SOIL CONSERVATION SERVICE
MASSACHUSETTS

GRADE STABILIZATION STRUCTURE

STANDARD

CODE 410
(Reported by No.)

DEFINITION

A structure used to control the grade and head cutting in natural or artificial channels.

PURPOSE

To stabilize the grade and control erosion in natural or artificial channels, to prevent the formation or advance of gullies, and to enhance environmental quality and reduce pollution hazards.

CONDITIONS WHERE PRACTICE APPLIES

General- In areas where the concentration and flow velocity of water require structures to stabilize the grade in channels or to control gully erosion. Special attention shall be given to maintaining or improving habitat for fish and wildlife where applicable.

This standard applies to all types of grade stabilization structures, including a combination of earth embankments and mechanical spillways and full-flow or detention-type structures. This standard also applies to channel side-inlet structures installed to lower the water from a field elevation, a surface drain, or a waterway to a deeper outlet channel. It does not apply to structures designed to control the rate of flow or to regulate the water level in channels or cranberry bogs (587).

Guidelines for selection of the type of structures are contained in Chapter 6, Engineering Field Manual.

Drainage Area- The drainage area above the structure must be protected against erosion to the extent that expected sedimentation will not shorten its planned effective life.

Legal- The landowner or operator must be advised that it is his or her responsibility to secure easements and necessary permits to comply with applicable federal and state laws and regulations.

CONSIDERATIONS

Water Quantity

1. Effects on volumes and rates of runoff, evaporation, deep percolation and ground water recharge.

2. Effects of the structure on soil water and resulting changes in plant growth and transpiration.

Water Quality

1. Ability of structure to trap sediment and sediment-attached substances carried by runoff.

2. Effect of structure on the susceptibility of downstream banks and stream beds to erosion.

3. Effects of the proposed structure on the movement of dissolved substances to ground water.

4. Effects on the visual quality of downstream water resources.

DESIGN CRITERIA

Site Investigations- Sufficient soil investigations shall be made of the structure site and borrow areas to determine the suitability of the site and materials for construction, structure stability and water holding ability, as applicable. Site investigations will be made in accordance with the National Engineering Manual (NEM), Part 531.

Alignment- The approach channel shall be designed so that no channel restriction or obstacles will interfere with the design flow entering the

principal or emergency spillway inlet. The principal spillway shall be in alignment with the downstream channel. The downstream channel should be straight and cleared of all obstructions which cause turbulence, backeddying and meandering for a distance of approximately fifty feet downstream from the spillway outlet.

Stable Grades- The structure must be designed for stability after installation. The crest of the inlet must be set at an elevation that stabilizes upstream head cutting. Stability of grades below structures shall be determined by velocity calculations or by inspection.

If the existing grade below the spillway is unstable, steps shall be taken to incorporate stabilizing features in the design of the spillway outlet and the discharge channel to avoid failure due to undercutting of the outlet. Generally, existing grades will be considered stable when:

1. The channel profile downstream has a uniform gradient.

2. Signs of scour on the channel bottom or sides are negligible or not apparent.

3. Grass and trees growing on the channel banks and bottom indicate that erosion has not been serious for a number of years.

4. Runoff is reduced substantially by detention structures, terraces or other practices.

Trees- All trees and shrubs shall be cleared and grubbed within a minimum distance of thirty (30) feet from an earth fill or any spillway. New plantings shall not be made within these limitations. For detention structures, clearing and grubbing will not be required below the normal waterline except on that portion of the area used as borrow or for placement of fill material. Clearing will be done where necessary to prevent accumulation of trash at the conduit inlet.

Embankment Dams

General- Class (a) dams that have a product of storage times the effective height of the dam of 3,000 or more, those more than 35 feet in effective height, and all class (b) and class (c) dams shall meet or exceed the requirements specified in Technical Release No. 60 (TR-60). See section 520.21, NEM, for definition of dam classes.

Class (a) dams that have a product of storage times the effective height of the dam of less than 3,000 and an effective height of 35 feet or less shall meet or exceed the requirements specified for ponds (378), except as modified herein.

The effective height of the dam is the difference in elevation, in feet, between the emergency spillway crest and the lowest point in the cross section along the centerline of the dam. If there is no emergency spillway, the top of the dam is the upper limit.

Hydrology- The minimum capacity of the principal and emergency spillways shall be that required to pass the peak flow expected from a 24-hour duration design storm of the frequency shown in Table 1, less any reduction because of detention storage. Included are full-flow, closed conduit structures with no reduction of peak flow because of detention storage.

Grade stabilization structures with a settled fill height of less than 15 feet and 10-year frequency, 24-hour storm runoff less than 10 acre-feet, shall be designed to control the 10-year frequency storm without overtopping. The mechanical spillway, regardless of size, may be considered in design and an emergency spillway is not required if the combination of storage and mechanical spillway discharge will handle the design storm. The embankment may be designed to meet the requirements for water and sediment control basins (638) rather than the requirements for ponds (378).

Trickle Tubes- If a principal spillway is not required, a trickle tube shall be installed to draw the water level down a minimum of one foot below the elevation of the vegetated spillway in order to allow the vegetated spillway to dry between storm events. If practical, the trickle tube should be installed around the end of the dam rather than through the embankment. An intake with non-perforated tubing installed in a trench around one end of the dam is an example of a trickle tube.

Table 1. MINIMUM SPILLWAY CAPACITY FOR STORAGE TYPE DAMS AND FULL-FLOW CLOSED CONDUIT STRUCTURES.

Drainage Area	Effective Fill Height	Maximum Storage	Minimum Design Frequency (24-hour Duration Storm)	
			Principal Spillway	Emergency Spillway
Acres	Ft.	Ac. Ft.	Yr.	Yr.
0- 20	0-20	50	- -	10
0- 20	20-35	50	2	25
20-100	0-20	50	2	25
20-100	20-35	50	2	50
100-200	0-20	50	2	25
100-200	20-35	50	5	50
200-400	0-20	50	5	25
200-400	20-35	50	10	50
All Others	0-35	--	10	50

Emergency Spillway- For grade stabilization structures with a settled fill height of 15 feet or greater or the runoff from the 10-year frequency, 24-hour duration storm of 10 acre-feet or more, an emergency spillway must be provided, unless the principal spillway is large enough to pass the routed emergency spillway design hydrograph peak discharge and the trash that comes to it without overtopping the dam. A closed conduit principal spillway with a cross sectional area of 3 sq. ft. or more, an inlet that will not clog, and an elbow designed to facilitate the passage of trash is the minimum design that may be used without an emergency spillway. If an emergency spillway is not provided, the principal spillway and any associated temporary storage shall be designed for the 50-year, 24-hour runoff and at least 1.0 foot of freeboard must be provided. This requires approval of the State Conservation Engineer.

Full-Flow Open Structures

General- Straight drop spillways, chute spillways and box inlet drop spillways shall be designed according to the principles set forth in the Engineering Field Manual for Conservation Practices, the National Engineering Handbook and other applicable SCS publications and reports. The minimum capacity shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in Table 2, less any reduction because of detention storage. Structures must not create unstable conditions upstream or downstream. Provisions must be made to ensure reentry of bypassed storm flows.

Freeboard- Freeboard providing sidewalls six inches higher than the water surface attained by the principal spillway design discharge shall be used. When freeboard is considered in the formula as given in the National Engineering Handbook, the formula shall govern freeboard requirements. An additional one foot shall be provided between the top of the sidewalls and the top of the settled embankment.

Toe Wall Structures- Toe wall drop structures may be used if the vertical drop is 4 feet or less, flows are intermittent, downstream grades are stable and tail water depth at design flow is equal

to or greater than one-third of the height of the overfall.

Table 2. CRITERIA FOR DETERMINING MINIMUM CAPACITY OF FULL-FLOW OPEN STRUCTURES.

Maximum Drainage Area	Vertical Drop	Frequency of minimum design, 24-hour duration storm	
		Principal Spillway Capacity	Total Capacity
Acres	Ft.	Yr.	Yr.
450	5 or less	5	10
900	10 or less	10	25
All others	- -	25	100

Drop Boxes on Road Culverts- The ratio of the capacity of drop boxes to road culverts shall be as required by the responsible road authority or as specified in Table 2 or 3, as applicable, less any reduction because of detention storage, whichever is greater. The drop box capacity (attached to a new or existing culvert) must equal or exceed the culvert capacity at design flow.

Island-Type Structures

If the mechanical spillway is designed as an island-type structure, its minimum capacity shall equal the capacity of the downstream channel. For channels with very small drainage areas, the mechanical spillway should carry at least the 2-year, 24-hour storm or the design drainage curve runoff, whichever applies. The minimum emergency spillway capacity shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in Table 2 for total capacity without overtopping the headwall extensions of the mechanical spillway. Provisions must be made for safe reentry of bypassed flow as necessary.

Side-Inlet Drainage Structures

The design criteria for minimum capacity of open-weir or pipe structures used to lower surface water from field elevations or lateral channels into deeper open channels are shown in Table 3. The minimum principal spillway capacity shall equal the design drainage curve runoff for all conditions.

Landscape Resources

In highly visible public areas and those associated with recreation, careful considerations should be given to landscape resources. Landforms, structural materials, water elements and plant materials should visually and functionally complement their surroundings. Excavated material and cut slopes should be shaped to blend with the natural topography. Shorelines can be shaped and islands created to add visual interest and valuable wildlife habitat. Exposed concrete surfaces may be formed to add texture or finished to reduce reflection and to alter color contrast. Site selection may be used to reduce adverse impacts or create desirable focal points.

General Criteria

Earth embankment and emergency spillways of structures for which criteria are not provided under the standard for ponds (378) or in TR-60 must be stable for all anticipated conditions. If earth spillways are used, they must be designed to handle the total capacity flow indicated in Tables 1, 2 or 3 without overtopping the dam. The foundation

preparation, compaction, top width and side slopes must ensure a stable dam for anticipated flow conditions. Discharge from the structure shall be sufficient that no crop damage results from flow detention.

Necessary sediment storage capacity must equal the expected life of the structure, unless a provision is made for periodic cleanout.

The earth embankment pond structures are potentially hazardous and precautions must be taken to prevent serious injury or loss of life. Protective guardrails, warning signs, fences or lifesaving equipment shall be added as needed.

If the area is used for livestock, the structure, earthfill, vegetated spillways and other areas should be fenced as necessary to protect the structure. Near urban areas, fencing may be necessary to control access and exclude traffic that may damage the structure or to prevent serious injury or death to trespassers.

Protection

The exposed surfaces of the embankment, earth spillway, borrow area and other areas disturbed during construction shall be seeded or sodded as necessary to prevent erosion. If climatic conditions preclude the use of vegetation, nonvegetative coverings such as gravel or other mulches may be used.

Table 3. DESIGN CRITERIA FOR DETERMINING MINIMUM CAPACITY OF SIDE-INLET, OPEN-WEIR OR PIPE-DROP-DRAINAGE STRUCTURES.

			Frequency of minimum design, 24-hour duration storm	
Maximum Drainage Area Acres	Vertical Drop Ft.	Receiving Channel Depth Ft.	Principal Spillway Capacity Yr.	Total Capacity Yr.
450	0 - 5	0 -10	*	*
450	5 -10	10 -20	*	10
900	0 -10	0 -20	*	25
All others	- -	- -	*	50

* Design Drainage Curve

PLANS AND SPECIFICATIONS

Plans and specifications are to be prepared for specific field sites, based on this standard. Plans and specifications include construction plans, drawings, job sheets, construction specifications, narrative statements in conservation plans, or other similar documents. These documents are to specify the requirements for installing the practice, such as the kind, amount, or quality of materials to be used, or the timing or sequence of installation activities.

Refer to the Grade Stabilization Specifications for general requirements applicable to all sites to assist with the preparation of the site specific specifications.

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SPECIFICATIONS

Specified materials shall provide stability, durability and safety characteristics required to achieve the planned objectives.

Specifications for grade stabilization structures within the scope of the standard for ponds (378) shall, as a minimum, be commensurate with those for ponds. Grade stabilization structures within the scope of TR-60 shall be constructed according to the guide specifications in the National Engineering Handbook, Section 20.

Materials, foundation preparation, fill placement, moisture control, compaction, principal and emergency spillway requirements shall comply with Pond Specifications (378) insofar as applicable. Fertilizing, seeding, and mulching will be applied in accordance with the Critical Area Planting Specifications (342). Refer to Waste Storage Structure Specifications (313) for the requirements for concrete.

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OPERATION AND MAINTENANCE

An operation and maintenance plan shall be developed and provided to the landowner or operator. This plan should consider the following general recommendations as applicable. Specific recommendations particular to the job being installed not covered by the following should be added.

1. Remove all debris that accumulates at the structure, and immediately upstream and downstream of the structure. Also, remove debris that blocks or obstructs the spillways, trash racks or pipelines as applicable.

   Use extreme care in removing debris from submerged inlets and pipes. Suction from the sudden release of water through a pipe can trap a person at the inlet of the pipe and cause drowning.

2. Maintain vigorous growth of desirable vegetative cover. This includes reseeding, fertilizing and controlled applications of herbicides when necessary. Periodic mowing may also be needed to control height. Operating equipment on steep slopes is a hazard, and extreme care should be taken. The use of protective frames, crush resistant cabs and seat belts is strongly recommended.

3. Avoid operating farm equipment too close to the structure.

4. Control livestock access to the structure. If fences are installed, they shall be maintained to prevent livestock entry.

5. Make sure all structure drains are functional and soil is not being transported through the drainage system; repair if not functioning. The screens and/or rodent guards shall also be kept in place.

6. Immediately repair any damage caused by rodent or burrowing animal activity. Barriers, such as woven wire, riprap, etc. may be installed to prevent recurring damage.

7. Remove woody vegetation from embankments and the emergency spillway.

8. Immediately repair any vandalism, vehicular or livestock damage to any earthfills, spillways, outlets or other appurtenances.

9. Determine and eliminate causes of settlement or cracks in the earthen sections and repair damage.

10. Repair spalls, cracks and weathered areas in concrete surfaces.

11. Repair or replace rusted or damaged metal, and paint.

12. Replace weathered or displaced rock riprap to constructed grade.

SUPPORTING DATA AND DOCUMENTATION

Field Data and Survey Notes- The following is the minimum data needed:

1. Profile along centerline of structure, along centerline of principal spillway, and along centerline of emergency spillway.

2. Survey of storage area to develop topography and storage volumes.

3. Soil investigation logs and notes to determine suitability of the site, materials for construction and structure stability.

Design Data- The following information shall be recorded in the design and/or the drawings, as applicable:

1. Record hazard class, drainage area, runoff curve number, frequency of design storm, required discharge of the principal and emergency spillways

2. Adequacy of land treatment in the watershed, and sediment storage computations for the structure.

3. Stage-storage/discharge curve for the site, principal spillway storm routing, and emergency spillway routing and design.

4. Drawings showing the layout of the structure. The drawings shall include a plan view, profiles along centerline of dam and centerline of emergency spillway, cross sections through dam at principal spillway and through emergency spillway. Drawings will include all dimensions as appropriate.

5. Drawings shall also include material and dimensions of the principal and emergency spillways and appurtenances; distances and elevations necessary to properly locate the fill, principal and emergency spillways and other features, details of pipe joints or coupling bands, anti-seep collars, drainage diaphragms and special requirements for pipe bedding.

6. The drawings shall specify the method of compaction required for the earthfill (see specifications).

7. Quantities of earthfill, pipe material and appurtenances, clearing, fencing, seeding and other items necessary for installation.

8. Calculations or statement of inspection to ensure stability of outlet channel.

Construction Check Data- The following information shall be recorded on survey note paper and on the drawings as appropriate to certify installation of the pond.

1. Profile along the top of dam, along centerline of principal spillway extending at least 100 ft. downstream of outlet, and along centerline of emergency spillway.

2. Cross section of the emergency spillway at the control section.

3. Check shots to verify installed elevations of principal spillway inlet and outlet.

4. Diameter, length and type of material for the principal spillway and appurtenances.

5. The number, size and location of anti-seep collars.

6. Statement on adequacy of seeding and fencing. Documentation for vegetation establishment shall include amounts of N, P_2O_5, and K_2O applied. Actual seeding mixture used and rates as pure live seed applied shall be noted.

7. Notes on site clean-up and disposal.

8. Sign and date as-built drawings to include statement that practice meets or exceeds plans and specifications.

References

1. *ASTM Standards*, American Society for Testing and Materials, Philadelphia, Pennsylvania.

2. *Design Note 6, Riprap Lined Plunge Pool for Cantilever Outlet*, USDA, Soil Conservation Service, Washington, DC.

3. *Engineering Field Manual*, USDA, Soil Conservation Service.

   - Chapter 2, *Estimating Runoff*
   - Chapter 3, *Hydraulics*
   - Chapter 4, *Elementary Soils Engineering*
   - Chapter 6, *Structures*
   - Chapter 11, *Ponds & Reservoirs*
   - Chapter 17, *Construction & Construction Materials*

4. *Massachusetts Technical Guide, Section IV, Standards and Specifications for Critical Area Planting (342)*, USDA, Soil Conservation Service.

5. *National Engineering Handbook*, USDA, Soil Conservation Service

   - Section 4, *Hydrology*
   - Section 5, *Hydraulics*
   - Section 11, Drop Spillways
   - Section 14, *Chute Spillways*

6. *National Handbook of Conservation Practices*, USDA, Soil Conservation Service.

7. *Standard Specifications for Materials and Methods of Sampling and Testing*, American Association of State Highway and Transportation Officials, Washington, D.C

8. *Standard Specifications for Highways and Bridges*, Massachusetts Department of Public Works, Boston, Massachusetts, 1988

9. *Technical Release 20, Computer Program for Project Formulation*, USDA, Soil Conservation Service

10. *Technical Release 49, Criteria for the Hydraulic Design of Impact Basins Associated with Full Flow in Pipe Conduits*, USDA, Soil Conservation Service.

11. *Technical Release 55, Urban Hydrology for Small Watersheds*, USDA, Soil Conservation Service.

12. *Technical Release 56, A Guide for Design and Layout of Vegetative Wave Protection for Earth Dam Embankments*, USDA, Soil Conservation Service.

13. *Technical Release 60, Earth Dams and Reservoirs*, USDA, Soil conservation Service.

14. *Technical Release 66, Simplified Dam Breach Routing Procedure*, USDA, Soil Conservation Service.

15. *Technical Release 69, Riprap for Slope Protection Against Wave Action*, USDA, Soil Conservation Service.

16. *Technical Release 77, Design and Installation of Flexible Conduits*, USDA, Soil Conservation Service.