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Natural Resources Conservation Service

Part 650 Engineering Field Handbook
National Engineering Handbook

Chapter 11 Ponds and Reservoirs

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Table of Contents

Table of Figures

Part 650 – Engineering Field Handbook

Chapter 11 – Ponds and Reservoirs

650.1100 General

A. Purpose and scope

(1) The purpose of this chapter is to provide guidance on the planning and design of ponds and reservoirs. The information provided here is intended for NRCS ponds designed and installed using conservation practice standard (378), but it can also be used with other conservation practices that involve the impoundment of water in a reservoir; including, but not limited to aquaculture ponds, dams, grade stabilization structures, sediment basins, irrigation reservoirs, waste treatment lagoons, and constructed wetlands. Figure 11-1 lists a variety of conservation practices that utilize water impoundments and their purposes.

(2) Chapter 11 is intended for use with low hazard potential. For definition of hazard class and design requirements for each class see Title 210, National Engineering Manual (210-NEM), Conservation Practice Standard Pond (Code 378), and NRCS Technical Release 60, Earth Dams and Reservoirs (TR-60).

Figure 11-1: Conservation Practices that Impound Water

Practice	Description	Purpose
Pond	Water impoundment made by constructing an embankment or by excavating a pit or dugout.	To provide water for livestock, fish and wildlife, recreation, fire control, develop renewable energy systems, and other related uses, and to maintain or improve water quality.
Aquaculture Pond	A water impoundment constructed and managed for farming of freshwater and saltwater organisms including fish.	Provide a favorable aquatic environment for producing, growing, and harvesting aquaculture crops.
Sediment Basin	A basin constructed with an engineered outlet, formed by embankment or excavation or a combination of the two.	To capture and detain sediment laden runoff, or other debris for a sufficient length of time to allow it to settle out in the basin.
Grade Stabilization Structure	A structure used to control of the grade and head cutting in natural or artificial channels.	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.
Dam	An artificial barrier that can impound water for one or more beneficial purposes.	Reduce downstream flood damage. Provide permanent water storage for one or more beneficial uses such as irrigation or livestock supply, fire control, municipal or industrial uses, develop renewable energy systems, or recreational uses. Create or improve habitat for fish and wildlife.
Irrigation Reservoir	An irrigation water storage structure made by constructing a dam, embankment, pit, or tank	Store water to provide a reliable irrigation water supply or regulate available irrigation flows. Provide storage for tailwater recovery and reuse. Reduce energy use or develop renewable energy systems.
Waste Treatment Lagoon	A waste treatment impoundment made by constructing an embankment and/or excavating a pit or dugout.	To biologically treat waste, such as manure and wastewater, and thereby reduce pollution potential.
Constructed Wetland	An artificial ecosystem with hydrophytic vegetation for water treatment.	For treatment of wastewater and contaminated runoff from agricultural processing, livestock, and aquaculture facilities, or for improving the quality of storm water runoff or other water flows lacking specific water quality discharge criteria.
Wetland Creation	The creation of a wetland on a site location that was historically non-wetland.	To establish wetland hydrology, vegetation, and wildlife habitat functions on soils capable of supporting those functions.
Wetland Enhancement	The augmentation of wetland functions beyond the original natural conditions on a former, degraded, or naturally functioning wetland site; sometimes at the expense of other functions.	To increase the capacity of specific wetland functions by enhancing hydric soils functions, hydrology, vegetation, or animal habitats

B. Types of impoundments

(1) Many terms are used to describe water impoundments, including ponds, reservoirs, lakes, wetlands, lagoons, dugouts, basins, and pits. No matter what term is used water impoundments can be grouped into two basic types based on construction methods. Water can be impounded by either construction of an embankment or by excavating a depression. Embankments are created by constructing a dam across a stream or watercourse and are usually built in areas where land slopes range from gentle to steep (fig. 11-2).

Figure 11-2: Embankment Pond

(2) An excavated pond is a body of water created by excavating a pit or dugout. These usually are constructed in relatively level areas. The fact that their capacity is obtained almost entirely by excavation, limits their use to locations where only a small supply of water is required (fig. 11-3).

Figure 11-3: Excavated Pond (Arkansas)

(3) Ponds are also built in gentle to moderately sloping areas where capacity is obtained by both excavation and the construction of a dam. For the purpose of classification, these are classified as embankment-type ponds if the depth of water impounded against the embankment exceeds 3 feet

650.1101 Planning Objectives

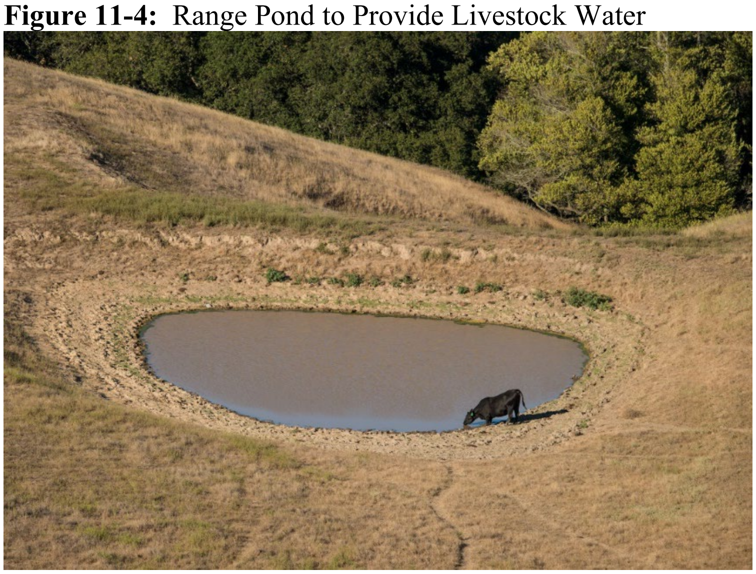
A. Water impoundments are integral parts of numerous conservation measures and can be designed to provide a variety of purposes. The following is an overview of the various purposes for which water impoundments are used to meet conservation objectives.

B. Water for Livestock

(1) Water is as important as forage in the production of livestock. Inadequate stock water development in pasture and range areas contribute to ae unstable livestock industry and livestock losses, prevent use of needed grazing areas, and encourage overgrazing in the vicinity of existing water supplies.

(2) Providing adequate water for livestock on range and pasture consists of developing enough water to satisfy stack needs and providing a proper distribution in relation to the available forage (fig. 11-4).

Figure 11-4: Range Pond to Provide Livestock Water



(3) A pond should be of a size that will meet the needs of all livestock that will use the surrounding grazing area. Figure 11-5, showing the average daily consumption of water by various kinds of livestock, should be helpful in estimating water needs.

Figure 11-5: Daily Consumption of Water by Livestock

Kind of livestock	Gallons per head per day	Liters per head per day
Beef cattle and horses	12–15	45–57
Dairy cows (drinking only)	15	57
Dairy cows (drinking and barn needs)	35	132
Hogs	4	15
Sheep	2	8

(4) The total depends on the stock served, amount of water that will be consumed at one pond' will average daily consumption per animal, the number of live-' and the length of period over which they are served.

C. Irrigation Storage

(1) The required storage capacity of a farm reservoir used for irrigation depends on several factors. These are the water requirements of the crops to be irrigated, the effective rainfall that can be expected during the growing season, the application efficiency of the irrigation method used, the losses due to evaporation and seepage, and the expected inflow into the pond. All of these can be estimated with reasonable accuracy and a water budget prepared to determine the required capacity of the reservoir.

(2) Where the acreages to be irrigated and the storage requirements are small, the preparation of water budgets is often not justified. In such cases, figure 11-6, or locally developed guides, can be used to determine storage requirements in small irrigation ponds and reservoirs.

Figure 11-6: Capacity Guide for Small Irrigation Reservoirs[1]

Climate	Annual rainfall		Pond capacity per unit storage2					
			Vegetable crops		Field crops		Perennial crops	
	inches	mm	Ac-ft/ac	cm/ha	Ac-ft/ac	cm/ha	Ac-ft/ac	cm/ha
Superhumid	Over 60	Over 1524	0.75	925	1.00	1233	1.25	1542
Humid	40–60	1016–1524	1.00	1233	1.50	1850	1.75	2159
Subhumid-moist	30–40	762–1016	1.50	1850	2.00	2467	2.50	3084
Subhumid-dry	20–30	508–762	2.00	2467	2.75	3392	3.50	4317
Semiarid	10–20	254–508	3.00	3700	4.00	4934	6.00	7401
Arid	Under 10	Under 254	Small reservoirs are not reliable					

[1]Based on the assumption that the watershed area is adequate to fill the reservoir at least once annually.
[2]Table is limited in use to 40 acres (16 ha) irrigated.

(3) Where irrigated acreages are large the preparation of a water budget is required. In such cases the problem should be referred to an experienced engineer or hydrologist.

D. Regulation of Irrigation Streams

(1) In some locations available irrigation streams fluctuate widely or become so small as to limit the method of application, reduce the efficiency of application, or require excessive amounts of labor. In such instances, on-farm regulating or "overnight storage" reservoirs may be constructed to regulate and increase the available irrigation stream. Reservoirs are filled by canal delivery, diversion, or pumping.

(2) The regulating reservoir should be located where it will serve the largest acreage possible consistent with the available water supply. The capacity of such a reservoir will vary with the stream size to be regulated and the period it is to be stored. Storage of the available inflow for 24 to 72 hours is common.

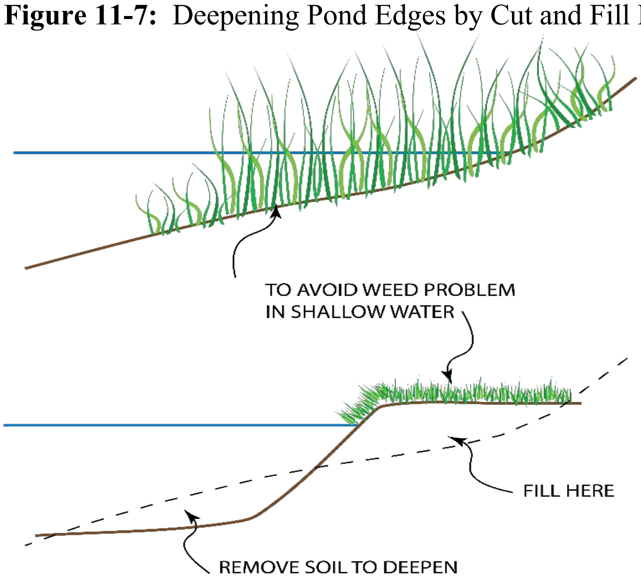
E. Field and Orchard Spraying

(1) Ponds may provide water for applying insecticides and fungicides to field and orchard crops. The amount of water needed for spraying is relatively small, but it is important that it be available when needed. About 100 gallons per acre for each application should be enough for most field crops. Orchards, however, may require 1,000 gallons or more per acre for each spraying.
(2) Suitable means should be provided to convey water from the pond to the spray tank. If the pond is of the embankment type, a pipe placed in the dam, and equipped with a valve and a flexible hose at the downstream end will permit the spray tank to be filled by gravity. If the pond is the excavated type, a small pump will be required to fill the tank.

F. Aquaculture

(1) Water impoundments can be used for farming of freshwater and saltwater organisms including fish, mollusks, crustaceans and aquatic plants. The type of species being grown will dictate the size and depth of the impoundment, the quantity and quality of the water supply, and the type of access for operation and maintenance.
(2) A pond that is constructed and managed properly may yield from 100 to 300 pounds of fish annually for each acre of water surface. This is about equal to the beef production realized from average improved grassland.
(3) Ponds with a surface of 114 acre to several acres can be managed for good fish production. Those less than two acres have proven popular since they are not as difficult to manage as the larger ones.
(4) Shallow water at the edges of a pond promotes waterweed growth, which makes fish management difficult, and provides a breeding place for mosquitoes. These problems can be overcome to a large extent by deepening the shallow edges around the pond. This can be done by borrowing from the pool edge during construction, or by cutting and filling as shown in figure 11-7.
(5) The impoundment may need to be protected from flooding, sedimentation and other contaminants. Precautions need to be taken to minimize the escape of non-native or otherwise harmful species to adjacent surface water bodies.

Figure 11-7: Deepening Pond Edges by Cut and Fill Method



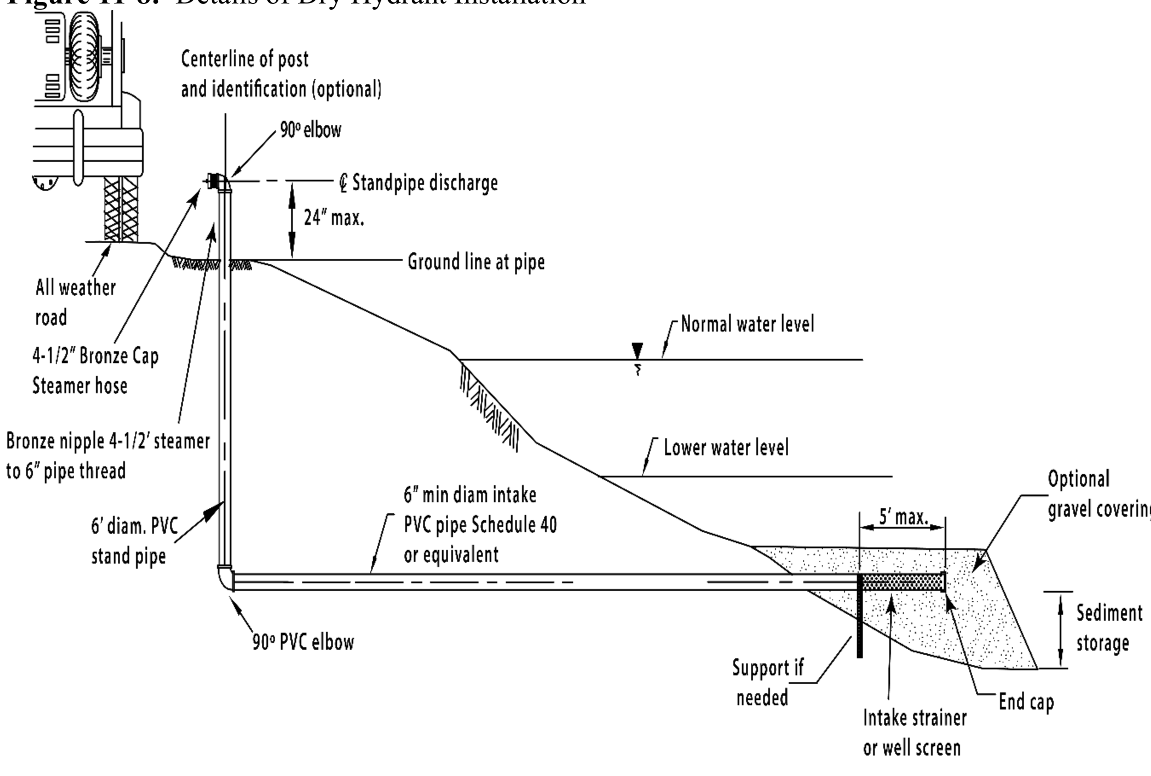
G. Fire Protection

(1) An impoundment located near buildings can be used for fire suppression by using a pump and enough length of hose to reach all sides of the farthest building. A satisfactory fire stream should not be less than 250 gallons per minute with a pressure at the nozzle of no less than 50 pounds per square inch (psi). Fire nozzles usually range from 1 to 1-1/2 inches in diameter. Use good quality rubber-lined fire hose, 2 1/2 to 3 inches in diameter. The length of the hose should preferably not exceed 600 feet.

(2) A typical example of a fire hose line is one consisting of 500 feet of 3-inch hose to which a 1-1/8 inch smooth nozzle is attached. A centrifugal pump operated a t 85 psi. will provide a stream of 265 gpm. with a nozzle pressure of 50 psi. Such a stream running for 5 hours would require 114-acre foot of water. Local dealers in pumps, engines, and similar equipment should be able to furnish the data required regarding pump capacities and engine horsepower.

(3) A dry hydrant can be added next to the impoundment to facilitate water withdrawal. A dry hydrant is a nonpressurized permanent pipe assembly system installed into a water source that permits the withdrawal of water by suction. Dry hydrants can be used by local fire departments when an all-weather surface access road a minimum of 12 feet wide is provided to facilitate movement by personnel and equipment during an emergency. A typical dry hydrant is shown in figure 11-8.

Figure 11-8: Details of Dry Hydrant Installation



H. Recreation

(1) A pond or reservoir can provide opportunities for swimming, boating, fishing, ice skating, bird watching and hunting. The surrounding area can be made into an attractive place for hiking, picnics and games. A ramp and access road may be needed to allow boats to be launched. Fishing piers and peninsulas can be added to provide greater fishing access. Trails can be developed to allow for hiking and pond access (fig. 11-9).

Figure 11-9: Pond Used for Recreation

(2) Native fish species can be stocked to improve fishing opportunities. State fish and wildlife agencies should be consulted when determining which species are native to the area, and at what rate they should be stocked to ensure proper ecological balance. Impoundments managed for fishing should be approximately 6 to 10 feet deep, depending on the desired species to be stocked, and at least a half-acre in size. A minimum depth of 8 feet over an area approximately 1000 square feet is needed for best management.

(3) Fish spawning areas, or shoals, need to be considered when designing impoundments for fishing. Spawning shoals are structures such as underwater sand bars or rock piles that provide shallow areas for breeding fish. Shallow water shoals can be created by adding multiple rows of large-sized rocks to the bottom of certain portions of the pond. Nylon mats can also be used as artificial spawning sites for stocked species such as largemouth bass. Placing several boulders, approximately 2to 3 feet in diameter, along the bottom of the pond may also augment fish habitat. These boulders will provide resting cover to fish populations. Leaving irregular bottom contours, stumps and rock outcrops in the reservoir also adds habitat. Tree limbs and other man-made fish attractors can be anchored below water level during construction for additional cover.

(4) When impoundments are stocked with fish, it is important to consider the effect of fish on amphibians and other aquatic life. Shallow-water areas should be provided for nursery areas for young fish and amphibians where access by larger predatory fish is minimal. Another alternative is to install a small, shallow impoundment for amphibians near the larger, deeper impoundments for fish.

(5) Where a pond is used for public recreation, there should be a supply of water adequate to overcome evaporation and seepage losses and maintain a desirable water level. The waters must be free of pollution, especially where they are used for swimming and bathing. If bathing is one of the intended activities, there should be an adequate depth of water in the vicinity of a gently sloping shore. Minimum facilities for public use and safety, such as access roads, parking areas, boat ramps or docks, fireplaces, picnic tables, and drinking and sanitary facilities, should be provided.

(6) To protect public health, most States have laws and regulations that require water supplies to meet certain prescribed standards if they are to be used for swimming and human consumption. Generally, water must be tested and approved before public use is permitted. There are also rules and regulations for building and maintaining public sanitary facilities. The State board of health or a similar agency administers such laws and regulations. Contact local health agencies to become familiar with regulations before making extensive plans to provide water for public recreation.

H. Wildlife Habitat

(1) The reservoir and adjacent land area can be managed for wildlife habitat. Impoundments can provide food, cover, and nesting habitat for a variety of species including amphibians, reptiles, fish, birds, and mammals. Migratory waterfowl often use them as resting places in their flight to and from the North. In some of the northern States ducks often use them as breeding places, particularly where there is an ample supply of good food. Upland game and game birds use ponds as watering places (fig. 11-10).

Figure 11-10: Wildlife Using Pond for Feeding

(2) A variety of water depths are needed to provide the greatest diversity. Deeper water provides habitat for fish. Amphibians prefer shallow, fishless waters for breeding and rearing. Shallow areas allow for aquatic plants that help maintain water quality, temperature, and oxygen levels; reduce bank erosion; and provide food, spawning grounds, and escape cover for wildlife. Leaving logs can provide basking and sunning opportunities for amphibians and turtles; egg-laying sites for fish, frogs, and salamanders; shelter for fish; and perches for birds.

(3) Islands can provide resting and escape cover, nesting habitat, and feeding areas for waterfowl and shorebirds. Wide (at least 50 feet) vegetated buffer areas provide essential nesting, winter, and escape cover for wildlife. They also increase the aesthetic qualities of the pond property and increase the amount of water infiltration of the soil.

(4) Upland areas can provide cover for reptiles, ground nesting birds, songbirds, and mammals by leaving downed trees, shrubs, rocks, and natural vegetation around the pond. A well-groomed pond does not support as many species as a messy one. When upland areas lack a variety of loafing and escape cover, brush piles can be constructed. Figure 11-11 provides information on desirable pond characteristics for various species.

I. Energy production

(1) Water impoundments can be used to produce electricity with the addition of turbine generators. Dams less than 35 feet high however create relatively small head (elevation change), requiring larger turbines to produce a given amount of energy. Larger turbines are more expensive and require larger flows (fig. 11-12). Constant flows are also needed for reliable energy production. (Source :McKinney, J.D., B. Bradley, J. Dodds, T.B.McLaughlin, C.L. Miller, G.L. Sommers, and B.N. Rinehart. 1983. "Microhydropower Handbook", Vols. 1 & 2. U.S. Department of Energy, Idaho Falls, ID.)

(2) The water in a reservoir can also be used for a water source heat pump to heat and cool buildings. An open source heat pump system draws water from the reservoir and then discharges the water back into the reservoir after use. A closed source system uses pipes that circulate fluids under the water to capture the heat exchange. Both systems have the potential to increase surface water temperatures in summer and decrease temperatures in winter which can have a negative effect on aquatic life habitat.

(3) Reservoirs used by heat pumps need to be large enough to give up the amount of heat needed and deep enough not to freeze solid in the winter. The size of the heat pump will determine how large and deep the impoundment needs to be. A minimum depth of 10 is recommended. The default maximum capacity for cooling dominated climate is 20 tons per acre and 10 tons per acre for heating dominated climates. Care must be taken to avoid placing large load on a small, relatively shallow body of water, this will increase the evaporation rate may result in an undesirable decline in water level and an elevated water temperature.

Figure 11-11: Pond Characteristics for Healthy Populations of Certain Groups of Organisms[1]

Group	Subgroup	Pond physical characteristics	Pond biological characteristics
Amphibians	Frogs and salamanders	Temporary or permanent water Muddy bottom Shallow and deep-water areas Clear water High oxygen content Low nitrogen content	Abundant aquatic floating, emergent, and submerged vegetation Absence of fish Good supply of aquatic invertebrates Trees and grasses around pond area Quality upland vegetation ranging from grasses and forbs to woodlands
Fish	Fish that eat plant material and invertebrates	Permanent water Clear water High oxygen content Constant range in temperature Spawning substrate	Aquatic floating, emergent, and submerged vegetation
	Fish that eat other fish	Permanent water Clear water High oxygen content Constant range in temperature Spawning substrate	Good supply of small fish Good supply of tadpoles
Birds	Shorebirds, waterfowl, wading birds, and songbirds	Permanent or temporary water Clear water Mudflats	Floating, emergent, and submerged vegetation Quality upland vegetation ranging from grasses and forbs to woodlands Good supply of fish and aquatic insects
Reptiles	Snakes	Suitable habitat for burrows Presence of compost or woodchip piles for nesting Suitable cover, such as rock piles Ponds located far from trafficked roads	Good supply of small mammals, amphibians, and lizards
	Turtles	Muddy bottom Presence of rock piles, stumps, and floating or suspended logs for basking Presence of sunny clearings or embankments for nesting	Submergent aquatic vegetation Good supply of fish and insects

[1] From Farm Pond Ecosystems, NRCS Fish and Wildlife Habitat Management Leaflet Number 29

Figure 11-12: Tailwater from Hydropower Generation

J. Grade stabilization

(1) Gullies can also be stabilized with low earth or rock structures and the base vegetated. Earthen embankments can be built across channels to stabilize grades, control erosion and prevent the advance of gullies.

(2) Planning grade stabilization treatment under these conditions may require that the gradient of the channel be reduced so that water will travel at a nonerosive velocity. Some type of structure 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 gradient.

K. Sediment Basin

A basin formed by an embankment and/or excavation can be used to capture and detain sediment laden runoff for enough time to allow sediment to settle out in the basin. The sediment basin needs to have sediment storage capacity, detention storage and temporary flood storage capacities.

L. Flood storage

(1) When fill or buildings are place within the flood plain the flood heights will increase due to the smaller area available for flood waters. The most common structural facility constructed to slow the rate of stormwater runoff is the stormwater pond. Stormwater ponds are essentially classified in two categories depending on their function—detention or retention. Depending on the physical constraints and conditions, they can be wet (permanent pool) or dry.

(2) Detention ponds provide only flood control measures and are known as dry ponds. The ponds help control the rate of flow by using a control device that maintains a set rate of release. Typically, the controlled device is placed at the entrance to the outlet pipe. The pond is intended to drain the stormwater within a given period to make the volume available for the next storm event (fig. 11-13).

Figure 11-13: Flood Detention Pond (St George, Utah)

(3) Retention ponds hold a permanent pool of water and are referred to as wet ponds. The outlet of the pond is placed at or above the desired pool elevation. The volume of the permanent pool is set by a desired residence time to allow microbes and vegetation in the water to filter nutrients and to allow suspended sediment to settle. Retention ponds will require more area than a detention pond. This is due to constraints the permanent pool.

M. Waste Treatment and Water Quality improvement

(1) A waste treatment impoundment can be made by constructing an embankment and/or excavating a pit or dugout. A waste treatment lagoon treats waste biologically by either anaerobic or aerobic digestion processes. A constructed wetland utilizes hydrophytic vegetation for water treatment. Both lagoons and wetlands can treat wastewater and contaminated runoff from agricultural processing, livestock, and aquaculture facilities. The treatment of manure and organic wastes generated by agricultural production or processing is limited to lagoons.

(2) A waste management system plan is needed to determine the size and management requirements of the waste treatment impoundment. For more detailed information see: Title 210, National Engineering Handbook, Part 637, “Environmental Engineering” (210-NEH-637); 210-NEH-651, “Agricultural Waste Management Field Handbook”; or 210-NEH-650, Chapter 13, “Wetland Restoration, Enhancement, or Creation” (210-NEH-650-13).

N. Landscape quality

(1) Water adds variety to a landscape and further enhances its quality. Reflections in water attract the eye and help to create a contrast or focal point in the landscape. A body of water visible from a home, patio, or entrance road increases the attractiveness of the landscape and often increases land value.

(2) Regardless of its purpose, a pond’s appearance can be improved by using appropriate principles and techniques of design. Good design includes consideration of size, site visibility, relationship to the surrounding landscape and use patterns, and shoreline configuration.

O. Multiple Uses

(1) Where possible, a pond should be constructed to provide water for two or more purposes. For example, it could be used to provide water for livestock, for fish production and for spraying one or more field crops. Storage requirements for each purpose should be sure of an adequate supply for all intended uses.
(2) The several purposes for which water is to be used should be compatible. Some combinations are not. For example, a pond would not: normally be used for both irrigation and recreation. Unless the reservoir is very large, most of the water might be removed during the irrigation season, thereby lowering the water level to a point where boating and swimming would not be practical.

J. Legal Requirements

Many States have laws that require permits to construct dams for water storage for any intended use. The technician should know the requirements in the State and comply with them in the planning, design, and layout of ponds and reservoirs.

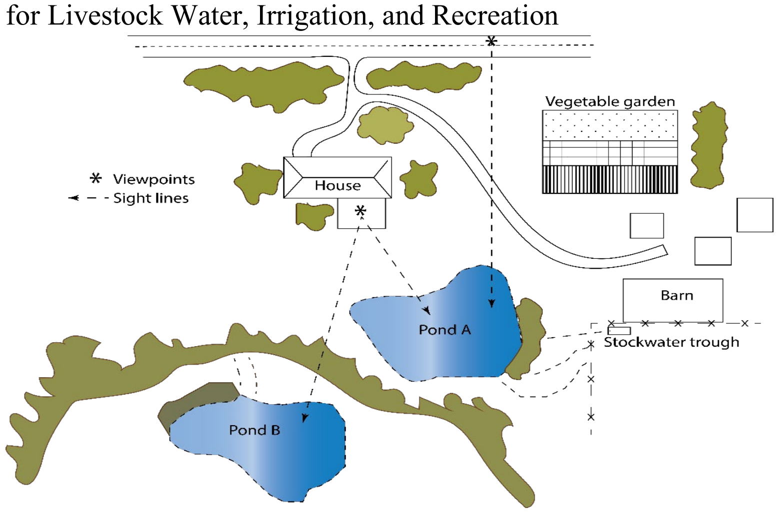
650.1103 Planning Considerations

A. Locating the impoundment

(1) Selecting a suitable site is important, and preliminary studies are needed before final design and construction. Analyzing the relationship of the site to ecological features within the landscape is critical to achieving planned objectives. If possible, consider more than one location and study each one to select the most ecologically appropriate, aesthetic, and practical site. Weighing both onsite and offsite effects of constructing a pond is essential in site selection.
(2) For economy, locate an embankment pond where the largest storage volume can be obtained with the least amount of earthfill. A good site generally is one where a dam can be built across a narrow section of a valley, the side slopes are steep, and the slope of the valley floor permits a large area to be flooded. When water supply is the objective, avoid large areas of shallow water because of excessive evaporation and the growth of noxious aquatic plants. However, if wildlife is an objective, a variety of water depths and aquatic plants are desirable. Waterfowl need various depths for breeding, courting, and feeding. Fish need areas 2 to 6 feet deep for feeding and nesting but will live at a depth of 10 feet or more.
(3) Another factor in selecting an embankment pond site is the availability of suitable fill material for building an embankment. Easy access to this material will reduce placement costs considerably. If fill material can be taken from the pool area without damaging its watertight integrity, the surrounding landscape will be left undisturbed and the borrow area will be under water after the pond is filled. Deepening the pool can also be advantageous for fish production and increased water storage.
(4) Ponds used for watering livestock should be made available in or near each pasture or grazing unit. Forcing livestock to travel long distances to water is detrimental to both the livestock and the grazing area. Space watering places so that livestock do not travel more than a quarter mile to reach a pond in rough, broken country or more than a mile in smooth, nearly level areas. Well-spaced watering places encourage uniform grazing and facilitate grassland management.
(5) Where water must be conveyed for use elsewhere, such as for irrigation or fire protection, locate the pond as close to the point of use as is practical.

(6) Ponds to be used for fishing, boating, swimming and other forms of recreation should be readily accessible by automobile, especially if the general public is charged a fee for use of the pond. The success of such an income-producing enterprise often depend on accessibility. Avoid sites under power lines. The wires may be within reach of a fishing rod held by someone fishing from the top of the dam.
(7) Avoid pollution of water by selecting a location where drainage from farmsteads, feeding lots, corrals, sewage lines, mine dumps and similar areas will not reach the ponds. Where this cannot be done practically, the drainage from such areas should be diverted from the pond.
(8) The pond should not be located where sudden release of the water, due to failure of the dam, would result in loss of life, injury to persons or livestock, damage to residences or industrial buildings, railroads or highways, or cause interruption of use or service of public utilities, Where the only suitable site presents one or more of these hazards, a more detailed investigation should be made to reduce the potential for failure.
(9) Be sure that no buried pipelines or cables cross a proposed pond site. They could be broken or punctured by the excavating equipment, which can result not only in damage to the utility, but also in injury to the operator of the equipment. If a site crossed by pipelines or cable must be used, you must notify the utility company before starting construction and obtain permission to excavate.
(10) Inspect the project area for the existence of cultural resources and any project impacts on such resources. Provide conservation and stabilization of archeological, historic, structural, and traditional cultural properties when appropriate.
(11) Consider pedestrian and vehicular circulation patterns when locating the pond. The reservoir could act as a barrier to movement and trails or access roads may need to be rerouted. Dams can be used to provide access across a water course. Top width and side slopes need to be compatible with the intended vehicle or pedestrian use. The dam may also need to be adjusted to align with adjacent farm lanes.
(12) When aesthetics are an intended purpose identify the major points from which the pond will be viewed and select the location with the best visibility (fig. 11-14). If possible, situate the pond so that the major sight line crosses the longest dimension of water surface. A viewer should see the water before noticing the dam, pipe inlet or spillway. Often minor changes in the dam alignment and spillway location can reduce their prominence or shift them from view.

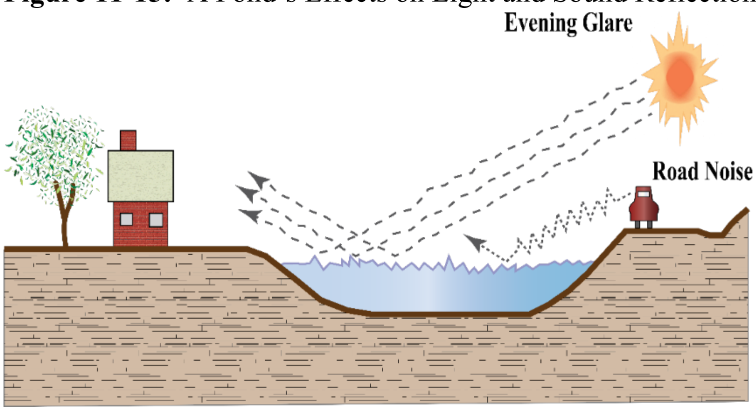
Figure 11-14: A Preliminary Study of Two Alternative Sites for a Pond to be Used for Livestock Water, Irrigation, and Recreation



(13) Water quality affects both the visual character and use of a pond. Clarity and color are visual indicators of water quality; however, visual observations can be misleading, and a chemical analysis may be necessary to determine the water's safety for specific uses such as swimming. Sediment, aquatic plants, and organic stains also affect the clarity and color of water; however, these can often be controlled.

(14) A smooth water surface can cast interesting reflections. It can also create a potential for unwanted glare and may transmit undesirable noise. To reduce the effects of light and sound, consider the relationship of the pond and surrounding areas (fig. 11-15).

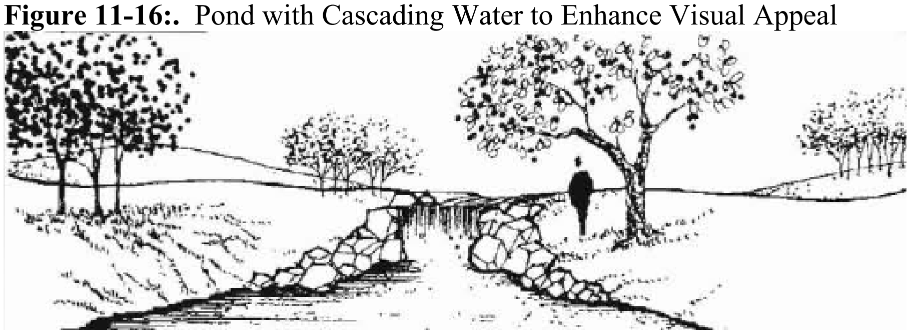
Figure 11-15: A Pond's Effects on Light and Sound Reflection



(15) Moving water is generally more interesting than still water, adding visual interest and pleasing sound.

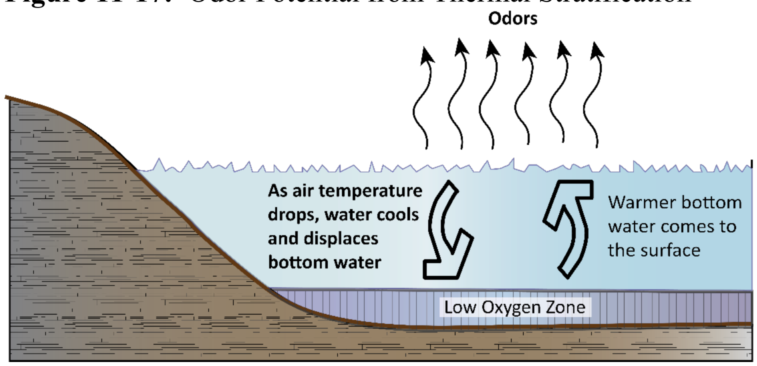
(16) Ponds can be enhanced by constructing a waterfall at the entrance of an embankment pond (fig. 11-16) or a cascade at the principal spillway outlet, provided there is proper protection against erosion.

Figure 11-16:. Pond with Cascading Water to Enhance Visual Appeal



(17) Odor may be associated with some purposes, such as waste treatment lagoons or constructed wetlands. If odor is a potential issue, consider the ponds location relative to human use areas and prevailing winds. Oder may also be associated with thermal stratification of deeper lakes and ponds during hot summer periods. It is not a problem, but it can create some potentially undesirable conditions. When a lake or pond becomes stratified, a 6 to 10-foot layer of warm well—oxygenated water persists near the surface. As these surface waters become colder in the fall, they exchange with the bottom layers that are low in oxygen and rich in nutrients. This, combined with increased decomposition of aquatic vegetation that further reduces oxygen levels, creates a situation that may kill fish (fig. 11-17). The rich bottom water may also create temporary unpleasant odors. Artificial aeration and agitation can help to prevent thermal stratification.

Figure 11-17: Odor Potential from Thermal Stratification



B. Adequacy of the Drainage Area

(1) Where surface runoff is the main source of water supply, the contributing drainage area must be large enough to yield enough runoff to maintain the water supply in the pond during all periods of intended use. However, the drainage area should not be so large that expensive overflow structures are needed to bypass excess storm runoff.

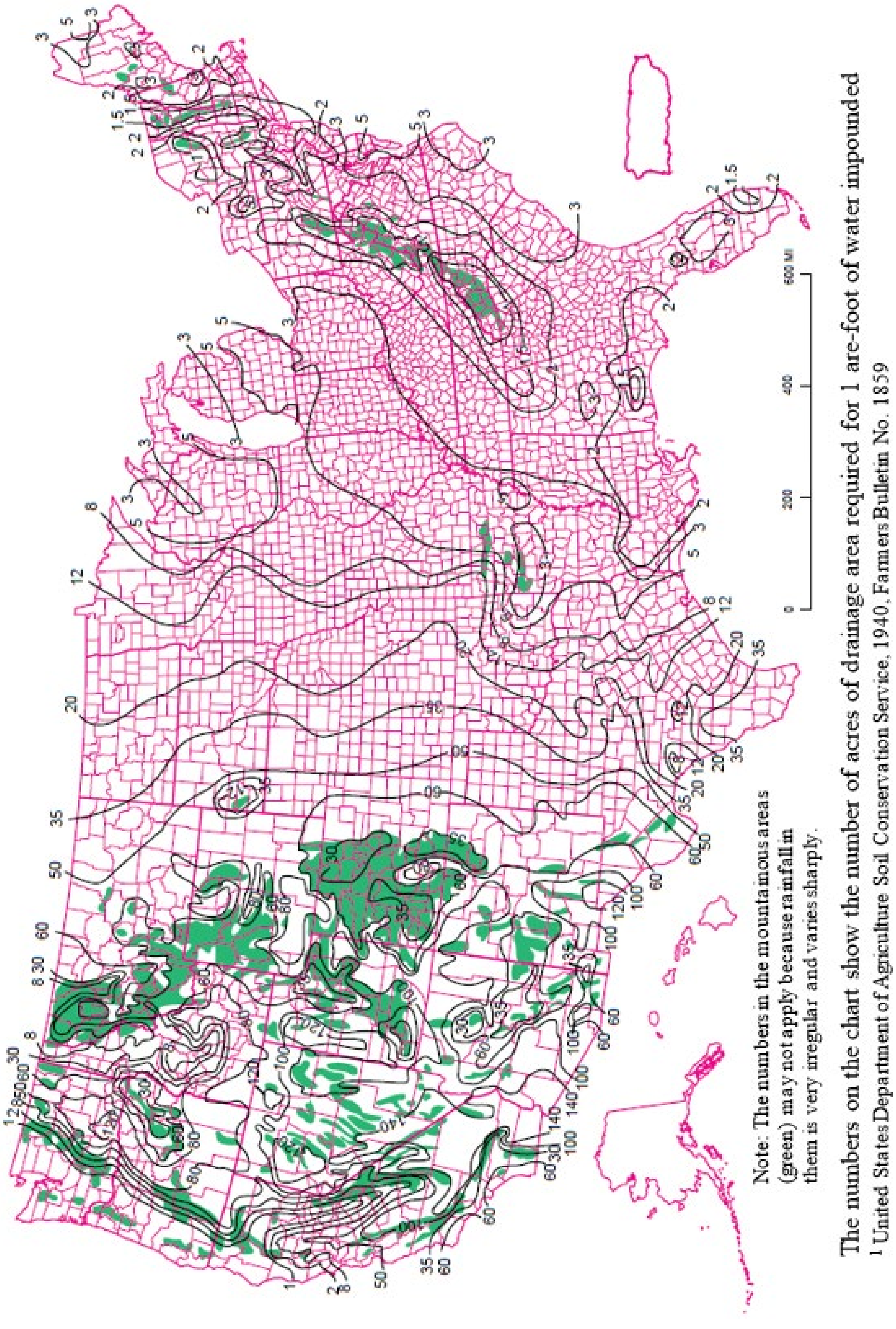
(2) The amount of runoff that can be expected annually from a watershed of a given area depends on so many factors that no set rule can be given for its determination. The physical characteristics of the watershed that have a direct effect on the yield of water are relief, soil infiltration, plant cover and surface storage. Storm characteristics such as the amount, intensity and duration of rainfall also affect water yield. These characteristics vary widely throughout the United States. Each must be considered when evaluating the watershed area conditions for a pond site.

(3) Figure 11-18 is a general guide for estimating the approximate size of a drainage area required for each acre-foot of storage in a pond to maintain normal pool level. If reliable local runoff information is available, use it in preference to the guide. The information in the guide map does not apply when ponds are used for irrigation.

(4) Average physical conditions in the area are assumed to be the normal runoff-producing characteristics for a drainage area, such as moderate slopes, normal soil infiltration, fair to good plant cover, and normal surface storage.

(5) To apply the information given in figure 11-18, some adjustments may be necessary to meet local conditions. Modify the values in the figure for drainage areas having characteristics other than normal. Consult local climatic and hydrological records to account for microclimates and other variations from the norm.

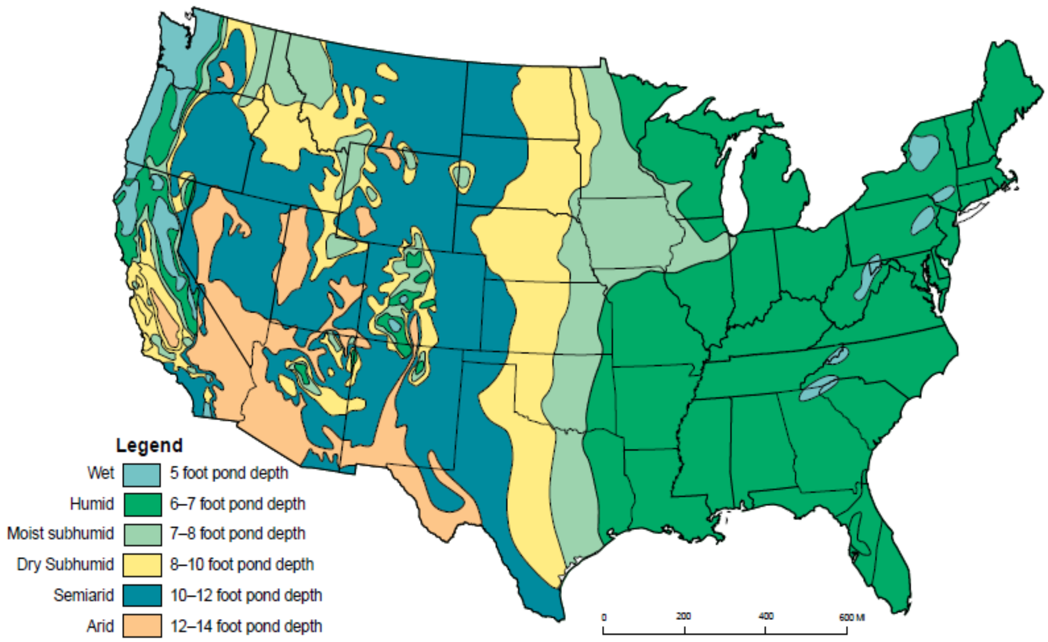
Figure 11-18: A General Guide for Use in Estimating the Approximate Size of Drainage Area Required for a Desired Storage Capacity in Either Excavated or Impounding Reservoirs1



C. Minimum Pond Depth

To ensure a permanent water supply, the water must be deep enough to meet the intended use and to offset seepage and evaporation losses. These losses vary in different sections of the country and from year to year in any one section. Figure 11-19 shows the recommended minimum depth of water for ponds if seepage and evaporation losses are normal. For satisfactory performance the seepage loss from a reservoir should ordinarily not exceed 2 to 3 inches per month. Average annual evaporation losses vary from 3 feet or less in some regions to 6 feet or more in others. Deeper ponds are needed where a year-round water supply is essential or where seepage losses may exceed 3 inches per month. See State standards and specifications for local minimum depths.

Figure 11-19: Recommended Minimum Depths of Ponds and Reservoirs (from Fig. 12 AH 590)



D. Drainage Area Protection

(1) To maintain the required depth and capacity of a pond, the inflow must be reasonably free of silt from an eroding watershed. The best protection is adequate application and maintenance of erosion control practices on the contributing drainage area. Land under permanent cover of trees, grass, or forbs is the most desirable drainage area. Cultivated areas protected by conservation practices, such as terraces, conservation tillage, stripcropping, or conservation cropping systems, buffer strips and other sediment traps are the next best watershed conditions.

(2) If an eroding or inadequately protected watershed must be used to supply pond water, delay pond construction until conservation practices are established. In any event, protection of the drainage area should be started as soon as you decide to build a pond.

E. Pond Capacity

(1) Estimate pond capacity to be sure that enough water is stored in the pond to satisfy the intended use requirements. A simple method follows:

(i) Establish the normal pond-full water elevation (typically the elevation of the principal spillway invert) and stake the waterline at this elevation.

(ii) Measure the width of the valley at this elevation at regular intervals and use these measurements to compute the pond-full surface area in acres.

(iii) Multiply the surface area by 0.4 times the maximum water depth in feet measured at the dam.

(2) For example, a pond with a surface area of 3.2 acres and a depth of 12.5 feet at the dam would have an approximate capacity of 0.4 x 12.5 x 3.2 = 16.0 ac ft. (1 acre-foot = 325,857 gallons). If a more accurate answer is required, the surface area at successive intervals of elevation may be determined and the average end-area method may be used to compute the volume.

F. Permits and Regulations Legal Requirements

(1) There are Federal, State and local laws that may require permits to construct dams for water storage for any intended use. These requirements need to be met during planning, design, and layout.

(2) Section 404, Clean Water Act

(i) Where a natural wetland exists, a section 404 permit may be necessary before construction can begin. Section 404 of the Clean Water Act (33 U.S.C. 1344) and section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 403) are two of the Federal authorities for jurisdiction in wetlands of the United States. Permits are evaluated and issued by the U.S. Army Corps of Engineers (USACE) and subject to review by U.S. Environmental Protection Agency (EPA). In addition, section 401 of the Clean Water Act may sometimes require a water quality certification permit for a wetland construction project. In general, wetland restorations are covered under the Nationwide Permit No. 27 for section 404 purposes. Contact with the local USACE permitting office is always a good idea to verify the project falls under the scope of the Nationwide Permit.

(3) Water Storage and Diversion

(i) Water law and water rights vary from east to west and State to State and can be very complicated. Western water rights, or the rights to adequate water supplies for certain uses, are controlled by each State and often by a local water district. Water rights may be obtained through outright purchase from local farmers or ranchers and, in some cases, through State assertion of water rights for protection and enhancement of natural resources in the public interest.

(ii) Eastern water rights or riparian rights rely on ownership of land along a water way and can include public navigability rights. In some States, a project on private land connected to public waters may make private waters public, so specific designs may be necessary to protect a landowner's rights and interests.

(4) Flood plains
  (i) In flood plains included in the National Flood Insurance Program, it is necessary to obtain a local permit for a project which has the potential to raise the 100-year flood elevation. Normally, it is prohibited to raise the flood elevation in the defined floodway, and areas outside the floodway are limited to 1 foot or less increase in flood elevation. It may be necessary to perform complex water surface profile analysis to document the projects effects on the flood elevation for a permit. The local permit program is usually administered by city or county government.
  (ii) The permitting entity will have information about the Federal Emergency Management Agency (FEMA)-funded flood studies, and data needed to perform an analysis. Most NRCS field offices have copies of the FEMA flood study maps for their district.
  (iii) Projects which store water above natural ground and/or include dikes can potentially increase the flood elevation.

(5) Dam Safety.—The requirements for dam safety permits vary widely across the country. The need for permits is usually based on some combination of storage volume and structure height. Many States consider embankments of 6 feet or less in height to be dams, and many wetland embankments store significantly more water above natural ground than the typical embankment pond.

(6) National Point Discharge Elimination System.—The EPA's National Pollutant Discharge Elimination System (NPDES) permit system is usually administered by the States. It requires permits for construction activities which have the potential to discharge sediment and other pollutants from construction sites until permanent cover has been established. Best management practices for sediment control, discharge of hazardous construction materials, and control of spills of equipment fuels and lubricants are usually required. Individual States have set permit requirements based on location of the activity, and size of the disturbed area. The permits are administered by the State agency responsible for environmental protection.

(7) Easements.—The number of potential easements on a project site are too numerous to mention in their entirety. Easements are recorded on property ownership documents. They may require a project proponent to obtain permission from the easement holder to conduct the activity. The following are some of the most common easement issues:
  (i) Utilities
  - Buried or overhead electrical, telephone, oil, gas, water, and other utilities owners will always have an easement across the property and will almost certainly have a concern with the alteration of the land over or under their easement or the construction activity.
  - They commonly require, at a minimum, that constructed access routes be maintained through the project. It is common to require the owner to pay the expense of new construction and land rights to relocate the utility.

(ii) Water storage or flowage—

- The landowner of a pond project must obtain an easement for any water stored on an adjoining property, both permanently and temporarily. Also included are any waters diverted away from their original, natural flow path. Many States have defined the minimum return period of the storage event. It is easy to overlook water storage requirements under State laws.
- An example would be a wetland structure designed to safely handle a 10-year storm discharge. The top of this structure was lower than the lowest elevation along the upstream property line. However, State law required that an easement be obtained up to the water surface during a 100-year runoff event. This same structure, when overtopping during the 100-year event, would back water across the property line.

(iii) Irrigation, drainage, and levee districts.—These entities often have easements on ditches, canals, dikes, levees, or other features in a wetland project area. In some cases, the actual boundary and width of these easements are indeterminate. Also, many old easement holding entities have disbanded, merged with other entities, or turned their easement over to another entity. In addition to easements, there may be set-back requirements. For instance, the USACE usually has a set-back distance for excavations adjacent to its project levees.

650.1105 Engineering Surveys

A. Once the location of the pond or reservoir has been determined, enough engineering surveys should be made so that the dam, spillway and other features of the pond can be planned.

B. Surveys for embankment-type ponds normally will consist of a profile of the centerline of the dam, a profile of the centerline of the earth spillway, and enough measurements for estimating the pond capacity. For the larger and more complex reservoirs, particularly those used to store water for Irrigation, a complete topographic survey of the entire pond site and cross-section surveys of embankment and spillway locations may be required.

C. The profile along the centerline of the proposed dam should extend up both sides of the valley above the expected elevation of the top of the dam and beyond the probable location of the earth spillway. The profile should show ground surface elevations at all significant changes in the ground slope and at intervals no greater than 50 feet. The profile assists in establishing critical elevations for the structure including normal pool, crest of the emergency spillway and top of the embankment. It is used also to compute the volume of earth required to construct the dam.

D. A similar profile should be run along the center of the earth spillway from a point on the upstream end, well below the selected normal water surface elevation, to a point on the downstream end where water can be safely discharged without damage to the structure. This profile serves as a basis for determining the slope and dimensions of the spillway.

E. Engineering surveys for excavated ponds are relatively simple where no water is stored against an embankment. Usually the four corners of the proposed excavation are located on the ground and rod readings taken at these points. These readings should be referenced to a benchmark and recorded. Engineering surveys for both embankment and excavated ponds may be recorded on approved standard forma or data sheets.

F. All surveys made at the pond site should be tied to reference points and a benchmark. At least two solid benchmarks must be set that will not be destroyed during construction and will last at least a few years in the event project construction is delayed. These may be a large spikes driven into a tree, an iron rod driven flush with the ground, a point on the concrete headwall of a culvert, or any other object so located that it can be expected to remain undisturbed until construction of the dam has been completed. These benchmarks will also be used for monitoring once construction is completed. They should be tied to locally recognized benchmarks with mean sea level vertical datum whenever possible, especially for large and perpetual projects. They should also be referenced to a horizontal datum system such as Universal Transverse Mercator (UTM) or State Plane Coordinate. Consider using 5/8-inch-diameter reinforcing steel bars at least 30 inches long, protected with a steel fencepost.

G. Surveys can be performed by many different technologies including transits, plane table and alidade, total station instruments, and Global Positioning Systems (GPS) (fig. 11-20). On sites where Laser Imaging Detection and Ranging (LIDAR) topography is available, it is still necessary to survey in benchmarks to the same datum. These are used to transfer design lines and grades to the ground surface. This is also the case where GPS topography has been provided. GPS topography must be "survey grade."

Figure 11-20: Setting a Benchmark with Survey Grade GPS

H. The types of information that may need to be collected for planning and design include:

(1) Surface Topography.—Includes the maximum potential flooded area of the impoundment during extreme storm runoff events and the maximum potential area of ground water rise. Include the areas that may experience a water surface profile increase in drainage ditches and stream channels.
(2) In small, noncomplex projects, spot elevations, profiles and cross sections may be adequate for survey.
(3) Location of roads, rights-of-way, utilities, or other public infrastructure.
(4) Potential flowage path of auxiliary spillways to the original downstream point of discharge of the hydrologic system.
(5) Potential downstream breach hazard areas of planned water impoundments to the point of discharge into the 100-year flood plain of downstream receiving waters.

(6) Location, size, and dimensions of hydraulic structures on and off project that will affect the flow of surface and subsurface water into and out of the impoundment. This includes road culverts, drain tiles, drainage ditches, conduits through embankments, and other structures.
(7) Location of property boundaries, project easement boundaries, buildings, structures, significant individual trees or timber boundaries, significant remnant or declining habitat, and fences.
(8) Existing benchmarks, boundary markers, or other control points which can be potentially referenced to the project horizontal and vertical datum.
(9) Profiles and cross sections at the planned location of significant water control structure conduits and embankments, if needed to provide enough detail.
(10) Locations of soil boring or test pit locations.
(11) Other special areas of concern such as known or potential cultural resource sites, hazardous material disposal areas, or endangered species nesting sites.

I. Figure 11-21 shows a sample set of notes for a farm pond design survey. Guidelines for surveying techniques and note keeping including electronic and GPS surveys can be found in 210-NEH-650-1, “Engineering Surveys”, as well as the archived Soil Conservation Service (SCS) Technical Release No. 62 (TR–62).

Figure 11-21: Sample Notes for a Pond Design Survey

Sta.	B.S.	H.I.	F.S.	Elev.	
	Profile ℄ of embankment				
BM 1	3.26	43.26		40.00	
0+0			3.7	39.6	Hub stake
+35			6.3	37.0	
+68			10.6	32.7	
T.P.1	0.47	31.42	12.31	30.95	
1+00			5.5	25.9	
+37			9.9	21.5	
+53			11.4	20.0	
+75			11.6	19.8	
2+00			11.9	19.5	
+19			11.1	20.3	
+32			11.1	20.3	
+36			12.6	18.8	
+40			13.2	18.2	
+43			12.9	18.5	
+46			11.8	19.6	
+59			11.6	19.8	
3+00			10.6	20.8	
+35			3.7	27.7	
TP 2	10.97	42.10	0.29	31.13	
+60			10.5	31.6	
4+00			6.7	35.4	

W. J. Sprinkle – Pond
Design Survey

J. Soruggs
R. Bishop
6-19-2020

1

Nail in root 30" oak 140'
N.W. of N end of dam

Bottom outlet channel
c-line of existing stream channel

Sta.	B.S.	H.I.	F.S.	Elev.	
		42.10			
4+20			6.6	35.5	
+60			6.1	36.0	
5+00			6.1	36.0	Hub stake
	Profile c-line Earth Spillway				
0+00			14.1	28.0	
+27			11.4	30.7	
+48			9.5	32.6	
+70			7.7	34.4	
1+30			6.6	35.5	
+50			6.6	35.5	
+85			6.8	35.3	
2+35			8.4	33.7	
+50			10.2	31.9	
TP 3	0.64	32.12	10.62	31.48	
3+00			4.1	28.0	
+50			8.2	23.9	
4+00			11.5	20.6	
TP 4	12.62	43.96	0.78	31.34	
BM1			3.96	40.00	Check

W. J. Sprinkle – Pond
Design Survey

2

c-line proposed earth spillway

c-line of embankment (extended)

650.1106 Embankment Ponds

Geologic Investigations

(1) Soils in the Ponded Area

(i) The suitability of a pond site depends on the ability of the soils in the reservoir area to hold water. The soil profile should contain a layer of material that is sufficiently impervious and thick to prevent high seepage losses. Clays and silty clays are excellent materials for this purpose. Sandy clays usually are satisfactory. Coarse textured sands and sand-gravel mixtures are highly pervious and therefore are generally unsuitable. The absence of a layer of relatively impervious material over a portion or portions of the ponded area does not necessarily mean that the site must be abandoned. It usually means, however, that these portions of the area will have to be treated by one of the several methods described later in this chapter under the heading, Sealing Farm Ponds. Any of these methods may prove to be expensive.

(ii) In some areas, such as coastal plains, lake plains, and river deltas, it is often possible to impound a limited depth of water over areas where no impervious layer exists in the soil profile but where a permanently high-water table exists at or near the ground surface.

(iii) Some of the limestone areas are especially hazardous for use as pond sites. There may be crevices, sinks, caverns or channels in the limestone below the soil mantle and not visible from the surface. These may drain the pond in a short time. In addition, the soils in these areas are often granular. The granules do not break down readily in water and the soils remain highly permeable. Without extensive investigations and laboratory tests, it is difficult to recognize all the factors that might make a limestone site undesirable, One of the best guides to the suitability of a site in such areas is the degree of success experienced with farm ponds in the immediate vicinity.

(iv) Borings or test pits should be made at intervals in the reservoir area to determine the nature of the soil profile. The frequency of these borings will depend on the occurrence of significant changes in the soil profile. The borings should be made to a depth necessary to identify the underlying materials that may affect the design or safety of the structure. A record, or log, of each boring or test pit should be made showing the location, 'depth and classes of materials encountered. The location of each boring should be marked on the ground so it can be referenced to other or more detailed surveys.

(2) Foundation Conditions

(i) The foundation under a dam must ensure stable support for the structure and provide the necessary resistance to the passage of water. The foundation conditions under the proposed dam site should be investigated thoroughly to ensure that the site is suitable and that a safe structure can be designed. The extent of the foundation examination will depend upon the complexity of the conditions encountered and on the height of the dam. The borings should be made to a depth necessary to identify the underlying materials that may affect the design or safety of the structure. Generally, the depth of the holes should be at least 1-1/2 times the height of the proposed dam. A record, or log, of each boring or test pit should be made showing the location, depth and classes of materials encountered. The location of each boring should be marked on the ground so it can be referenced to other or more detailed surveys.

(ii) Ensure there are not any steep drop-offs in the rock surface of the foundation under the dam. Steep drop-offs in the rock surface can result in cracking of the embankment. Study the natural banks (abutments) at the ends of the dam as well as the supporting materials under the dam. If the dam is to be placed on rock, the rock must be examined for thickness and for fissures and seams through which water might pass.

(iii) Coarse-textured materials, such as gravel, sand, and gravel-sand mixtures, provide good support for a dam, but are highly pervious and do not hold water. Such materials can be used only if they are sealed to prevent seepage under the dam. Install a cutoff core trench of impervious material under the dam or blanket the upstream face of the dam and the pond area with a leak-resistant material. Fine-textured materials, such as silts and clays, are relatively impervious, but have a low degree of stability. They are not good foundation materials, but generally are satisfactory for the size of dams discussed in this handbook. Flattening the side slopes of some dams may be necessary to reduce the unit load on the foundation. Remove peat, muck, and any soil that has a high organic-matter content from the foundation.

(iv) Good foundation materials, those that provide both stability and imperviousness, are a mixture of coarse- and fine-textured soils. Some examples are gravel sand-clay mixtures, gravel-sand-silt mixtures, sand-clay mixtures, and sand-silt mixtures.

(v) Less desirable but still acceptable foundation materials for ordinary pond dams are gravelly clays, sandy clays, silty clays, silty and clayey fine sands, and clayey silts that have slight plasticity.

(3) Fill Material

(i) Fill material must be available in enough quantities for construction of the dam and should be located close enough to the site so that placement costs will not be excessive. Soil borings should be made in the selected borrow areas in order to estimate the kinds and amounts of suitable fill materials available.

(ii) Materials selected for construction of a dam must have enough strength for the dam to remain stable and a sufficiently low permeability, when compacted, to prevent harmful seepage of water through the dam.

(4) Soils in the Spillway Area

In most cases it is necessary to bypass excess storm runoff around the embankment of a farm pond through an excavated earth spillway. For economic reasons, suitable material excavated from the spillway should be used in the earthfill. Thus, soil borings should be made along the approximate centerline of the proposed spillway to determine the type of material that will be encountered, its erodibility, and its suitability for use in the embankment.

(5) Records of Soil Investigations

(i) A permanent record of all soil borings and test pits made in the reservoir area, foundation, borrow area, and spillway area should be maintained in the work unit office. Form NRCS-ENG-538, “Soil Investigation to Determine Suitability of Proposed Pond Site,” figure 11-22, or a similar form, should be used to record soil borings.

(ii) See 210-NEH-650-4 for guidance in the classification of the soils encountered, and in determining their suitability as foundation or construction materials.

Figure 11-22: Soil Investigation Form

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

NRCS-ENG-538
5-86 (REDRAWN 7-01)

SOIL INVESTIGATION TO DETERMINE SUITABILITY OF PROPOSED POND SITE

FARMERS NAME *John M. Doe*
DISTRICT *Greenville*
DATE *May 5, 2020*
COUNTY *Greenville*
NRCS PHOTO SHEET NO. *AX-168-422*
WORK UNIT *Greenville*

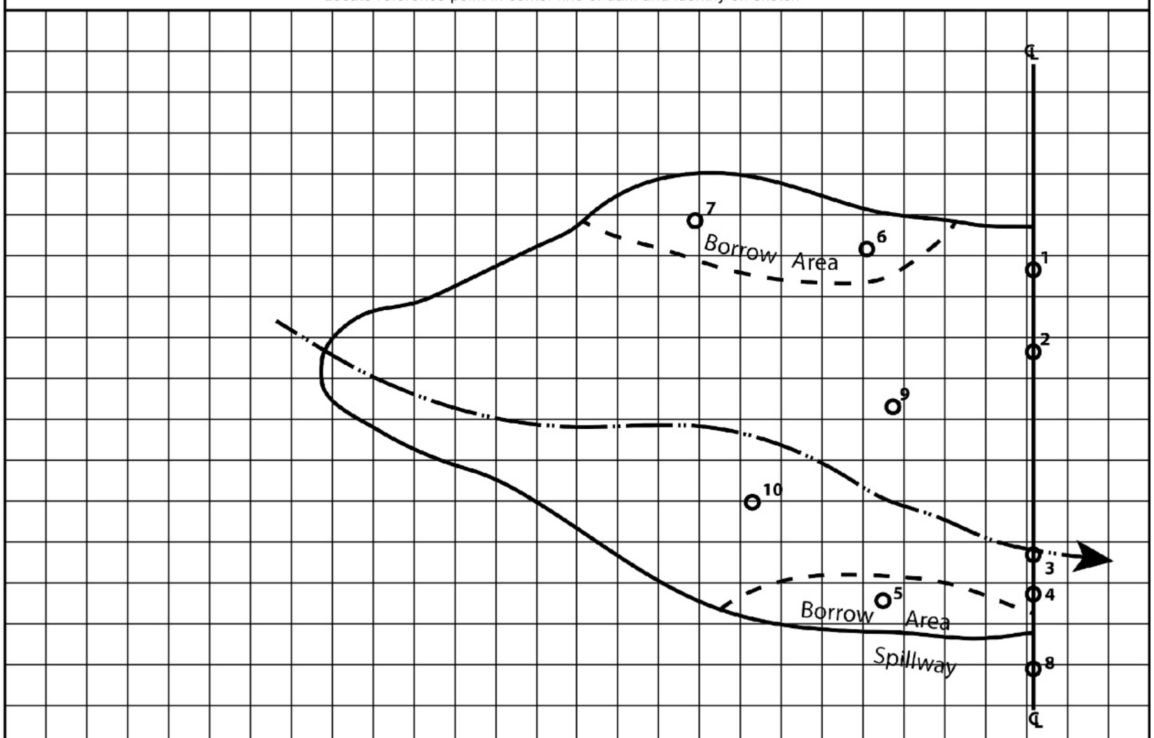
WATERSHED AREA MEASURMENTS

CROPLAND *10* ACRES PASTURE *14* ACRES
WOODLAND *11* ACRES TOTAL *35* ACRES

POND CLASS

H. Smith
WORK UNIT CONSERVATIONIST

SKETCH OF PROPOSED POND SHOWING WHERE BORINGS WERE MADE (Approx. scale 1 in.= ________ft.)
Locate reference point in center line of dam and identify on sketch



BORING NUMBER AND PROFILE
Make and list dam - site and spillway borings firt - then ponded area and borrow pit borings - separate with vertical red line.
(Continued on back where necessary) Show water table elevations on dam - site borings.

SHOW DEPTH SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1.0	sm	sm	ml	sm	sc	sm	sm	sc	ml	ml																
2.0	cl	sm	ml	cl	sc	cl	sm	sc	sm	ml																
3.0	cl	sm	sm	cl	sc	cl	sm	sc	sm	ml																
3.5	ch	cl	sm	cl	sm	cl	cl	sm	sm	sm																
4.0	ch	cl	cl	ch	sm	cl	cl	sm	sm	sm																
5.0	ch	cl	cl	ch	cl	ch	cl	cl	ch	cl																
6.0	ch	ch	ch	ch	ch	ch	ch	cl	ch	cl																

BORINGS MADE BY ____________ SIGNATURE AND TITLE ____________

Figure 11-22: Soil Investigation Form - continued

NRCS-ENG-538
(CONTINUATION)

TYPES OF MATERIAL ENCOUNTERED IN BORINGS
(USE ONE OF THE SYSTEMS BELOW)

UNIFIED CLASSIFICATION

GW - Well graded gravel; gravely sand mix
GP - Poorly graded gravels
GM - Silty gravels; gravel-sand-silt mix
GC - Clayey gravels; gravel-sand-clay mix
SW - Well grsded sands; sand -gravel mix
SP - Poorly graded sands
SM - Silty sand
SC - Clayey sands; sand-clay mixtures
ML - Silt; silty, v. fine sands; sandy or clayey silt
CL - Clays of low to medium plasticity
CH - Inorganic clays of high plasticity
MH - Inorganic Silts with high plasticity
OL - Organic silts and silty clays, low plasticity
OH - Organic clays, medium to high plasticity

USDA CLASSIFICATION

g - gravel
s - sand
vfs - very fine sand
sl - sandy loam
fsl - fine sandy loam
l - loam
gl - gravely loam
si - silt
sil - sillt loam
cl - clay loam
sicl - silty clay loam
scl - sandy clay loam
sic - silty clay
c - clay

1. Suitable material for embankment is available [X] YES [ ] NO (Indicate where located on the sketch on reverse side)

REMARKS:

Material in borrow areas and spillway area is suitable for embankment fill

2. Explain hazards requiring special attention in design (Seepage, spring, rock, etc.)

Clean out old channel to good material. This should extend for its entire length under the embankment. Backfill with material from borrow area, and compact as required for maximum density.

GENERAL REMARKS:

Site is satisfactory for stock water pond.

27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54

650.1107 Auxiliary Spillways

A. An auxiliary spillway is an earth or a vegetated channel, usually designed to discharge flow in excess of the principal spillway design discharge. Where watersheds are small and long duration flows are not a problem, it may be feasible to handle the runoff safely with only a vegetated spillway.

B. Auxiliary spillways, as discussed here, apply to both the vegetated and non-vegetated spillways, the latter being used where climatic or soil conditions make it impossible to grow or maintain a suitable grass cover. Emergency spillways are usually excavated but may exist as a natural spillway such as natural draw, saddle or drainageway. In either case the spillway must discharge the design peak flow at a non-erosive velocity to a safe point of release. Ordinarily, emergency spillways, whether vegetated or non-vegetated, should not be built on fill material.

C. Soil borings generally are required for auxiliary spillways if a natural site with good plant cover is available. If spillway excavation is required, the investigations should be thorough enough to determine whether the soils can withstand reasonable velocities without serious erosion. Avoid loose sands and other highly erodible soils.

D. Design Spillway Capacity

(1) Auxiliary spillways should have the minimum capacity to discharge the peak flow expected from a design storm of the frequency and duration required by the appropriate conservation practice standard less any reduction creditable to conduit discharge and detention storage. Figure 11-23 show the minimum design storm and frequency. The procedure for determining peak flood flow is presented in 210-NEH-650-2, “Estimating Runoff Volume and Peak Discharge”.

Figure 11-23: Minimum Auxiliary Spillway Capacity

Minimum design storm[2]							
Drainage area		**Effective height of dam[1]**		**Detention storage**		**Frequency**	**Minimum duration**
(acre)	(hectare)	(feet)	(m)	(acre-feet)	(*dam^3)	*(years)*	*(hours)*
≤ 20	≤ 8	≤ 20	≤ 6	< than 50	<60	10	24
≤ 20	≤ 8	> 20	> 6	< than 50	<60	25	24
> 20	> 8	≤ 20	≤ 6	< than 50	<60	25	24
All others		-		-		50	24

1 Defined under “Conditions where Practice Applies.”

2 Select rain distribution based on climatological region.

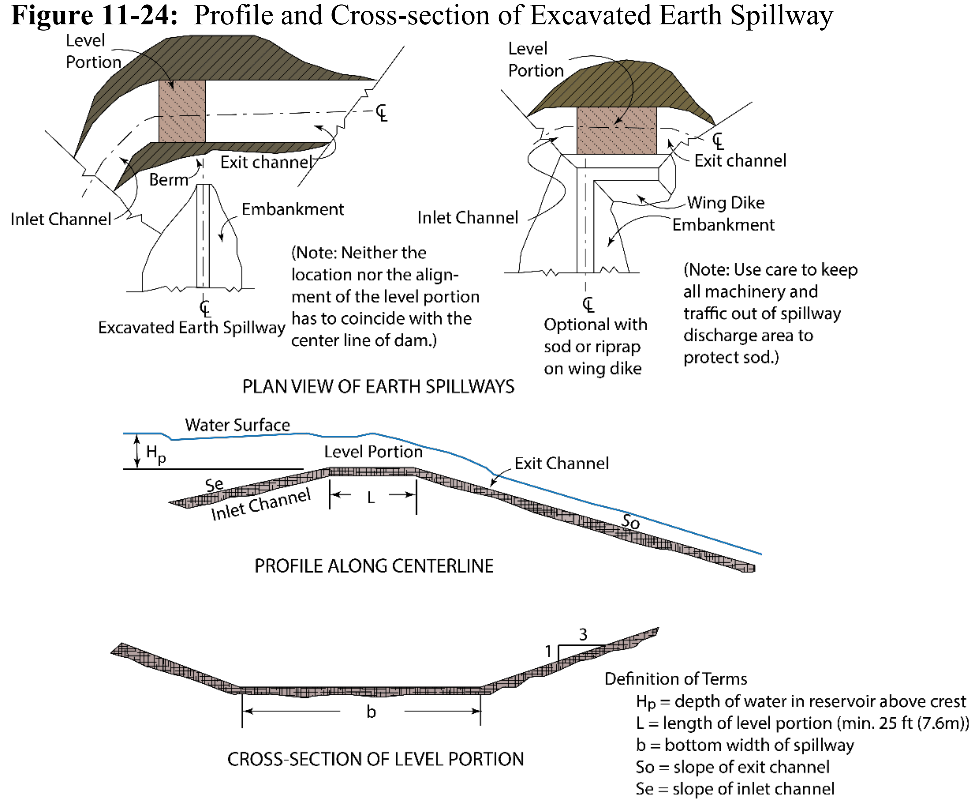
* dam^3 (cubic dekameter) = 1,000 m^3

E. Excavated Spillways

(1) Elements of Excavated Spillways

(i) Excavated spillways consist of the three elements shown in figure 11-24. These are inlet channel, level portion, and exit channel. Each element has a special function. The flow enters the spillway through the inlet channel. The depth of flow H_p located upstream from the level portion is controlled by the inlet channel, level portion, and exit channel. The flow is controlled in the level portion and then discharged through the exit channel. Flow in the exit channel can be either subcritical, critical, or super critical.

Figure 11-24: Profile and Cross-section of Excavated Earth Spillway



(ii) Excavation of the inlet channel. or the exit channel, or both, may be omitted where the natural slopes meet the minimum slope requirements. The direction of slope of the exit channel must be such that discharge will not flow against any part of the dam. Wing dikes, sometimes called kicker levees or training levees, may be used to direct the outflow to a safe point of release.

(iii) The spillway should be excavated into original earth for the full design depth. Where this is not practical, the end of the dam and any earthfill constructed to confine the flow should be protected by vegetation or riprap. It is desirable that the entrance to the inlet channel be widened so it is at least 50 percent greater than the design bottom width of the level portion. The inlet channel should be reasonably short and should be planned with smooth, easy curves for alignment. It should have a slope toward the reservoir of not less than 2.0 percent, except in rock, to insure drainage and Low inlet losses.

(iv) The level portion should be located near the intersection of the extended centerline of the dam with the centerline of the spillway and have a length of at least 25 feet (7.5 meters).

(v) The exit channel must have a slope that is adequate to discharge the peak flow within the channel. The slope, however, must be no greater than that which will result in maximum permissible velocities for the soil type or the planned grass cover. The exit channel should be straight and should confine the outflow to a point where the water may be released without damages to the fill.

(2) Selecting Spillway Dimensions

(i) With the required discharge capacity, the degree of retardance, permissible velocity, and the natural slope of the exit channel known, the bottom width of the level and exit sections and the depth of the flow (H_p) may be computed. The natural slope of the channel should be altered as little as possible. For dams having an effective height of 20 feet or require a minimum of 10-foot bottom width for auxiliary spillways.

(ii) The selection of the degree of retardance for a given spillway will depend mostly upon the height and density of the cover chosen (fig. 11-25). Generally, after the cover is selected, the retardance with a good uncut condition will. be the one to use for capacity determination. Since a condition offering less protection and less retardance exists during the establishment period and after mowing, it may be advisable to use a lower degree of retardance when designing for stability.

Figure 11-25: Guide to Selection of Vegetal Retardance

Stand	**Average length of vegetation, inches (cm)1**	**Degree of retardance**
Good	Higher than 30 (76)	A
	11 to 24 (28 to 61)	B
	6 to 10 (15 to 25)	C
	2 to 6 (5 to 15)	D
	Less than 2 (5)	E
Fair	Higher than 30 (76)	B
	11 to 24 (28 to 61)	C
	6 to 10 (15 to 25)	D
	2 to 6 (5 to 15)	D
	Less than 2 (5)	E

[1] SI units in ()

(iii) When the anticipated average rise of a spillway is more frequent than once in 5 years, the maximum permissible velocities shall be in accordance with figure 11-26 for vegetated spillways and figure 11-27 for earth spillways. For vegetated spillways only, the maximum permissible velocity may be increased 10 percent when the anticipated average use is not more frequent than once in 5 years or 25 percent when the anticipated average use is not more frequent than once in 10 years.

Figure 11-26: Permissible Velocities for Vegetated Spillway[1] Vegetation

	Permissible velocity2							
	Erosion resistance3 soils				Easily erodible4 soils			
	Slope of exit channels (%)							
	0–5		5–10		0–5		5–10	
	ft/s	m/s	ft/s	m/s	ft/s	m/s	ft/s	m/s
Bermuda grass Bahia grass	8	2.4	7	2.1	6	1.8	5	1.5
Buffalo grass Kentucky bluegrass Smooth bromegrass tall fescue Reed Canary grass	7	2.1	6	1.8	5	1.5	4	1.2
Sod forming grass-legume mixtures	5	1.5	4	1.4	4	1.2	3	0.9
Lespedeza sericea Weeping love grass Yellow bluestem Native grass mixtures	3.5	1.1	3.5	1.1	2.5	0.8	2.5	0.8

1. SCS-TP-61
2. Increase values 10 percent when the anticipated average use of the spillway is not more frequent than once in 5 years or 25 percent when the anticipated average use is not more frequent than once in 10 years.
3. Those with a higher clay content and higher plasticity. Typical soil textures are silty clay, sandy clay, and clay.
4. Those with a high content of fine sand or silty and lower plasticity or - non-plastic. Typical soil textures are fine sand, silt, sandy loam, and silty loam.

Figure 11-27: Permissible Velocities for Earth Spillways[1]

Original materials excavated	**Feet/second[2]**	**Meters/second[2]**
Fine sand, non-colloidal	1.50	0.46
Sandy loam, non-colloidal	1.75	0.53
Silt loam, non-colloidal	2.00	0.61
Alluvial silts, non-colloidal	2.00	0.61
Ordinary firm loam	2.50	0.76
Volcanic ash	2.50	0.76
Fine gravel	2.50	0.76
Stiff clay, very colloidal	3.75	1.14
Graded, loam to cobbles, non-colloidal	3.75	1.14
Alluvial silts, colloidal	3.75	1.14
Graded, silt to cobbles, colloidal	4.00	1.22
Coarse gravel, non-colloidal	4.00	1.22
Cobbles and shingles	5.00	1.52
Shales and hardpans	6.00	1.83

1. From TR No. 60 Earth Dams and Reservoirs, Oct 1985
2. Values shown apply to clear water, no detritus

(iv) Water surface profiles were calculated by computer for all the anticipated spillway conditions and based on the retardances described in SCS TP-61. Critical slope and depth proved to be of minor importance in setting H_p, so figures 11-28 through 32 were developed from the water surface profiles and will carry the design flow as shown. Figures 11-28 through 32 give minimum and maximum slope requirements for the various discharges q, velocities V, and retardance given.

(v) Some velocities in figures 11-28 through 32 show different discharges in ft /s/ft (m /s/m) for the same H_p values. The H_p values are set to ensure design q at the minimum slope, but velocities at minimum slope may not reach maximum velocity. The maximum velocity will only be achieved where the exit channel is at maximum slope. Rounding is also part of the reason. Figures 11-28 through 32 are not appropriate for bottom widths less than 8 feet (2.4 m). Figure 11-32 should be used for earth spillways.

Figure 11-28: H_p and Slope Range for Discharge, Velocity, and Crest Length, Retardance A

Max velocity V		Discharge per unit width q		H_p Crest length (L)								Slope range	
				25 ft	7.6m	50 ft	15.3 m	100 ft	30.5 m	200 ft	61 m	Min	Max
ft/s	m/s	ft^3/s	m^3/s	ft	m	ft	m	ft	m	ft	m	(%)	(%)
3	0.9	3	0.28	2.3	0.70	2.5	0.76	2.7	0.76	3.1	0.94	1	11
4	1.2	4	0.37	2.3	0.70	2.5	0.76	2.8	0.76	3.1	0.94	1	12
4	1.2	5	0.46	2.5	0.75	2.6	0.79	2.9	0.79	3.2	0.98	1	7
5	1.5	6	0.56	2.6	0.79	2.7	0.83	3.0	0.83	3.3	1.01	1	9
6	1.8	7	0.65	2.7	0.82	2.8	0.85	3.1	0.85	3.5	1.07	1	12
7	2.1	10	0.92	3.0	0.91	3.2	0.98	3.4	0.98	3.8	1.16	1	9
8	2.4	12.5	1.16	3.3	1.01	3.5	1.07	3.7	1.07	4.1	1.25	1	10

Figure 11-29: H_p and Slope Range for Discharge, Velocity, and Crest Length, Retardance B

Max velocity V		Discharge per unit width q		H_p Crest length (L)								Slope range	
				25 ft	7.6m	50 ft	15.3 m	100 ft	30.5 m	200 ft	61 m	Min	Max
ft/s	m/s	$ft^3/$	m^3/s	ft	m	ft	m	ft	m	ft	m	(%)	(%)
2	0.6	1	0.09	1.2	0.37	1.4	0.43	1.5	0.46	1.8	0.55	1	12
2	0.6	1.25	0.116	1.3	0.39	1.4	0.43	1.6	0.49	1.9	0.58	1	7
3	0.9	1.5	0.14	1.3	0.39	1.5	0.46	1.7	0.52	1.9	0.58	1	12
3	0.9	2	0.19	1.4	0.43	1.5	0.46	1.7	0.52	1.9	0.58	1	8
4	1.2	3	0.28	1.6	0.48	1.7	0.52	1.9	0.58	2.2	0.67	1	9
5	1.5	4	0.37	1.8	0.55	1.9	0.58	2.1	0.64	2.4	0.73	1	8
6	1.8	5	0.46	1.9	0.58	2.1	0.64	2.3	0.70	2.5	0.76	1	10
7	2.1	6	0.56	2.1	0.64	2.2	0.67	2.4	0.73	2.7	0.82	1	11
8	2.4	7	0.65	2.2	0.67	2.4	0.73	2.6	0.79	2.9	0.88	1	12

Figure 11-30: H_p and Slope Range for Discharge, Velocity, and Crest Length, Retardance C

Max velocity V		Discharge per unit width q		H_p Crest length (L)								Slope range	
				25 ft	7.6m	50 ft	15.3 m	100 ft	30.5 m	200 ft	61 m	Min	Max
ft/s	m/s	ft³/s	m³/s	ft	m	ft	m	ft	m	ft	m	(%)	(%)
2	0.6	0.5	0.046	0.7	0.21	0.8	0.24	0.9	0.27	1.1	0.34	1	6
2	0.6	1	0.09	0.9	0.27	1.0	0.30	1.2	0.34	1.3	0.40	1	3
3	0.9	1.25	0.116	0.9	0.27	1.0	0.30	1.2	0.37	1.3	0.40	1	6
4	0.9	1.5	0.14	1.0	0.30	1.1	0.34	1.2	0.37	1.4	0.43	1	12
4	1.2	2	0.19	1.1	0.34	1.2	0.37	1.4	0.43	1.6	0.49	1	7
5	1.5	3	0.28	1.4	0.37	1.4	0.43	1.6	0.49	1.8	0.55	1	6
6	1.8	4	0.37	1.5	0.43	1.6	0.49	1.8	0.55	2.0	0.61	1	12
8	2.4	5	0.46	1.7	0.49	1.8	0.55	2.0	0.61	2.2	0.67	1	12
9	2.7	6	0.56	1.8	0.55	2.0	0.61	2.1	0.64	2.4	0.73	1	12
9	2.7	7	0.65	2.0	0.61	2.1	0.64	2.3	0.70	2.5	0.76	1	10
10	3.0	7.5	0.70	2.1	0.64	2.2	0.67	2.4	0.73	2.6	0.79	1	12

Figure 11-31: H_p and Slope Range for Discharge, Velocity, and Crest Length, Retardance D

Max velocity V		Discharge per unit width q		H_p Crest length (L)								Slope range	
				25 ft	7.6m	50 ft	15.3 m	100 ft	30.5 m	200 ft	61 m	Min	1008BMax
ft/s	m/s	ft³/s	m³/s	ft	m	ft	m	ft	m	ft	m	(%)	(%)
2	0.6	0.5	0.046	0.6	0.18	0.7	0.21	0.8	0.24	0.9	0.27	1	6
3	0.9	1	0.09	0.8	0.24	0.9	0.27	1.0	0.31	1.1	0.34	1	6
3	0.9	1.25	0.116	0.8	0.24	0.9	0.27	1.0	0.31	1.2	0.37	1	4
4	1.2	1.25	0.116	0.8	0.31	0.9	0.27	1.0	0.31	1.2	0.37	1	10
4	1.2	2	0.19	1.0	0.37	1.1	0.34	1.3	0.40	1.4	0.43	1	4
5	1.5	2.5	0.14	0.9	0.34	1.0	0.31	1.2	0.37	1.7	0.40	1	12
5	1.5	2	0.19	1.0	0.37	1.2	0.37	1.3	0.40	1.5	0.43	1	9
5	1.5	3	0.28	1.2	0.37	1.3	0.40	1.5	0.46	1.7	0.52	1	4
6	1.8	2.5	0.23	1.1	0.34	1.2	0.37	1.4	0.43	1.5	0.46	1	11
6	1.9	3	0.28	1.2	0.37	1.3	0.40	1.5	0.46	1.7	0.52	1	7
7	2.1	3	0.28	1.2	0.37	1.3	0.40	1.5	0.46	1.7	0.52	1	12
7	2.1	4	0.37	1.4	0.43	1.5	0.46	1.7	0.52	1.9	0.58	1	7
8	2.4	4	0.37	1.4	0.43	1.5	0.46	1.7	0.52	1.9	0.58	1	12
8	2.4	5	0.46	1.6	0.48	1.7	0.52	1.9	0.58	2.0	0.61	1	8
10	3.0	6	0.56	1.8	0.55	1.9	0.58	2.0	0.61	2.2	0.67	1	12

Figure 11-32: H_p and Slope Range for Discharge, Velocity, and Crest Length, Retardance E

Max velocity V		Discharge per unit width q		H_p Crest length (L)								Slope range	
				25 ft	7.6m	50 ft	15.3 m	100 ft	30.5 m	200 ft	61 m	Min	Max
ft/s	m/s	ft^3/s	m^3/s	ft	m	ft	m	ft	m	ft	m	(%)	(%)
2	0.6	0.5	0.046	0.5	0.15	0.5	0.15	0.6	0.18	0.7	0.21	1	2
3	0.9	0.5	.046	0.5	0.15	0.5	0.15	0.6	0.18	0.7	0.21	1	9
3	0.9	1	0.09	0.7	0.21	0.7	0.21	0.8	0.24	0.9	0.27	1	3
4	1.2	1	0.09	0.7	0.21	0.7	0.21	0.8	0.24	0.9	0.27	1	6
4	1.2	1.25	0.116	0.7	0.21	0.8	0.24	0.9	0.27	1.0	0.31	1	5
5	1.5	1	0.09	0.7	0.21	0.7	0.21	0.8	0.24	0.9	0.27	1	12
5	1.5	2	0.19	0.9	0.27	1.0	0.31	1.1	0.34	1.2	0.37	1	4
6	1.8	1.5	0.14	0.8	0.24	0.9	0.27	1.0	0.31	1.1	0.34	1	12
6	1.8	2	0.19	0.9	0.27	1.0	0.31	1.1	0.34	1.2	0.37	1	7
6	1.8	3	0.28	1.2	0.36	1.2	0.36	1.3	0.40	1.5	0.46	1	4
7	2.1	2	0.19	0.9	0.27	1.0	0.31	1.1	0.34	1.2	0.37	1	12
7	2.1	3	0.28	1.2	0.36	1.2	0.36	1.3	0.40	1.5	0.46	1	7
8	2.4	3	0.28	1.2	0.36	1.2	0.36	1.3	0.40	1.5	0.46	1	10
8	2.4	4	0.37	1.4	0.43	1.4	0.43	1.5	0.46	1.7	0.52	1	6
10	3.0	4	0.37	1.4	0.43	1.4	0.43	1.5	0.46	1.7	0.53	1	12

(vi) Spillway side slopes should be no steeper than 3:l unless the spillway is excavated into rock, in which case the side slopes may be vertical.

(vii) Usually the selected bottom width of the channel should not exceed 35 times the design depth of flow. Where this ratio of bottom width to depth is exceeded, the channel is likely to be damaged by meandering flow and accumulated debris. Whenever the required bottom width of the spillway is excessive, consideration should be given to the use of a spillway at each end of the dam. These two spillways need not be of equal width so long as their total capacity meets requirements. In cases where the required discharge capacity exceeds, the ranges shown in the figures 11-28 through 11-32, or topographic conditions will not permit the construction of the exit channel bottom with a slope that falls within the ranges shown in figures 11-28 through 11-32, the design is beyond the scope of this manual.

(viii) To use figures 11-29 through 11-32, use the following example

- Given:

  $Q = 87\ ft^3/s$ (Determined from 210-NEH-650-2)
  So = 4% (Determined from profile or to be excavated)
  L = 50 ft

  Spillway to be excavated in an erosion resistant soil and planted to a sod forming grass-legume mixture. After establishment, a good stand averaging from 6 to 10 inches in height is expected.

- Find:

  Permissible Velocity (V), bottom width of spillway (b) and depth of water in the reservoir above the crest (H_p)

- Solution:
  From figure 11-26 using sod forming grass-legume mixtures the permissible velocity, V = 5fps. From figure 11-25 average length of vegetation 6 to 10 inches select Retardance C. Use same retardance for both capacity and stability.
  For C Retardance enter figure 11-30 from left at maximum velocity of V = 5fps, 4% slope is in the slope range of 1-6 with q of 3fps/ft. Then

$$b = \frac{Q}{q} = \frac{87\ cfs}{3cfs/ft} = 29ft$$

  From figure 11-30 read H_p for L of 50 ft as 1.4 ft

  The results are displayed in figure 11-33

Figure 11-33: Sample Form for Recording Solution to Example Where One Retardance is Used for Stability and Capacity

Erosion resistance soil: Yes No
Cover type: Grass-legume mixture
Condition: good
Height: 6 to 10 inches
Slope: 4%

Q (cfs)	V_{max} (fps) (fig. 11-26)	Retardance (fig 11-25) stability	capacity	L (ft.)	q (cfs/ft)	B (ft) stability	H_p (ft) capacity	S_o (%) Slope range Min	Max
87	5	C	C	50	3	29	1.4	1	6

(ix) See Appendix 11A for a method to determine principal spillway discharge requirements adjusted for temporary storage provided in the reservoir. Emergency spillway design flow may be adjusted to consider the outflow through the principal spillway.

F. Natural Spillways

(1) Many times, large expanses of good sod are destroyed to provide the minimum slopes for an excavated spillway. This may increase the construction cost and will increase maintenance costs. Wherever there is a good vegetative cover in the spillway area and the topography suitable, consideration should be given to the use of a natural spillway. The discharge capacity can be computed by the following procedures.

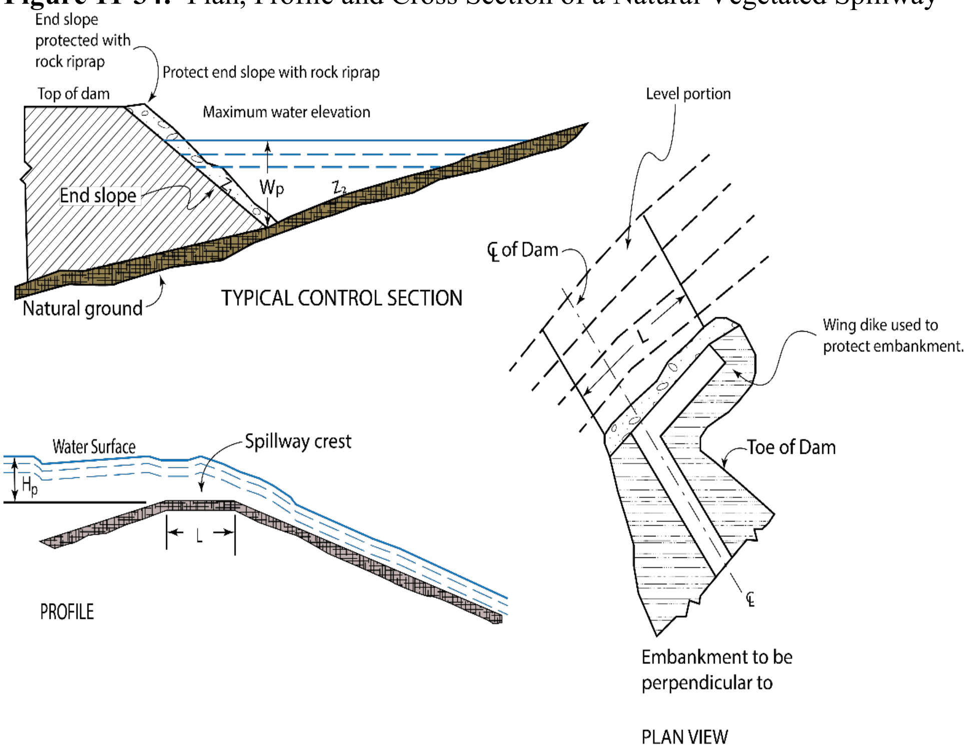
(2) Discharge through Natural Vegetated Spillways

(i) In a natural spillway the outflow takes place around the end of the embankment on natural or undisturbed ground. The number of possible cross sections and profile shapes is so great that an analysis here of the rate of flow for each condition is impractical.

(ii) In most cases the level portion of the flow route will be V-shaped, one side determined by the embankment end slope and wing dike, and the other by the natural ground. The ground slope should be determined along a line perpendicular to the contour direction within the flow depth range. See figure 11-34.

(iii) The end of the dam should be approximately perpendicular to the contours of the abutment. A short wing dike may be used to protect the toe of the embankment. The exit slope away from the control section should be within the slope ranges given in figure 11-35 and 36.

Figure 11-34: Plan, Profile and Cross Section of a Natural Vegetated Spillway



(iv) Discharge (Q), velocity (V) and depth of water in the reservoir above the crest (H_p), were determined using water surface profiles calculated by computer. The spillway was segmented into 2-foot (0.6-meter) segments, then using data from water surface profiles a discharge for each segment was determined for a specific depth, length of flow, and retardance. Total Q is the sum of the discharges of each segment. Figure 11-35 and 36 was then developed using the given parameters.

H. Determining the Maximum Water Elevation in Reservoir

(1) With the required discharge capacity (Q), the end slope of the embankment (Z_1), and the slope of the natural ground (Z_2), known; the maximum depth of water above the level portion (H_p), can be obtained from Figure 11-35 and 36. The depth is added to the elevation of the spillway crest to determine the maximum elevation to which water will rise in the reservoir.

Figure 11-35: H_p Discharge through Natural Vegetated Spillways with 3:1 End Slope Z1 (English units)

Natural Ground Slope Z_2	H_p	Retardance A		Retardance B		Retardance C		Retardance D		Retardance E		Slope	
		Q	V	Q	V	Q	V	Q	V	Q	V	Min	Max
(%)	ft	ft^3/s	ft/s	ft^3/s	ft/s	ft^3/s	ft/s	ft^3/s	ft/s	ft^3/s	ft/s	(%)	(%)
0.5	1.0	19	0.3	28	0.5	47	1.3	68	1.8	130	2.8	0.5	0.5
	1.1	21	0.3	35	0.5	76	1.5	108	2.1	154	3.0		
	1.2	29	0.4	39	0.6	97	1.6	122	2.3	204	3.2		
	1.3	36	0.4	53	0.6	125	2.0	189	2.5	250	3.4		
	1.5	61	0.4	87	1.1	210	2.2	291	2.9	393	3.8		
	1.8	81	0.5	187	1.8	384	2.9	454	3.5	651	4.5		
	2.0	110	0.5	286	2.1	524	3.3	749	3.8	860	4.8		
1	1.0	10	0.4	16	0.5	31	2.0	45	2.6	64	3.4	1	1
	1.1	13	0.4	18	0.6	50	2.3	63	2.8	90	3.7		
	1.2	15	0.5	21	0.8	62	2.5	78	3.1	99	4.0		
	1.3	22	0.6	39	1.0	86	2.7	144	3.4	139	4.3		
	1.5	40	0.7	75	1.8	133	3.1	186	4.0	218	5.1		
	1.8	56	0.8	126	2.3	288	3.8	296	4.5				
	2.0	98	1.1	184	2.8	328	4.3	389	5.0				
	2.5	171	1.2	472	4.1	680	5.4						
2	1.0	6	0.5	9	0.8	18	2.5	27	3.3	36	4.2	1	2
	1.1	7	0.7	14	1.0	29	2.8	39	3.6	50	4.5		
	1.2	9	0.8	19	1.1	40	3.1	51	3.9	64	4.9		
	1.3	13	0.9	26	1.6	50	3.4	70	4.3	85	5.3		
	1.5	21	1.0	39	2.0	70	3.9	109	5.1	127	6.3		
	1.8	26	1.1	74	2.5	126	4.8	194	5.9				
	2.0	52	1.3	111	3.2	190	5.4	229	6.4				
	2.5	88	2.8	248	5.2	339	6.8						
3	1.0	4	0.7	7	0.8	15	2.8	21	3.7	28	4.8	1	3
	1.1	5	0.5	10	0.9	24	3.2	31	4.0	38	5.2		
	1.2	7	0.9	14	1.1	33	3.6	41	4.4	49	5.6		
	1.3	10	1.0	20	1.5	42	3.8	57	4.8	67	6.1		
	1.5	16	1.2	34	2.8	62	4.4	89	5.7	104	7.2		
	1.8	23	1.3	57	3.0	112	5.5	143	6.7				
	2.0	39	1.5	81	3.7	163	6.2	194	7.2				
	2.5	85	3.1	212	6.0	300	7.8						
4	1.0	6	1.0	11	1.4	25	3.9	31	4.8	38	6.1	1	4
	1.5	15	1.3	29	3.1	49	4.8	69	5.5	81	7.9		
	1.8	20	1.4	47	4.1	98	6.1	116	7.3				
	2.0	30	1.6	65	4.7	139	6.7	161	7.8				
	2.5	72	3.3	167	6.6	238	8.5						
5	1.5	13	1.4	23	3.3	38	5.2	55	6.7	63	8.4	1	5
	1.8	17	1.5	37	4.4	76	6.5	95	7.9				
	2.0	23	1.7	48	5.1	112	7.1	130	8.1				
	2.5	64	3.7	149	7.1	191	9.2						

Figure 11-36: Discharge through Natural Vegetated Spillways with 3:1 End Slope Z1(SI units)

Natural ground Slope Z2		Retardance											
		A		B		C		D		E		Slope	
	Hp	Q	V	Q	V	Q	V	Q	V	Q	V	Min	Max
(%)	m	m3/s	m/s	m3/s	m/s	m3/s	m/s	m3/s	m/s	m3/s	m/s	(%)	(%)
0.5	0.30	0.54	0.09	0.79	0.15	1.44	0.40	1.93	0.55	3.68	0.85	0.5	0.5
	0.33	0.59	0.09	0.99	0.15	2.15	0.46	3.06	0.64	4.36	0.91		
	0.36	0.82	0.12	1.10	0.18	2.75	0.49	3.45	0.70	5.78	0.97		
	0.40	1.02	0.12	1.50	0.18	3.54	0.60	5.35	0.76	7.08	1.04		
	0.46	1.73	0.12	2.46	0.33	5.95	0.67	8.24	0.88	11.13	1.16		
	0.55	2.29	0.12	5.30	0.55	10.87	0.88	12.85	1.07	18.43	1.37		
	0.61	3.11	0.15	8.10	0.64	14.84	1.01	21.21	1.16	24.35	1.46		
1	0.30	0.28	0.12	0.45	0.15	0.88	0.61	1.27	0.79	0.81	1.04	1	1
	0.33	0.35	0.12	0.51	0.18	1.42	70	1.78	85	2.50	1.13		
	0.36	0.42	0.15	0.59	0.24	1.76	0.76	2.21	0.95	2.80	1.22		
	0.40	0.62	0.18	1.10	0.30	2.43	0.82	3.23	1.04	3.94	1.31		
	0.46	1.13	0.21	2.12	0.55	3.77	0.95	5.27	1.22	6.17	1.55		
	0.55	1.58	0.24	3.57	0.70	7.93	1.16	8.38	1.37				
	0.361	2.78	0.33	5.21	0.85	9.29	1.31	11.02	1.52				
	0.76	4.84	0.76	13.36	1.25	19.26	1.65						
2	0.30	0.17	0.15	0.25	0.24	0.51	0.76	0.76	1.01	1.12	1.28	1	2
	0.33	0.20	0.21	0.40	0.30	0.82	0.85	1.10	1.10	1.42	1.37		
	0.36	0.26	0.24	0.54	0.34	1.13	0.94	1.44	1.19	1.81	1.49		
	0.40	0.37	0.27	0.74	0.49	1.42	1.04	1.98	1.31	2.41			
	0.46	0.59	0.30	1.10	0.61	1.98	1.19	3.09	1.55	3.60			
	0.55	0.74	0.34	2.09	0.76	3.57	1.46	5.49	1.80				
	0.61	1.47	0.40	3.14	0.98	5.38	1.65	6.48	1.98				
	0.76	2.49	0.85	6.74	1.58	9.60	2.07						
3	0.30	0.11	0.21	0.20	0.24	0.43	0.85	0.59	1.13	0.79	1.46	1	3
	0.33	0.14	0.24	0.28	0.27	0.68	0.97	0.88	1.22	1.08	1.58		
	0.36	0.20	0.27	0.40	0.33	0.93	1.10	1.16	1.34	1.39	1.71		
	0.40	0.28	0.30	0.56	0.46	1.19	1.16	1.61	1.46	1.90	1.86		
	0.46	0.45	0.37	0.96	0.85	1.76	1.34	2.52	1.74	1.94	2.19		
	0.55	0.65	0.40	1.61	0.91	3.17	1.68	4.05	2.04				
	0.61	1.10	0.46	2.29	1.13	4.62	1.89	5.49	2.19				
	0.76	2.41	0.95	6.00	1.83	8.50	2.38						
4	0.30	0.17	0.30	0.31	0.43	0.71	1.19	0.88	1.46	1.08	1.86	1	5
	0.46	0.43	0.40	0.82	0.94	1.39	1.46	1.95	1.68	2.29	2.41		
	0.55	0.57	0.43	1.33	1.24	2.78	1.86	3.28	2.23				
	0.61	0.85	0.49	1.84	1.43	3.94	2.04	4.56	2.38				
	0.76	2.04	1.01	4.73	2.01	6.74	2.59						
5	0.46	0.37	0.43	0.65	1.01	1.08	1.59	1.56	2.04	1.78	2.56	1	5
	0.55	0.48	0.46	1.05	1.34	2.15	1.98	2.69	2.41				
	0.61	0.65	0.52	1.36	1.55	3.17	2.16	3.68	2.47				
	0.76	1.81	1.13	4.22	0.16	5.41	2.80						

(2) Figure 11-35 and 36 were developed for an end slope of 3:l and natural ground slopes of 1 to 5 percent. An example showing the use of figure 11-35 is as follows:

English units	**SI units**
Given	Given:
Q = 86 ft3/s (From Chapter 2)	Q = 2.43 m /a (From Chapter 2)
Vegetation: Bermuda grass Good Stand	Vegetation: Bermuda grass Good Stand
Height: 6 to 10 inches	Height: -15 to 25 cm
Slope of Natural Ground 1.0%	Slope of Natural Ground 1.0%
Solution:	Solution:
From figure 11-23:	From figure 11-23:
Determine a Retardance of C	Determine a Retardance of C
From figure 11-32:	From figure 11-33:
Enter under Z_2 slope 1%	Enter under Z_2 slope 1%
Under Retardance C column	Under Retardance C column
find a Q = 86 ft^3/s	find a Q = 2.43 m^3/s
at H_p = 1.3 ft and	at H_p = 0.40 m and
V = 2.7 f/s	V = 0.82 m/s

(3) Velocity is well below the maximum permissible velocity of 8 ft/s (2.4 m/s) given in figure 11-26. H_p can be determined by interpolation when necessary. For a Q greater than listed in figure 11-35 and 36, the spillway should be excavated according to the information in the Excavated Auxiliary Spillways section.

(4) With the required discharge capacity (Q), the end slope of the embankment (Z_1), and the slope of the natural ground (Z_2) known, the maximum depth of water above the level portion (H_p) can be obtained from figure 11-35 or 36. The depth is added to the elevation of the spillway crest to determine the maximum elevation to which water will rise in the reservoir.

J. Protection Against Erosion

Earth spillways should be protected against erosion by a good vegetal cover, if soil and climate permit. As soon after construction as is practical, the entire spillway area should be thoroughly prepared for seeding or sodding. Liberal amounts of fertilizer should be used where moisture is available or can be applied. In cases where the subsoil is low in fertility, it may be desirable to save the topsoil and spread it in the excavated spillway. Adapted perennial grasses or perennial grasses and legumes should be sown, protected, and treated until a good stand has been established. Mulching is usually necessary to protect the seeding on the spillway slopes. Irrigation of the spillway area is often needed to assure adequate germination and growth, particularly when seeding must be done during relatively dry periods. Where the added cost is justified, sprigging or sodding with suitable grasses will afford quick protection.

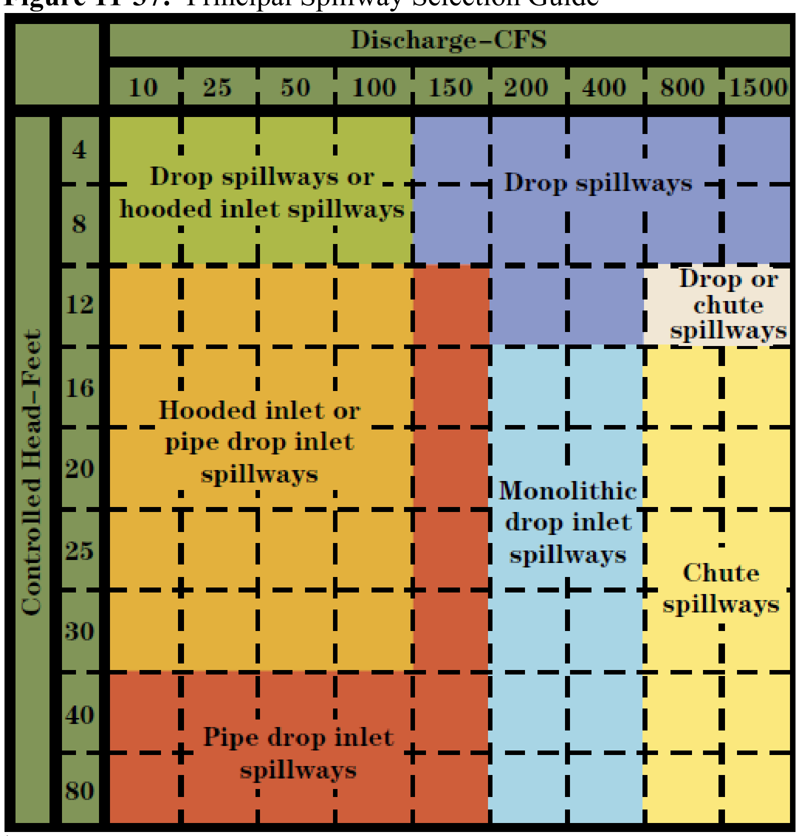
650.1108 Principal Spillways

A. The principal spillway is constructed of permanent material, and usually is designed to provide flood protection or to reduce the frequency of operation of the auxiliary spillway. Its discharge capacity depends upon the purpose of the reservoir and the use for which the spillway is designed. If the reservoir is to be used for retarding flood flow, it discharges a low percentage of the peak flow. At locations where an auxiliary spillway is not feasible the principal spillway should be designed to discharge the runoff for the design storm.

B. The principal spillway normally is sized to control the runoff from a storm ranging from a 1-year to a 10-year frequency event. This depends on the size of the drainage area. For pond sites where the drainage area is small (less than 20 acres) and the condition of the vegetated spillway is good, no principal spillway is required except where the pond is spring fed or there are other sources of steady baseflow. In this case, a small pipe shall be installed.

C. Several types of structures can be used for principal spillways, such as concrete chutes, pipes and monolithic drop inlets. Different structure types have different abilities to manage water levels precisely or pass high capacity flows. A general guide for water control structure selection based on capacity and structure height is shown in figure 11-37. 210-NEH-650-3, *Hydraulics*, provides tools for analysis and design of water control structures. This chapter will focus on pipe structures, for other types of spillways see 210-NEH-650-6, “Structures”.

Figure 11-37: Principal Spillway Selection Guide[1]



[1] 210-NEH-650-13, “Wetland Restoration, Enhancement, or Creation”, figure 13-36

D. Pipe is either placed under or through the embankment to carry the design storm flow. The crest elevation of the entrance should be 12 inches or more below the top of the control section of the auxiliary spillway based on the inlet head requirement of the outlet.

E. The pipe should be large enough to discharge flow from springs, snowmelt, or seepage. It should also have enough capacity to discharge prolonged surface flow following an intense storm. This rate of flow generally is estimated. If both spring flow and prolonged surface flow can be expected, the pipe should be large enough to discharge both.

F. Commonly the principal spillway may be a hooded or canopy inlet with a straight pipe or may be a drop inlet (vertical section) that has a pipe barrel through the dam. The pipe shall be capable of withstanding external loading with yielding, buckling, or cracking. The pipe joints and all appurtenances need to be watertight. Pipe materials may be smooth metal, corrugated metal, or plastic. Design limitations exist with all materials.

G. A small principal spillway pipe, formerly called a trickle tube, only handles a small amount of flow. Its purpose is to aid in keeping the auxiliary spillway dry during the passage of small storm events.

H. Hooded or canopy inlets are common. A disadvantage of this type inlet is the larger amount of stage (head over the inlet crest) needed to make the pipe flow at full capacity. Conversely, a drop inlet spillway requires less stage because the size of the inlet may be enlarged to make the barrel flow full.

I. Pipe Requirements

(1) Many types of material are available for pipe conduits. Typically, conduits of the following materials are used, ductile iron, welded steel, corrugated steel, corrugated aluminum, reinforced concrete (pre-cast or site-cast), or plastic. Pipe conduits through dams of less than 20 feet total height may also be cast iron or unreinforced concrete.

(2) Pipe conduits need be designed and installed to withstand all external and internal loads without yielding, buckling, or cracking. Positive projecting condition requires rigid pipe in the design. Flexible pipe may be used if the maximum deflection is limited to 5 percent.

(3) All pipe Joints passing through the embankment need to be watertight and remain watertight under all internal and external loading including pipe elongation due to foundation settlement.

(4) If needed a concrete cradle or bedding can be installed to provide improved support for the pipe to reduce or limit structural loading to allowable levels.

(5) If Cantilever outlet sections are used, they need to be designed to withstand the cantilever load. Pipe supports can be used if needed. Other suitable devices such as a Saint Anthony Falls stilling basin, or an impact basin may be used to provide a safe outlet.

(6) In areas that have traditionally experienced pipe corrosion, or in embankments with saturated soil resistivity less than 4000 ohms-cm or soil pH less than 5, the steel pipe and couplings need to be protected against corrosion. Protective coatings can consist of asphalt, polymer over galvanizing, aluminized coating or coal tar enamel as appropriate for the pipe type. Plastic pipe that will be exposed to direct sunlight needs to be ultraviolet-resistant and protected with a coating or shielding, or provisions provided for replacement as necessary.

(7) To retard seepage through the embankment along the outside surface of the pipe, compact the fill around the pipe and use a filter and drainage diaphragm around the pipe like that shown in figure 11-37.

(8) When the effective height of the dam is 15 feet or greater and the effective storage of the dam is 50 acre-ft. or more, use a filter and drainage diaphragm in lieu of anti-seep collars to control seepage on all pipes extending through the embankment to the downstream slope. The diaphragm should be located downstream of the centerline of a homogeneous embankment or downstream of the cutoff trench. The diaphragm should be a minimum of 3 feet thick and extend around the pipe surface a minimum of 2 times the outside diameter of the pipe ($2xD_o$). When a cradle or bedding is used under the pipe, the vertical downward 2Do is measured from the bottom of the cradle or bedding. If bedrock is encountered within the 2Do measurement, the diaphragm should terminate at the bedrock surface. The location of the diaphragm should never result in a minimum soil cover over a portion of the diaphragm measured normal to the nearest embankment surface of less than 2 feet. If this requirement is exceeded, the filter and drainage diaphragm should be moved upstream until the 2-foot minimum is reached. The outlet for the filter and drainage diaphragm should extend around the pipe surface a minimum of 1.5 times the outside diameter of the pipe (1.5Do) that has 1 foot around the pipe being a minimum. For more guidance on design of filter diaphragms use 210-NEH-628-45, “Filter Diaphragms.”

(9) In most cases where the embankment core consists of fine-grained materials, such as sandy or gravely silts and sandy or gravely clay (15 to 85 percent passing the No. 200 sieve), an aggregate conforming to ASTM C-33 fine concrete aggregate is suitable for the filter and drainage diaphragm material. A fat clay or elastic silt (more than 85 percent passing No. 200 sieve) core requires special design considerations, and an engineer experienced in filter design should be consulted.

(10) Using a filter and drainage diaphragm has many advantages. Some are as follows:

- (i) They provide positive seepage control along structures that extend through the fill.
- (ii) Unlike concrete antiseep collars, they do not require curing time.
- (iii) Installation is easy with little opportunity for constructed failure. The construction can consist mostly of excavation and backfilling with the filter material at appropriate locations.

(11) Antiseep collars can be used instead of the filter and drainage diaphragm. Antiseep collars have been used with pipe spillways for many years. More fabricated materials are required for this type of installation. Both types of seepage control are acceptable; in either case, proper installation is imperative.

(12) If an antiseep collar is used, it should extend into the fill a minimum of 24 inches perpendicular to the pipe. If the dam is less than 15 feet high, one antiseep collar at the centerline of the fill is enough. For higher dams, use two or more collars equally spaced between the fill centerline and the upstream end of the conduit when a hood-inlet pipe is used. If a drop-inlet pipe is used, the antiseep collars should be equally spaced between the riser and centerline of the fill.

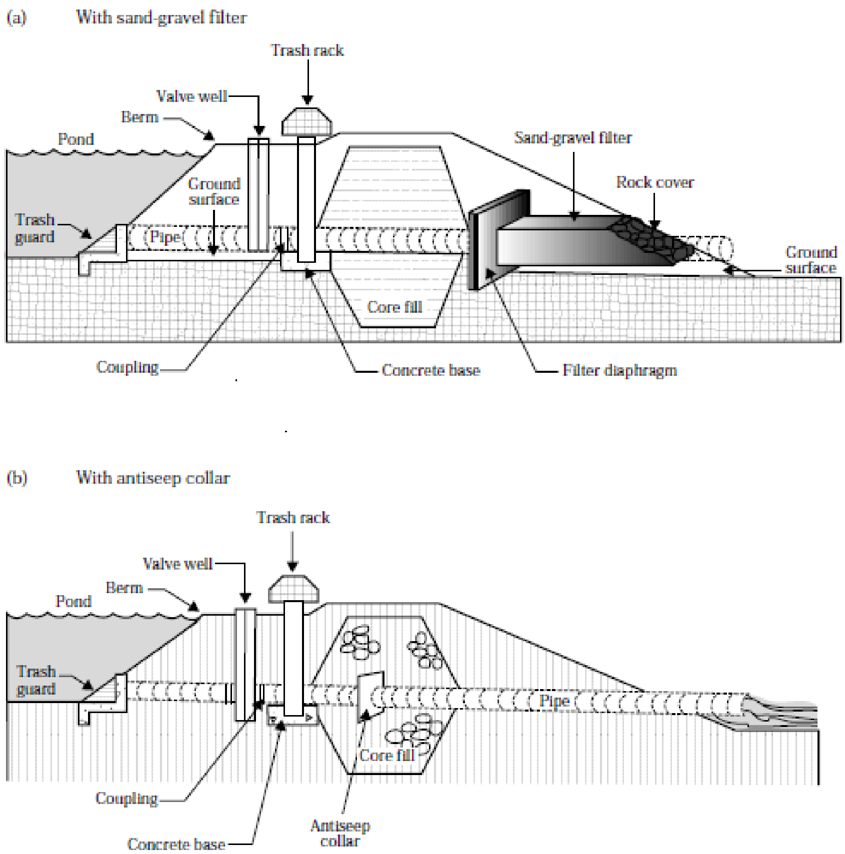
(13) Use trash racks to keep pipes from clogging with trash and debris. Of the many kinds of racks that have been used, the three shown in figure 25 have proved the most successful.

(14) Extend the pipe 6 to 10 feet beyond the downstream toe of the dam to prevent damage by the flow of water from the pipe. For larger pipes, support the extension with a timber brace.

J. Drop Inlet Spillways

(1) One type of principal spillway that is commonly used with farm ponds and reservoirs is the drop inlet spillway. It consists of a pipe barrel located under the embankment with a riser connected to the upstream end. The elevation of the crest of the riser determines the normal pool level in the reservoir. This type of spillway may be used to drain the pond or to supply water for irrigation or other purposes by installing a valve or gate in the upstream end of the barrel (fig. 11-38).

Figure 11-38: Drop Inlet Pipe Spillways



(2) With the required discharge capacity determined, use figure 11-39 or 11-40 to select an adequate pipe size for the barrel and riser. Figure 11-39 is for barrels of smooth pipe, and figure 11-39 is for barrels of corrugated metal pipe. The diameter of the riser must be somewhat larger than the diameter of the barrel if the tube is to flow full. Recommended combinations of barrel and riser diameters are shown in the tables. In these tables the total head is the vertical distance between a point 1 foot above the riser crest and the centerline of the barrel at its outlet end. Small diameter pipes are particularly susceptible to clogging with trash and rodents. For this reason, no barrel smaller than 6 inches in diameter and no riser smaller than 8 inches in diameter should be used. Where the riser is to be constructed of reinforced concrete or concrete block, the inside dimensions should not be smaller than 24 by 24 inches. Typical installations of drop inlet spillways and details of the antivortex device are shown in figure 11-41.

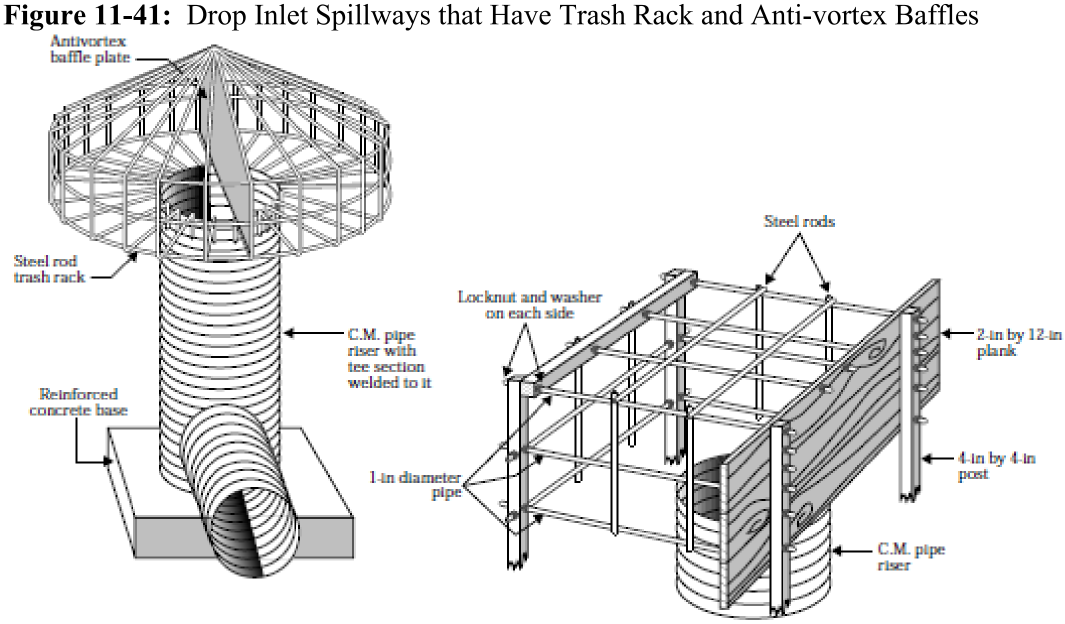
Figure 11-39: Discharge Values for Smooth Pipe Drop Inlets

Total head		Ratio of barrel diameter to riser diameter, inches (mm)											
		6:8	(150:200)	8:10	(200:250)	10:12	(250:300)	12:16	(300:400)	16:24	(400:600)	18:36	(450:900)
ft	(m)	cfs	(cms)	cfs	(cms)	cfs	(cms)	cfs	(cms)	cfs	(cms)	cfs	(cms)
6	1.82	1.54	0.044	3.1	0.088	5.3	0.150	8.1	0.229	13.6	0.385	20.6	0.583
8	2.44	1.66	0.047	3.3	0.093	5.7	0.161	8.9	0.252	14.8	0.419	22.5	0.637
10	3.05	1.76	0.050	3.5	0.099	6.1	0.173	9.6	0.272	15.8	0.447	24.3	0.688
12	3.65	1.86	0.053	3.7	0.105	6.5	0.184	10.2	0.289	16.8	0.476	26.1	0.739
14	4.27	1.94	0.055	3.9	0.110	6.8	0.193	10.7	0.303	17.8	0.504	27.8	0.787
16	4.87	2.00	0.057	4.0	0.113	7.0	0.198	11.1	0.314	18.6	0.527	29.2	0.827
18	5.48	2.06	0.058	4.1	0.116	7.2	0.204	11.5	0.326	19.3	0.547	30.4	0.861
20	6.09	2.10	0.059	4.2	0.119	7.4	0.210	11.8	0.334	19.9	0.564	31.3	0.886
22	6.70	2.14	0.061	4.3	0.122	7.6	0.215	12.1	0.343	20.5	0.580	32.2	0.912
24	7.32	2.18	0.062	4.4	0.125	7.8	0.221	12.4	0.351	21.0	0.595	33.0	0.934
26	7.92	2.21	0.063	4.5	0.127	8.0	0.227	12.6	0.357	21.5	0.609	33.8	0.957

Figure 11-40: Discharge Values for Corrugated Metal Pipe Drop Inlets

Total head		Ratio of barrel diameter to riser diameter, inches (mm)											
		6:8	(150:200)	8:10	(200:250)	10:12	(250:300)	12:16	(300:400)	16:24	(400:600)	18:36	(450:900)
ft	(m)	cfs	(cms)	cfs	(cms)	cfs	(cms)	cfs	(cms)	cfs	(cms)	cfs	(cms)
6	1.82	0.85	0.024	1.73	0.049	3.1	0.088	5.1	0.144	8.8	0.249	14.1	0.399
8	2.44	0.90	0.025	1.85	0.052	3.3	0.093	5.4	0.153	9.4	0.266	15.0	0.425
10	3.05	0.94	0.027	1.96	0.056	3.5	0.099	5.7	0.161	9.9	0.280	15.9	0.450
12	3.65	0.98	0.028	2.07	0.059	3.7	0.105	6.0	0.170	10.4	0.294	16.7	0.473
14	4.27	1.02	0.029	2.15	0.061	3.8	0.108	6.2	0.176	10.8	0.306	17.5	0.496
16	4.87	1.05	0.030	2.21	0.063	3.9	0.110	6.4	0.181	11.1	0.314	18.1	0.513
18	5.48	1.07	0.030	2.26	0.064	4.0	0.113	6.6	0.187	11.4	0.323	18.6	0.527
20	6.09	1.09	0.031	2.30	0.065	4.1	0.116	6.7	0.190	11.7	0.331	18.9	0.535
22	6.70	1.11	0.031	2.34	0.066	4.2	0.119	6.8	0.193	11.9	0.337	19.3	0.547
24	7.32	1.12	0.032	2.37	0.067	4.2	0.119	6.9	0.195	12.1	0.343	19.6	0.555
26	7.92	1.13	0.032	2.40	0.068	4.3	0.122	7.0	0.198	12.3	0.348	19.9	0.564

Figure 11-41: Drop Inlet Spillways that Have Trash Rack and Anti-vortex Baffles

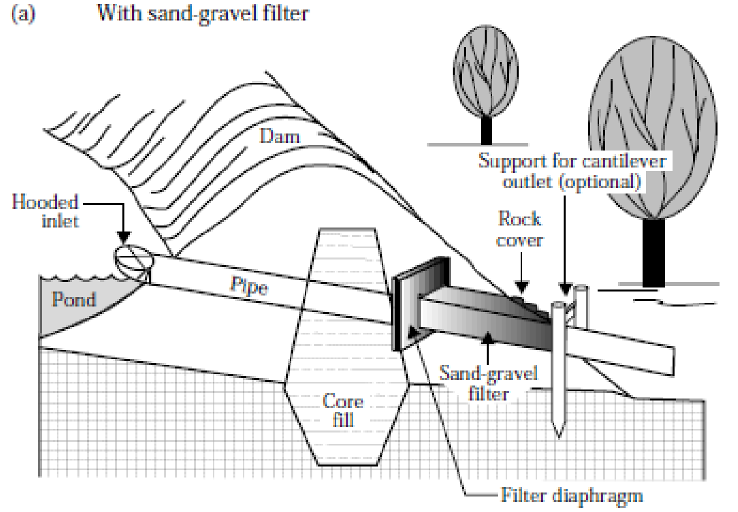


K. Hood Inlet Spillways

(1) Another type of principal spillway commonly used with farm ponds and reservoirs is the hood inlet spillway. It consists of a pipe laid in the earth embankment in a manner that the elevation of the invert of the pipe at its upstream end establishes the normal pool level in the reservoir (fig. 11-42). The inlet end of the pipe is cut at an angle to form the hood. An anti-vortex device, usually made of metal, is attached to the entrance of the pipe to increase the hydraulic efficiency of the tube (fig. 11-43). The hood inlet spillway often can be constructed at less cost than the drop inlet type because there is no expense for a riser. This type of spillway has one major disadvantage in that it cannot be used as a drain or water supply pipe.

Figure 11-42: Dam with Hooded Inlet Pipe Spillway

(a) With sand-gravel filter



(b) With antiseep collar

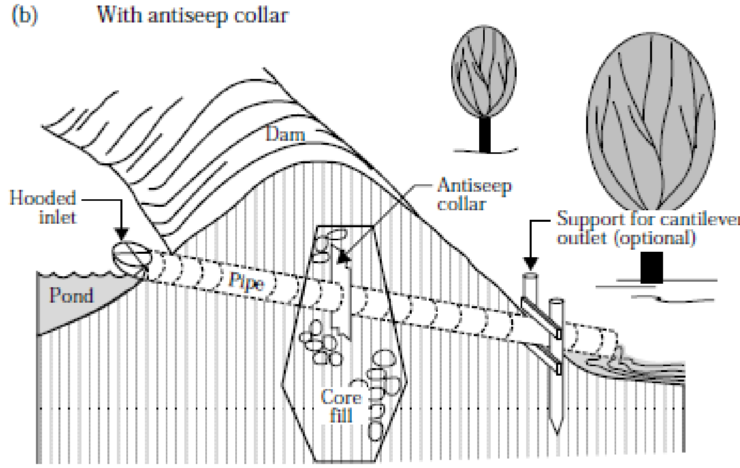
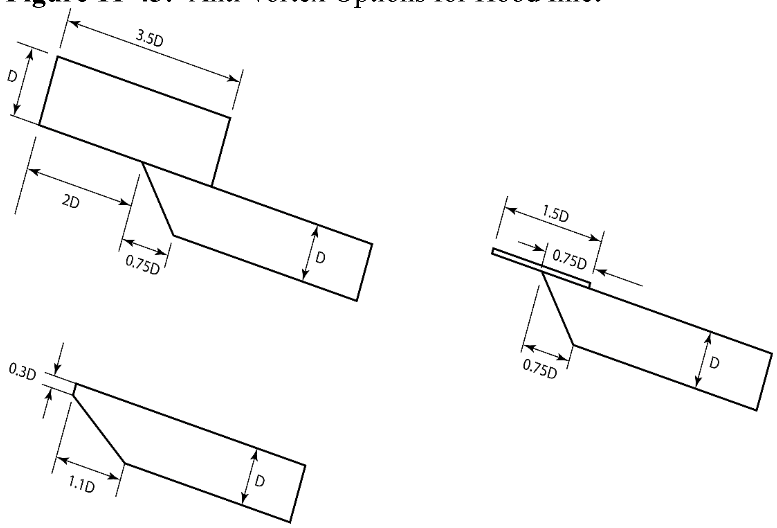


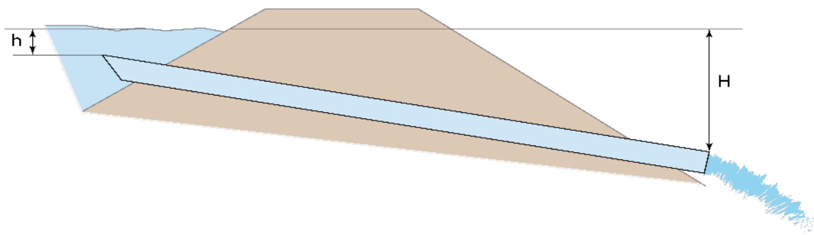
Figure 11-43: Anti-vortex Options for Hood Inlet



(2) Pipe smaller than 6 Inches in diameter should not be used because of the danger of becoming clogged. The crest elevation of the emergency spillway should be located a distance above the invert or crest elevation of the hood inlet spillway at least equal to the value of the minimum head required to provide full pipe flow, but in no case less than 12 inches.

(3) The required diameter for a hood-inlet pipe can be selected from figure 11-44 or 11-45 after estimating the discharge capacity, Q, and determining the total head, H. The tables also show the minimum head, h, required above the invert or crest elevation of the pipe entrance. Unless you provide this minimum head, the pipe will not flow full. See 210-NEH-650-6, "Structures," for further design information and typical installations

Figure 11-44: Minimum Head, h, Required Above the Invert to Provide Full Flow for Various Sizes of Smooth Pipe and Values of Total Head, H[1]

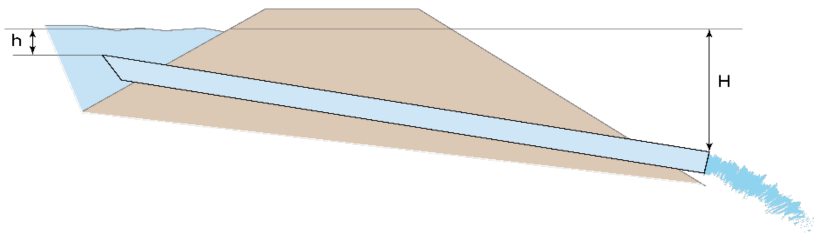


Total Head	Diameter of pipe (inches) English units											
	6		8		10		12		15		18	
H (ft)	h (ft)	Q (cfs)	h (ft)	Q (cfs)	h (ft)	Q (cfs)	h (ft)	Q (cfs)	h (ft)	Q (cfs)	h (ft)	Q (cfs)
6	0.63	1.63	0.85	3.0	1.04	5.3	1.23	8.5	1.54	14.0	1.82	21.2
8	0.65	1.87	0.86	3.5	1.06	6.0	1.27	9.3	1.57	15.5	1.87	23.3
10	0.66	1.93	0.87	3.8	1.08	6.6	1.3	10.2	1.60	17.0	1.91	25.4
12	0.67	2.06	0.88	4.1	1.09	7.1	1.32	10.9	1.63	18.3	1.94	27.5
14	0.67	2.18	0.89	4.3	1.11	7.5	1.33	11.6	1.65	19.5	1.96	29.4
16	0.68	2.28	0.90	4.5	1.13	7.8	1.35	12.2	1.67	20.5	1.98	31.0
18	0.69	2.36	0.91	4.7	1.14	8.1	1.36	12.7	1.69	21.4	2.00	32.5
20	0.69	2.43	0.92	4.9	1.15	8.4	1.37	13.2	1.70	22.2	2.02	33.0
22	0.70	2.5	0.93	5.0	1.16	8.7	1.38	13.6	1.71	23.0	2.04	35.1
24	0.70	2.56	0.93	5.1	1.16	9.0	1.39	14.0	1.72	23.7	2.05	36.3
26	0.71	2.60	0.94	0.52	1.17	9.3	1.4	14.4	1.73	24.4	2.07	37.5

Total Head	Diameter of pipe in (mm) SI units											
	150		200		250		300		380		450	
H (m)	h (m)	Q (cms)	h (m)	Q (cms)	h (m)	Q (cms)	h (m)	Q (cms)	h (m)	Q (cms)	h (m)	Q (cms)
1.83	0.19	0.05	0.26	0.08	0.32	0.15	0.37	0.24	0.47	0.40	0.55	0.60
2.44	0.20	0.05	0.26	0.10	0.32	0.17	0.39	0.26	0.48	0.44	0.57	0.66
3.05	0.20	0.05	0.27	0.11	0.33	0.19	0.40	0.29	0.49	0.48	0.58	0.72
3.66	0.20	0.06	0.27	0.12	0.33	0.20	0.40	0.31	0.50	0.52	0.59	0.78
4.27	0.20	0.06	0.27	0.12	0.34	0.21	0.41	0.33	0.50	0.55	0.60	0.83
4.88	0.21	0.06	0.27	0.13	0.34	0.22	0.41	0.35	0.51	0.58	0.60	0.88
5.49	0.21	0.07	0.28	0.13	0.35	0.23	0.41	0.36	0.52	0.61	0.61	0.92
6.10	0.21	0.07	0.28	0.14	0.35	0.24	0.42	0.37	0.52	0.63	0.62	0.93
6.71	0.21	0.07	0.28	0.14	0.35	0.25	0.42	0.39	0.52	0.65	0.62	0.99
7.32	0.21	0.07	0.28	0.14	0.35	0.25	0.42	0.40	0.52	0.67	0.62	1.03
7.92	0.22	0.07	0.29	0.01	0.36	0.26	0.43	0.41	0.53	0.69	0.63	1.06

[1]/ Length of pipe used in calculations is based on a dam with 12-foot (3.66 m) top width and a 2.5:1 side slope. Pipe flow based on a Manning's n=0.012

Figure 11-45: Minimum Head, h, Required Above the Invert to Provide Full Flow for Various Sizes of Corrugated Pipe and Values of Total Head, H[1]



Total Head	Diameter of pipe (inches) English units											
	6		8		10		12		15		18	
H (ft)	h (ft)	Q (cfs)	h (ft)	Q (cfs)	h (ft)	Q (cfs)	h (ft)	Q (cfs)	h (ft)	Q (cfs)	h (ft)	Q (cfs)
6	0.59	0.92	0.78	1.9	0.97	3.3	1.17	5.3	1.46	9.1	1.75	14.5
8	0.59	1.00	0.79	2.1	0.98	3.6	1.18	5.8	1.48	10.0	1.77	16.0
10	0.60	1.06	0.79	2.2	0.99	3.9	1.19	6.3	1.49	10.9	1.79	17.3
12	0.60	1.12	0.80	2.3	1.00	4.2	1.20	6.7	1.50	11.6	1.80	18.5
14	0.61	1.26	0.81	2.6	1.01	4.4	1.21	7.1	1.51	12.2	1.82	19.6
16	0.61	1.22	0.81	2.5	1.01	4.6	1.21	7.4	1.52	12.7	1.82	20.5
18	0.61	1.26	0.81	2.6	1.02	4.8	1.22	7.6	1.53	13.2	1.83	21.3
20	0.62	1.30	0.82	2.7	1.03	4.9	1.23	7.8	1.54	13.7	1.85	21.9
22	0.62	1.33	0.83	2.8	1.03	5.0	1.24	8.0	1.55	14.1	1.86	22.5
24	0.63	1.35	0.83	2.8	1.04	5.1	1.25	8.2	1.56	14.5	1.88	23.0
26	0.63	1.37	0.84	2.90	1.05	5.2	1.26	8.3	1.58	14.7	1.89	23.4

Total Head	Diameter of pipe in (mm) SI units											
	150		200		250		300		380		450	
H (m)	h (m)	Q (cms)	h (m)	Q (cms)	h (m)	Q (cms)	h (m)	Q (cms)	h (m)	Q (cms)	h (m)	Q (cms)
1.83	0.18	0.03	0.24	0.05	0.30	0.09	0.36	0.15	0.45	0.26	0.53	0.41
2.44	0.18	0.03	0.24	0.06	0.30	0.10	0.36	0.16	0.45	0.28	0.54	0.45
3.05	0.18	0.03	0.24	0.06	0.30	0.11	0.36	0.18	0.45	0.31	0.55	0.49
3.66	0.18	0.03	0.24	0.07	0.30	0.12	0.37	0.19	0.46	0.33	0.55	0.52
4.27	0.19	0.04	0.25	0.07	0.31	0.12	0.37	0.20	0.46	0.35	0.55	0.56
4.88	0.19	0.03	0.25	0.07	0.31	0.13	0.37	0.21	0.46	0.36	0.55	0.58
5.49	0.19	0.04	0.25	0.07	0.31	0.14	0.37	0.22	0.47	0.37	0.56	0.60
6.10	0.19	0.04	0.25	0.08	0.31	0.14	0.37	0.22	0.47	0.39	0.56	0.62
6.71	0.19	0.04	0.25	0.08	0.31	0.14	0.38	0.23	0.47	0.40	0.57	0.64
7.32	0.19	0.04	0.25	0.08	0.32	0.14	0.38	0.23	0.48	0.41	0.57	0.65
7.92	0.19	0.04	0.26	0.08	0.32	0.15	0.38	0.24	0.48	0.42	0.58	0.66

1/ Length of pipe used in calculations is based on a dam with 12-foot (3.66 m) top width and a 2.5:1 side slope. Pipe flow based on a Manning's n=0.012

650.1109 Drain and Water Supply Pipes

A. Drainpipes

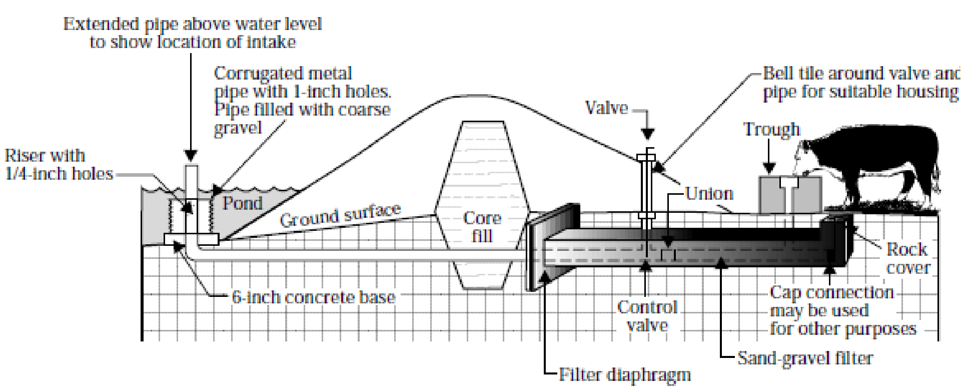
Some State agencies require that provision be made for draining farm ponds, fluctuating the water surface elevation to eliminate breeding places for mosquitos, or meeting other State requirements. Providing for drainage of farm ponds is a desirable practice in that it permits good fish management and allows for maintenance and needed repairs without cutting the fill or resorting to other devices to remove the water. The drainpipe should be extended beyond the upstream toe of the dam and be equipped with a suitable gate or valve.

B. Water Supply Pipes

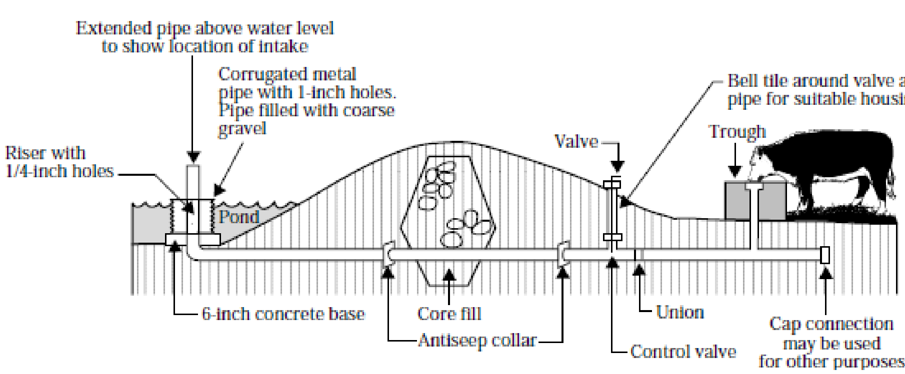
A water supply pipe should be installed under or through the dam where water is to be used below the dam, such as for stock water, irrigation, or filling a spray tank. This pipe usually is in addition to the principal spillway or trickle tube. The water supply pipe should have water-tight joints and be equipped with a suitable valve and strainer at its upper end. For small rates of flow, such as are needed to fill livestock or spray tanks, 1½-inch diameter steel pipe is generally used. Where larger rates of flow are required, such as for irrigation purposes, larger diameter pipe are commonly used. See figure 11-46 for a sketch of a stock watering facility.

Figure 11-46: Embankment Pond Equipped with a Stock Watering Facility

(a) Pipe with sand-gravel filter



(b) Pipe with antiseep collars



650.1110 Design of Earthfill Embankments

A. Foundations

(1) It is possible to construct a safe earthfill dam on almost any foundation if the foundation has been thoroughly investigated and the design and construction procedures are adapted to site conditions. Some foundation conditions require construction measures that are relatively expensive which, In the case of small farm ponds, cannot be justified. Sites with such foundation conditions ordinarily should be abandoned.

(2) The most satisfactory foundation is one that consists of or is underlain at a shallow depth by a-thick layer of relatively impervious consolidated material. Such foundations cause no stability problems. Where a suitable layer occurs at the surface, no special measures are required. It is sufficient to remove the topsoil and scarify or disk the area to provide a bond with the material in the dam.

(3) Where the impervious layer is overlain by previous material a compacted clay cutoff, extending from the surface of the ground into the impervious layer, is required to prevent possible failure by piping and to prevent excessive seepage.

(4) Where the foundation consists of highly pervious sand or sand-gravel mixture and any impervious clay layer is beyond economical reach with available equipment, a detailed investigation should be made. While such a foundation might be satisfactory insofar as stability is concerned, corrective measures will be required to prevent excessive seepage and possible failure.

(5) A foundation consisting of or underlain by a highly plastic clay or unconsolidated material requires a very careful investigation and design in order to obtain stability.

(6) Water impounded on bedrock foundations seldom gives cause for concern unless the rock contains seams, fissures or crevices through which water may escape at an excessive rate. Where rock is encountered in the foundation, a very careful investigation of the nature of the rock is required

(7) See 210-NEH-650-4, “Elementary Soils Engineering,” for further guidance.

B. Foundation Cutoffs

(1) Where the foundation consists of pervious materials at or near the surface, with rock or impervious materials at a greater depth, seepage through the pervious layer should be reduced to prevent piping and possible dam failure. Usually a cutoff joining the impervious stratum in the foundation with the base of the dam is needed.

(2) The most common type of cutoff is constructed of compacted clayey material. A trench is cut parallel to the centerline of the dam to a depth that extends well into the impervious layer (see fig 11-47). The trench is extended into and carried up the abutments of the dam as far as pervious material exists that might allow seepage under the embankment. The trench should have a bottom width of not less than 8 feet but adequate to allow use of equipment necessary to obtain proper compaction. Its sides should be no steeper than 1.5:1. The trench should be filled with successive thin layers of relatively impervious material; each layer being thoroughly compacted at near optimum moisture conditions before the succeeding layer is placed. Any water collected in the trench should be removed before backfilling operations are started.

Figure 11-47: A Core Trench is Cut Along the Centerline of a Dam

(3) Seepage control is to be included if (1) pervious layers are not intercepted by the cutoff, (2) seepage could create swamping downstream, (3) such control is needed to ensure a stable embankment, or (4) special problems require drainage for a stable dam. Seepage may be controlled by (1) foundation, abutment, or embankment filters and drains; (2) reservoir blanketing; or (3) a combination of these measures

C. Embankment Top Width

(1) A conservative top width for dams under 10 feet in height is 8 feet. The top width should be increased as the height of the dam increases. Figure 11-48 contains recommended top widths for embankments of various heights. See State standards and specifications for local requirements.

(2) Where the top of the embankment is to be used for a roadway, the top width should provide for a shoulder on each side of the traveled way to prevent raveling. The top width in such cases should not be less than 16 feet.

Figure 11-48: Recommended Top Widths for Earth Embankments

Height of dam		**Top width**	
(ft)	**(m)**	**(ft)**	**(m)**
Under 10	Under 3	8	2.4
10 to 15	3 to 4.5	10	3
15 to 20	4.5 to 6	12	3.6
20 to 25	6 to 7.6	12	3.6

D. Embankment Side Slopes

(1) The side slopes of a dam depend primarily on the stability of the material in the embankment. The greater the stability of the fill material, the steeper the side slopes may be. The more unstable materials require flatter side slopes. Figure 11-49 contains recommended maximum (steepest) slopes for the upstream and downstream faces of dams constructed of various materials. See State standards and specifications for local requirements.

Figure 11-49: Recommended Side Slopes for Earth Embankment

Fill material		Side slopes Horizontal to vertical	
		Upstream	**Downstream**
Clay (CH) Clayey sand (SC) Silty clay (CL)	 Sandy clay (CL) Silty sand (SM)	3 to 1	2 to 1
Clayey gravel (GC)	Silty gravel (GM)	2 1/2 to 1	2 ½ to 1
Silt (ML)	Clayey silt (ML)	3 to 1	3 to 1

(2) For stability, the slopes should not be steeper than those shown in figure 11-49, but they can be flatter if they provide surface drainage. The side slopes need not be uniform but can be shaped to blend with the surrounding landforms (fig. 11-50). Finish-grading techniques used to achieve a smooth landform transition include slope rounding and slope warping. Slope rounding is used at the top and bottom of cuts or fills and on side slope intersections. Slope warping is used to create variety in the horizontal and vertical pitch of finished slopes (fig. 11-51). Additional fill can be placed on the backslope and abutments of the dam, if needed, to achieve this landform transition.

Figure 11-50: Dam Side Slopes are Curved and Shaped to Blend with Surrounding Topography

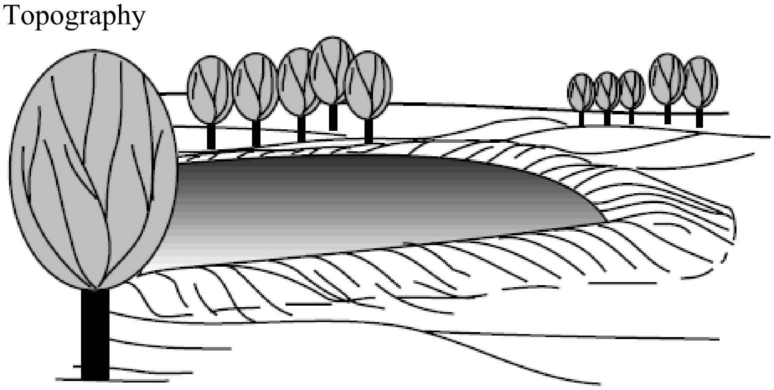
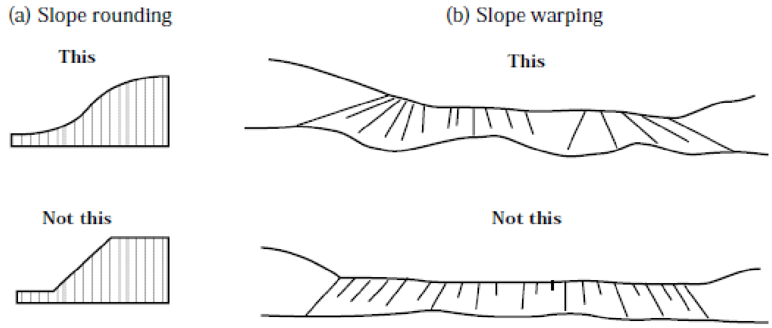


Figure 11-51: Finished Grading Techniques for Blending into the Landscape



E. Freeboard

Freeboard is the added height of the dam provided as a safety factor to prevent waves or runoff from storms greater than the design frequency from overtopping the embankment. It is the vertical distance between the elevation of the water surface in the pond when the spillway is discharging at designed depth and the elevation of the top of the dam after all settlement has taken place. Where the maximum length of a pond is less than 660 feet, a freeboard of not less than 1.0 foot should be provided. For ponds with lengths between 660 and 1,320 feet the minimum freeboard should be 1.5 feet. For ponds up to 1/2 mile in length, or for any pond having more than a 20-arce drainage area, or embankment more than 20 feet effective height the minimum freeboard should be 2.0 feet, See State standards and specifications for local requirements.

F. Allowance for Settlement

(1) Settlement or consolidation depends on the character of the materials in both the dam and the foundation and on the construction method. To allow for settlement, build earth dams somewhat higher than the design dimensions. If the dam is adequately compacted in thin layers under good moisture conditions, there is no reason to expect any appreciable settlement in the dam itself, but the foundation may settle. For a compacted fill dam on unyielding foundation, settlement is negligible.

(2) Most foundations are yielding, and settlement may range from l to 6 percent of the height of the dam, mainly during construction. The settlement allowance for a rolled-fill dam should be about 5 percent of the designed dam height. In other words, the dam is built 5 percent higher than the designed height. After settlement, the height of the dam will be adequate. Most pond dams less than 20 feet high, however, are not rolled fill. For these dams the total settlement allowance should be about 10 percent.

G. Earthwork Computation

(1) The estimate of the volume of borrow required should include the dam, allowance for settlement, backfill for the cutoff trench, backfill for existing stream channels and holes in the foundation area, and any other embankment the contractor is required to perform.

(2) Volume estimates for dams generally are made of the required number of cubic yards of earthfill in place. Probably the most efficient method of estimating the volume of earthfill is the sum-of-end-area method. The ground surface elevations at all points along the centerline of the dam where the slope changes significantly are established by the centerline profile. With the settled top elevation of the dam established, you can obtain the settle fill height at each of these points by subtracting the ground surface elevation from the settle top elevation. With the fill heights, side slopes, and top width established, find the end areas at each of these stations along the centerline in figure 11-52.

Figure 11-52: End Areas in Square Feet of Embankment Sections for Different Side Slopes and Top Widths[1]

Fill Height		Side Slope										Top Width									
		2.5:1		2.5:1		3:1		3.5:1		4:1		8ft (2.4m)		10ft (3m)		12ft (3.7m)		14ft (4.3m)		16ft (4.9)	
		2.5:1		3:1		3:1		3.5:1		4:1											
		2:1		2:1		2.5:1		3:1		3:1											
		3:1		3.5:1		3.5:1		4:1		5:1											
(ft)	(m)	(ft^2)	(m^2)	(ft^2)	(m^2)	(ft^2)	(m^2)	(ft^2)	(m^2)	(ft^2)	(m^2)	(ft^2)	(m^2)	(ft^2)	(m^2)	(ft^2)	(m^2)	(ft^2)	(m^2)	(ft^2)	(m^2)
1.0	0.3	3	1	3	1	3	1	4	1	4	1	8	1	10	1	12	1	14	1	16	1
1.2	0.4	4	1	4	1	4	1	5	2	6	2	10	1	12	1	14	1	17	2	19	2
1.4	0.4	5	1	5	2	6	2	7	2	8	2	11	1	14	1	17	2	20	2	22	2
1.6	0.5	6	2	7	2	8	2	9	3	10	3	13	1	16	1	19	2	22	2	26	2
1.8	0.5	8	2	9	3	10	3	11	3	13	4	14	1	18	2	22	2	25	2	29	3
2.0	0.6	10	3	11	3	12	4	14	4	16	5	16	1	20	2	24	2	28	3	32	3
2.2	0.7	12	4	13	4	15	4	17	5	19	6	18	2	22	2	26	2	31	3	35	3
2.4	0.7	14	4	16	5	17	5	20	6	23	7	19	2	24	2	29	3	34	3	38	4
2.6	0.8	17	5	19	6	20	6	24	7	27	8	21	2	26	2	31	3	36	3	42	4
2.8	0.9	20	6	22	7	24	7	27	8	31	10	22	2	28	3	34	3	39	4	45	4
3.0	0.9	23	7	25	8	27	8	32	10	36	11	24	2	30	3	36	3	42	4	48	4
3.2	1.0	26	8	28	9	31	9	36	11	41	12	26	2	32	3	38	4	45	4	51	5
3.4	1.0	29	9	32	10	35	11	40	12	46	14	27	3	34	3	41	4	48	4	54	5
3.6	1.1	32	10	36	11	39	12	45	14	52	16	29	3	36	3	43	4	50	5	58	5
3.8	1.2	36	11	40	12	43	13	51	15	58	18	30	3	38	4	46	4	53	5	61	6
4.0	1.2	40	12	44	13	48	15	56	17	64	20	32	3	40	4	48	4	56	5	64	6
4.2	1.3	44	13	49	15	53	16	62	19	71	22	34	3	42	4	50	5	59	5	67	6
4.4	1.3	48	15	53	16	58	18	68	21	77	24	35	3	44	4	53	5	62	6	70	7
4.6	1.4	53	16	58	18	63	19	74	23	85	26	37	3	46	4	55	5	64	6	74	7
4.8	1.5	58	18	63	19	69	21	81	25	92	28	38	4	48	4	58	5	67	6	77	7
5.0	1.5	63	19	69	21	75	23	88	27	100	30	40	4	50	5	60	6	70	7	80	7
5.2	1.6	68	21	74	23	81	25	95	29	108	33	42	4	52	5	62	6	73	7	83	8
5.4	1.6	73	22	80	24	87	27	102	31	117	36	43	4	54	5	65	6	76	7	86	8
5.6	1.7	78	24	86	26	94	29	110	33	125	38	45	4	56	5	67	6	78	7	90	8
5.8	1.8	84	26	93	28	101	31	118	36	135	41	46	4	58	5	70	6	81	8	93	9
6.0	1.8	90	27	99	30	108	33	126	38	144	44	48	4	60	6	72	7	84	8	96	9
6.2	1.9	96	29	106	32	115	35	135	41	154	47	50	5	62	6	74	7	87	8	99	9
6.4	2.0	102	31	113	34	123	37	143	44	164	50	51	5	64	6	77	7	90	8	102	10
6.6	2.0	109	33	120	37	131	40	152	46	174	53	53	5	66	6	79	7	92	9	106	10
6.8	2.1	116	35	127	39	139	42	162	49	185	56	54	5	68	6	82	8	95	9	109	10
7.0	2.1	123	37	135	41	147	45	172	52	196	60	56	5	70	7	84	8	98	9	112	10
7.2	2.2	130	40	143	43	156	47	181	55	207	63	58	5	72	7	86	8	101	9	115	11
7.4	2.3	137	42	151	46	164	50	192	58	219	67	59	5	74	7	89	8	104	10	118	11
7.6	2.3	144	44	159	48	173	53	202	62	231	70	61	6	76	7	91	8	106	10	122	11
7.8	2.4	152	46	167	51	183	56	213	65	243	74	62	6	78	7	94	9	109	10	125	12
8.0	2.4	160	49	176	54	192	59	224	68	256	78	64	6	80	7	96	9	112	10	128	12
8.2	2.5	168	51	185	56	202	61	235	72	269	82	66	6	82	8	98	9	115	11	131	12
8.4	2.6	176	54	194	59	212	65	247	75	282	86	67	6	84	8	101	9	118	11	134	12
8.6	2.6	185	56	203	62	222	68	259	79	296	90	69	6	86	8	103	10	120	11	138	13
8.8	2.7	194	59	213	65	232	71	271	83	310	94	70	7	88	8	106	10	123	11	141	13

[1/] To find the end area for any fill height, add square feet given under staked side slopes to that under the top width for total section. Example: 6.4-foot 3:1 front and back slopes, 14-foot top width —123 plus 89, or 212 square feet for the section. Any combination of slopes that adds to 5, 6, or 7 may be used. A combination of 3.5:1 front and 2.5:1 back gives the same results as 3:1 front and back.

Figure 11-52: End Areas in Square Feet of Embankment Sections for Different Side Slopes and Top Widths[1] - continued

Fill Height		Side Slope										Top Width									
		2.5:1		2.5:1		3:1		3.5:1		4:1		8ft (2.4m)		10ft (3m)		12ft (3.7m)		14ft (4.3m)		16ft (4.9)	
		2.5:1		3:1		3:1		3.5:1		4:1											
		2:1		2:1		2.5:1		3:1		3:1											
		3:1		3.5:1		3.5:1		4:1		5:1											
(ft)	(m)	(ft²)	(m²)	(ft²)	(m²)	(ft²)	(m²)	(ft²)	(m²)	(ft²)	(m²)	(ft²)	(m²)	(ft²)	(m²)	(ft²)	(m²)	(ft²)	(m²)	(ft²)	(m²)
9.0	2.7	203	62	223	68	243	74	284	86	324	99	72	7	90	8	108	10	126	12	144	13
9.2	2.8	212	64	233	71	254	77	296	90	339	103	74	7	92	9	110	10	129	12	147	14
9.4	2.9	221	67	243	74	265	81	309	94	353	108	75	7	94	9	113	10	132	12	150	14
9.6	2.9	230	70	253	77	276	84	323	98	369	112	77	7	96	9	115	11	134	12	154	14
9.8	3.0	240	73	264	81	288	88	336	102	384	117	78	7	98	9	118	11	137	13	157	15
10.0	3.0	250	76	275	84	300	91	350	107	400	122	80	7	100	9	120	11	140	13	160	15
10.2	3.1	260	79	286	87	312	95	364	111	416	127			102	9	122	11	143	13	163	15
10.4	3.2	270	82	297	91	324	99	379	115	433	132			104	10	125	12	146	14	166	15
10.6	3.2	281	86	309	94	337	103	393	120	449	137			106	10	127	12	148	14	170	16
10.8	3.3	292	89	321	98	350	107	408	124	467	142			108	10	130	12	151	14	173	16
11.0	3.4	303	92	333	101	363	111	423	129	484	148			110	10	132	12	154	14	176	16
11.2	3.4	314	96	345	105	376	115	439	134	502	153			112	10	134	12	157	15	179	17
11.4	3.5	325	99	357	109	390	119	455	139	520	158			114	11	137	13	160	15	182	17
11.6	3.5	336	103	370	113	404	123	471	144	538	164			116	11	139	13	162	15	186	17
11.8	3.6	348	106	383	117	418	127	487	149	557	170			118	11	142	13	165	15	189	18
12.0	3.7	360	110	396	121	432	132	504	154	576	176			120	11	144	13	168	16	192	18
12.2	3.7	372	113	409	125	447	136	521	159	595	181			122	11	146	14	171	16	195	18
12.4	3.8	384	117	423	129	461	141	538	164	615	187			124	12	149	14	174	16	198	18
12.6	3.8	397	121	437	133	476	145	556	169	635	194			126	12	151	14	176	16	202	19
12.8	3.9	410	125	451	137	492	150	573	175	655	200			128	12	154	14	179	17	205	19
13.0	4.0	422	129	465	142	507	155	591	180	676	206			130	12	156	14	182	17	208	19
13.2	4.0	436	133	479	146	523	159	610	186	697	212			132	12	158	15	185	17	211	20
13.4	4.1	449	137	494	151	539	164	628	192	718	219			134	12	161	15	188	17	214	20
13.6	4.1	462	141	509	155	555	169	647	197	740	226			136	13	163	15	190	18	218	20
13.8	4.2	476	145	524	160	571	174	667	203	762	232			138	13	166	15	193	18	221	21
14.0	4.3	490	149	539	164	588	179	686	209	784	239			140	13	168	16	196	18	224	21
14.2	4.3	504	154	555	169	605	184	706	215	807	246			142	13	170	16	199	18	227	21
14.4	4.4	518	158	570	174	622	190	726	221	829	253			144	13	173	16	202	19	230	21
14.6	4.5	533	162	586	179	639	195	746	227	853	260			146	14	175	16	204	19	234	22
14.8	4.5	548	167	602	184	657	200	767	234	876	267			148	14	178	16	207	19	237	22
15.0	4.6	562	171	619	189	675	206	787	240	900	274			150	14	180	17	210	20	240	22
15.2	4.6	578	176	635	194	693	211	809	246	924	282			152	14	182	17	213	20	243	23
15.4	4.7	593	181	652	199	711	217	830	253	949	289			154	14	185	17	216	20	246	23
15.6	4.8	608	185	669	204	730	223	852	260	973	297			156	14	187	17	218	20	250	23
15.8	4.8	624	190	687	209	749	228	874	266	999	304			158	15	190	18	221	21	253	23
16.0	4.9	640	195	704	215	768	234	896	273	1024	312			160	15	192	18	224	21	256	24
16.2	4.9	656	200	722	220	787	240	919	280	1050	320					194	18	227	21	259	24
16.4	5.0	672	205	740	225	807	246	941	287	1076	328					197	18	230	21	262	24
16.6	5.1	689	210	758	231	827	252	964	294	1102	336					199	19	232	22	266	25
16.8	5.1	706	215	776	237	847	258	988	301	1129	344					202	19	235	22	269	25
17.0	5.2	722	220	795	242	867	264	1012	308	1156	352					204	19	238	22	272	25
17.2	5.2	740	225	814	248	888	271	1035	316	1183	361					206	19	241	22	275	26
17.4	5.3	757	231	833	254	908	277	1060	323	1211	369					209	19	244	23	278	26
17.6	5.4	774	236	852	260	929	283	1084	330	1239	378					211	20	246	23	282	26
17.8	5.4	792	241	871	266	951	290	1109	338	1267	386					214	20	249	23	285	26
18.0	5.5	810	247	891	272	972	296	1134	346	1296	395					216	20	252	23	288	27
18.2	5.5	828	252	911	278	994	303	1159	353	1325	404					218	20	255	24	291	27
18.4	5.6	846	258	931	284	1016	310	1185	361	1354	413					221	21	258	24	294	27
18.6	5.7	865	264	951	290	1038	316	1211	369	1384	422					223	21	260	24	298	28
18.8	5.7	884	269	972	296	1060	323	1237	377	1414	431					226	21	263	24	301	28
19.0	5.8	902	275	993	303	1083	330	1264	385	1444	440					228	21	266	25	304	28
19.2	5.9	922	281	1014	309	1106	337	1290	393	1475	449					230	21	269	25	307	29
19.4	5.9	941	287	1035	315	1129	344	1317	402	1505	459					233	22	272	25	310	29

[1/] To find the end area for any fill height, add square feet given under staked side slopes to that under the top width for total section. Example: 6.4-foot 3:1 front and back slopes, 14-foot top width —123 plus 89, or 212 square feet for the section. Any combination of slopes that adds to 5, 6, or 7 may be used. A combination of 3.5:1 front and 2.5:1 back gives the same results as 3:1 front and back.

Figure 11-52: End Areas in Square Feet of Embankment Sections for Different Side Slopes and Top Widths[1] - continued

Fill Height		Side Slope										Top Width									
		2.5:1		2.5:1		3:1		3.5:1		4:1		8ft (2.4m)		10ft (3m)		12ft (3.7m)		14ft (4.3m)		16ft (4.9)	
		2.5:1		3:1		3:1		3.5:1		4:1											
		2:1		2:1		2.5:1		3:1		3:1											
		3:1		3.5:1		3.5:1		4:1		5:1											
(ft)	(m)	(ft²)	(m²)	(ft²)	(m²)	(ft²)	(m²)	(ft²)	(m²)	(ft²)	(m²)	(ft²)	(m²)	(ft²)	(m²)	(ft²)	(m²)	(ft²)	(m²)	(ft²)	(m²)
19.6	6.0	960	293	1056	322	1152	351	1345	410	1537	468					235	22	274	25	314	29
19.8	6.0	980	299	1078	329	1176	358	1372	418	1568	478					238	22	277	26	317	29
20.0	6.1	1000	305	1100	335	1200	366	1400	427	1600	488					240	22	280	26	320	30
20.2	6.2	1020	311	1122	342	1224	373	1428	435	1632	497					242	23	283	26	323	30
20.4	6.2	1040	317	1144	349	1248	381	1457	444	1665	507					245	23	286	27	326	30
20.6	6.3	1061	323	1167	356	1273	388	1485	453	1697	517					247	23	288	27	330	31
20.8	6.3	1082	330	1190	363	1298	396	1514	462	1731	527					250	23	291	27	333	31
21.0	6.4	1103	336	1213	370	1323	403	1543	470	1764	538					252	23	294	27	336	31
21.2	6.5	1124	342	1236	377	1348	411	1573	479	1798	548					254	24	297	28	339	32
21.4	6.5	1145	349	1259	384	1374	419	1603	489	1832	558					257	24	300	28	342	32
21.6	6.6	1166	356	1283	391	1400	427	1633	498	1866	569					259	24	302	28	346	32
21.8	6.6	1188	362	1307	398	1426	435	1663	507	1901	579					262	24	305	28	349	32
22.0	6.7	1210	369	1331	406	1452	443	1694	516	1936	590					264	25	308	29	352	33
22.2	6.8	1232	376	1355	413	1479	451	1725	526	1971	601					266	25	311	29	355	33
22.4	6.8	1254	382	1380	421	1505	459	1756	535	2007	612					269	25	314	29	358	33
22.6	6.9	1277	389	1405	428	1532	467	1788	545	2043	623					271	25	316	29	362	34
22.8	6.9	1300	396	1430	436	1560	475	1819	555	2079	634					274	25	319	30	365	34
23.0	7.0	1322	403	1455	443	1587	484	1851	564	2116	645					276	26	322	30	368	34

[1/] To find the end area for any fill height, add square feet given under staked side slopes to that under the top width for total section. Example: 6.4-foot 3:1 front and back slopes, 14-foot top width —123 plus 89, or 212 square feet for the section. Any combination of slopes that adds to 5, 6, or 7 may be used. A combination of 3.5:1 front and 2.5:1 back gives the same results as 3:1 front and back.

(3) For example, assume that a dam has slopes of 3 to 1 on both upstream and downstream sides and a top width of 12 feet. For a point along the centerline where the fill height is 15.0 feet, the exhibit shows that the end area at that point is 675 sq ft plus 180 sq ft or 855 sq ft. The number of cubic yards of fill between two points on the centerline of the dam is equal to the sum of the end areas at the two points multiplied by the distance between these points and divided by (2 x 27) or 54. The total volume of earthfill in the dam is the sum of all such segments. A sample volume estimate illustrating the use of the "sum of end areas" method is presented in figure 11-53.

Figure 11-53: Sample Volume Computations Using "Sum of End Areas" Method

Station	Ground elevation	Fill height (feet)	End area1 (sq feet)	Sum of end areas (sq feet)	Distance (feet)	Double volume (cu feet)
0 + 50	35.0	0.0	0	44	18	792
0 + 68	32.7	2.3	44	401	32	12,832
1 + 00	25.9	9.1	357	1,066	37	39,442
1 + 37	21.5	13.5	709	1,564	16	25,024
1 + 53	20.0	15.0	855	1,730	22	38,060
1 + 75	19.8	15.2	875	1,781	25	44,525
2 + 00	19.5	15.5	906	1,730	19	32,870
2 + 19	20.3	14.7	824	1,648	13	21,424
2 + 32	20.3	14.7	824	1,805	4	7,220
2 + 36	18.8	16.2	981	2,030	4	8,120
2 + 40	18.2	16.8	1,049	2,064	3	6,192
2 + 43	18.5	16.5	1,015	1,911	3	5,733
2 + 46	19.6	15.4	896	1,771	13	23,023
2 + 59	19.8	15.2	875	1,650	41	67,650
3 + 00	20.8	14.2	775	1,023	35	35,805
3 + 35	27.7	7.3	248	324	25	8,100
3 + 60	31.6	3.4	76	76	36	2,736
3 + 96	35.0	0.0	0			
Total 2						379,548

1. End areas based on 12-foot top width and 3 to 1 slopes on both sides.
2. Double volume in cu.ft. is divided by 54 to obtain volume in cu.yds.

$379{,}548/54 =$ $7029\ cu.yds.$

Allowance for settlement (5%) = 351 *cu. yds*.

Total volume = 7,380 *cu.yds*.

(4) The sample volume estimate of 7,380 cubic yards includes only that volume of earth required to complete the dam itself. An estimate of the volume of earth required to backfill the core trench, old stream channels and other required excavation should be made and added to the estimate made for the dam. For example, assume that in addition to the volume figure 11-50, there is a cutoff trench to be backfilled. The dimensions of the trench are as follows:

Average depth = 4.0 feet
Bottom width = 8.0 feet
Side slopes = 1 to 1
Length = 177 feet

The volume of backfill is computed as follows:

End area = (8 x4) + (4 x 4)
= 32 + 16 = 48 square feet
Volume = $(48 \times 177)/27$ = 315 cubic yards

(5) Adding this to the volume required for the dam itself, the total volume becomes 7,380 + 315 = 7,695 cubic yards.

H. Grading and Shaping

(1) Pond construction may require large quantities of earth to be moved, resulting in embankments, spoil piles, and cut slopes. When possible, fill material for embankments should come from the auxiliary spillway excavation. Balancing the cut and fill from the auxiliary spillway and dam will reduce earthmoving costs. If more material is needed it should be taken from the pool area to prevent disturbance elsewhere.

(2) Several grading techniques can be used to reduce the erosion potential and to blend the modified Landforms into the landscape. Slopes should be shaped to be compatible with surrounding uses, such as recreation or farming. Shaping dam abutments creates a smooth landform transition (fig. 11-54). Rounding slopes at the top and bottom of cuts and fills helps blend them into existing landforms and enhances slope stability (fig. 11-55). Fill added to the back slope also adds diversity. These techniques can be used to simulate surrounding landforms and minimize negative visual effects.

Figure 11-54: Smooth Landform Transitions at the Abutments

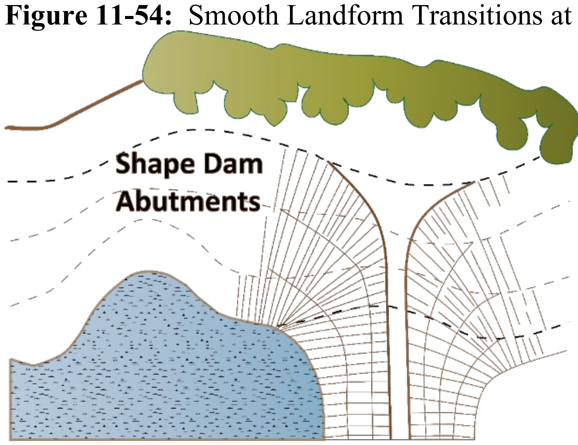
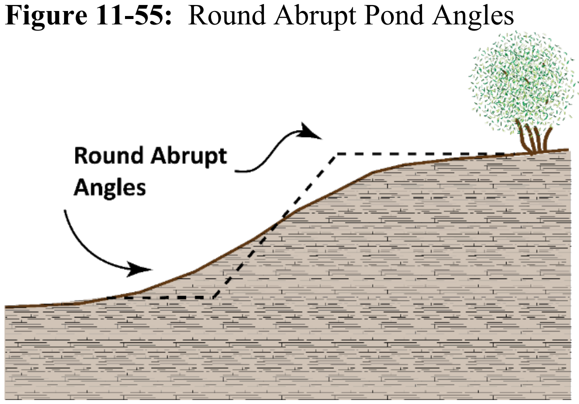
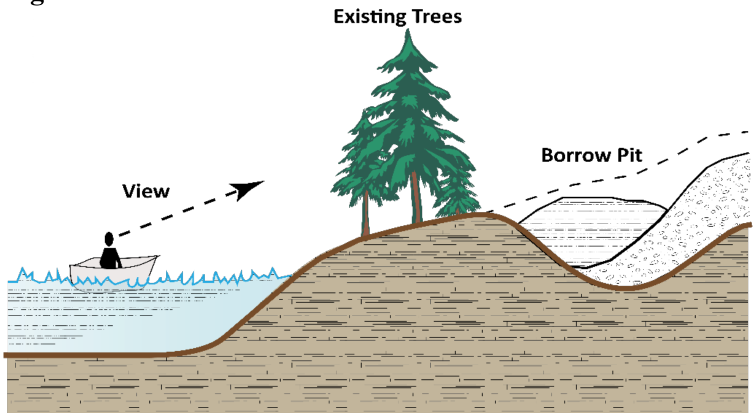


Figure 11-55: Round Abrupt Pond Angles



(3) Borrow areas, located outside the pool area, should be shaped to blend with existing Landforms by using appropriate earth grading and shaping techniques. When large areas are disturbed, clumps of trees can be left to reduce the apparent size of the disturbance. Trees left along the edge can help to screen the area from the major viewing points (fig. 11-56).

Figure 11-56: Trees Used to Screen Borrow Areas



(4) Landforms can often form the impoundment with minimum excavation. In some cases, a curved dam is more desirable than a straight one. Curvature can be used to retain existing landscape elements, reduce the apparent size of the dam, blend the dam into surrounding natural landforms, and provide a natural-appearing shoreline (fig. 11-57).

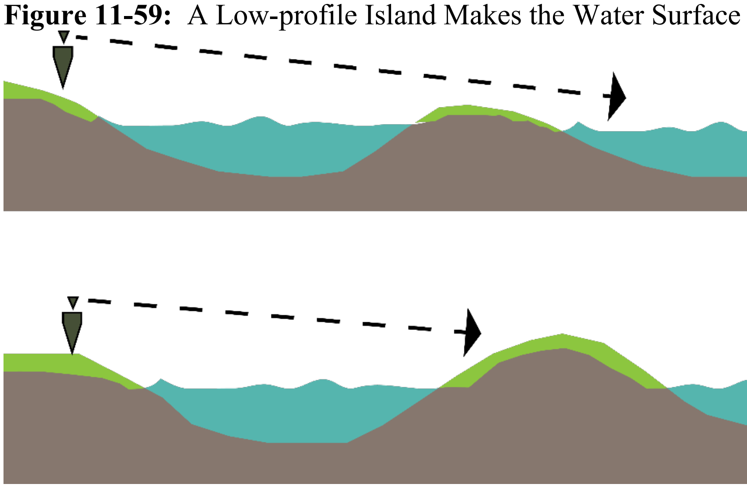
(5) Peninsulas and islands can make a pond more interesting by creating diversity in the water's edge. (figs. 11-58). Peninsulas give the illusion that the pond extends farther into the distance than it does. Islands add visual diversity and a good environment for fish and wildlife. Areas adjacent to these landforms can be deepened to enhance opportunities for fishing. A low-profile island makes the water surface more visible (fig. 11-59), and an irregular profile adds interest. The shape of the island should complement the shoreline.

(6) Shore areas can be shaped to make beaches and boat ramps or to discourage aquatic vegetation and insect problems. Gentle slopes above the shoreline increase the apparent size of the pond by increasing visibility. Steep slopes below the shoreline reduce aquatic vegetation and make fluctuations less noticeable by reducing mud flats.

Figure 11-57: Using Curvature to Blend the Dam into Surrounding Natural Landforms

Figure 11-58: Peninsula Adding Visual Diversity

Figure 11-59: A Low-profile Island Makes the Water Surface More Visible



I. Plans and Specifications

(1) All information developed during the design process should be recorded in the form of an engineering plan for the pond. This plan should show all pertinent elevations and dimensions of the dam, the dimensions and extent of the cutoff trench and other areas requiring backfill, the location and dimensions of the trickle tube and other planned appurtenances, and all other information pertinent to the construction of the dam. The plan should also include a bill of materials listing the quantity and type of all construction materials required. A sample plan of a farm pond embankment is shown in figures 11-60 and 11-61.

(2) Applicable engineering standards and construction specifications have been developed in each State for ponds and reservoirs. To obtain a quality job of construction-the owner and contractor must understand all requirements. Both the owner and the contractor should be furnished copies of the plans and specifications.

650.1111 Staking for Construction

A. Staking is a means whereby the information on the farm pond plans is transmitted to the job site. This information will provide lines, grades, and elevations required for construction of the job in accordance with the plans. Consideration should be given to the contractor's wishes in staking so that he can make the most effective use of the stakes. The quality and appearance of the completed job will reflect the care and thoroughness exercised in the staking procedure.

B. The areas to be cleared usually will consist of the dam site, the spillway site, the borrow area, and the area over which water is to be impounded. Each of these areas should be clearly marked with stakes or flags. In the case of the pond area, the-proposed waterline should be located accurately with a level and rod. Clearing stakes should be at least 15 feet outside this waterline to give a cleared area around the edge of the reservoir.

C. The embankment is located by setting stakes along its centerline at intervals of 50 feet or less. Usually this will have been done during the initial planning survey. Fill and slope stakes are then set both upstream and downstream from the centerline stakes marking the points of intersection of the side elopes with the ground surface. See 210-NEH-650-1 for procedures on slope staking.

D. The earth spillway is located by staking the centerline and then setting cut and slope stakes along the lines of intersection of the spillway side slopes with the natural ground surface. The procedure for setting these stakes is the same as for staking the embankment, except that they are cut stakes rather than fill stakes. They should be offset so they will remain in place for ready reference during construction.

E. Where suitable fill material must be obtained from a borrow area, it is essential that this area be clearly located. Cut stakes should be set to control excavation within the limits of suitable material and to drain the borrow area.

F. A principal spillway or trickle rube should be located by stakes offset from the centerline of the conduit and placed at intervals not exceeding 50 feet. The principal spillway should be located where it will rest on a firm foundation. Cuts from the tops of the stakes to the grade elevation of the tube should be plainly marked on the stakes. The locations of the riser, drainage gate, anti-seep collars, conduit, outlet structure, and other appurtenances should be located by additional stakes, clearly marked.

G. Figure 11-62 presents a sample set of construction layout notes for an embankment and earth spillway. Design, layout, and check notes may be recorded on approved standard forms or data sheets.

Figure 11-60: Sample Plan of Farm Pond

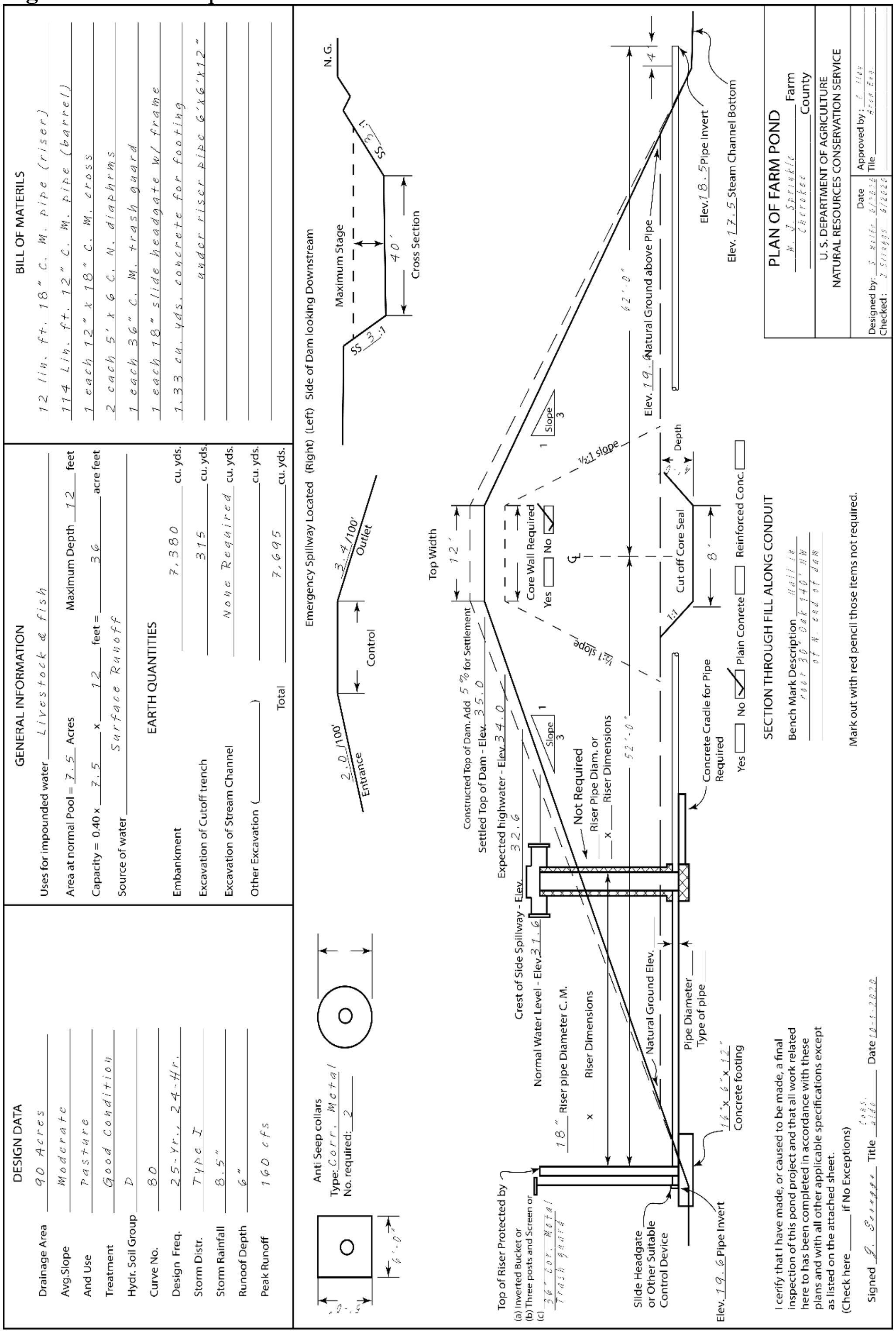


Figure 11-61: Sample Profiles of Embankment and Spillway

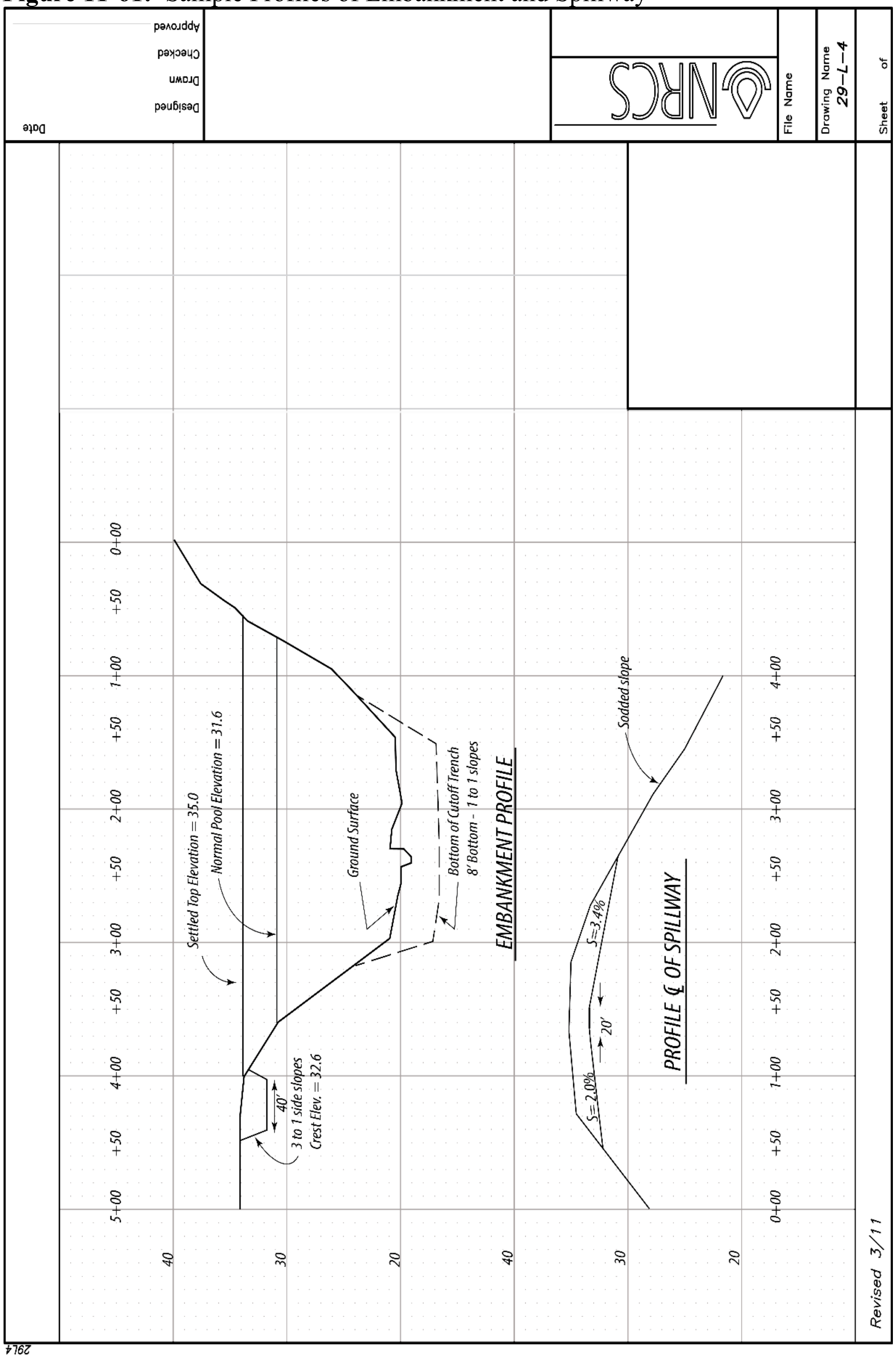


Figure 11-62: Construction Layout Note

Sta.	B.S.	H.I.	F.S.	Elev.	Planned Top Elev.
		Embankment			
BM 1	1.64	41.64		40.00	
0+50			6.6		35.0
0+68			6.6		35.0
T.P. 1	1.12	30.11	12.65	28.99	+0.1
1+00			-4.9		35.0
					+0.5
+37			-4.9		35.0
					+0.7
+53			-4.9		35.0
					+0.7
2+00			-4.9		35.0
					+0.8
+32			-4.9		35.0
					+0.7
+59			-4.9		35.0
					+0.7
3+00			-4.9		35.0
					+0.7
+35			-4.9		35.0
					+0.4

W. J. Sprinkle – Pond
Const. Layout

J. Scruggs
R. Bishop
6-20-2020

1

Nail in root 30" oak 140'
N.W. of N end of dam

	℄	
6.6 F=0.0-6.0	6.6 F=0.0	6.6 F=0.0-6.0
8.8 F=2.2-12.6	8.9 F=2.3	9.0 F=2.4-13.2
3.9 F=8.8-32.4	4.2 F=0.1	4.7 F=9.8-34.8
8.0 F=12.9-44.7	8.6 F=13.5	9.0 F=13.9-47.7
9.6 F=14.5-49.5	10.1 F=15.0	10.8 F=15.7-53.1
9.9 F=14.8-50.4	10.6 F=15.5	11.1 F=16.0-54.0
9.3 F=14.5-49.5	9.8 F=14.7	10.5 F=15.4-52.2
9.6 F=14.5-49.5	10.3 F=15.2	10.8 F=15.7-53.1
8.8 F=13.7-47.1	9.3 F=14.2	10.0 F=14.9-50.7
2.4 F=7.3-27.9	2.4 F=7.3	2.7 F=7.6-28.8

Sta.	B.S.	H.I.	F.S.	Elev.	Planned Top Elev.
		30.11			
TP 2	12.62	41.42	1.31	28.80	
3+60			+6.4		35.0
					+0.2
+96			+6.4		35.0
	Earth Spillway				Bottom Elev.
+27			+10.9		30.5
+48	Approach section		+10.4		31.0
+70	Slope = 2.0%		+10.0		31.4
1+30			+8.8		32.6
+50	c-line Berm Control section		+8.8		32.6
+85	Exist Section		+10.0		31.4
2+25	Slope = 3.4%		+11.4		30.0
+50					29.2

W. J. Sprinkle – Pond
Const. Layout

2

	℄	
9.8 F=3.4-16.2	9.8 F=3.4	9.9 F=3.5-16.5
6.4 F=0.0-6.0	6.4 F=0.0	6.4 F=0.0-6.0

Bottom width = 40' side slope 3:1

	10.7 C=0.2	10.4 C=0.5-21.5
9.2 C=1.2-23.6	8.8 C=1.6	8.4 C=2.0-26.0
1.2 C=1.8-25.4	7.0 C=3.0	6.6 C=3.4-30.2
6.7 C=2.1-26.3	5.9 C=2.9	5.6 C=3.2-29.6
6.7 C=2.1-26.3	5.9 C=2.9	5.6 C=3.2-29.6
6.5 C=3.5-30.5	6.1 C=3.9	5.7 C=4.3-32.9
8.1 C=3.5-29.9	7.7 C=3.7	7.3 C=4.1-32.3
9.1 C=2.3-26.9	8.7 C=2.7	8.3 C=3.1-29.3

650.1112 Construction Methods and Specifications

A. Attention to the details of construction and adherence to the drawings and specifications are as important as adequate investigation and design. Careless and shoddy construction can make an entirely safe and adequate design worthless and cause failure of the dam. Adherence to specifications and prescribed construction methods becomes increasingly important as the size of the structure and the failure hazards increase. Good construction is important regardless of size, and the cost is generally less in the long run than it is for dams built carelessly. Specifications for the work should conform to State standards and specifications applicable to the site and the purpose of the structure.

B. Clearing and grubbing

(1) Clear the foundation area and excavated earth spillway site of trees and brush. In some States this is required by statute. Cut trees and brush as nearly flush with the ground as practicable and remove them and any other debris from the dam site. Should you or your contractor elect to uproot the trees with a bulldozer, you must determine if the tree roots extend into pervious material and if the resultant holes will cause excessive seepage. If so, fill the holes by placing suitable material in layers and compact each layer by compacting or tamping.

(2) All material cleared and grubbed from the pond site, from the earth spillway and borrow areas, and from the site of the dam itself should be disposed of. This can be done by burning, burying under 2 feet of soil, or burying in a disposal area, such as a sanitary landfill.

(3) Minimal clearing conserves site character and minimizes the difficulty and expense of reestablishing vegetation. Confine clearing limits to the immediate construction areas to avoid unnecessary disturbance.

(4) Removing all vegetation within the construction limits is not always necessary. Selected groupings of desirable plants can be kept. Trees and shrubs can often survive a 1- to 2-foot layer of graded fill over their root systems or they can be root-pruned in excavated areas. Tree wells and raised beds can also be used to retain vegetation (fig. 11-63).

Figure 11-63: A Tree Well Preserves Vegetation

(5) Clearing limits should be irregular to create a natural appearing edge and open area (fig. 11-64). Further transition with vegetated surroundings can be accomplished by feathering clearing edges. Density and height of vegetation can be increased progressively from the water's edge to the undisturbed vegetation (fig. 11-65). Feathering can be accomplished by selective clearing, installation of new plants, or both.

Figure 11-64:. Irregular Clearing Around the Pond Helps Create a Natural Appearing Edge

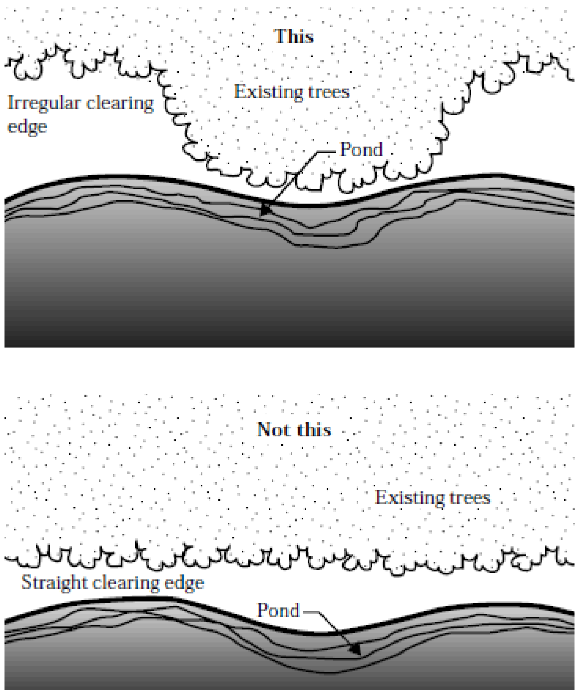
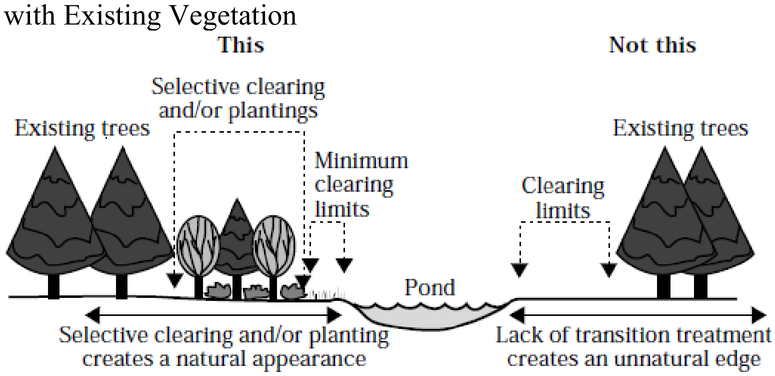


Figure 11-65: Feathering Vegetation at the Ponds Edge Makes a Natural Transition with Existing Vegetation



(6) Clearing limits should be irregular to provide a natural-appearing edge and open area (fig. 11-66). This can be done by feathering the clearing edges, which means creating a gradual transition of density and height of vegetation from the opening to the undisturbed vegetation (fig. 11-67). Feathering is done by selective trimming, new plantings, or both.

Figure 11-66: Irregular Clearing Limits to Provide Open Area

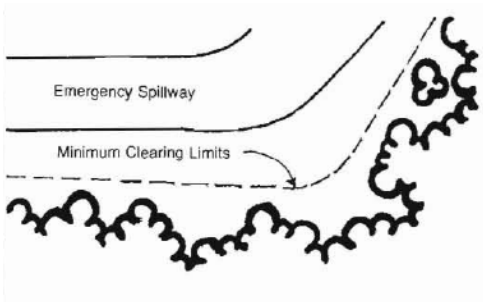
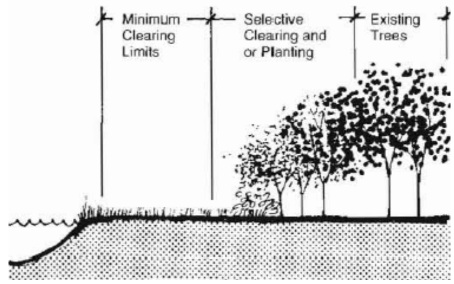
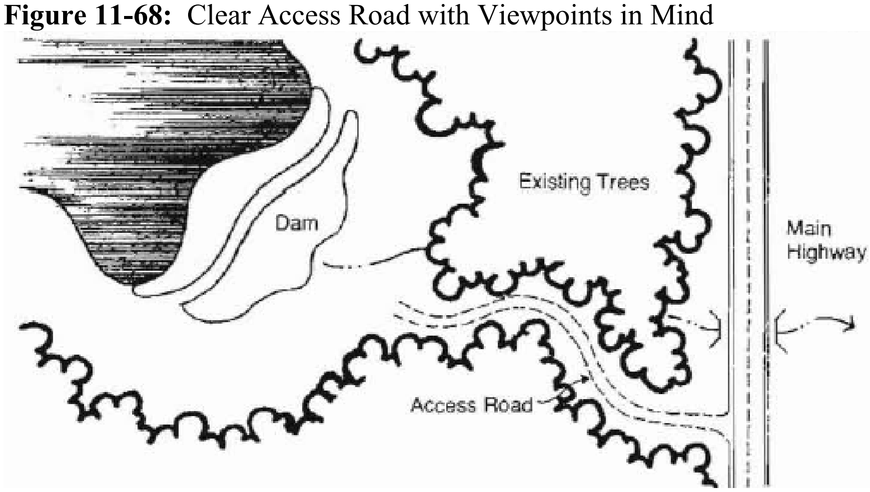


Figure 11-67: Feathering the Clearing Edges to Provide Gradual Transition



(7) It may be necessary to clear some vegetation for access roads or trails but be careful that the resulting alignment doesn't reveal undesirable views (fig. 11-68). Initial roads used for construction can be designed to provide access in the future for recreation or other uses when construction is completed.

Figure 11-68: Clear Access Road with Viewpoints in Mind



C. Preparing the Foundation—

(1) Preparing the foundation includes treating the surface, excavating and backfilling the cutoff trench, and excavating and backfilling existing stream channels. If the foundation has an adequate layer of impervious material at the surface or if it must be blanketed by such a layer, you can eliminate the cutoff trench. Remove sod, boulders, and topsoil from the entire area over which the embankment is to be placed. This operation is best performed by using a tractor-pulled or self-propelled wheeled scraper. The topsoil should be stockpiled temporarily for later use on the site.

(2) Fill all holes in the foundation area, both natural and those resulting from grubbing operations, with suitable fill material from borrow areas. Use the same method of placement and compaction as used to build the dam. Where necessary, use hand or power tampers in areas not readily accessible to other compacting equipment.

(3) After filling the holes, thoroughly break the ground surface and turn it to a depth of 6 inches. Roughly level the surface with a disk harrow and then compact it so that the surface materials of the foundation are as well compacted as the subsequent layers of the fill. Dig the cutoff trench to the depth, bottom width, and side slopes shown on the drawings. Often the depths shown on the drawings are only approximate; you need to inspect the completed trench before backfilling to be sure that it is excavated at least 12 inches into impervious material throughout its entire length.

(4) Material removed from the trench can be placed in the downstream third of the dam and compacted in the same manner as the earthfill if the material is free of boulders, roots, organic matter, and other objectionable material.

(5) A dragline excavator and a tractor-pulled or self-propelled wheeled scraper are the most satisfactory equipment for excavating cutoff trenches. Before backfilling operations are attempted, pump all free water from the cutoff trench. Some material high in clay content takes up more than twice its own weight of water and becomes a soggy mass. Such clay puddled in the cutoff of a dam may require many years to become stable. Also, in drying it contracts and may leave cracks that can produce a roof of the overlying impervious earthfill section and provide passageways for seepage through the dam.

(6) Backfill the cutoff trench to the natural ground surface with suitable fill material from designated borrow areas. Place the backfill material in thin layers and compact it by the same methods used to build the dam.

(7) Deepen, slope back, and widen stream channels that cross the embankment foundation. This is often necessary to remove all stones, gravel, sand, sediment, stumps, roots, organic matter, and any other objectionable material that could interfere with proper bonding of the earthfill with the foundation. Leave side slopes of the excavated channels no steeper than 3:1 when the channels cross the embankment centerline. If the channels are parallel to the centerline, leave the side slopes no steeper than 1:1. Backfill these channels as recommended for the cutoff trench.

D. Installing the Pipe Spillway—

(1) Install the pipe, riser (if applicable), filter and drainage diaphragm or antiseep collars, trash rack, and other mechanical components of the dam to the lines and grades shown on the drawings and staked at the site. To minimize the danger of cracks or openings at the joints caused by unequal settlement of the foundation, place all pipes and other conduits on a firm foundation.

(2) Install pipes and filter and drainage diaphragm or antiseep collars and tamp the selected backfill material around the entire structure before placing the earthfill for the dam. The same procedure applies to all other pipes or conduits.

E. Excavating the Earth Spillway—

The completed spillway excavation should conform as closely as possible to the lines, grades, bottom width, and side slopes shown on the drawings and staked at the site. Leave the channel bottom transversely level to prevent meandering and the resultant scour within the channel during periods of low flow. If it becomes necessary to fill low places or depressions in the channel bottom caused by undercutting the established grade, fill them to the established grade by placing suitable material in 8-inch layers and compacting each layer under the same moisture conditions regardless of the placement in or under the embankment.

F. Building the Dam

(1) Clear the dam and spillway area of trees, brush, stumps, boulders, sod, and rubbish. The sod and topsoil can be stockpiled and used later to cover the dam and spillway (fig. 33). This will help when vegetation is established. Get suitable fill material from previously selected borrow areas and from sites of planned excavation. The material should be free of sod, roots, stones more than 6 inches in diameter, and any material that could prevent the desired degree of compaction. Do not use frozen material or place fill material on frozen foundations.

(2) Selected backfill material should be placed in the core trench and around pipes and antiseep collars, when used. The material should be compacted by hand tamping or manually directed power tampers around pipes. Begin placing fill material at the lowest point and bring it up in horizontal layers, longitudinal to the centerline of dam, approximately 6 inches thick. For fill placement around risers, pipes and filter, and drainage diaphragms, the horizontal layers should be approximately 4 inches thick. Do not place fill in standing water. The moisture content is adequate for compaction when the material can be formed into a firm ball that sticks together and remains intact when the hand is vibrated violently, and no free water appears. If the material can be formed into a firm ball that sticks together, the moisture content is adequate for compaction. Laboratory tests of the fill material and field testing of the soil for moisture and compaction may be necessary for large ponds or special conditions.

(3) If the material varies in texture and gradation, use the more impervious (clay) material in the core trench, center, and upstream parts of the dam. Construction equipment can be used to compact earthfill in an ordinary pond dam. Equipment that has rubber tires can be routed so each layer is sufficiently covered by tire tracks. For dams over 20 feet high, special equipment, such as sheepsfoot rollers, should be used.

650.1113 Pond and Reservoir Protection

A. A farm pond should not be considered complete until proper protection from erosion, wave action, livestock and other sources of damage-has been provided. Ponds that lack such protection may be short-lived, and the cost of maintenance is usually high,

B. Protection Against Erosion

In most areas the exposed surfaces of the dam, spillway, borrow areas and other disturbed surfaces can be protected against erosion by establishing a good cover of sod-forming grass in accordance with the local Technical Guide.

C. Protection from Wave Action

Occasionally there is need for better protection against wave action than will be provided by a grass cover (fig. 11-69). Some methods used to provide this protection are earth berms, log booms, and rock riprap (fig. 11-70)

Figure 11-69: Bank Erosion Form Wave Action

Figure 11-70: Soil Cement Mat Used to Protect Against Wave Action

D. Berms

A berm, 8 to 10 feet in width, located at normal pond level often will provide adequate protection from wave action. The face of the dam above the berm should be protected by vegetation.

E. Booms

A boom may consist of a single or double line of logs chained together and securely anchored to each end of the dam. The logs should be tied end to end as close together as is practical. There should be enough slack in the line to allow the boom to adjust itself to fluctuating levels in the reservoir. Double rows of logs should be framed together to act as a unit. The boom should be placed to float about 6 feet upstream from the face of the dam for best results. In the case of a curved dam, anchor posts may be required on the face of the dam as well as at the ends in order to prevent the boom from riding on the slope. Booms afford a high degree of protection and are relatively inexpensive, especially in areas where timber is readily available. They should prove satisfactory for the smaller, less important structures.

F. Riprap

(1) Where the water level in the pond can be expected to fluctuate widely or where a high degree of protection is required, the use of rock riprap is a most effective method of control. Riprap should extend from the top of the dam down the upstream face to a level at least 3 feet below the lowest expected level of the water in the reservoir. Riprap may be placed by machine or by hand. Machine placing requires more stone but less labor in placing. The layer of stone should be at least 12 inches thick. Stones should be durable and large enough not to be displaced by waves.

(2) Where riprap is not continuous to the upstream toe, a berm should be provided on the upstream face to support the layer of riprap.

G. Other Methods

Other methods include increasing the top width of the dam, flattening the front slope of the embankment, and applying a layer of coarse sand and gravel on a 10:1 slope. These methods are applicable to arid areas where vegetation is not dependable, and rock and timber is not readily available.

H. Fencing

The complete fencing of embankment-type ponds is recommended where livestock are grazed or fed in adjacent areas. The fencing provides the protection needed to develop and maintain vegetative cover. When combined with a watering facility below the dam, fencing provides good drinking water and eliminates the danger of pollution by livestock. Fencing also improves wildlife environment.

650.1114 Checking for Compliance with Standards

A. While both the owner and the contractor have responsibilities for compliance with standards, inspection is also required if high standards are to be maintained.

B. Inspection During Construction

(1) There are numerous items in the construction of a farm pond that must be checked during construction. Since it will be impossible for work unit personnel to spend as much time as may be desirable on the job, responsibility must be assumed by the owner. The owner or his representative should be encouraged to watch the construction and report his observations to the work unit staff. If corrective action is necessary, the owner can be advised of the course to follow. The following are items that might be checked by the owner.

(i) All clearing and grubbing operations should be completed according to specifications before any work on the embankment is started.
(ii) Before embankment construction begins the foundation should be properly prepared. The completed cutoff trench should be inspected to ensure that it is excavated to impervious material and is free of water before it is backfilled.
(iii) The completed installation of the drop inlet spillway, drainpipe anti-seep collars and other appurtenance should be inspected before embankment construction is started. Materials used and location, alignment, grades and dimensions should be checked for compliance with the plans.
(iv) The earth excavation and the selecting, placing, spreading and compacting of the material in the embankment should be inspected frequently to ensure that the specifications are met.

C. Final Inspection and Measurements

(1) The final inspection by the technician should include enough profile and cross-section readings to ensure that the height, top width, side slopes and other dimensions shown on the plans have been met. Elevations of the top of the trickle tube or principal spillway with relation to the contra1 section of the spillway should be taken. Cross sections and profile of the emergency spillway should be surveyed to ensure that it is constructed in accordance with the plan dimensions and left in the specified condition.
(2) The final inspection should be made immediately after completion of the work and before the contractor moves his equipment from the site. Since this may not always be possible, training of local contractors to understand and meet construction requirements can save time of both the contractor and the technical staff.

D. Records of the Completed Work

All observations and measurements made in connection with the final inspection of farm pond construction should be recorded in engineering loose-leaf or field notebooks and noted in red on the construction plans. A sample of the measurements required is shown in the Construction Check Notes, figure 11-71, The notes should be filed in accordance with State memorandums. Some State laws require a formal completion report and as-built plans.

Figure 11-71: Construction Check Notes

Sta.	B.S.	H.I.	F.S./G.R.	Elev.	Planned Top Elev. 5% added
		Embankment			
BM 1	0.92	40.92		40.00	
D					
1+00			+5.4		35.5
0+53			+5.2		35.7
2+00			+5.1		35.8
+32			+5.2		35.7
			9.36	31.56	31.60
			22.4	18.5	18.5
+59			+5.1		35.8
3+00			5.2		35.7
+60			+5.7		35.2
	Earth spillway				Planned bottom Elev.
0+48			+9.9		31.0

W. J. Sprinkle – Pond
Const. Check

J. Scruggs
R. Bishop
6-28-2020

1

Nail in root 30" oak 140'
N.W. of N end of dam

℄

5.2

20.4	13.1	9.5	4.9	4.8	5.1	9.4	12.9	21.6
51	30	20	6.5	0	6.5	20	30	54

5.0

20.1	12.9	9.6	5.0	4.9	4.9	9.5	13.0	21.3
50	30	20	6.5	0	7.0	20	30	53

Crest 18" C. M. trickle tube riser
Invert 12" C. M. trickle tube barrel.

4.9

19.6	12.8	9.4	4.9	4.8	5.0	9.2	12.7	20.8
49	30	20	6.5	0	7.0	20	30	52

5.4

10.

Sta.	B.S.	H.I.	F.S./G.R.	Elev.	Planned bottom Elev.
		40.92			
0+70			+9.5		31.4
1+30			+8.3		32.6
+50	c-line Berm Control section		+8.3		32.6
+85			+9.5		31.4
2+35			+10.9		30.0
3+00			+13.4		27.5
BM 1				0.92	40.00

Pond area cleared and all vegetation has been disposed of. A stand of fescue grass has been obtained on embankment, spillway and borrow areas. All other applicable specifications have been met.

Certified: J. Scruggs
Conservation Aide

W. J. Sprinkle – Pond
Const. check

2

℄

7.9	9.8	9.8	9.7	9.6	9.6	6.1
26.2	21	10	0	10	21	31.0

8.4

6.9	8.3	8.4	8.3	8.4	8.5	5.0
25.2	21	10	0	10	22	35.9

9.7

7.7	11.2	11.2	11.1	11.2	11.1	6.8
300.	20	10	0	10	22	35.0

13.5

Note: All rod readings in excess of 13.0 ft were taken by use of a hand level.

650.1115 Pond and Reservoir Maintenance

A farm pond must be adequately maintained if its purposes are to be realized throughout its expected life. Severe damage to, or total failure of, dams and spillways have been caused by lack of maintenance. For these reasons, it is important that the owner carry out the measures described in the following paragraphs.

A. Inspection and Repairs

(1) Farm ponds should be inspected periodically, especially after heavy rains, to determine the need for minor repairs. Immediate repair often eliminates the need for more costly repairs later.

(2) Rills on the slopes of the dam and washes in the earth spillway should be filled with suitable material. and thoroughly compacted. These areas should be reseeded or resodded and fertilized as needed. Should the upstream face of the earthfill wash or slough due to wave action, protective devices such as booms or riprap should be installed. If there is seepage through or under the dam, an engineer should be consulted to recommended proper corrective measures.

(3) The vegetative cover on the dam and earth spillway should be maintained by mowing and fertilizing when needed. Proper mowing prevents the formation of woody growth and tends to develop a cover and root system more resistant to runoff. Fences should be kept in good repair.

(4) Appurtenances such as trickle tubes, trash racks, outlet structures, valves and watering troughs should be kept free of trash.

(5) Burrowing animals may cause severe damage to farm pond dams or spillways. If such damage remains unrepaired it may lead to failure. A thick layer of sand or gravel on the fill discourages burrowing. Poultry netting can be used effectively, but it will rust out and need replacement. If these pests persist, aggressive trapping and poisoning should be undertaken.

B. Sanitation

(1) It is desirable to keep the water in a farm pond as clean and unpolluted as possible. Unnecessary trampling by livestock should not be permitted. Where it is not practical to exclude livestock from a pond by fencing, small rocks or gravel should be used to pave the approaches to the water. Drainage from barn lots, feed yards, bedding grounds, outhouses, septic tanks, or other sources of contamination should be diverted from farm ponds. This is especially important where the water supply is to be used for harvesting ice, fish and wildlife development, or recreation.

(2) In areas where surface waters encourage the breeding of mosquitoes, the pond should be stocked with top-feeding fish. Gambusia minnows are particularly effective. Where malaria prevails, aquatic growth and shoreline vegetation should not be permitted, and special precautions should be observed in the planning, construction, and operation of the pond. Most States in malarial sections have health regulations covering these precautions which should be followed.

(3) In some areas the development of algae and other forms of plant life in reservoirs may become objectionable. Generally, these are harmless, but they may cause disagreeable tastes or odors, encourage bacterial development, and make the pond unsightly. Treatment with bluestone (copper sulfate) will check the development of algae. The usual dosage is 2 or 3 pounds per million gallons of water, well distributed throughout the reservoir. Overdosage may be harmful to both wildlife and livestock.

650.1116 Excavated Ponds

A. Types of Excavated Ponds

An excavated pond is the simplest type to construct and is the only type that can be constructed in relatively flat terrain. The fact that the capacity of these ponds is obtained almost solely from excavation limits their practical size, Since excavated ponds can be constructed to expose a minimum water surface area in proportion to volume, they are advantageous where evaporation losses are high, and water is scarce. See figures 11-72 and 11-73. The ease with which they can be constructed, their compactness, their relative safety from flood flow damage, and their low maintenance requirements make them popular in many sections of the country. Two kinds of excavated ponds are possible. One is fed by surface runoff and the other is fed by ground water aquifers, usually layers of sand and gravel. Some ponds may be fed from both sources.

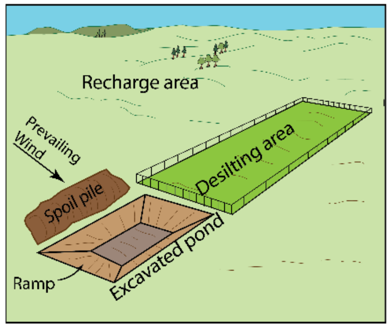
B. Location of Excavated Ponds

(1) The location of excavated pods depends on the purpose 'for which the water is to be used and on other factors discussed previously in this chapter.
(2) Excavated ponds fed by surface runoff may be located on almost any type of topography. They are, however, most satisfactory and most used in areas with comparatively flat terrain. A pond may be in a broad natural drainageway or to one side of a drainageway if the runoff can be diverted into the pond. The low point of a natural depression is often a good location for an excavated pond. After the pond is filled, excess runoff escapes through natural drainageways. Thus, locations with favorable discharge conditions should be selected.
(3) An excavated pond fed by ground water aquifers can be located only where shallow underground flow exists or where the permanent water table is within a few feet of the surface. See figure 11-74.

C. Soils Investigation

(1) Where the excavated pond is to be fed by surface runoff, relatively impervious soil at the site is essential to avoid excess seepage losses. Clays and silty clays extending below the planned reservoir depth are most desirable, and site8 with sandy clays usually prove satisfactory. Sites where soils are porous or are underlain by sands or gravel should be avoided unless the owner is prepared to bear the expense of an artificial lining, Soil underlain by limestone containing crevices, sinks or channels should be avoided.
(2) The performance of nearby existing ponds in a similar soil is a good indicator of the suitability of a proposed site. Such observations of existing ponds should be supplemented by subsurface investigations. Some indication of the permeability of the soil may be obtained by filling the test holes with water and observing the seepage characteristics of the material.

Figure 11-72: Excavated Pond and Typical Sections. Note Fenced Desilting Area Above Pond



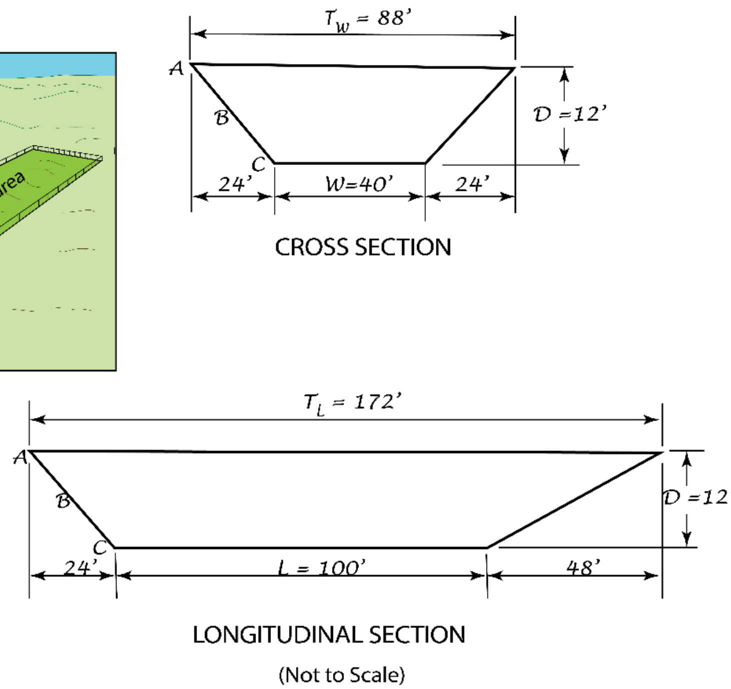


Figure 11-73: Cross Sections of Excavated Pond Showing Methods of Waste Material Disposal

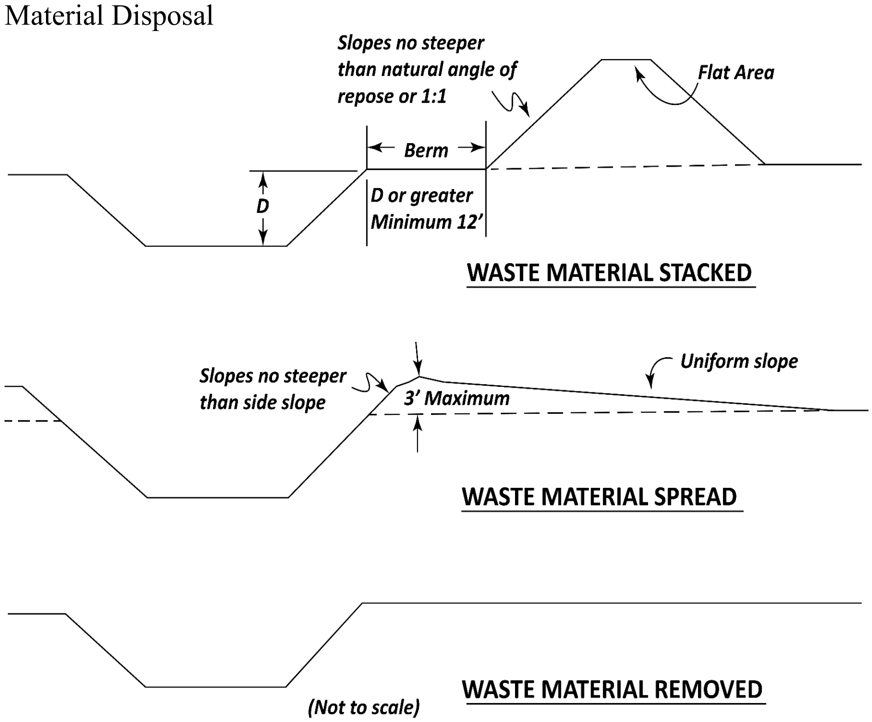
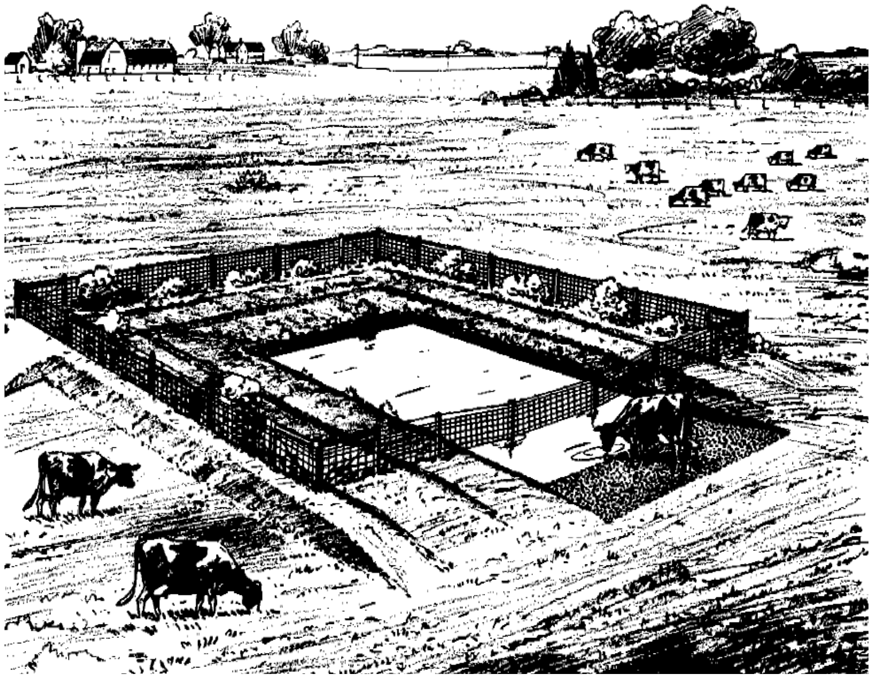


Figure 11-74: Excavated Pond Fed by Ground Water



(3) Sites proposed for aquifer-fed excavated ponds require a thorough subsurface investigation. Test holes should be bored to determine the existence and physical characteristics of the water-bearing material. The level to which water will rise in the test holes usually indicates the normal water level in the completed pond. The vertical distance between this level and the ground surface will determine the volume of excavation required that will not contribute to the usable capacity of the pond. From an economic standpoint, this vertical distance between water level and ground surface ordinarily should not exceed 6 feet.

(4) The rate at which the water rises in the test holes should also be observed. A rapid rate of rise indicates a high yielding aquifer. It also indicates that the water may be expected to return to its normal level within a short time after drawdown. A slow rate of rise in the test holes indicates a low yielding aquifer and a slow rate of recovery in the pond. Observations of the test holes should be made during drier seasons to avoid being misled by a temporary high-water table.

D. Spillway and Inlet Requirements

(1) Where an excavated pond, fed by surface runoff, is located on sloping terrain a portion of the excavated material may be used to create a low dam around the lower end and sides of the pond to increase its capacity. In such cases, an earth spillway is required to pass excess storm runoff around the dam. The procedures for planning the spillway and providing for protection against erosion are the same as those previously discussed under embankment ponds.

(2) Sometimes surface runoff must enter an excavated pond through a channel or ditch rather than through a broad shallow drainageway. In such cases the overfall from the ditch bottom to the bottom of the pond may create a serious erosion problem. Scouring will take place in the side elope of the pond and for a considerable distance upstream in the ditch. The resulting sediment will reduce the depth and capacity of the pond. Protection can best be provided using one or more lengths of pipe of adequate size placed in the ditch, backfilled, and extended over the side slope of the excavation. The extended portion of the pipe may be cantilevered over timber supports. The required diameter of the pipe for an on-channel pond will depend on the peak rate of runoff that may be expected to occur once in 10 years. The procedure for estimating peak rates of runoff is presented in 210-NEH-650-2, "Estimating Runoff Volume and Peak Discharge." Figure 11-75 shows the capacity of various sizes of pipe inlets. Where more than one pipe inlet is required, their combined capacity should equal or exceed the estimated peak rate of runoff.

Figure 11-75: Diameters of Pipe Inlets Required to Discharge Various Rates of Inflow into Excavated Ponds

Pond Inflow, Q		Pipe Diameter 1/		Pond Inflow, Q		Pipe Diameter 1/	
(cfs)	**(cms)**	**(inches)**	**(mm)**	**(cfs)**	**(cms)**	**(inches)**	**(mm)**
0 – 6	0 – 0.17	15	380	30 - 46	0.85 – 1.3	36	900
6 – 9	0.17 – 0.25	18	450	46 – 67	1.3 – 1.9	42	1050
9 – 13	0.25 – 0.36	21	530	67 – 92	1.9 – 2.6	48	1200
13 – 18	0.36 – 0.51	24	600	92 – 122	2.6 – 3.5	54	1350
18 – 30	0.51 – 0.85	30	750	122 – 158	3.5 – 4.5	60	1500

1/ Based on a free outlet and a minimum pipe slope of 1 percent with the water level 0.5 foot above the top of the pipe at the upstream end.

(3) For off-channel ponds, the pipe size should be such that it will divert from the channel enough runoff from normal annual rainfall or low flows to supply the reservoir. Here, duration of flow is of prime importance.

(4) Off-channel ponds also can be filled by pumping from the stream during storm flows. The pump must be large enough to fill the pond before stream flow returns to normal.

(5) In areas where a considerable amount of silt is carried by the inflowing water a grassed filter strip should be provided in the drainageway immediately above the pond. The width of this strip should be equal to or somewhat greater than the width of the pond and its length should be 100 feet or more. The perennial grasses used should create a high "n" value so that flows through the grass will be reduced in velocity to a point where the silt will settle out and the water entering the pond will be relatively silt-free. See small insert, figure 11-72.

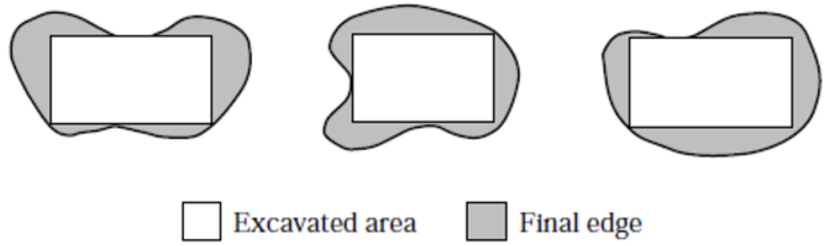
650.1117 Planning and Excavated Pond

A. Shape and Capacity

(1) Excavated ponds may be constructed to almost: any shape desired, however, a rectangular shape usually is the most convenient for excavating equipment.

(2) Rectangular ponds should not be constructed, however, where the resulting shape would be in sharp contrast to surrounding topography and landscape patterns. An irregularly shaped pond with smooth, flowing shorelines is far more interesting and appears larger. A pond can be excavated in a rectangular form and the edge shaped later with a blade scraper to create an irregular configuration (fig. 11-76).

Figure 11-76: Geometric Excavation Graded to Create More Natural Configuration



(3) The required capacity of an excavated pond fed by surface runoff is determined by the purpose for which water 'is needed and the amount of inflow that can be expected. These factors have been discussed under embankment ponds.
(4) The required capacity of an excavated pond fed by an underground water-bearing layer is difficult to determine since the estimated rate of inflow into the pond can rarely be estimated with reasonable accuracy. For this reason, the pond should be constructed in such manner that it can be enlarged if the origina1 capacity proves inadequate.
(5) A pond's apparent size is not always the same as its actual size. For example, the more sky reflected on the water surface, the larger a pond appears. A pond surrounded by trees will appear smaller than a pond the same size without trees or with some shoreline trees (fig. 11-77). The point from which a pond is viewed will also determine its apparent size. From ground level a pond will appear smaller than from a higher position. An elevated viewpoint can be achieved by using excess spoil material to construct mounds (fig.11-78), or by locating the pond near existing raised landforms. A pond's depth, shape, and size are affected by the amount of sediment that accumulates; so, it is important to minimize sedimentation for many reasons, including maintaining its intended appearance.

Figure 11-77: Viewing Pond from an Elevated Viewpoint

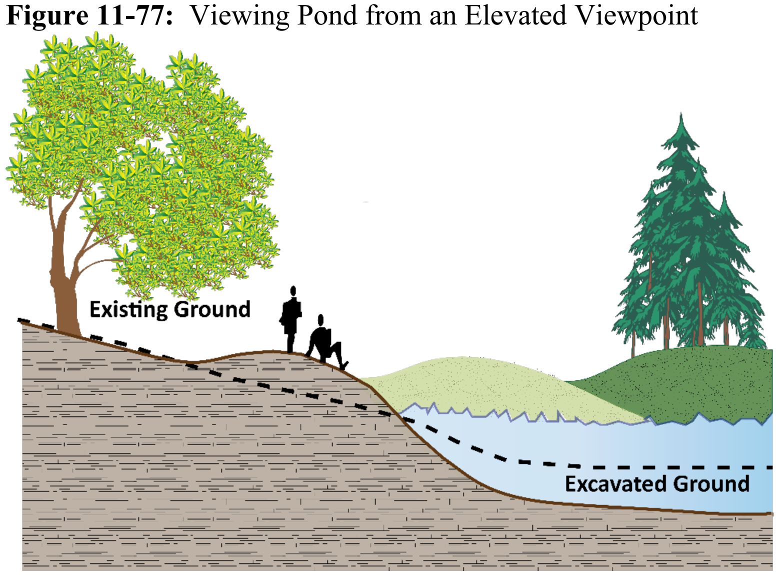
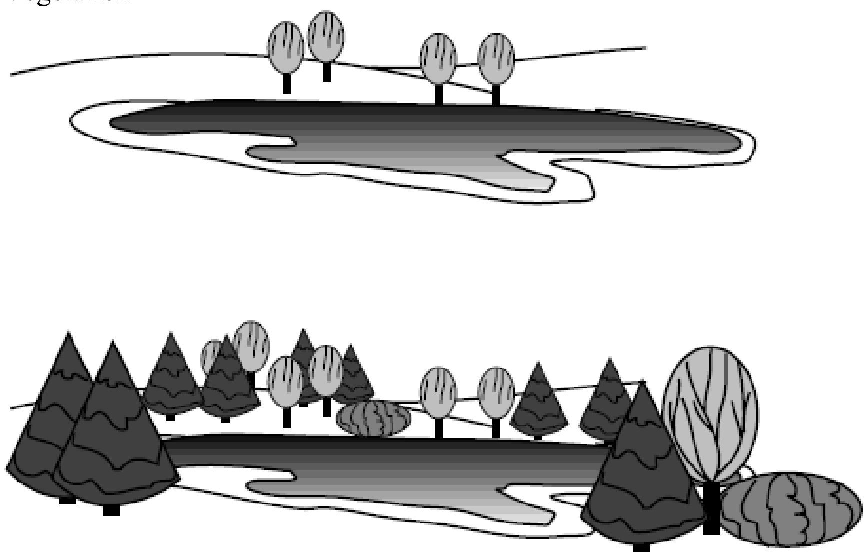


Figure 11-78: The Apparent Size of the Pond is Influenced by Surrounding Vegetation



B. Selecting Pond Dimensions

(1) The selected dimensions of an excavated pond will depend upon the required capacity. Excavated ponds fed by surface runoff should have a depth equal to or greater than the minimum required by State standards and specifications. Where an excavated pond is fed from ground water, the depth should extend well into the water-bearing material. The maximum depth will depend on the climatic conditions, the nature of the material to be excavated, and the type of equipment to be used in excavating the pond.

(2) The width of an excavated pond will not ordinarily be limited, except that the type and size of the excavating equipment may become a limiting factor. For example, if a dragline is used the length of the boom will determine the maximum width of excavation that can be made with proper placement of the waste material.

(3) The minimum length of the pond should be that needed to obtain the required pond capacity. However, this length may need to be increased to meet the needs of the excavating equipment, such as a carryall.

(4) The side elopes of an excavated pond should not be steeper than the natural angle of repose of the material being excavated. This angle will vary with different soils, but in most cases the side slopes should be flatter than 1:1

(5) Where the water is to be used for watering livestock, a ramp with a slope of 4:1, or flatter, should be provided at one or both ends for access Regardless of the intended use of the water, these flat slopes at the ends of the pond are necessary when tractor-pulled scrapers or bulldozers are used for construction.

C. Estimating the Volume of an Excavated Pond

(1) After the dimensions and side slopes of the pond have been selected, it is usually necessary to prepare an estimate of the volume of excavation. Such an estimate determines the cost of the pond and serves as a basis for payment if the work is done by contract.

(2) The volume of excavation required can be estimated with enough accuracy by use of the prismoidal formula:

$$V = \frac{(A + 4B + C)}{6} \times \frac{D}{27}$$

where:

V = volume of excavation in cubic yards
A = area of excavation at the ground surface in square feed
B = area of excavation at the mid-depth point (1/2 D) in square feet
C = area of excavation at the bottom of the pond in square feet
D = average depth of the pond, in feet
27 = factor converting cubic feet to cubic yards

(3) As an example, assume a pond with a depth, D, of 12 feet; a bottom width, W, of 40 feet, and a bottom length, L, of 100 feet as shown in figure 11-71.

(4) The side slope at the ramp end is 4:1 and the remaining slopes are 2:1. The volume excavation, V, is computed as follows:

Top length = 12 (2) + 12(4) + 100 = 172 feet
Top width = 12(2)(2) + 40 = 88 feet
A = 88 x 172 = 15,136 square feet

Mid-length = 6(2) + 6(4) + 100 = 136 feet
Mid-with = 6(2)(2) + 40 = 64 feet
4B = 4(64 x 136) = 34, 816 square feet
C = 40 x 100 = 4,000 square feet
(A + 4B + C) = 59,952 square feet

Then V = 53,952/6 x 12/27 = 3,996 cubic yards (or 4,000 cubic yards)

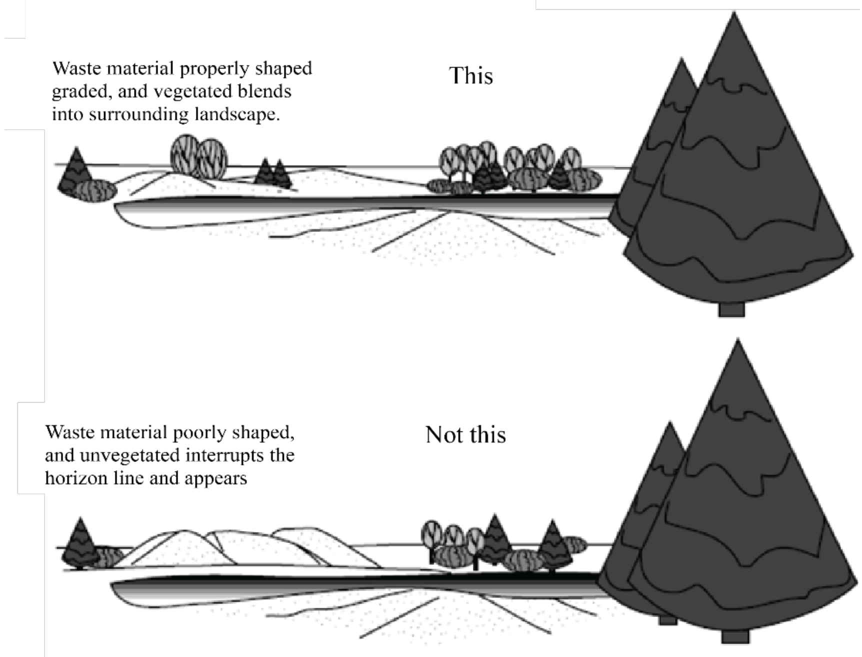
(5) Assuming that the normal water level in the pond is at the ground surface, the volume of water that can be stored in the pond is 4,000 cu, yds. x 0.00062, or 2.48 acre-feet. To convert to gallons multiply 4,000 cu. yds. by 202.0 to get 808,000 gallons. The same procedure is used to compute the volume of water that can be stored in the pond when the normal water level is below the ground surface. In this case, the value assigned to the depth, D, is the actual depth of water in the pond rather than the depth of excavation.

D. Disposal of Waste Materials

(1) Plan the placement or disposal of the material excavated from the pond in advance of construction operations. Adequate placement prolongs the useful life of the pond, improves its appearance, and facilitates maintenance and establishment of vegetation. The waste material can be stacked, spread, or removed from the site as conditions, nature of the material, and other circumstances warrant.

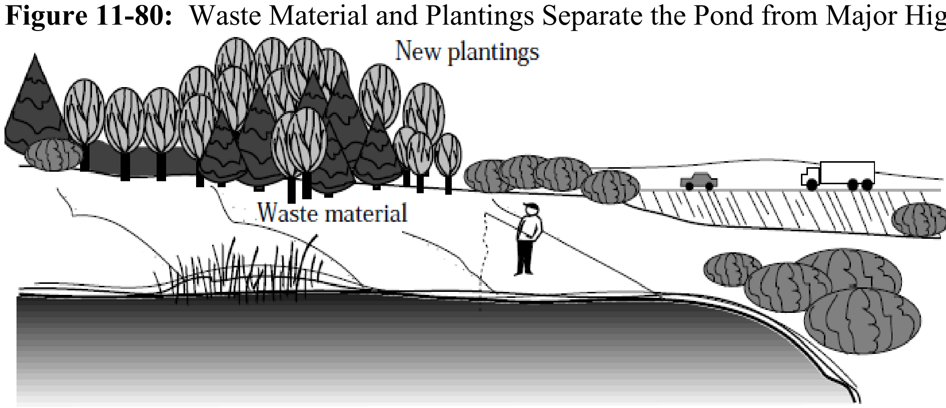
(2) If waste material is not removed from the site, place it so that its weight does not endanger the stability of the side slopes and rainfall does not wash the material back into the pond. If the material is stacked, place it with side slopes no steeper than the natural angle of repose of the soil. Do not stack waste material in a geometric mound, but shape and spread it to blend with natural landforms in the area. Because many excavated ponds are in flat terrain, the waste material may be the most conspicuous feature in the landscape. Avoid interrupting the existing horizon line with the top of the waste mound (fig. 11-79).

Figure 11-79: Correct Disposal of Waste Material



(3) Waste material can also be located and designed to be functional. It can screen undesirable views, buffer noise and wind, or improve the site's suitability for recreation (fig. 11-80). In shaping the material, the toe of the fill must be at least 12 feet from the edge of the pond. In the Great Plains you can place the waste material on the windward side of the pond to serve as a snow fence for collecting drifts in the pond. These banks can also reduce evaporation losses by breaking the force of prevailing winds across the pond.

Figure 11-80: Waste Material and Plantings Separate the Pond from Major Highway



(4) Perhaps the most satisfactory method of handling waste material is to remove it from the site. Complete removal, however, is expensive and can seldom be justified unless the material is needed nearby. Waste material can sometimes be used advantageously for filling nearby low areas in a field or in building farm roads. If State or county highway maintenance crews need such material, you may be able to have them remove it. Figure 11-72 shows cross sections of a pond illustrating the methods of placement and disposal of waste material.

650.1118 Excavated Pond Construction

A. The pond site and waste areas should first be cleared of all woody vegetation. .The limits of the excavation and spoil placement areas should be staked, and the depth of cut from the ground surface to the pond bottom should be indicated on the stakes.

B. Excavation and the placement of the waste material are the principal items of work required in the construction of this type of pond. The type of equipment used will depend on climate and physical conditions at the site, and on the equipment available.

C. In areas of low rainfall almost any type of equipment may be used, and the choice of type is determined by availability. The most used are tractor-pulled wheeled scrapers, draglines, and bulldozers. Due to its inefficiency in transporting material, the use of a bulldozer for excavation is usually limited to relatively small ponds.

D. In high-rainfall areas and in areas where a ground water table exists within the limits of excavation, the dragline is most used since it can operate satisfactorily in water, The dragline is used exclusively for ponds fed by ground water aquifers.

E. The excavation should be made, and the waste material placed as near to the staked lines and grades as skillful operation of the equipment will permit. Where the pond is constructed by a dragline, other types of equipment may be required to shape or spread the waste material. Bulldozers and graders are commonly used for this purpose.

F. Excavated-ponds should be protected against erosion damage by a good cover of sod-forming grasses on the side slopes of the pond above the normal water level, the berms, the waste banks, and the emergency spillway, where required.

650.1119 Sealing Methods

A. General

(1) Excessive seepage losses in farm ponds usually are due to the selection of a site where the soils are too permeable to hold water. This may be the result of inadequate site investigations in the planning stage. However, the need for water may be so important as to justify the selection of a permeable site. In such cases, plans for reducing seepage losses by sealing should be part of the design.

(2) The problem of reducing seepage losses is one of reducing the permeability of the soils to a point where the losses become tolerable. Losses may be reduced by the methods discussed below, the choice of which will depend largely on the proportions of coarse-grained sand and gravel and fine-grained silt and clay in the soil. A thorough investigation of the materials to be sealed should be made by a soil’s scientist before the method of sealing is selected. In some cases, it may be necessary to have a laboratory analysis of the materials.

B. Sealing by Compaction Alone

(1) Pond areas containing a high percentage of coarse-grained material can be made relatively impervious by compaction alone if the material is well graded from small gravel or coarse sand to fine sand, clay, and silt. This method of sealing is the least expensive of those presented in this chapter, but its use is limited to the soil conditions described.

(2) The pond area should be cleared of all trees and other vegetation and all stump holes, crevices, and similar areas should be filled with relatively impervious material. The soil should be scarified to a depth of 8 to 10 inches with a disk, rototiller, pulverizer, or similar equipment and all rocks and tree roots should be removed. The loosened soil should be rolled under optimum moisture conditions to a dense, tight layer with four to six passes of a sheepsfoot roller (fig. 11-81).

Figure 11-81: Using a Sheepsfoot Roller to Compact the Pond Surface

(3) The thickness of the compacted seal should not be less than 8 inches for impoundments up to 10 feet in depth. Since seepage losses vary directly with the depth of water impounded, the thickness of the compacted seal should be increased proportionately when the depth of water exceeds 10 feet. This will require compacting the soil in two or more layers not exceeding 8 inches in thickness over that portion of the pond where the water depth exceeds 10 feet. In these cases, the top layer or layers of soil will have to be removed and stockpiled while the bottom layer is being compacted.

C. Use of Clay Blankets

(1) Pond areas containing high percentages of coarse-grained soils but lacking sufficient amounts of clay to prevent high seepage losses can be sealed by blanketing. The blanket should cover the entire area over which water is to be impounded. It should consist of material containing a wide range of particle sizes varying from small gravel or coarse sand to fine sand and clay in the desired proportions. Such material should contain approximately 20 percent by weight of clay particles.

(2) The thickness of the blanket will depend on the depth of water to be impounded. The minimum thickness should be 12 inches for all depths of water up to 10 feet. The minimum should be increased by 2 inches for each foot of water over 10 feet. The construction procedure is like that described previously for constructing earth embankments.
(3) Clay blankets require protection from cracking that results from drying or freezing and thawing. A cover of gravel, 12- to 18-inches thick, placed over the blanket may be used for this purpose. Blanketed areas should be protected by a cantilevered pipe or rock riprap where flow into the pond is concentrated.

D. Sealing with Bentonite

(1) Seepage losses in well graded coarse-grained soils may be reduced by the addition of bentonite. Bentonite is a fine textured colloidal clay that will absorb several times its own weight in water. At complete saturation it will swell from 8 to 15 times its original volume. When bentonite is mixed in the correct proportions with the coarse-grained material, and the mixture is thoroughly compacted and saturated, the particles of Bentonite will fill the pores in the material and make it nearly impervious. A laboratory analysis of the material is essential to determine the amount of Bentonite that should be applied per unit of area. Rates of application range from 1 to 3 pounds per square foot, depending on site conditions. Bentonite, upon drying, will return to its original volume and leave cracks in the pond area. For this reason, Bentonite is not recommended for ponds where a wide fluctuation in the water level is expected.
(2) As with other methods, the pond area should be cleared of all vegetation and all holes, crevices, and areas of exposed gravel should be filled or covered with suitable compacted material.
(3) The soil moisture level in the area to be treated should be optimum for good compaction. If the area Is found to be too wet, sealing operations should be postponed until moisture conditions are satisfactory. If the material is too dry, water should be added by sprinkling.
(4) The Bentonite should be spread uniformly over the area to be treated at the rate determined by the laboratory analysis. The Bentonite is then thoroughly mixed with the soil to a depth of at least 6 inches with a rototiller, disk, or similar equipment. The area should then be compacted with four to six passes of a sheepsfoot roller.
(5) Since considerable time may elapse between application of the Bentonite and the filling of the pod it may be necessary to protect the treated area by mulching with straw or hay anchored to the surface by the final passes of the sheepsfoot roller. Treated areas subject to inflow should be protected by riprap or other mechanical means.

E. Treatment with Chemical Additives

(1) Excessive seepage losses often occur in fine grained clay soils because of the arrangement of the clay particles which form a honeycomb structure. Such soils are said to be aggregated and have a relatively high permeability rate. The application of small amounts of certain chemicals to these aggregates may result in collapse of the open structure and rearrangement of the clay particles. The chemicals used are called dispersing agents.
(2) For chemical treatment to be effective, the soils in the pond area should contain more than 50 percent of fine-grained material (silt and clay finer than .074 mm diameter) and at least 15 percent of clay finer than .002 mm diameter. The soils should contain less than 0.5 percent soluble salts (based on dry soil weight). Chemical treatment is not effective in coarse grained soils.

(3) While there are many soluble salts that meet the requirement of a dispersing agent, sodium polyphosphates are most used. tetrasodium pyrophosphate (TSPP) and sodium tripolyphosphate (STPP) are most effective. These dispersants should be finely granular with 95 percent passing a No. 30 sieve and less than 5 percent passing a No. 100 sieve. They usually are applied at a rate of from 0.05 to 0.10 pounds per square foot. Sodium chloride, which is less effective, is applied at a rate of from 0.20 to 0.33 pounds per square foot. A laboratory analysis of the soils in the pond area is essential to determine which of these dispersing agents will be most effective and the rate at which it should be applied.

(4) The dispersing agent is mixed with the surface soil and compacted to form a blanket. For depths of water up to 8 feet, the blanket thickness should be at least 6 inches. For depths of water greater than 8 feet, the blanket should be 12 inches thick treated in two 6-inch lifts. A minimum thickness of 12 inches is recommended for all areas in the range of water surface fluctuation.

(5) The area to be treated should be cleared of all vegetation and trash. Rock outcrops and other exposed areas of highly permeable material should be covered with from 2 to 3 feet of fine-grained soil. This material should then be thoroughly compacted, in cavernous limestone areas, the success or failure of the seal may depend upon the thickness and compaction of this initial blanket.

(6) The soil moisture level in the area to be treated should be near optimum for compaction down to a depth of 12 inches. If the soil is too wet treatment should be postponed. Polyphosphates release water from the soil and the job could easily become too wet to handle. If the soil is too dry, water should be added by sprinkling.

(7) The dispersing-agent should be applied uniformly over the pond area at a rate determined by the laboratory analysis. The dispersant may be applied with a seeder, drill, fertilizer spreader or by hand broadcasting (fig. 11-82).

Figure 11-82: Applying Soda Ash to the Pond Bottom

(8) The dispersing agent should be thoroughly mixed into each 6-inch layer with a disk, rototiller, pulverizer or similar equipment. Operating the mixing equipment in two directions will produce best results. Each chemically treated layer should be thoroughly compacted with 4 to 6 passes of a sheepsfoot roller.

(9) The treated blanket should be protected from puncture by livestock trampling. Areas near the normal waterline should also be protected from erosion by covering with a 12- to 18-inch blanket of gravel or other suitable bacterial. Areas where inflow into the pond is concentrated should be protected with riprap or other erosion resistant materials such as concrete or metal pipe.
(10) Due to rapid technologic advancements, new chemical additives are being developed constantly. Some of these may prove useful in reducing seepage losses.

F. Use of Flexible Membranes

(1) Another method of reducing excessive seepage losses is the use of flexible membranes of polyethylene, vinyl, and butyl rubber (fig 11-83).

Figure 11-83: An Arizona Pond with a Flexible Membrane Liner

(2) Thin films of these materials are structurally weak but, if kept intact, they are almost completely watertight. Polyethylene film are less expensive and have better aging properties than vinyl. Vinyl is more resistant to impact damage and is readily darned and patched with a solvent cement. Polyethylene can be joined or patched only by heat sealing. Butyl rubber can be joined or patched with a special cement.
(3) These thin films must be protected from mechanical damage if they are to be serviceable. All polyethylene and vinyl rubber membranes should have a cover of earth or earth and gravel not less than 6 inches thick. Butyl rubber membranes need to be covered only in areas subject to travel by livestock. In these areas, a minimum cover of 9 inches should be used over all types of membranes. The bottom 3 inches of cover should not be coarser than silty sand.
(4) All membranes should be of a quality that meets or exceeds the minimum requirements shown in the State standards and specifications for pond sealing or lining. The minimum normal thickness should equal or exceed the value shown below for the soil material being covered and the type of membrane used.

Figure 11-84: Minimum membrane normal thickness

Soil Material Not Coarser than	Polyethylene	Vinyl	Butyl Rubber
Sands, clean or silty	8 mil.	8 mil.	15 mil
Gravels, clean, silty or clayey	15 mil	15 mil	30 mil

(5) The area to be lined should be drained and allowed to dry until the surface is firm and will support the men and equipment that must travel over it during installation of the lining.
(6) The pond area should be cleared of all vegetation and all roots, sharp stones or other objects that might tend to puncture the film, If the material over which the lining is to be placed is stony or of very coarse texture, it should be covered with a cushion layer of fine textured material before the lining is placed. All banks, side slopes and fills within the area to be lined should be uniformly sloped no steeper than 1:l for exposed lining and 3:l for covered lining. The cover material my slide on the lining if placed on steeper slopes.
(7) Certain plants penetrate vinyl and polyethylene film. For this reason; it is desirable to sterilize the subgrade with chemicals, particularly the aide slopes where nut grass, Johnson grass, quack grass, and other plants having a high penetrating power are present. Sterilization is not required where butyl rubber membranes are used.
(8) The top edges of the lining should be anchored in a trench excavated completely around the area to be lined at the planned elevation of the top of the lining. The trench should be 8 to 10 inches deep and about 12 inches wide. The lining should then be anchored by burying 8 to 12 inches of the lining in the anchor trench and securing it with compacted backfill.
(9) The linings are usually laid in sections or strips with a 6-inch overlap for seaming. Vinyl and butyl rubber linings should be laid smooth but in a loose state. Polyethylene should have up to 10 percent slack. Extreme care must be exercised in handling to avoid puncture.
(10) The materials used to cover the membrane should be free of large clods, sharp rocks, sticks and other objects that would puncture the lining. The cover should be placed to the specified depth without damage to the membrane.

650.1120 Fencing

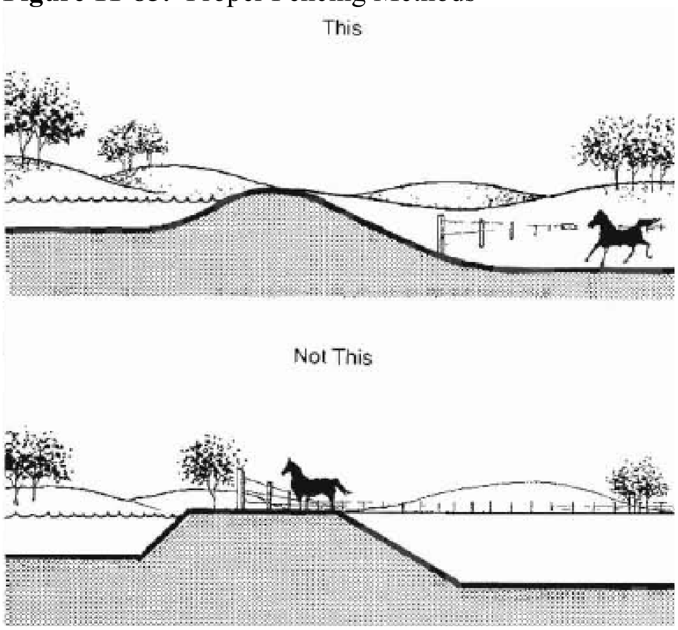
A. Fencing may be needed to protect the impoundment from livestock or for safety reasons. Complete fencing is recommended if livestock are grazed or fed in adjacent fields. Fencing provides the protection needed to develop and maintain a good plant cover on the dam, the auxiliary spillway, and in other areas. It enhances clean drinking water and eliminates damage or pollution by livestock. If you fence the entire area around the pond and use the pond for watering livestock, install a gravity-fed watering trough just downstream from the dam and outside the fenced area.

B. Fencing also enables you to establish an environment beneficial to wildlife. The marshy vegetation needed around ponds for satisfactory wildlife food and cover does not tolerate much trampling or grazing.

C. Not all ponds used for watering livestock need to be fenced. On some western and midwestern ranges, the advantages derived from fencing are more than offset by the increased cost and maintenance and the fact that fewer animals can water at one time. A rancher with many widely scattered ponds and extensive holdings must have simple installations that require minimum upkeep and inspection. Fencing critical parts of livestock watering ponds, particularly the earthfill and the auxiliary spillway, is usually advantageous even if complete fencing is impractical.

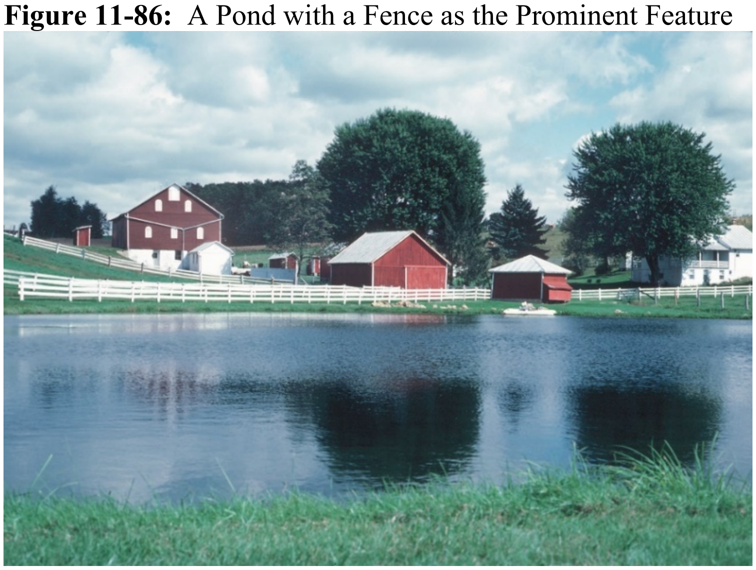
D. Fencing should be appropriate for the planned use and compatible with design objectives. The location and type of fencing should be considered carefully. Locating a fence at the toe of a slope rather than at the top reduces its prominence (fig. 11-85). Fences placed along existing edges or among trees are also less noticeable.

Figure 11-85: Proper Fencing Methods



E. Some types of fences are less apparent than others because of their design and the materials used. A wire fence will be more obtrusive if it is heavy gauge and reflective. Chain-link fencing, for example, can be vinyl-coated in black or natural colors that make it blend into its surroundings. When the objective is to make fencing a prominent feature, wood rails, solid boards, panels, or board and batten styles may be appropriate (fig. 11-86).

Figure 11-86: A Pond with a Fence as the Prominent Feature



650.1121 Appurtenant Structures

The number of structural elements associated with a pond varies with the type of pond and its intended use. Depending on the objective, these elements can be camouflaged or developed into focal points. Generally, however, it is best to reduce the contrast of inlet structures and their components. Large concrete surfaces can be textured or tinted to reduce reflectiveness (fig. 11-87). Reflective metal risers and pipes can be painted to be more compatible with existing conditions. Recreation structures (picnic shelters, restrooms, docks, bridges, and the like) should be unified in style, and materials. Other structures such as pumping plants should be designed to fit into the site and blend with their surroundings or be screened from view.

Figure 11-87: A Pond Structure with Textured Concrete Surfaces

650.1122 Pond Operation and Maintenance

A. A pond, no matter how well planned and built, must be adequately maintained if its intended purposes are to be realized throughout its expected life. Lack of operation and maintenance has caused severe damage to many dams and spillways. Some structures have failed completely. For these reasons an operation and maintenance plan needs to be developed for landowner. The plan should include such things as—

(1) Periodic inspections.—ponds need to be examined periodically, and especially after heavy rains, to determine whether it is functioning properly or needs minor repairs. Repairing damage immediately generally eliminates the need for more costly repairs later. Damage may be small, but if neglected it may increase until repair becomes impractical and the entire structure must be replaced.

(2) Maintenance of embankment and spillways.—Rills on the side slopes of the dam and any washes in the auxiliary spillway need to be filled immediately with suitable material and compacted thoroughly.

(3) If the upstream face of the earthfill shows signs of serious washing or sloughing because of wave action, install protective devices, such as booms or riprap. If seepage through or under the dam is evident corrective measures should be made before serious damage occurs. In some localities burrowing animals such as badgers, gophers, beaver, and prairie dogs cause severe damage to dams or spillways. If this damage is not repaired, it may lead to failure of the dam. Keep pipes, trash racks, outlet structures, valves, and watering troughs free of trash at all times.
(4) Using a submerged inlet or locating the inlet in deeper water discourages beavers from the pipe inlets. A heavy layer of sand or gravel on the fill discourages burrowing to some extent. Poultry netting can be used, but in time it rusts out and needs to be replaced.
(5) Maintenance of plant cover.—The protective plant cover on the dam and on the auxiliary spillway needs to be maintained to promote vigor, mow it frequently and fertilize when needed and reseed or re-sod areas as needed. Mowing prevents the growth of woody plants where undesirable and helps develop a cover and root system more resistant to runoff. If the plant cover is protected by fencing, keep the fences in good repair.
(6) Maintain water quality.—Water in the pond should be kept as clean and unpolluted as possible. Do not permit unnecessary trampling by livestock, particularly hogs. If fencing is not practical, the approaches to the pond can be paved with small rocks or gravel. Divert drainage from barn lots, feeding yards, bedding grounds, or any other source of contamination away from the pond. Clean water is especially important in ponds used for wildlife, recreation, and water supply.
(7) Control vectors.—In areas where surface water encourages mosquito breeding, stock the pond with top feeding fish. In malaria areas, do not keep any aquatic growth or shoreline vegetation and take special precautions in planning, building, and operating and maintaining the pond. Most States in malaria areas have health regulations covering these precautions. These regulations should be followed.
(8) Control noxious aquatic growth.—In some areas, algae and other forms of plant life may become objectionable. They can cause disagreeable tastes or odors, encourage bacterial development, and produce an unsightly appearance.

B. Nuisance Wildlife and Vegetation

(1) Impoundment s will attract a variety of wildlife and vegetative species. Keystone wildlife species such as beaver, muskrat, crayfish, and alligator may pose unique challenges to the design and maintenance of impoundments. Embracing such organisms and their activities through innovative design and management will reduce long-term maintenance costs while promoting natural processes. Listed below are some of the more common problem species and planning considerations for their control.
(2) Waterfowl
    (i) In urban and industrial areas, large numbers of ducks and geese have the ability to damage lawns and landscaped areas. Overuse by waterfowl can damage community parks or make them unpleasant to humans, and large numbers of waterfowl can adversely affect water quality in water supply reservoirs. Due to excessive waterfowl waste, wetlands may receive a high load of organics and become a source of unpleasant odors and mosquitoes.
    (ii) Discouraging the public from feeding waterfowl and planting a vegetated border of tall, rigid stemmed herbaceous vegetation around the shoreline are ways to deter waterfowl loafing. It would not be prudent to locate impoundments that attract large numbers of geese near urban airports.

(3) Mosquitoes

(i) Dozens of mosquito species may breed in an impoundment, but very few of these species, termed vector mosquitoes, are of concern to humans. Vector mosquito species generally breed in shallow, stagnant water where they are safe from predators and in waters that have high organic content in degraded waters with a compromised ecological community.

(ii) To reduce the attractiveness to breeding mosquitoes, addressing nutrient and organic enrichment concerns and stabilizing hydrology within the wetland is of utmost importance, especially in urban areas. In addition, some species of mosquito avoid breeding in waters that house a diverse community of predatory insects or a large number of organisms that would compete for the same food resources as mosquito larvae. Thus, managing for a diverse ecological community can help to deter and control mosquito reproduction.

(iii) If fish are present, vector mosquitoes may not be a problem unless there are extensive areas of shallow water less than 6 inches deep with fine-stemmed vegetation where fish cannot maneuver. In some situations, it may be acceptable for populations of small, native wetland fish to be stocked and managed in suitable habitat within their natural range to provide mosquito larvae control. Before introducing any species of fish, local fisheries experts should be consulted, and careful consideration should be given to possible adverse impacts on populations of other native species, fish or otherwise.

(iv) The use of pesticides to control mosquitoes is generally not recommended unless used as a last resort in areas where human health concerns are high. An exception to this would be applying pesticides to waste treatment wetlands that receive high levels of pollutants and do not support diverse biotic assemblages of plants and animals. Pesticides must be chosen carefully and applied following label instructions. The application of pesticides near water could have significant negative impacts on nontarget species.

(v) *Bacillus thuringiensis israelensis* or *Bacillus sphaericus* (BTI) is a biocontrol microbial larvicide which is ingested by and kills mosquito and other true fly (Dipteran) larvae. To date, BTI is not known to harm other insect or vertebrate species. True fly larvae are critically important decomposers of organic material and are the most abundant macroinvertebrate prey within riparian sediments. Keeping this in mind, treating impoundments with BTI to reduce mosquito concerns could have the potential to negatively impact other true fly species and their predators, a consideration that must be addressed especially when providing adequate wildlife habitat and food resources are targeted goals for management.

(vi) Artificial drawdown or drainage is a common, but ineffective practice used to control mosquitoes in some areas. The act of draining water bodies increases the amount of shallow, stagnant, short hydroperiod pools preferred by mosquitoes, while reducing the populations of organisms that prey on and compete with mosquito larvae. Contrary to traditional drainage measures, restoring and maintaining hydrology within the realm of historic, natural variability will have a greater effect in controlling mosquito populations without compromising nontarget organisms. Reducing access, using repellents, wearing appropriate clothing, and avoiding wet areas during peak mosquito activity periods and seasons are effective means in avoiding mosquito nuisance concerns.

(4) Fish

(i) Carp and other rough fish that invade impoundments can potentially destroy the aquatic plant community or compete with other species for resources, reducing populations of desirable plants and animals. Designing impoundments that will experience natural drawdown due to seasonal or semi-permanent hydrology will allow for natural control against rough fish. Although fish populations can be reduced by netting, the most effective method of rough fish control in water bodies equipped with water control structures is to conduct a complete drawdown and allow the bottom sediments to dry. Special care must be taken to be sure that small pools of water do not remain when a complete drawdown is needed. Careful timing of water drawdown and potential impacts to nontarget plants and animals should be considered.

(ii) Impoundments with inflows or outflows connected to other water bodies may allow for fish passage and may require barriers to fish movement to keep undesirable fish out of, or in some circumstances within, the water body being managed.

(5) Vegetation

Some species of vegetation can become very prolific and cause problems in achieving planned functions and values. For example, cattails can cover an entire shallow (less than 2 ft deep), nutrient-enriched impoundment, eliminating other desirable vegetation or open water habitat. However, dense stands of cattails can also provide water quality benefits by removing nutrients and pollutants and provide habitat for some species such as the yellow headed blackbird. Vegetation can be controlled chemically, mechanically, biologically, or a combination thereof. For sites with foreseen vegetation management challenges, water control structures may be planned to facilitate complete drainage and tillage of the bottom or that allow water depth to be increased by at least 3 feet for a growing season. In addition, muskrats can be used as biological control agents for cattails, as can beavers for tree control.

(6) Mammals

(i) It is claimed that the beaver is a close second to humans in the ability to change a landscape. For this reason, beavers can commonly become a problem where they may burrow into banks or dikes or dam outflows (fig. 11-88). Adjacent to urban areas and within tree plantings, beavers may eat shrubbery and ornamental trees. The best defense against beaver invasion is to select vegetation beavers do not like. Consider using screened culverts and water control structures with anti-beaver devices or installing drains that prevent beavers from controlling the water level.

(ii) Muskrat and nutria are two other mammals that can cause problems in permanent water over 3 feet deep. Their burrowing activities may place embankments at risk unless extra width is planned. Like beavers, these animals start their burrows in deeper water, so planning for a wide, shallow berm or very gradual slope will help prevent problems. This same technique works well in circumstances where burrowing crayfish may be of concern to the stability of structures. If muskrats or nutria become problems, they can be controlled by trapping.

Figure 11-88: Beaver Dam Obstruction

650.1123 Pond Safety

A. Ponds, like any body of water, attract people so that there is always a chance of injury or drowning. The following steps should be taken to help prevent injuries or drowning.

B. Before construction

(1) Almost all States have laws on impounding water and on the design, construction, and operation and maintenance of ponds. In many States small farm ponds are exempt from any such laws. You should become familiar with those that apply in your State and be sure that you comply with them.
(2) Find out what local or State laws are regarding liability in case of injury or death resulting from use of a pond, whether the use is authorized or not. This is particularly important if pond will be open to the public and if a fee is charged for its use. The landowner may need to protect themself with insurance.
(3) You should decide how the water is going to be used so that you can plan the needed safety measures before construction starts. For example, if the water is to be used for swimming, guards over conduits are required. You may wish to provide for beaches and diving facilities; the latter require a minimum depth of about 10 feet of water.

C. During construction

The contractor should take other safety measures during pond construction. Remove all undesirable trees, stumps, and brush and all rubbish, wire, junk machinery, and fences that might be hazardous to boating and swimming. Eliminate sudden drop-offs and deep holes.

D. After completion

Mark safe swimming areas and place warning signs at all danger points. Place lifesaving devices, such as ring buoys, ropes, planks, or long poles, at swimming areas to facilitate rescue operations should the need arise. Place long planks or ladders at ice skating areas for the same reason.

Figure 11-89: Pond with Rope Safety Ladders Attached

650.1124 References

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D. U.S. Department of Agriculture, Natural Resources Conservation Service. 2017. Title 210, National Engineering Handbook, Part 633 Soils Engineering, Chapter 26, Gradation Design of Sand and Gravel Filters. Washington, DC

650.1125 Acknowledgements

A. This chapter was prepared by the USDA NRCS, under the direction of Noller Herbert, Director, Conservation Engineering Division (CED), Washington, D.C. This chapter was originally compiled by George M. Renfro, Agricultural Engineer, Soil Conservation Service (SCS), Fort Worth, TX, in 1980.

B. This revision was prepared by the following committee, assigned by Robert Snieckus, National Landscape Architect, CED, NRCS (Retired).

C. Claudia Hoeft, National Hydraulic Engineer, CED, NRCS, Washington D.C.

D. Don Woodward, National Hydraulic Engineer, CED, NRCS (Retired).

E. Mark Locke, National Design Engineer, CED, NRCS, Washington D.C.

F. Rosanna Brown, Landscape Architect, National Design, Construction, and Soil Mechanics Center, NRCS, Fort Worth, TX.

G. Gary Wells, former Landscape Architect, National Design, Construction, and Soil Mechanics Center, NRCS, Lincoln, NE.

H. Steve Durgin, National Design Engineer, CED, NRCS, (Retired).

I. Clarence Prestwich, National Agricultural Engineer, CED, NRCS, Washington, D.C.

Appendix 11A

A. Figures 11-A1, 11-A2, and A3 can be used to determine the capacity of principal spillways considering temporary storage. Figure 11-A1 is a plot of Vs versus Vr to determine which figure to use. Figure 11-A2 is for pipe flow structures with a discharge over 0.47 ft3/s/acre (300 csm) and figure 11-A3 is for pipe flow structures with a discharge under 0.47 ft3/s/acre.

(1) Description of terms:
Vs = Volume of temporary storage, acre-feet or in.
Vr = Volume of runoff, acre-feet or in.
Qo = Required principal spillway discharge, ft^3/s (Table A) and $ft^3/s/acre$ (Table B)
Qi = Peak flow from design storm, ft^3/s

Figure 11A-1: Plot of Vs versus Vr

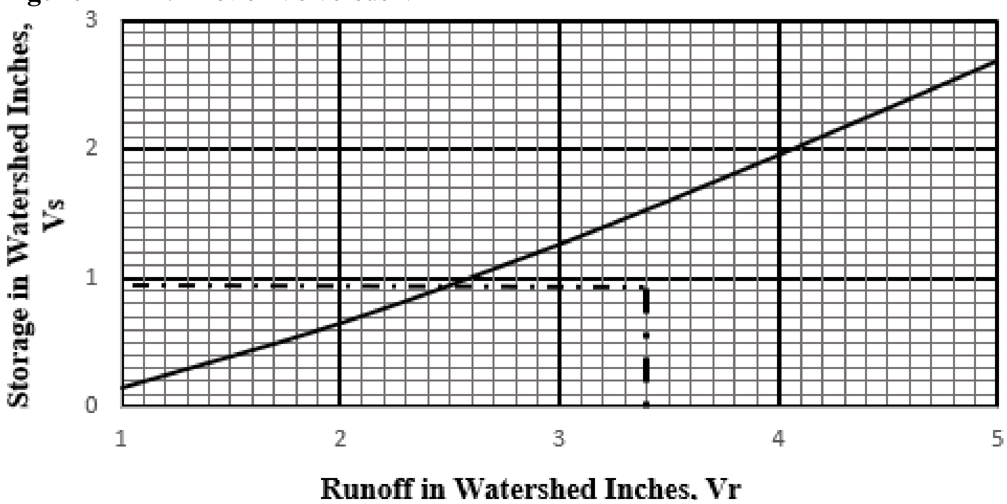

Figure 11A-2: Values of Qo/Qi for Pipe Flow Structures with a Discharge over 0.47 ft3/s/acre (300 csm)

$\frac{Vs}{Vr}$	0.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	1.00	.99	.98	.96	.95	.94	.92	.91	.90	.88
0.1	.87	.85	.84	.82	.81	.79	.76	.76	.75	.74
0.2	.70	.67	.64	.61	.58	.56	.52	.52	.50	.48
0.3	.47	.45	.44	.42	.41	.40	.38	.38	.37	.36
0.4	.35	.32	.30	.28	.26	.24	.23	.21	.20	.19
0.5	.18	.17	.16	.15	.14	.13	.12	.12	.11	.11
0.6	.10	.10	.09	.09	.08	.08	.07	.07	.07	.07
0.7	.06	.06	.06	.06	.05	.05	.05	.05	.04	.04
0.8	.04	.04	.04	.04	.04	.03	.03	.03	.03	.03

Figure 11A-3: Values of Qo/Qi for Pipe Flow Structures with a Discharge under 0.47 ft3/s/acre (300 csm)

$\frac{Vs}{Vr}$	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.2**	**2.4**	**2.6**	**2.8**	**3.0**	**3.2**	**3.4**
1.0	0.89	0.39	0.19	0.10	0.06																	
1.2		0.62	0.33	0.20	0.12	0.08	0.05	0.04														
1.4			0.57	0.31	0.21	0.14	0.09	0.07	0.05													
1.6				0.57	0.33	0.23	0.16	0.11	0.08	0.06												
1.8					0.59	0.37	0.25	0.19	0.13	0.09	0.06											
2.0						0.64	0.42	0.27	0.21	0.14	0.09	0.06										
2.2							0.62	0.45	0.32	0.23	0.13	0.08	0.05									
2.4								0.65	0.49	0.34	0.20	0.12	0.08	0.05								
2.6										0.49	0.28	0.17	0.11	0.08	0.05							
2.8										0.69	0.41	0.25	0.16	0.11	0.08	0.05						
3.0											0.55	0.34	0.22	0.15	0.11	0.08	0.05					
3.2												0.49	0.31	0.20	0.14	0.10	0.08	0.05				
3.4												0.66	0.44	0.28	0.19	0.14	0.10	0.08	0.05			
3.6													0.56	0.39	0.26	0.19	0.14	0.10	0.08	0.05		
3.8														0.49	0.34	0.23	0.16	0.13	0.10	0.08	0.05	
4.0														0.65	0.45	0.31	0.22	0.17	0.13	0.09	0.07	0.05
4.2															0.55	0.41	0.28	0.20	0.16	0.12	0.09	0.07
4.4																0.49	0.36	0.25	0.21	0.14	0.12	0.09
4.6																0.62	0.45	0.33	0.27	0.19	0.15	0.12
4.8																	0.55	0.43	0.33	0.23	0.19	0.14
5.0																		0.49	0.39	0.31	0.23	0.18

B. Example #1

Given:

Vs = 5.9 acre-feet or 0.94 in.
Vr = 21.1 acre-feet or 3.4 in.
Qi = 360 ft^3/s
D.A. = 75 acres

Find: Qo

Solution:

Find the point for Vs of 0.94 in. and Vr of 3.4 in. in - figure 11-A1. Since the point is below the line, use figure 11-A2.

$Vs/Vr = Vs0.94/Vr3.4$ = 0.28 (vs and Vr must be in the same units)
Qo/Qi = 0.50 (from figure 11-A2)
Qo = 0.50 x Qi = 0.50 x 360 ft $^3/s$ = 180 ft^3/s

C. Example #2:

Given:

Vs = 34 acre-feet or 1.6 in.
Vr = 3.2 in.
Qi = 420 ft^3/s
D.A. = 256 acres (drainage area)

Find: Qo

Solution:

Use figure 11-A3 (determined from Figure 11-A1)
Qo = 0.31 $ft^3/s/acre$ (from fig 11-A3) = 0.31 $ft^3/s/acre$ x 256 = 79 $ft^3/s/$