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Chapter 10 Gully Treatment



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Part 650 – Engineering Field Handbook

Chapter 10 – Gully Treatment

650.1000 Introduction

(A) Purpose and Scope

(1) Chapter 10 provides conservation professionals with a guide for the stabilization of active gullies by vegetative, structural measures or a combination thereof. The focus of this chapter is on gullies formed by precipitation runoff and seeps.

(2) This chapter is national in scope and will often be supplemented with regional and local information. Additional background on specific designs and sample calculations are available in other sources such as Title 210, National Engineering Handbook, Part 654, "Stream Restoration Design Guide" (210-NEH-654)– Technical Supplement 14P, "Gullies and Their Control".

(B) Definition

(1) One of the most severe erosion forms addressed by the Natural Resources Conservation Service (NRCS) measures are gullies. Gullies are entrenched channels extending into areas with previously undefined or weakly defined channels. Gullies can be thought of as extensions of a watershed drainage system up into the landscape.

(2) If unchecked, gullies can erode and deliver sediment through a variety of processes that cause loss in soil productivity, channel entrenchment and headward expansion into the landscape. Under extreme conditions, gullies can expand into hillslopes extending up to the topographic watershed divide. Active gullies are recognized by headcuts (primary nickpoints), where there is an abrupt drop in elevation. A photograph of a gully impacting a steep field is shown in Figure 10-1.

Figure 10-1: Typical gully formation showing steep sides and upslope expansion



(C) Impacts of Gullies

(1) Gullies are significant erosion forms that adversely impact the economy by reducing agricultural productivity, lowering the value of farmland, and increasing the cost of constructing and maintaining rural infrastructure.

(2) Gullies directly reduce productivity by making areas of land unfarmable (Figure 10-2). Gullies are part of the system where fertile topsoil is transported off the sloped areas of fields lowering yields. The degradation of farmland interferes with farm operations, undermine farm improvements, endangers livestock, covers bottom lands with deposits of soil, and mars the natural beauty of the landscape.

Figure 10-2: Gullies can rapidly expand and adversely impact farmland



(3) Gullies can lower the local groundwater table, which reduces water storage in headwater stream reaches. The reduction in groundwater can decrease baseflow in downstream reaches.

(4) Gullies increase the cost of public infrastructure when they encroach on highways and roads, force the lengthening of bridges, and increase sediment deposition that fills road ditches, plugs road culverts and reduces the capacity of drainage channels.

(5) Gullies can extend into wetland areas, adversely altering wetland hydrology and even serving to drain them. The impact of gullies is particularly pronounced on wetlands that meet the definition of Slope wetlands in the hydrogeomorphic (HGM) classification system where groundwater inflows support wetland hydrology. Further discussion on wetland impacts and the definition of wetland types is found in 210-NEH-650, Chapter 19, “Hydrology Tools for Wetland Identification and Analysis” (210-NEH-650-19)

(6) The adverse effects of gullies can extend throughout the watershed. Sediment sourced from gully erosion can adversely impact water quality, fill channels, increase flooding, and kill native vegetation. Sediments from gully erosion can ultimately fill reservoirs, shortening their effective life. A reservoir that has been severely impacted with excessive sedimentation from its watershed is shown in Figure 10-3.

Figure 10-3: Floodwater storage in this watershed dam has been severely impacted by sedimentation



(7) Gullies can vary in scale and impact. Some gullies can heal through natural vegetative succession over time while many are more permanent and will get larger. Still other gullies are ephemeral and can be plowed over, only to reappear during wet seasons.

(D) Causes of Gullies

(1) It is important that conservation professionals be acquainted with the practices and conditions that cause gullies. This knowledge is necessary to assist the landowner in selecting farming practices, land use changes, structures or even cultural measures which will prevent further erosion and help to control existing gullies.

(2) Gullies are caused by runoff water that concentrates in surface depressions and drainageways, flowing at a velocity sufficient to detach and carry away soil particles. The power to erode increases as the stream increases in size, velocity, and duration. The severity of gully development depends on several factors including soil type, vegetation, rainfall, concentration of flow, the presence of springs, and human disturbances.

(3) Gullies on HGM Slope class wetland landscapes will have groundwater discharging from the banks and will have continuous baseflow. Groundwater discharge through the banks usually contributes to unstable slopes.

(4) If the depression or drainageway is not protected from erosion, a gully will form and be enlarged by subsequent flows until the gully system reaches equilibrium. Many large gullies have formed because simple steps were not taken to stop them in their early stages.

(5) Drainageways which collect runoff water that may form gullies may be natural or may have been caused by:

- Improperly located farm roads, field and access roads, and trails.
- Livestock trails.
- Up-and-down slope cultivation.
- Unprotected terrace outlets and unvegetated waterways.
- Unrepaired breaks in terraces and diversions.
- Improperly designed drainage or diversion channels without needed vegetative or structural protection.
- Lack of vegetation and rilling on bare slopes.
- Rainfall that exceeds the capacity of drainage or conservation structures.
- Improperly designed and/or placed road drainage structures.
- Built-up fence rows or property boundaries.
- Grass waterways that need sediment removal.
- Improper land use
- Soluble salts or other adverse runoff water components that destroy vegetation.

(6) It is important for conservation professionals to apply appropriate assessment tools in the correct context. For example, the assessment of fluvial concepts is useful in many situations but are not applicable in all cases. There are reaches where the landscape does not feature a defined floodplain associated with a stream channel. A channel may have existed prior to gully formation, but the stable channel capacity often cannot be defined in terms of geomorphological principles such as “bankfull discharge,” or “channel forming discharge.” In many cases, the pre-gully landscape did not feature a channel at all.

650.1001 Planning

(A) Process Overview

(1) Gully treatments should be planned according to the NRCS Nine Step Conservation Planning Process, described in the National Planning Process Handbook (NPPH).

(2) In the initial planning phase, it is critical that a planner collect and analyze data about a gully erosion site. By identifying existing resource concerns and opportunities for improvement the planner facilitates communication with a client so that their objectives may also be properly identified. Clear objectives and an accurate assessment of existing conditions defines the scope of the project and allows a designer to more easily formulate and choose between design alternatives

(B) General Planning Considerations

(1) Gully control can best be attained through a plan that considers the cause of the gulling including the history of the site, what may have caused the gully to form, the watershed conditions, as well as treatment of the gully itself.

(2) Gullies occur on a variety of landscapes and land covers. A conservation plan for, or the conservation treatment of, any piece of land should consider all needed and feasible gully stabilization work. It is important to determine the planning objectives before selecting treatment alternatives. Some gullies can be addressed by simply changing grazing or farming practices that reduce the stress while many require direct intervention and a comprehensive plan. The plan may include treatments and practices such as critical area plantings, grassed waterways or outlets, grade stabilization structures, structures for water control, diversions, filter strips, riparian forest buffers, ponds, and water and sediment control basins. The plan should consider conservation practices that can work singly, or as systems, to accomplish the following:

(i) Interception of runoff water above the gullied area with a diversion or terraces that provides for a stable outlet of the runoff.

(ii) Retention of runoff water on the drainage area by tillage practices, vegetation and structures.

(iii) Drainage of seep water

(iv) Elimination of the gully by filling and shaping the drainageway to a stable outlet with earth moving equipment for critical area planting or grassed waterway development.

(v) Revegetation, either by natural processes or by critical area planting and grassed waterway development to a stable outlet.

(vi) Changing farming practices

(vii) Construction of grade stabilization structures to control the grade of the gully and detain or impound water.

(viii) Installation of modified subsurface (underground) outlets at tile drain outfalls to restore groundwater.

(ix) Installation of structures for water control (structural and/or plant based) in series to raise the water surface profile of surface and groundwater, to induce channel aggradation and promote the growth of hydrophytic and phreatophytic vegetation.

(x) Complete exclusion of livestock.

(xi) Control of sediment from active gullies with Water and Sediment Control Basins.

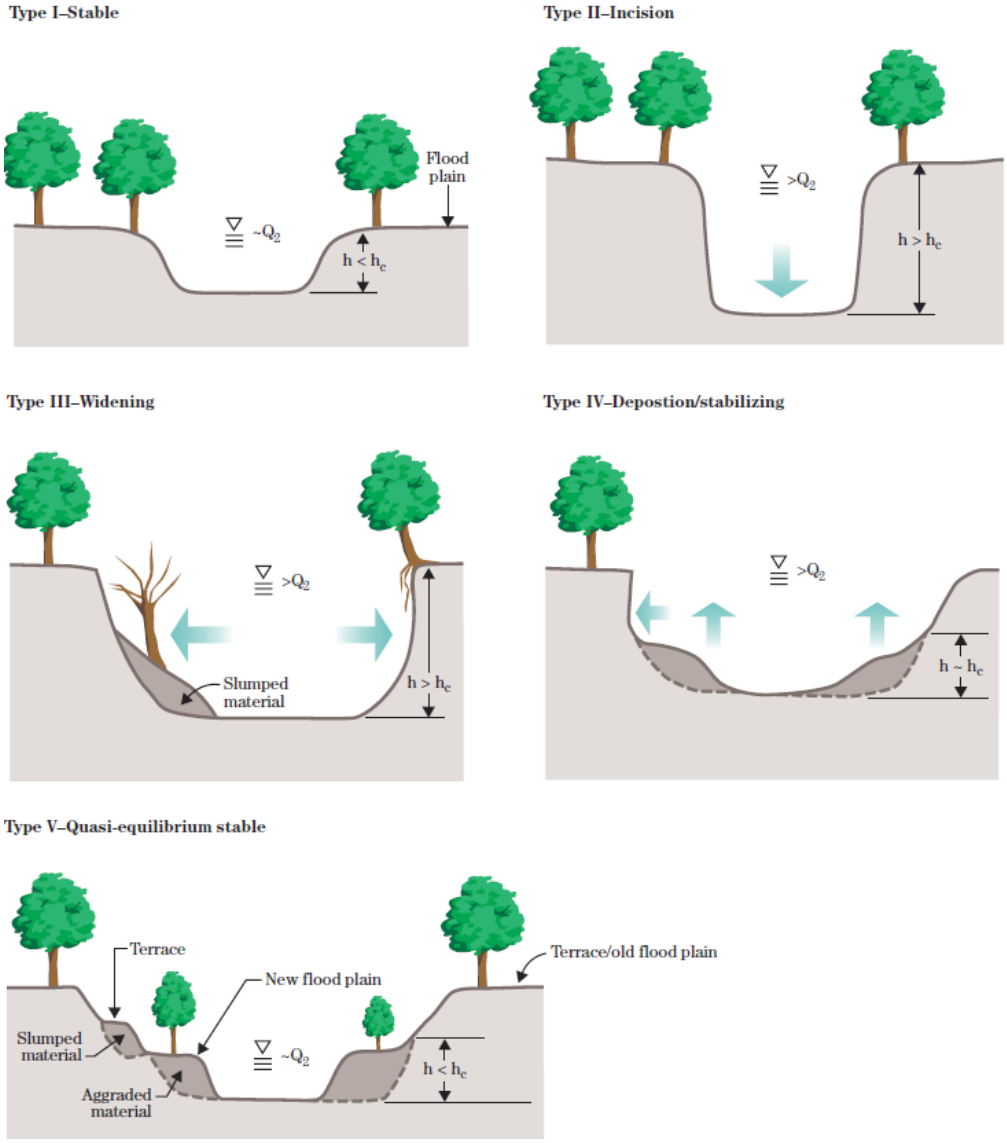
(xii) Soil Bio-engineering techniques to stabilize wet or unstable banks.

(3) Problem identification for gully treatment should include an assessment of the cause of the erosion as well as how it is expected to proceed. This can be facilitated using a variety of evaluation tools including the Channel Evolution Model (CEM) as well as an understanding of soils and hydrology at the site.

(C) Channel Evolution Model

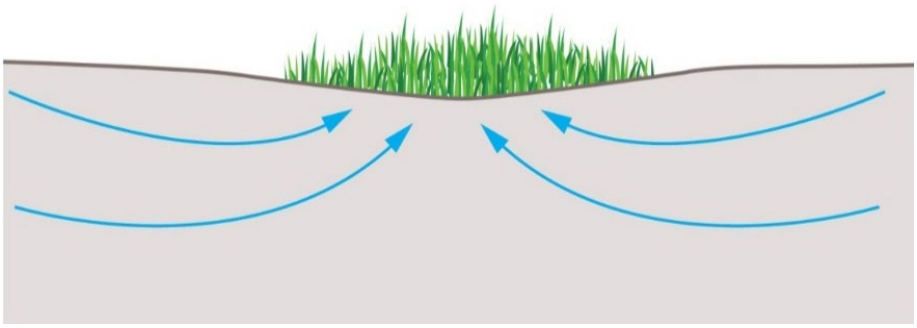
(1) The Channel Evolution Model (CEM) was developed to help predict the changes a channel may go through during the process of headcutting. The CEM can be used to help determine whether to treat the channel bed, banks, or both. This model is expressed as a sequence of Types expressed usually with sections that indexes the flow depth (h) occurring during the 2 year storm (Q2) relative to the critical bank height (hc) where the banks become geotechnically unstable. The CEM is illustrated in Figure 10-4.

Figure 10-4: The Channel Evolution Model (from Figure 3-4a 210-NEH-654-3)



(2) The Type I class in the CEM represents a stable channel or water course. In a field, this may also be a swale or a broad, saturated and vegetated slough (Figure 10-5). This may be classified as an HGM Slope type wetland.

Figure 10-5: A vegetated swale - CEM Type I without channel



(3) Erosive storm events or a reduction in ground cover/channel resistance can cause the waterway to transition into a Type II and begin to down cut. Increased channel conveyance due to downcutting, ditch cleanout, or channel bank erosion below a site can also cause a transition to Type II. As this transition starts, a channel is formed or, if a stable channel had existed, it deepens. At this point, both channel bed and bank stabilization must be incorporated. This may be vegetative, structural or a combination of both.

(4) As the channel forms and deepens, support to the banks is reduced and the channel begins to widen. This is a Type III. If the waterway is in this stage, vegetative bank stabilization alone may be adequate. However, significant grading may also be required, which disturbs potentially stable land and may make the problem worse.

(5) Left untreated, the gully will begin to form a new equilibrium. Sediment from the banks and from upstream will deposit and form a new quasi floodplain at a lower elevation. This is a Type IV and will eventually transition into a Type V. The entire process can result in significant negative impacts to the adjacent land as well as to receiving waterways below the gully. In addition, the process may cycle and repeat in an untreated gully. If the Channel is Type IV or V, a vegetative treatment may be adequate.

(6) If the gully is very large, it may not be possible to restore the original ground surface. It is also important to determine if the gully channel bottom is actively incising or there are nick points advancing into the area of interest, or if the active erosion is limited to the banks.

(7) If the soil map unit on the site is one that is associated with stream floodplains; the site is probably a degraded stream channel and may not respond well to gully treatment techniques. If the soil is hydric, or has attributes associated with groundwater inflow, it may be a degraded wetland.

(8) The site in Figure 10-6 shows a gully that is advancing into an intact HGM Slope type wetland. Gullies on HGM Slope landscapes will have groundwater discharging from the banks and will have continuous baseflow. This waterway is draining groundwater discharge from the wetland. Groundwater discharge through the banks usually contributes to unstable slopes. The wetland in the background corresponds to CEM Type I or possibly an old CEM Type IV. The channel in the foreground is in Type II and transitioning into Type III. Addressing the gully at this point will be significantly more economical than allowing it to proceed. However, it would be important to examine downstream conditions as well.

(9) See 210-NEH-654-3 for more information on the development of CEM and its application in fluvial systems.

Figure 10-6: Newly formed gully advancing into a HGM Slope wetland



650.1002 Gully Treatments

(A) Overview

(1) Gullies can be treated by a variety of techniques ranging from land management, water retention, vegetation control, and/or by structural measures. Different approaches may be needed for landowners amid differing situations. Not one approach is suitable in all situations. In many situations a combination of techniques must be used to address a gully.

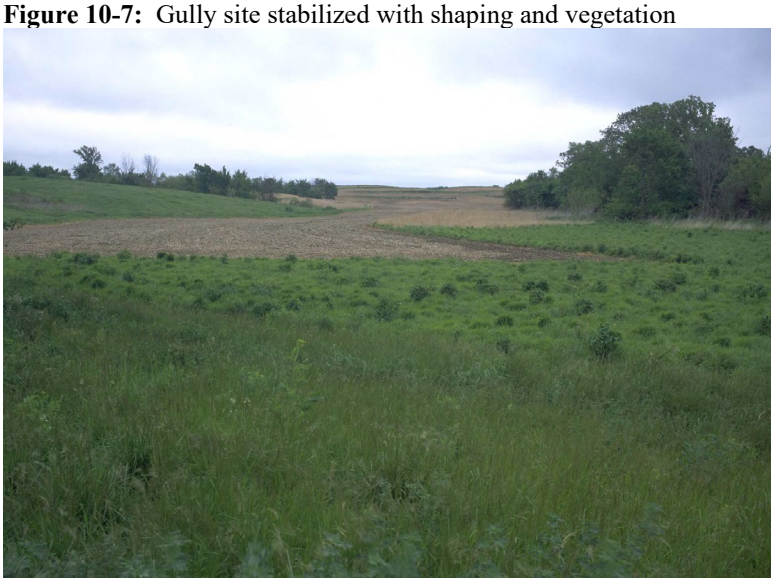
(2) The NRCS has several conservation practice standards which address specific measures. Detailed techniques for gully treatment in a variety of conditions are also included in 210-NEH-654 – "Stream Restoration Design Guide" – Technical Supplement 14P, "Gullies and Their Control".

(B) Gully Treatment by Vegetative Means

(1) The objective of most gully control work is to stabilize the gully surfaces by vegetative means. Vegetative techniques are key elements to reversing land uses or conditions that have artificially left watersheds barren. Vegetation improves soil cover, promote water absorption, root development, and soil stability. All other measures should lead to the objective of vegetative stabilization, except in areas where rainfall is too low to support a good vegetative cover, or a local groundwater table does not exist to support hydrophytes or phreatophytes.

(2) Many active gully systems, regardless of size or condition, will usually regain a cover of natural vegetation if it is properly protected and is in an area where vegetation will readily grow. Diversion or retention of the surface water which caused the gully, protection from over grazing or heavy use by livestock, protection from fire, and the removal of other causes of disturbance usually result in growth of natural vegetation. This vegetation will, in time, cover the gully, promote topsoil development, and heal the erosion scars (Figure 10-7).

Figure 10-7: Gully site stabilized with shaping and vegetation



(3) Nearly all structural measures used, particularly in grassland areas, depend upon vegetation to support them and to stabilize the soil exposed to excessive runoff.

(4) Of most importance in revegetation is the exclusion of livestock or mechanical disturbance (vehicle, farm equipment, etc.) from the gullied area.

(5) Many gullied areas or gully banks are not in good condition for vegetative growth since the fertile topsoil has been washed away, slopes are steep, and the battering of raindrops on the unprotected soil has produced conditions adverse to plant survival. Soil tests may be needed to determine if amendments are necessary to reestablish vegetation. Bank sloping may be necessary before vegetation can be expected to do an adequate job of gully stabilization. However, it is important to note that bank work will only be effective if the cause of the downcutting has been fully addressed. Even after vegetation recovery, gullies remain susceptible to reactivation if conditions change.

(6) Adapted grasses, trees, shrubs, or vines provide good protection to gullied areas planned for critical area planting. The desired uses of the area after stabilization helps to determine the type of vegetation to be established. Treatments that disturb the ground often need rapid cover and revegetation. Seed mixtures generally include grasses with quick response. The goal is to provide cover that will help control erosion, but still allow the desired perennial plants to germinate and grow without any invasive species getting a chance to establish. The use of sod is an excellent method of providing cover in disturbed areas where irrigation is available or adequate rainfall is expected. When available and appropriate to the area of treatment, native grass, forb, shrub, and tree species should be considered. When rapid cover is unlikely or added insurance is needed, straw or other mulch is recommended to protect the topsoil and seed from erosion until the seed germinates and becomes established. Another option is the use of a manufactured erosion control product such as erosion control blanket or turf reinforcement mat in combination with seeding.

(7) The restored hydrologic conditions should also be considered when selecting plant species. The hydrologic condition includes surface flow depth, velocities, groundwater depth and fluctuations. Landscape Architects and local Plant Materials Center expertise should be consulted.

(8) A stabilized gully may be used for multiple purposes such as a grassed waterway for terrace outlets, wildlife habitat, woodland area, pasture, or restored headwater wetland. It should be shaped to the proper size and proportion based on slope, drainage area and land use. It should not be cultivated, manipulated, or used in a way that will weaken or destroy the re-established vegetation. The best possible use should be selected after considering the size of the gully, its location with respect to other land uses on the farm, the control measures needed, and the type of maintenance required.

(9) If a gullied drainageway is to be used as a grassed waterway for terrace outlets, the gully should be shaped to a proper size and proportion to maintain a stable flow velocity. See 210-NEH-650-7 and 210-NEH-654-8 for more information on stable velocity calculations. Erosion-resistant grasses or sod should be well established before any terraces or diversions are constructed to empty into the channel. An erosion control blanket or turf reinforcement mat can also be used in combination with vegetative seeding. Trees, vines and shrubs ordinarily are generally not used in waterways.

(10) If the original conditions supported a headwater wetland, and hydrologic restoration is the goal, the practices should return the groundwater inflows and groundwater table as close to prior conditions before gully formation.

(11) Critical area planting of a gullied area in pastureland will be affected by the intensity of grazing on the area. Limited grazing of a grass vegetation during the establishment stage is often beneficial in controlling competitive weeds and shrubs. Overgrazing will seriously hinder establishment. Gullied areas in pastures might be better managed by permanently protecting these areas from all grazing and retained for wildlife use after planting with grasses, shrubs, vines or trees suitable for wildlife habitat. In wooded or gullied areas adjacent to woods, it is desirable to plant trees of an adapted species and use the area as protected woodland.

(12) In gullied areas where erosion is slow and not having an immediate economic, safety or environmental impact, the slowest but cheapest method of gully control is protection from disturbance. Good results may be obtained, and heavy expense avoided by the simple process of fencing the area to exclude grazing or cultivation. However, if the gully has progressed to a significant size, protection by itself may not be sufficient.

(C) Gully Treatment by Filling and Shaping

(1) Elimination of the gully or critically gullied area by filling and shaping may be the most practical or feasible means of treatment in preparation for critical area planting or grassed waterway development (Figure 10-8), as long as the downstream end of the waterway is stabilized first. When this method of treatment is used, the gully or gullied area is shaped and smoothed so that the area can be established to vegetation and maintained with regular farm equipment. Where practical, the gully should be reshaped to provide stable velocities and other desirable hydraulic characteristics. See 210-NEH-650-7, for more information on the design of grassed waterways.

(2) During backfill of gullies, the soil should be compacted since uncompacted material offers little resistance to erosion. It is best to fill field gullies during the time of year when a close growing crop may be seeded immediately on the disturbed area to protect it from erosion. Partial filling or shaping should be discouraged since the partial blocking of the waterway often causes overfalls and increased gully erosion. This can result in more land and soil being lost than if the gully were untreated.

(3) Reshaped gully slopes on steep slopes (over 25% but can be less for some soil conditions) can be difficult to stabilize with standard erosion control practices. Soil from an appropriate borrow area is typically used to fill in and reshape the treatment area. Adjacent soils may be highly erodible and intensive erosion control measures may be needed to prevent gully formation in these areas.

Figure 10-8: Gully site stabilized with filling, shaping and planting to a grass waterway



(D) Gully Treatment by Water Diversion or Retention

(1) Reduction of the runoff which flows through a gully is one of the most effective control measures. This may be accomplished by diverting all or most of the runoff to a protected outlet or by holding excess rainfall on the land in the drainage area. Where these methods are feasible, they should be installed before other needed control measures are attempted within the gully.

(i) Water Diversion

- Water diversions intercept and transmit stormwater away from the gully. They are appropriate when roads, terraces, parking lots, urban and housing developments, water transmission or other activities have captured or diverted flow into the gully channel. Removing other contributing flow sources can help stabilize active gullies and are used when there is a place to safely divert the water. However the designer should note that, the larger the contributing drainage, the less likely this technique will be effective.
- Care should be given to the outlet location of the diverted water to prevent causing additional problems. The diversion outlet should be on relatively flat to moderately sloping terrain with good cover and infiltration capability. Where it is not possible to empty a diversion onto a smooth, well-vegetated area or into a protected outlet, the water should not be diverted; otherwise, the diverted runoff may cause gullying in the disposal area (Figure 10-9). It may be possible to divert water from several gully heads to a common location and install a single (potentially more economical) stabilizing structure rather than multiple structures.
- Diversions usually are constructed from the upper side of the diversion ridge to provide a wide channel section and easier construction. If possible, diversions constructed adjacent to a gully or at the head of a gully nick point

or overfall should be generally located away from the edge of the gully a distance equal to at least three times the depth of the gully. This will provide space for the gully banks to slough and stabilize, or to be shaped, without endangering the diversion. However, this general guidance may need to be modified for certain soil types.

- Where a small gully has started on an area of sparse vegetation in pastureland, it is often possible to stop head cutting by constructing an eyebrow-shaped ridge above the gully head with the ends of the ridge leading slightly downslope onto good grass cover. This is a temporary measure and requires considerable skill and care in the selection of outlet areas. Prompt application of revegetative measures in the gully should follow this practice.

Figure 10-9: Gully forming by emptying terraces into an unprotected outlet



(ii) Water Retention

- Proper land use, management, conservation cropping, and tillage practices are the first steps in holding water on the drainage area of a gully. These can be supplemented, as necessary and feasible, by other water-holding measures to further reduce the runoff into the gully.
- Level impounding terraces provide storage and can be farmed where cropland is involved in the drainage area of the gully (Figure 10-10) and works particularly well in in arid and semi-arid climates. The ends may be left partially open, if necessary, to drain part of the water from the terrace channel to prevent drowning out of crops or pasture vegetation as long as the exit area is stabilized to safely handle the overflow. If level terraces are to retain all the runoff in humid areas, they should be constructed only on permeable soils and mild slopes. Designers should note that level terraces can be compromised by overflow during frequent or large storm events. See 210-NEH-650-8 for specifics on terrace design.
- Runoff water often can be prevented from entering or flowing through relatively large gullies using carefully located earthen dams and graded terraces. The gully head can be flooded out with a pond which may stop gully erosion.

- Selection of a dam site and the elevation of its spillway is very important. The dam should be located downstream of the gully head such that the upstream pool will be high enough, or the long-term upstream channel slope flat enough to stop the headward (upstream) extension of the gully. The site should provide enough natural storage so that the auxiliary spillway will not flow often. Generally, a principal spillway or trickle tube is needed to reduce frequency and duration of auxiliary spillway flow. In some instances, a good location for an auxiliary spillway does not exist, so all the design flow will need to be passed thru the principal spillway.
- In many areas where gullies are formed by runoff from small drainage areas in arid and semi-arid climates, small earth dams are used to stop headward cutting and to furnish temporary stock water after periods of rainfall. Such structures, however, give better protection if equipped with a drop inlet that will slowly release the impounded runoff water and provide storage space for runoff from succeeding rains. Since there will be only occasional spillway discharge, vegetative practices and natural reproduction of native vegetation below the fill will have an opportunity to control the gully at little cost.
- The two types of earth dam structures described above are often designed as water and sediment control basins or grade stabilization structures which are also discussed in the next section.

Figure 10-10: Terrace system protecting field from gully formation



(E) Gully Treatment by Grade Stabilization Structures

(1) It is not always possible to keep runoff water out of gullies by retaining or diverting the water and the runoff must flow through the gully channel. To do this adequately may require that both vegetation and structures are planned and established in the gully at critical times of the year.

(2) Planning gully treatment under these conditions may require that the gradient of the channel be reduced so that water will travel at a nonerosive velocity for the soil type and vegetative condition. Grade stabilization structures may be required at overfalls, abrupt changes in gradient, entrances of branch gullies or at other critical points to supplement vegetation in stabilizing the channel.

(i) Structural Measures

- Structural measures should be used for gully control only when other measures are not applicable or adequate. Structures are often installed at the end of grassed waterways to allow runoff to leave the waterway without causing gully formation.
- The following types of structural measures are used in gully control work. Photographs are provided in Figures 10-11, 10-12, and 10-13. An outlet basin or other channel stabilization measures at the downstream end is generally required for any of these structures. See 210-NEH-650-6, "Structures" for technical information and design requirements. Figure 6-4 in 210-NEH-650-6 provides a good comparison of the structural measures and helps with the selection of the most appropriate structure. Guidance is also available in 210-NEH-654-14, Technical Supplement 14G. Depending on the amount of elevation drop, multiple structures in series may be needed.
  - **Straight drop spillway** - This type of structure is generally used in the lower reaches of water diversion systems, such as terraces, diversions, outlets, and waterways; for large overfalls adjacent to streams; or for drainage.
  - **Box inlet drop spillway** - This type of structure has the same general usage as the straight drop spillway but is better adapted to larger flows and sites where the channel width is limited.
  - **Hood or canopy inlet spillway** - This type of structure uses a straight-pipe principal spillway in an earth embankment to control head cutting or to safely drop water to a lower level. This approach is often used where the topography is sufficient to maintain head on the pipe inlet during design conditions. This is usually found on a steep slope but can also be found in confined waterways.

Figure 10-11: Concrete drop structures at outlet of grassed waterways



- **Drop inlet spillway** - This type of structure has the same general usage as the hood inlet and has the added advantages of permitting drainage of the pond or fluctuating the water level for management purposes. However, this type can often handle more flows than a hood inlet. The drop inlet spillway allows a pipe structure to be used in places where there isn't enough topography to implement a hood inlet spillway. The depth of the drop inlet automatically builds the needed head and the 'drop' in a drop inlet absorbs the energy of the water in the fall.
- **Chute spillways** - A rock chute, loose riprap, concrete block or formed concrete structure may be used to safely transfer water to a lower elevation. Chute spillways are particularly applicable to high flows and where excess trash and debris may clog a pipe and structure. The chute slope and width can be adjusted to match the outfall topography. Formless chutes are limited to areas where temperature variations are moderate, and conditions are favorable for building the shape of the structure in the soil. The rock chute or loose riprap structure requires designing and specifying rock size and gradation. 210-NEH-654, Technical Supplement 14C, "Stone Sizing Criteria" provides stone sizing techniques.

Figure 10-12: Gullies treated with aluminum drop structure, shaping, and critical area planting

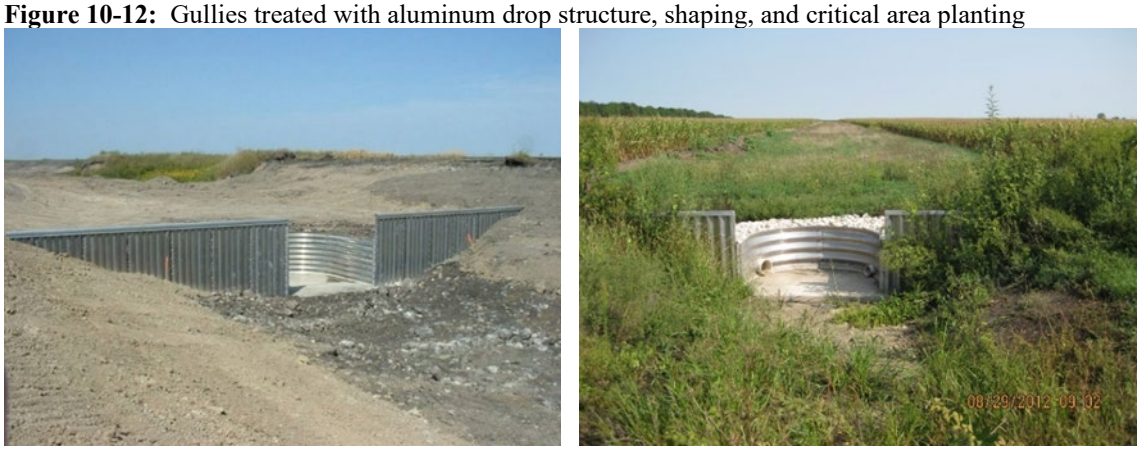
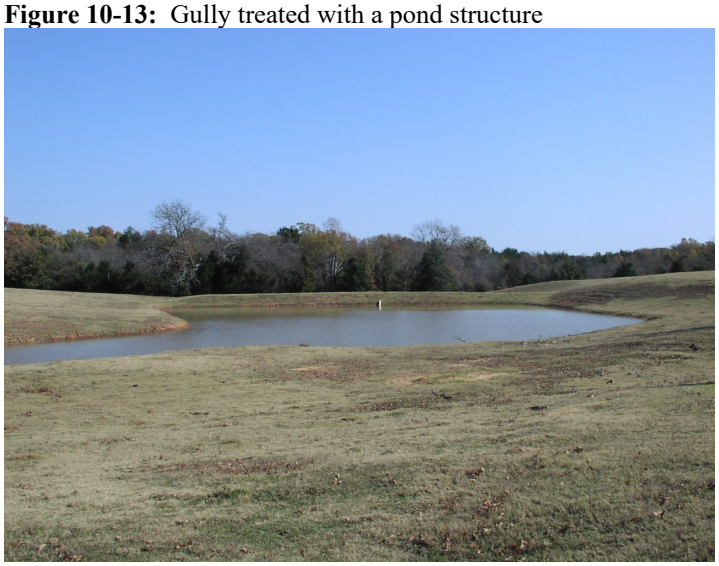


Figure 10-13: Gully treated with a pond structure



(ii) Earthfill Structures with Vegetated Spillway Only:

- Earthfill structures with vegetated spillway may be used as grade stabilization structures and to impound sediment or water for gully treatment, especially in arid or semi-arid climates. They may also provide temporary livestock water or be used as Water and Sediment Control Basins. This system has limited use because a vegetated spillway stable enough to withstand frequent flows can seldom be found in the right location in gullied areas, Information on design and installation of earthfill structures with vegetated spillways can be found in 210-NEH-650-11, "Ponds and Reservoirs".

(iii) Gully Plugs

- A gully plug is a small earthen dam constructed at one or more locations along the gully. Branch packing and wattle check dams can also be used as gully plugs for small gullies. Information on these and other soil bioengineering applications of gully plugs is provided in 210-NEH-654-14, Technical Supplement 14I. Regardless of the size, the gully plug provides grade control and retains sediment. A key factor in gully plug success is growth of the vegetation.

(iv) Gully Farming

- Gullies can also be stabilized with low earth or rock structures with vegetation in the areas between the structures. This approach stops the gully development in a CEM Type III condition and is illustrated in Figure 10-14. In arid and semi-arid areas, the flows collected at the gully can add to soil moisture and collected soils can increase soil fertility. This approach has been used to facilitate agricultural activities for low resource farming in the developing world.

Figure 10-14: Gullies treated with low structures and gully farming



(F) Gully Treatment and Sediment Control with Water and Sediment Control Basins

(1) Water and Sediment Control Basins are used where physical conditions or landownership prevent the treatment of the sediment source by the installation of gully control measures.

(2) This type of structure is a dam, usually equipped with a pipe principal spillway, constructed across a waterway or at some other suitable location to form a sediment storage basin. A debris basin is used to preserve the capacity of reservoirs, ditches, canals, diversions, waterways or streams and to prevent undesirable deposition on bottomlands. This is done by storing a high percentage of the sediment and other debris moving out of the drainage area.

(3) The capacity of a debris basin is governed by the volume of sediment expected to be trapped at the site during the planned useful life of the structure or the improvements it is designed to protect. Where it is assured that periodic removal of debris will take place, the design capacity may be reduced accordingly.

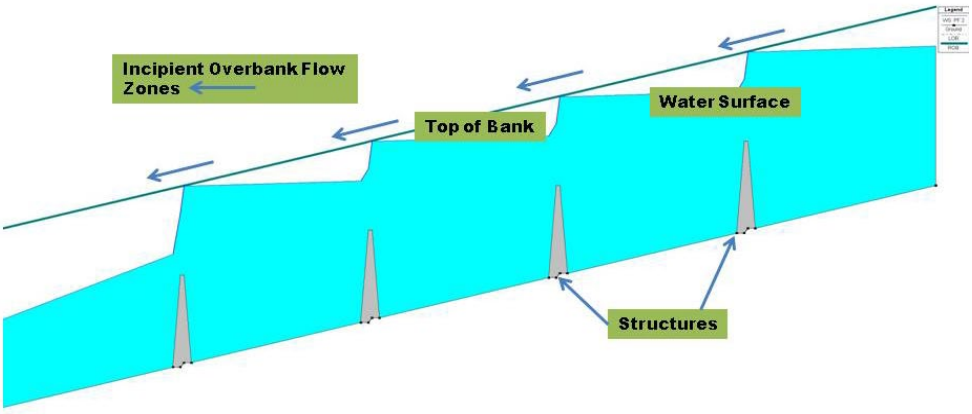
(4) Usually the design, layout and construction principles for Water and Sediment Control Basins are identical to those for principal spillway-type grade stabilization structures or tile outlet terraces. Only the primary purpose of the structure may differ. Therefore, previous discussions in this chapter or in 210-NEH-650-8 and 210-NEH-650-11 of this handbook will apply, depending upon the type of debris basin being considered.

(G) Gully Treatment by Structures for Water Control

(1) Structures for water control can be used to induce channel deposition and to raise both the surface and groundwater profile. They usually must be installed in series so that each structure provides tailwater protection to the upstream structure. They must also be installed with a spacing and height that creates minimal water surface profile drop across the structures when flow is at the top of the gully bank. This approach reduces the potential of a failure due to flanking when out of bank flows return to the gully downstream of the structure. A bank key is still important to reduce the potential for piping around the structure but erosion around the structures from return water is reduced by designing the structures to have a minimal drop during out of gully flows.

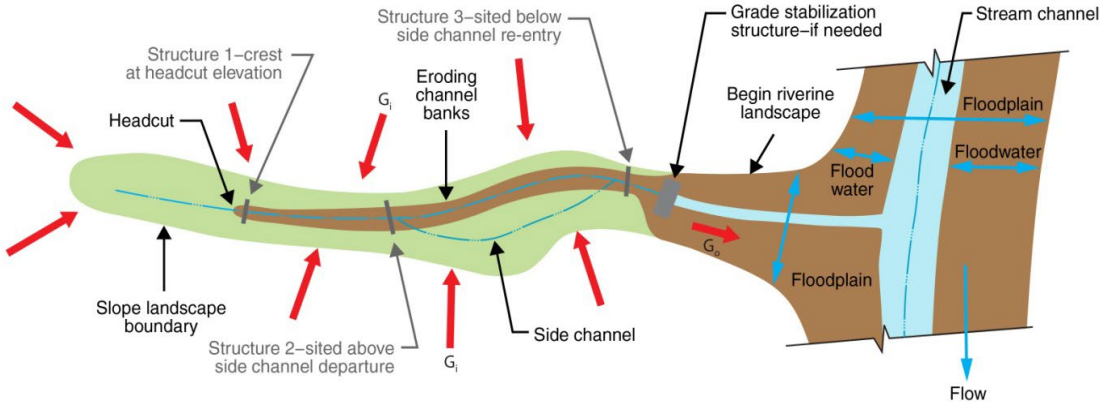
(2) The critical condition for stability is the flow range between incipient out-of-bank flow and complete backwater conditions (Figure 10-15). Lower flows are within bank, and higher flows have minimal water surface profile drop.

Figure 10-15: Critical water flow profile



(3) Ideally, structures should be placed downstream of points of concentrated flow reentry, and upstream of points where concentrated flow leaves the watercourse channel. If a stable reach does not exist downstream of the last structure, a Grade Stabilization structure may be needed. This could be a separate structure, or the last structure could be designed to serve two purposes. These structures are often installed in conjunction with soil bio-engineering techniques which work to reduce flow velocities, further induce deposition and channel aggradation, decrease the gully cross-section, and stabilize the banks. Figure 10-16 shows a schematic layout which accounts for concentrated flow points, the placement below a head cut, and the placement of the last downstream structure.

Figure 10-16: Layout of Structures



(4) This low impact and cost-effective approach have been commonly applied in wetland and stream restoration projects and is effective for upland watershed restoration. Figure 10-17 shows the use of rock structures for stabilization and the establishment of a Slope HGM class wetland. If a systematic approach is applied, their use can result in raising the groundwater table, increasing the frequency and extent of surface inundation, increasing upland sediment deposition, and stabilizing advancing headcuts.

(5) This concept is very similar to the stream bed stabilization technique called “rock riffles” or “loose rock structures.” This stream restoration technique is used to reconnect a degraded channel to the floodplain. Further design guidance is available in 210-NEH-654-14 Technical Supplement 14G.

Figure 10-17: Stone water control structures used for stabilization of a slope wetland



650.1003 Surveys

A. Preliminary surveys should be adequate to determine the gradient and cross sections of gullies to be treated with vegetation alone or in combination with filling and shaping. In some cases, hand level data may be satisfactory.

B. A thorough field survey of site locations should be made for any structure measure so that the most economical type of structure can be designed. Profile and cross-section surveys are needed to show the characteristics of the watercourse above and below the planned structure location. The profile should go far enough downstream to reach a stable outlet. The presence or absence of a stable outlet will determine the selection of the appropriate measure. The structure may affect the flow of water for quite a distance above and below its proposed site or influence other structures. Topographic and soils information as well as a geologic investigation if often needed on the structure site for detailed design. Decisions on these surveys should be made in the field based on the type of structure being considered.

C. Earth fill structures with drop spillways or chutes may need additional field surveys when an auxiliary spillway is included. Profile and cross-section surveys of the proposed spillway sites may be needed for a design that provides adequate capacities at nonerosive velocities.

D. Field surveys should also record the location, pertinent elevations, and sizes of any bridges, culverts, fence lines, buildings, etc., which might influence the design of the structure. Determinations must be made as to the size and shape of the watershed and all other factors that influence runoff and the design of the structure. Additional guidance is available in 210-NEH-650-1.

E. As previously discussed in this chapter, the designer should consider soil testing to determine if/what amendments are necessary to establish vegetation.

650.1004 Design Guidelines

A. Guidance for the design of gully treatment measures will be found in 210-NEH-650-6, “Structures”, 210-NEH-650-7, “Waterways”, 210-NEH-650-8, “Terraces”, 210-NEH-650-9, “Diversions”, and 210-NEH-650-11, “Ponds and Reservoirs”. Detailed techniques for gully treatment are also available in in 210-NEH-654-14, Technical Supplements 14G, 14I and 14P. 210-NEH-654, Technical Supplement 14C, “Stone Sizing Criteria” provides stone sizing techniques.

B. A permanent grade stabilization structure generally must have a stable downstream grade with minimal degrading after the protective measures are established. If a stable grade is not available within a reasonable distance of the site, the potential loss of grade should be estimated and compensated for in the structure design by lowering the apron floor, adding launchable material, and/or adding other structures in the channel below. Where there is significant grade control required at the structure location, a pipe structure may be more suitable than an overfall structure, if topography or storage permits. Stable grade analysis is addressed in detail in 210-NEH-654-8. Permanent grade stabilization design in fluvial environment sis addressed in 210-NEH-654-14, Technical Supplement 14G.

C. The type of structure and the site selection will be influenced to some extent by the availability of materials. For example, if a drop inlet structure is being considered, suitable core and fill material should be readily available. Available rock suitable for a rubble masonry structure may be the deciding factor on the type of drop spillway to construct.

D. The type of foundation for any proposed site may determine the type and size of structure to be constructed. Wet, seepy foundations are not suitable for large concrete structures unless the design includes extensive corrective measures. This may be the place where a drop inlet structure can work but persistent or excessive seepage must generally be addressed with any structure. Dry, unstratified foundations are suitable for almost any type of structure. Where there are wet areas on the structure site, drop spillways or chutes can be constructed in a drier area and the waterflow diverted to them.

E. When the structure is to control erosion at the gully head or overfall, the site selection should be carefully made. The crest of any erosion control structure should be set at an elevation which anticipates the upstream movement of the gully head during the healing period. It should drown the gully head to prevent further movement.

F. The location for a suitable auxiliary spillway is another important factor in selecting a site for any erosion control or detention dam where part of the flow is carried through the dam by a principal spillway. In some cases, drop spillways will need an auxiliary spillway to help carry the less frequent peak flows around the end of the embankment. Therefore, site selection and design should include full consideration of this important feature.

G. In the event an auxiliary spillway location is not available, all of the design flow will be required to be passed thru the principal spillway. If an auxiliary spillway is not needed, it is good practice to provide a planned overtopping location away from the main structural measures in the system. This should be where any damage could be more easily repaired. This provision typically looks like a “low spot” where an auxiliary spillway might normally be placed, but without any shaped inlet, control section, or exit slope.

H. Scour at the outlet of the principal spillway is one of the important factors leading to failure of an overfall structure. Scour may be controlled by giving proper consideration in the design to the:

(1) Stability of the grade below the structure.
(2) Velocities occurring in the downstream channel.
(3) Tailwater elevations for different flow stages.
(4) Dissipation of water energy in the outlet.

I. Scour below drop spillways or chutes usually is reduced as the tailwater elevation is increased, so placing the floor or outlet apron of the structure at a lower elevation increases the protection of the structure. Scour at the outlet end of drop inlets is reduced by having the pipe section extend beyond the toe of the fill with a cantilever outlet, either with or without a pipe support, or otherwise protecting against undercutting of the pipe. One such method of protection is the use of a rock (or concrete rubble) outlet basin/plunge pool.

J. The peak and volume of runoff are almost directly proportional to the length and size of the watershed. The site chosen for a structure may be adapted to a drop spillway, but the drainage area and runoff may be too large for this type of stabilizing structure. For large runoff volumes or high peak flows, storage may be required to reduce the peak discharge. The need for storage should be considered at the time the preliminary site selection is made.

K. Consideration should be given to the land use at the proposed site or immediately adjacent to it. Drop spillways or chutes may be placed in cropland since they do not require permanent or temporary storage that can damage crops. They also have a very small trap efficiency so there is minimal crop damage due to sedimentation. Improper land use above, adjacent to, or below the structure site may seriously reduce the effectiveness of the structure or stability of the downstream grade. Needed land treatment measures and proper land use should be applied to the watershed when excessive runoff or siltation would seriously affect the life and efficiency of the structure.

L. It is important to assess and account for effects of flooding and sedimentation on adjacent land. Specifically, it is important to assure that it will not cause adverse flooding or sedimentation either adjacent or upstream of the site. Consideration should be given to design elements such as freeboard.

M. Sediment load from the drainage area must be considered in the design of structures. Gullies which produce large amounts of sediment may require an earth dam with a drop-inlet type debris basin. If selected for use on the site, the earthen dam should be designed with adequate sediment capacity for the design life of the structure. Open structures can be used to pass heavy sediment loads when the sediment source cannot be treated and cost or topography limit opportunities to store sediment behind a structure. However, the consequences to land and structures downstream of passing sediment must be examined. An O&M plan is needed which includes measures for periodic cleanout.

N. Extreme size should be avoided. If the drainage area is large enough to require a width of spillway notch greater than the width of the channel, the cost of construction may be prohibitive and poor hydraulic conditions at the structure site may result. In such cases, it may be desirable to consider a box inlet drop spillway or attempt to control only the lateral gullies entering the main gully.

O. Final selection of the location, type and design of permanent structures, larger than those normally used in terrace outlet works, should be with the advice and consultation of those skilled in geology, hydrology, design and construction. 210-NEH-650-2, 210-NEH-650-3, 210-NEH-650-4, and 210-NEH-650-6 contain additional criteria used in design.

650.1005 Installation of Measures

A. 210-NEH-650-1 describes surveys for setting line and grade stakes for construction of the various structures.

B. Careful clearing and excavation of the site is important since the surfaces between the structure and the sides and bottom of the gully are points of weakness. All backfill should be compacted.

C. Structures should be placed so that the discharge from the spillways will not cause embankment damage or side-cutting or undermining of the downstream banks.

D. Any overfall above an erosion control structure should be sloped to allow water to enter the pool area without additional erosion, even though the inlet crest may be equal to or higher than the gully head elevation. Flooding out overfalls is a very effective approach to retarding the advancement of headcuts.

E. The channel below any structure should be shaped as needed during construction of the structure. Irregular banks in the outlet channel of an entrenched structural spillway may erode, affecting the hydraulics at the outlet and depositing sediment that forms to the desired shape for the outlet channel as well as resulting in undesirable benches downstream.

F. The following should be considered in the establishment of any type of vegetation.

(1) The amount of runoff entering the gully should first be reduced to the extent practical for the establishment period.
(2) Since gullied areas have had much of the topsoil washed away, it will be difficult to establish plants on the remaining subsoil.
(3) Preparation of a good seedbed for sod, sprigs, seed, small plants, cuttings or vines, along with the application of fertilizer and soil amendments, is necessary to obtain rapid vegetative growth.
(4) If the gully banks are not too steep or do not receive large amounts of runoff, mulches of straw, hay, light brush or other organic materials are valuable in protecting newly planted vegetation from raindrop erosion. In some areas, it may be necessary to protect mulches from displacement by winds. This can be done by crimping straw mulch, or by following manufacturer's instructions with erosion control blanket products.
(5) Use of rolled erosion control product (RECP) may be necessary to secure mulches or to provide additional temporary erosion control until vegetation can be established.
(6) Protection from fire, heavy grazing and heavy hoof and foot traffic is important for permanent control.
(7) Plantings should be made during the season and under climatic conditions suitable for survival and rapid growth. In some situations, supplemental irrigation may be required.
(8) Maintenance of vegetative cover is as important as the original establishment of the cover.
(9) A strip of grass of variable width around the gullied area should be included in the planting area to ensure control of the area and to protect by slowing velocities that could impact the more slowly established plantings in the severely damaged area. Where the gully lies in or adjacent to a cultivated field, a strip of vegetation at least 25 feet wide should be established and maintained next to the gully banks.
(10) Areas that tend to remain wet may require subsurface drains to maintain favorable conditions for growth of vegetation. However, this should be approached with due considerations to wetland issues.

650.1006 Maintenance

A. Considerable damage, as well as loss of structures may result from failure to protect and maintain the structures properly. Providing regular maintenance in a timely manner often saves costly repair when an unusual storm occurs. Maintenance of vegetative cover is as important as the original establishment of the cover. Provide Operation and Maintenance instructions to help ensure success.

B. Periodic checks should be made of all gully control works. Inspections should be conducted annually and after major storm events. The following maintenance practices are important:

(1) Inspect all structures, earthen embankments, spillways, and other significant appurtenances. Repair or replace damaged components promptly.
(2) Promptly remove accumulated sediment when it reaches the pre-determined storage elevation.
(3) Protect all vegetative plantings from grazing until established and then allow only limited use. For example: Landowners should only allow animals to graze when pasture conditions are ideal and dry.

(4) Eliminate competition from undesirable weeds and grasses in vegetative plantings. Remove trees, brush, and invasive species.
(5) Protect all plantings from heavy hoof and foot traffic
(6) Protect all plantings from fire.
(7) Make immediate repairs of breaks or low spots in terraces, diversions or structures.
(8) Remove trash and debris from drop inlets or weirs.
(9) Sod or seed spot failures in vegetative plantings. Fertilize vegetation as required.
(10) Mow or properly graze waterway areas.
(11) Inspect sides, corners and wingwalls of all structures and repair cracks in earth caused by settling, rodent burrows, dry weather, etc., before the structure is weakened.

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650.1008 Acknowledgments

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B. In 2020, Jon Fripp working under the direction of Clarence Prestwich, national agricultural engineer, Natural Resources Conservation Service (NRCS), Washington, DC, prepared this revised and updated chapter. This chapter includes additional guidance as well as revisions to follow current format requirements. The material developed by Richard Weber and Jon Fripp in 2012 has now been formally included.

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