minimum Aluminum Thickness (in)[2]
12-24	16	0.06
30	14	0.075
36	14	0.075
42	14	—
48	14	—

Source: NRCS, 2008.

Notes: 1. For corrugated steel pipe:

a. Maximum pipe diameter is 48 inches;

b. 2 2/3 x ½ corrugations except 3x1 corrugations for over 36 inches in diameter;

2. For corrugated aluminum pipe with 2 2/3 x ½ corrugations:

a. Pipe can be riveted or helical fabrication;

b. Pipe shall not be placed in soils having a pH less than four (4) nor greater than nine (9);

c. Maximum allowed pipe diameter is 36 inches.

If anti-seep collars are used in lieu of a drainage diaphragm, ensure that they have watertight connections to the pipes. Set maximum spacing at approximately 14 times the minimum projection of the collar measured perpendicular to the pipe. Use a collar material compatible with the pipe material. Design anti-seep collars to increase the seepage path along the pipe by 15%.

Construction

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, and that it conforms to MDOT, ASCI, or other appropriate standards.

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

4. If Riprap is used to stabilize outlets, underlay it with 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 specifications in the Riprap BMP.

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

6. Sign or mark open structures to alert people in the vicinity about potential dangers.

Maintenance

Because UGSS are subject to high flow conditions, periodically inspect them to ensure that erosion is not occurring, and that vegetation is adequately established. Inspect these structures at least once a year and after events which exceed the design storm. Investigate the discharge point to ensure that the concentrated flows are not causing erosion downstream. Check the emergency bypass/spillway for erosion. Check the structure for cracked concrete, uneven or excessive settling, piping, and proper drain functioning. Immediately repair or replace failing structures. Address vegetation and erosion problems as soon as weather permits.

Literature Cited

Natural Resource Conservation Service (NRCS). 1982. *Concrete Box Toewall Drop Spillway*. Michigan Standard Drawing Number MI-321-B. *(The link provided was broken and has been removed)*

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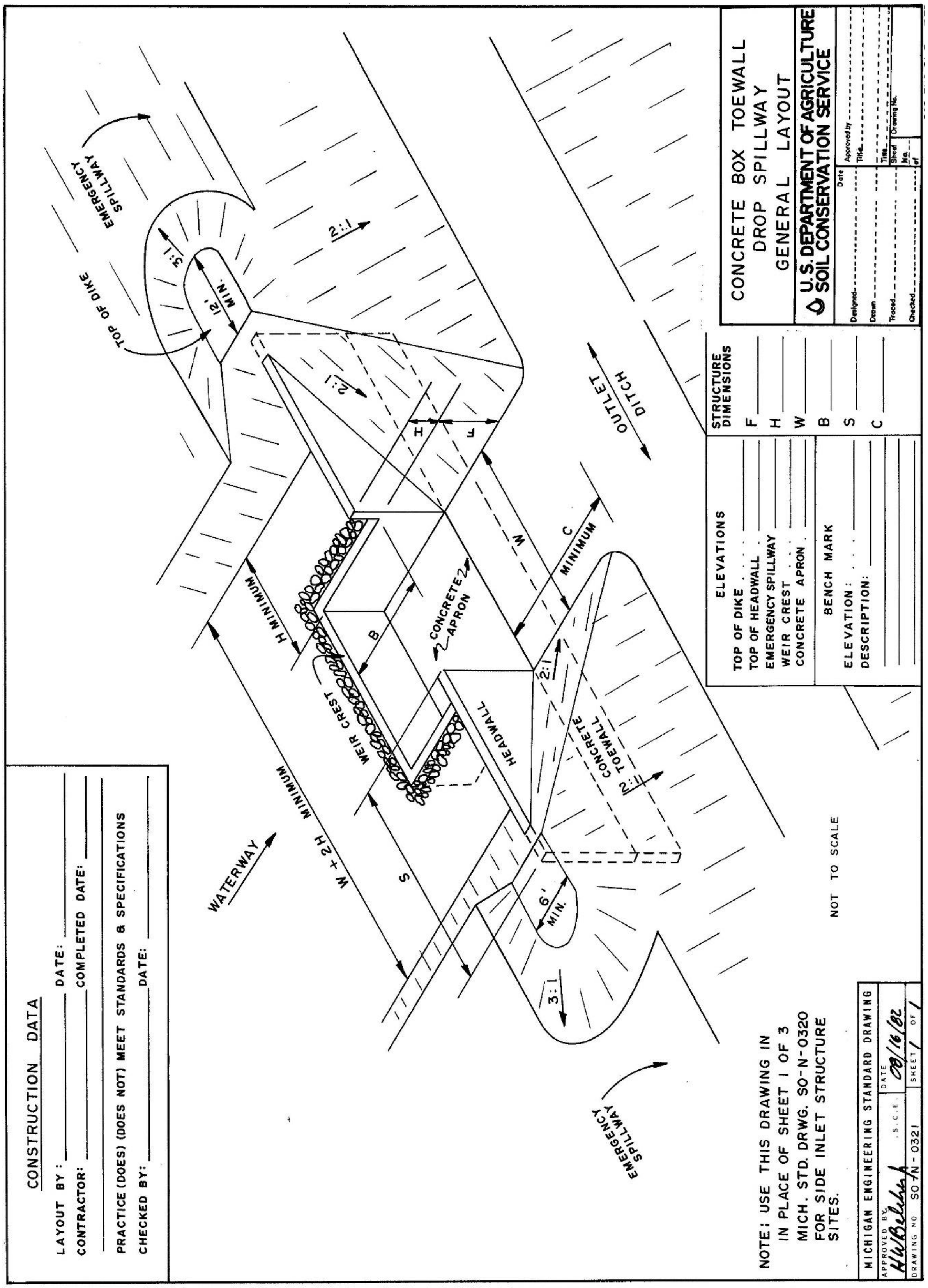

Figure 1. Concrete Block Toewall Drop Spillway
Source: NRCS, 1982.

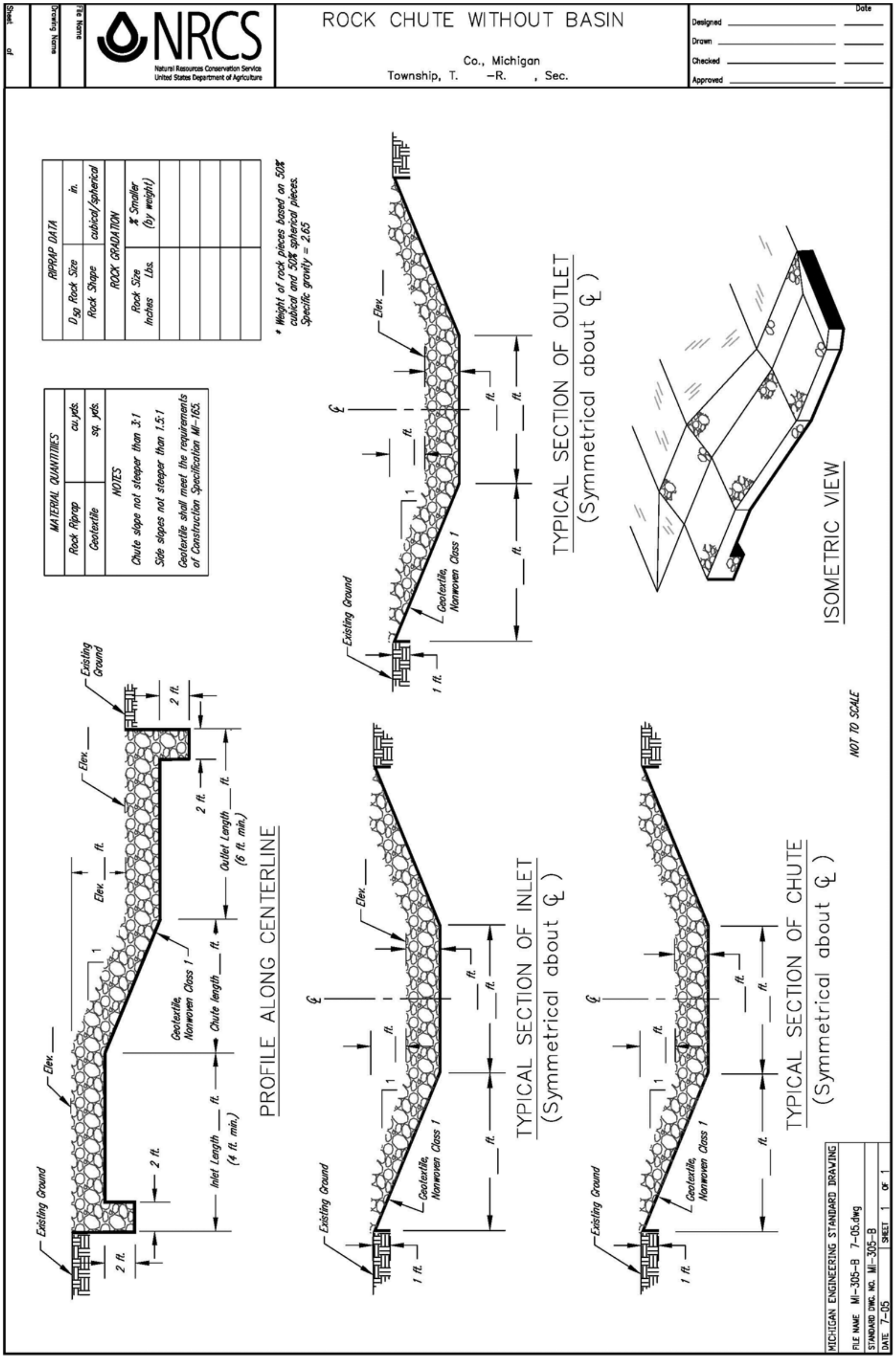

Figure 2. Rock Chute
Source: NRCS, 2005.

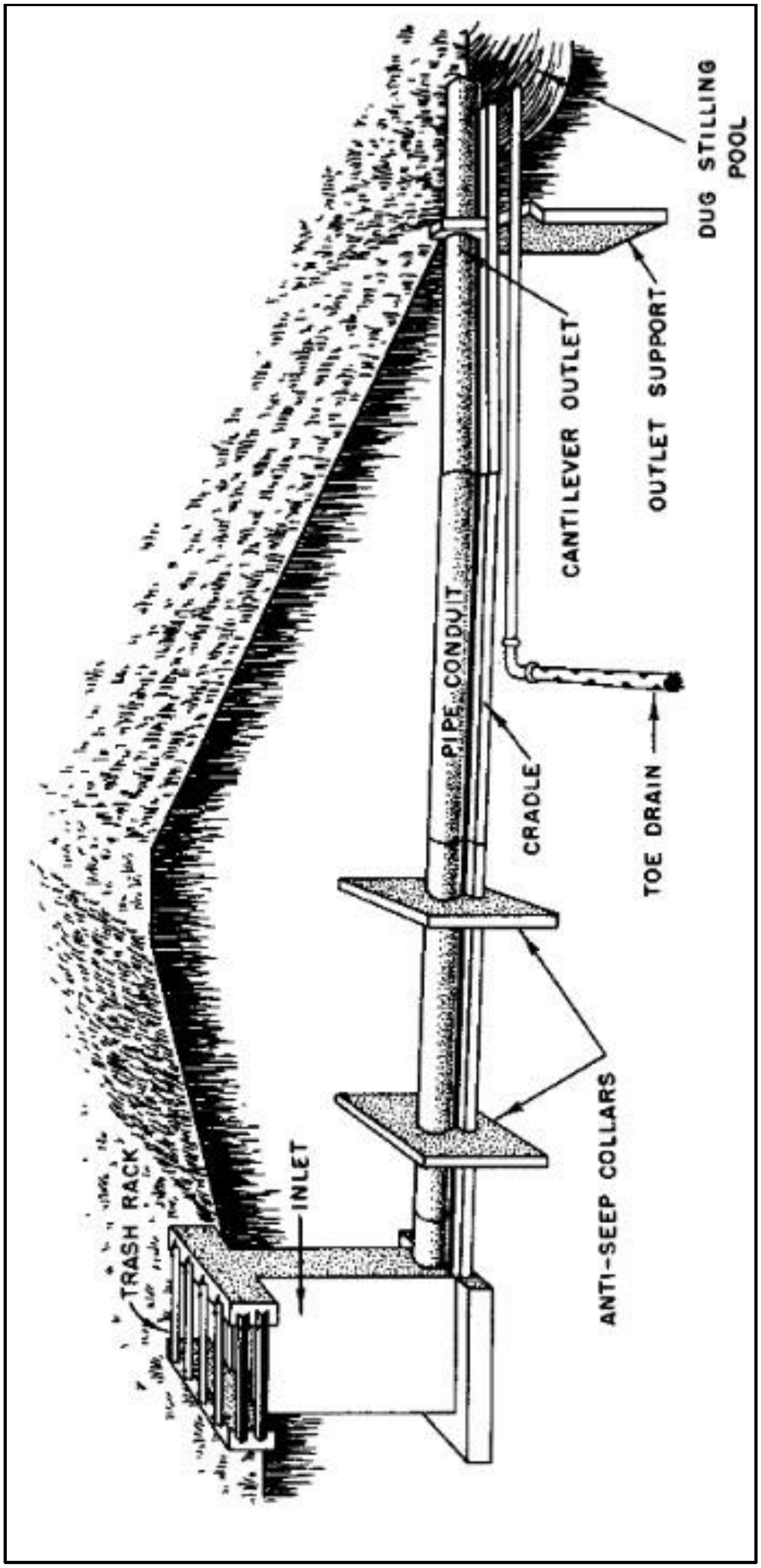

Figure 3. Typical Drop Inlet Structure
Source: NRCS, 2012.