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CHAPTER 1 EROSION CONTROL STRUCTURES

INTRODUCTION

Structures discussed in this technical note under the general term erosion control structure are generally used in gullies, watercourses or channels to provide permanent protection at points that cannot be adequately protected by less costly means and/or to retard runoff and store sediment which is causing harmful deposits on valuable farmland or grassland, drainage or irrigation systems, or in water storage structures. In some cases, they may be used to divert water into waterspreading systems, or into other subwatersheds. Such structures may be constructed of earth, rubble masonry, or concrete and located at places such as:

1. Gullies at or near ends of grassed waterways.
2. Individual terraces or diversions which must be spilled into fairly deep drainageways or gullies.
3. Drainage ditches which must be emptied into deeper ditches, creeks or rivers.
4. Heads of active gullies, overfalls, abrupt changes in gradient; entrances of branch gullies, or other critical points
5. Gullies or severely eroded areas which carry large amounts of sediment causing damage to valuable land or structures below.

The more common types of permanent erosion control structures are listed as follows:

1. Earth Dams
2. Formless Concrete Chutes
3. Reinforced Concrete Chute Spillways
4. Masonry Drop Spillways
5. Reinforced Concrete Drop Spillways
6. Rubble Masonry Overfall Dams
7. Corrugated Metal Toewall Drop Structures
8. Rock Gabion Chutes

Depending upon the primary purpose and the location with respect to other practices, the above structures may be planned and installed as Grade Stabilization Structures, Structures for Water Control, Sediment Basins or Diversion Dams, or other appropriate practices. (Refer to practice standards and specifications in the National Handbook of Conservation Practices (NHCP)).

Selection of Structures

The selection of the structures to be used for any particular job is largely a problem of determining the type that will provide the necessary capacity and meet other requirements and yet give the most economical construction and maintenance costs. Consideration must be given to alternative practices which would give the desired control at a lesser cost. The maximum limit of cost or damage that can be sustained is the cost of doing nothing and letting the present condition continue. This can be measured in terms of the net value of production, with and without the structure; in the benefited area during the life expectancy of the proposed structure. The life expectancy normally will be ten to fifty years. Aspects of this cost are the inconveniences and expense of farming or ranching gullied areas, and the reduced value of the farm or ranch as a whole when dissected by gullies.

Economic Feasibility

The economic feasibility of permanent erosion control measures should be determined by weighing their costs against the cost limit described above. Items to consider in the cost analysis include the cost of installation, the annual maintenance costs and the value of the production lost by the installation of the control measures. The installation cost can be reduced to the approximate annual cost by dividing the total installation cost by the expected life of the structures. When a detailed analysis is required, the installation cost should be amortized at the appropriate interest rate for a period equal to the expected life of the structure. In some instances, the most feasible treatment for the area is proper land use, protection from grazing or over-use, and letting nature solve the problem.

TYPES

Earth Dams

Description---The earth dam type erosion control structure is an impounding structure that has been located and designed to provide protection against erosion and/or damaging deposition of sediment or debris. The influence of the dam extends over an appreciable area either upstream or downstream or both. This type of structure usually is equipped with a principal spillway and a vegetated emergency spillway.

The principal spillway is generally a closed conduit spillway of one of three types, namely: (1) drop inlet, (2) hood inlet culvert type, or (3) inclined tube type. Sometimes it may consist of a chute or drop spillway type structure. The principal spillway is sized in respect to the routed principal spillway storage as it relates to the desirable frequency of operation of the emergency spillway.

The emergency spillway is designed to pass excess runoff (that not stored or discharged through the principal spillway) around the dam. It is vegetated except when cut in rock or other non-erosive material. The spillway is proportioned so that the routing of the design flood event will pass the spillway at the safe velocity determined for the site.

Functional use---The earth dam erosion control structures are used for any of the following purposes:

1. To control the headward extension and enlargement of gullies.
2. To protect valuable farmland or grassland or water storage from damaging deposition or debris.
3. In connection with a waterspreading system, to divert the water from a stream or watercourse into the spreading area, or to serve as a detention dam to meter the water into the system. If the purpose is to divert water, existing farm pond standards and specifications will apply. Where detention and sediment storage capacity are involved, the structure will be designed according to criteria discussed in this chapter.
4. To provide temporary flood storage in order to reduce flooding below the structure.

Advantages

1 The earth dam erosion control structure may be used where it is desired to use detention of runoff or sediment to solve the erosion problem.
2. This type of structure may be less costly than other erosion control structures because fill material can be secured at the site and experienced contractors usually are available.
3. It can be used for the dual purpose of controlling erosion and providing water for livestock and/or wildlife, if the location is suitable and there is a need for the water supply.
4. A secondary use may be to serve as a roadway across deep gullies.
5. It is adaptable to a wide variety of site conditions. Detention storage, if available, can be used to reduce frequency of flow through the emergency spillway or the size of the principal spillway.

Disadvantages

1 The use of earth dams for erosion control is limited to those sites where the required capacity for runoff and sediment storage, suitable fill material and adequate spillways can be economically obtained.
2. Vegetation usually is required to protect the embankment and emergency spillway against erosion, thus requiring such practices as fencing, fertilizing and controlled grazing to insure adequate vegetative cover at all times.
3. The structure may be more expensive than vegetative or other means of control. Its use should be recommended only after exploring other methods.

Site selection---The use of earth dams for erosion control is limited to locations that have suitable terrain. Since this type structure may use detention storage to help solve the erosion or sediment problem and since the safety and successful operation of the structure depend largely upon the adequacy of the spillway, particular note should be made of these two items during the site investigation.

A careful study of each site should be made to determine

1 The volume of storm runoff, erosion and sediment yield, and conservation measures that might be applied to improve the watershed conditions.

2. Possible dam sites, the suitability of foundation conditions, availability of suitable fill materials, available storage capacity, and spillway conditions.

This information will indicate whether or not an earth dam erosion control structure can be economically installed to meet the requirements of the individual job.

The location of an earth dam, designed to protect against head erosion, must be such that the dam will have influence far enough upstream to submerge the overfall(s). To obtain best results, the crest of the principal spillway should be placed level with the crest of the overfall to be protected. Sufficient detention storage or principal spillway capacity should be provided to permit passage of the 25-year frequency flood at a safe velocity in the emergency spillway. Under such conditions the reservoir fills with water and the overfall is submerged, controlling erosion at this point. When it is not practical to set the crest of the principal spillway level with the overfall, the projected grade from the crest of the principal spillway to the crest of the overfall should not exceed the silting grade. The silting grade is dependent on soil conditions and can be determined best by investigating the grades of existing gullies in the area that appear to be stable. As a general rule, the silting grade should be kept below 0.5% to insure that the overfall eventually will disappear.

A satisfactory emergency spillway must be available at the site to assure stability of the structure. Unstable spillways are the chief cause of failure of this type of erosion control structure. The main factors causing vegetated spillway failures are too frequent operation and continual flow of a small stream of water through the spillway. The latter causes the soil to become saturated and the vegetative cover loses its binding qualities. Scouring occurs and small channels are formed which increase in size whenever subjected to either trickle or flash flow. Therefore, in selecting sites for this type of structure, every effort should be made to obtain the best spillway possible and to consider providing sufficient detention storage or principal spillway capacity, based on the quality of the spillway, to control frequency of operation and to eliminate prolonged trickle flow.

Use should be made of any existing natural depression adequate in size to pass the designed outflow into an adjacent drainageway, and which is protected against erosion by native vegetation. It is sometimes possible to take the emergency spillway discharge away from the gully, or problem area, by spilling it over a small divide or ridge onto a well vegetated area. In this case the spill area should be thoroughly examined to make sure that the additional water will not create other erosion problems, or be diverted onto neighboring property. Natural vegetated spillways and natural exit channels are desirable, especially in semi-arid areas where difficulty is encountered in establishing adequate protective vegetation Natural spillways should have a broad and flat cross section so as to distribute the flow over as wide as an area as possible.

Some sites will require all parts of the emergency spillway(s) to be excavated. In such cases the spillway should be so located as to hold excavation to a minimum, and constructed to designed dimensions and grades which provide for uniform distribution of flow throughout its entire length. The grade of the exit channel should merge with the stable downstream grade of the draw or gully and there should be no abrupt turns. The excavated spillway should be vegetated with the most erosion-resistant grass adapted to the site, unless it is constructed in a nonerodible material.

In selecting sites for this type of structure, consideration also should be given to the stability of the draw or gully below the dam. Since the spillway discharge usually is returned to the draw or gully immediately downstream from the dam, the channel gradient must be stable if the structure is to be effective. Stability of grade is dependent on soil type, extent of vegetation, velocity of flow, and frequency and extent of flow. As a general rule the velocity is the best criterion for ascertaining the stability of grade. Examination of existing channels in the area also will help to determine stable grades. SCS TP-61, "Handbook of Channel Design," gives information on safe velocities for earth and vegetal lined channels. It should be kept in mind that slightly higher velocities are permissible for intermittent spillway flows than those permitted for continuous or prolonged flows. If the grade is not stable at the structure site, the principal spillway outlet can be recessed below the gully floor to the intersection of the projection of a stable grade upstream from the point where a stable grade exists. Under such a plan, erosion will occur in the channel to a point where a stable grade is reached. The other alternative is to construct one or more structures downstream to bring the grade within limits.

Foundation conditions should be suitable for embankment construction and suitable fill material should be available within an economical range of the site. Investigation and selection of foundation and fill material, as a minimum requirement, should be in accordance with existing procedures given in the Engineering Field Manual for Conservation Practices. Reservoir seepage is not a major concern in this type of structure except where stock water storage is involved, or where the seepage might affect the stability of the dam.

Selection of a site for an earth dam erosion control structure essentially involves checking the site to determine if the structure will meet the purpose of the practice and be more economical than other types. If it meets these criteria, it should be designed to meet the particular needs.

Design---The adequate design of an earth dam erosion control structure requires the gathering and use of specific data. The scope and detail of this data depends upon the size and cost of the structure involved. Some of the data may be secured from aerial photos, published contour maps, or by reconnaissance survey. Some of the information will have to be secured by engineering surveys.

1 Design surveys---The fo owing data should be secured and recorded:

a The watershed boundary should be shown on a map together with the following information:

(1) The size in acres.
(2) The percentage of each land use, amounts of applied land treatment or practices and the condition of the vegetative cover. This information is needed to determine the proper hydrologic soil-cover complex curve number.
(3) The predominant soil types, to determine the hydrologic soil groupings.
(4) The length of the longest watercourse from the proposed site to the ridge in feet.
5) The difference in elevation between the proposed site and the farthermost point, in feet, but omit appreciable drops due to gully overfalls, waterfalls, etc.

b Profile and cross sections of the gully or draw and topography of the proposed site. The following details should be obtained:

1 Profile upstream from the probable dam site far enough to include the entire area of the gully to be influenced by the dam and below the proposed site to the point where a stable grade is reached. The profile should be plotted on cross section paper using a horizontal scale of not more than 200 feet to the inch and a vertical scale of not more than 5 feet to the inch. The profile is needed to determine the elevation of the dam components, to make any needed changes in the proposed dam location, and to help determine stability of channel below dam, etc.
(2) A profile of the proposed centerline of the dam. Extend the elevations well above the anticipated height of the dam. Plot on cross section paper showing elevations of most desirable spillway sites. Where there is a question as to the stability of grade below the structure, cross sections should be taken every 200 to 400 feet as far as necessary to determine the safe allowable grade below the structure based on velocity calculations.

A topographic map of the proposed site, including the entire reservoir and spillway area. The contours should be plotted on two foot intervals, and they should extend up to or beyond the anticipated height of the dam. The contour map is needed to determine the elevations of the dam, emergency spillway, and principal spillway needed to provide the necessary storage, etc. The contour map may be made with a telescopic alidade and plane table or by taking cross sections between distinguishable points on an aerial photo.
All profiles, cross sections, and topographic information should be referenced to a common benchmark.

After the location of the spillway has been definitely established, profile and cross sections of the spillway should be made for design and construction purposes

2. Design criteria---When the basic data has been secured, this type structure should be designed in accordance with the requirements of the appropriate practice standard and specification (NHCP) and the following criteria:

   a. Detention Storage - The volume of detention storage will be contingent upon the level of protection needed and the capacity of the principal spillway. The detention storage capacity and the size of the principal spillway should be proportioned so that the least expensive combination which will provide the desired level of protection can be determined.

      When the purpose of the structure is to stabilize a watercourse or gully, the required detention capacity may vary from that required to produce flow in the spillways to that required to store the 25-year flood event. Where little detention storage is required, particular care must be taken to see that the emergency spillway is so located and protected that excess runoff will be discharged into the channel below the dam without the possibility of the development of an overfall which may work up the spillway and destroy the dam; or, the spillway should be extended to empty into a smooth, well protected area or into a nearby stabilized drain.

      When the purpose of the structure is to protect downstream land or structures from sediment or debris or to stabilize the area below, detention capacity for no less than a 10-year frequency flood should be provided.

      Earth dams with "trickle tubes" installed for the purpose of protecting the emergency spillway from prolonged base flow usually would not have detention storage or principal spillway capacity enough to effect significant reduction in the emergency spillway discharge. These should be designed in accordance with existing criteria for ponds.

b Sediment Storage - Adequate sediment storage capacity should be provided in this type structure to insure a reasonable useful life for the structure. When the purpose of the structure is to protect downstream land or structures from sediment or debris, capacity to store no less than the 10-year accumulation of sediment should be provided. For the larger, more expensive structures, or where the land or structures being protected below have a high economic value, the period may need to be increased to a 50-year maximum.

Where the structure is for grade stabilization only and has a low detention storage-drainage area relationship, sediment storage ordinarily will not be considered.

Sediment rates for the various resource areas based on the farm pond survey may serve as a guide in determining the sediment rates to use for design of the sediment storage capacity. (See Table 1-4, Weighted Average Estimated Gross Erosion Rates.)

c. Principal Spillway - This type structure usually should be equipped with a principal spillway to release the water from the detention storage area. At sites where the detention storage will cover sizeable areas of grass or cropland, the minimum release rate should be based on the period of time the plants can withstand inundation. Where spring flow and/or prolonged surface flow can be expected the release rate should be increased to include both these flows and the detention flow.

The average release rate needed to drain the detention storage within the interval of the time selected can be determined by the following formula:

$$Q \text{ in cfs} = \frac{\text{Storage in Acre Feet}}{\text{Removal time in days}} \times 0.50417$$

The average discharge used shall be 80 percent of the capacity of the principal spillway with the head assumed to be at the emergency spillway crest elevation. Since small diameter tubes are particularly susceptible to clogging with trash, no pipe less than 6 inches in diameter should be used. A minimum of 8 inch diameter is preferable.

The crest of the principal spillway of grade stabilization structures should be set level with the top of the overfall being treated. If it is necessary to set the crest below the elevation of the overfall, the projected grade to the overfall never should exceed the silting grade of the channel. The detention pool will be between the lip of the principal spillway and the crest of the emergency spillway. Where stock water is involved, the necessary storage to provide the livestock needs is provided between the sediment pool and the detention pool.

Pipe, such as asbestos cement, plastic, steel, concrete and corrugated metal, may be used for principal spillway installations. Steel or corrugated metal pipe usually is used for this purpose because of the simplicity of installation.

Principal spillways may be of the drop inlet, hood inlet or inclined tube type. In some cases it may need to be only a horizontal straight pipe. In such cases both ends of the pipe usually are submerged and it functions as a culvert. Discharge capacities of culverts can be determined by the formula $Q = CA\sqrt{2gH}$, where H is the difference in elevation between the water surfaces at the inlet and outlet of the pipe. The proper coefficients (c) are given in King's Handbook of Hydraulics, based on the various sizes and lengths of pipe. Table 1-5 contains pertinent data for solving the formula.

The adaptability and design of hood inlets is given in USDA, SCS, Engineering Division, Technical Release Number 3 - "Hood Inlets for Culvert Spillways".

The drop inlet type principal spillway consists of pipe under the embankment with a larger diameter riser at its upper end. The cross sectional area of the riser pipe usually should be at least 1.5 times the cross-sectional area of the barrel in order for the barrel to flow full. The drop inlet type principal spillway should be designed by using the following formulae:

Weir Flow - $Q_W = 3.5 \quad H_W^{\frac{3}{2}}$

Where L = Circumference of the vertical riser pipe in feet.

H_W - Head on the weir in feet

Orifice Flow - $Q_O \quad 0.6A\sqrt{2gH_O}$

Where A = Cross-sectional area of orifice in sq. ft.

H_O = Head on orifice in ft.