



*An Online CPD Course  
brought to you by  
CEDengineering.ca*

## **A Guide to Excavated and Embankment Ponds**

Course No: C08-022  
Credit: 8 PDH

---

Allen Hughes, P.E.

---



Continuing Education and Development, Inc.

P: (877) 322-5800  
[info@cedengineering.ca](mailto:info@cedengineering.ca)



## **A Guide to Excavated and Embankment Pond Systems**

This course is a comprehensive guide, describing embankment and excavated pond design procedures, outlining the requirements for building each type of pond.



## **Table of Contents:**

Chapter One: Introduction to Pond Systems

Chapter Two: Water Needs for Constructing a Pond

Chapter Three: Site and Design Considerations

Chapter Four: Storm Runoff Considerations

Chapter Five : Construction of an Embankment Pond

Chapter Six: Dam and Spillway Requirements

Chapter Seven: Planning and Building the Earthfill Dam

Chapter Eight: Constructing an Excavated Pond

Chapter Nine: Pond Operation, Management, and Maintenance

Chapter Ten: Pond Aesthetics

# Chapter One: Introduction to Pond Systems

## Need for water storage

It's likely that since the days of primitive civilizations and before, we have had the need to dig holes in the ground to store rainwater and detain stream water.

As civilizations became more advanced, so became our water-damming and reservoir-building skills.

On U.S. soil, by the 80's more than 2.1 million ponds had been built by land users on privately owned land, with the demand for more, ever increasing.



## **Demand for water storage**

The demand for water has always been of paramount importance to the survival and flourishing of humanity, and ponds are one of the most reliable and economical means in which to store surficial water.

Ponds serve a wide variety of purposes, including water for livestock and for irrigation, fish production, field and orchard spraying, fire protection, energy conservation, wildlife habitat, recreation, erosion control, and landscape improvement.

This course describes both embankment and excavated types of pond systems, and outlines the requirements for building each.

## Why call it a system?

Seems as though calling a pond a “system” is a bit of an overstatement, but in fact it is a system of independent and equally important components:

- Water, of course!
- Anaerobic and Aerobic Bacteria
- Outlet and Containment Structures (Spillways, Dams, Hardware)
- Piping Systems
- Aquatic Plants and Marine life
- Sealing Materials and Geotextiles
- Aeration systems and Dyes
- Filtration and Screening

# Types of Ponds



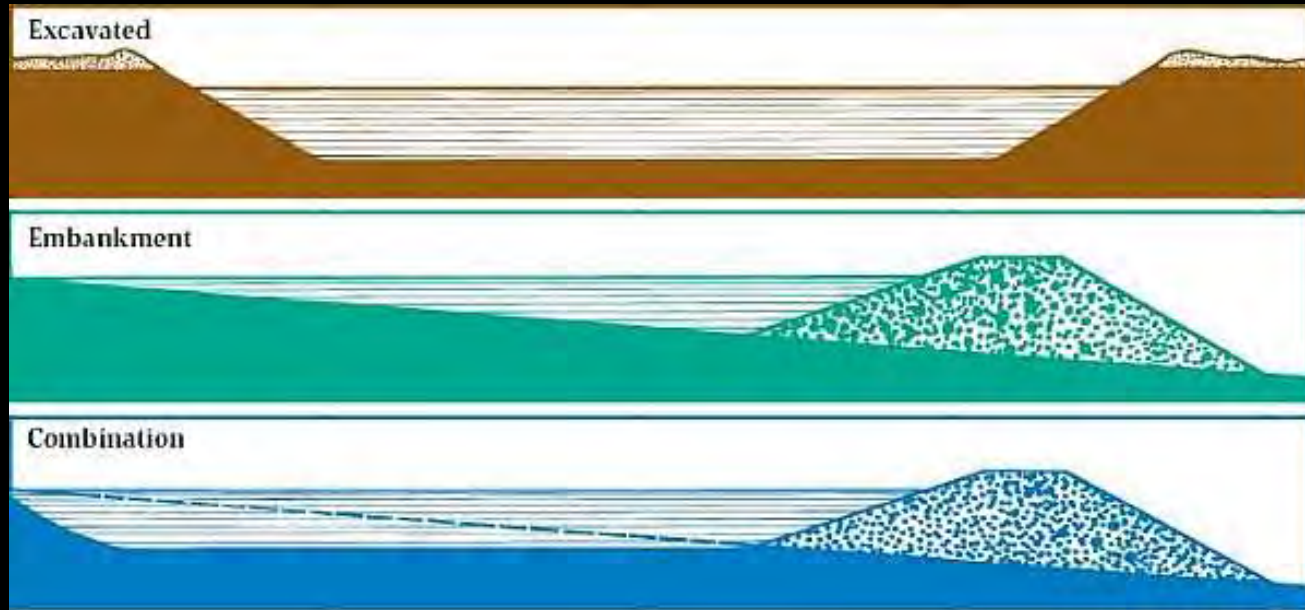
## Two general types of ponds

The type of pond that is best for a given site will be determined to a great extent by the topography of the land and the principal use of the pond.

It is usually necessary to move more earth when constructing an excavated pond as opposed to the watershed (embankment) type of pond system.

*The two general types of ponds:*

- **Watershed or embankment ponds** - are formed by constructing a dam to collect stream or surface runoff
- **Excavated ponds** - are formed by digging down into the water table in an area that is relatively flat or built in an area where surface runoff can be channelled appropriately



### Third type of pond

- **Combination pond** – this pond is built using a combination of both excavated and embankment water detention principles.



## **Issues with watershed (embankment) ponds**

Watershed ponds are more likely to have problems with muddy water, high siltation rates, and rapid fluctuations in flow rates, aquatic weeds, temperature fluctuations, and wild fish invasions.

## **Use of an upstream settling pond to benefit watershed ponds**

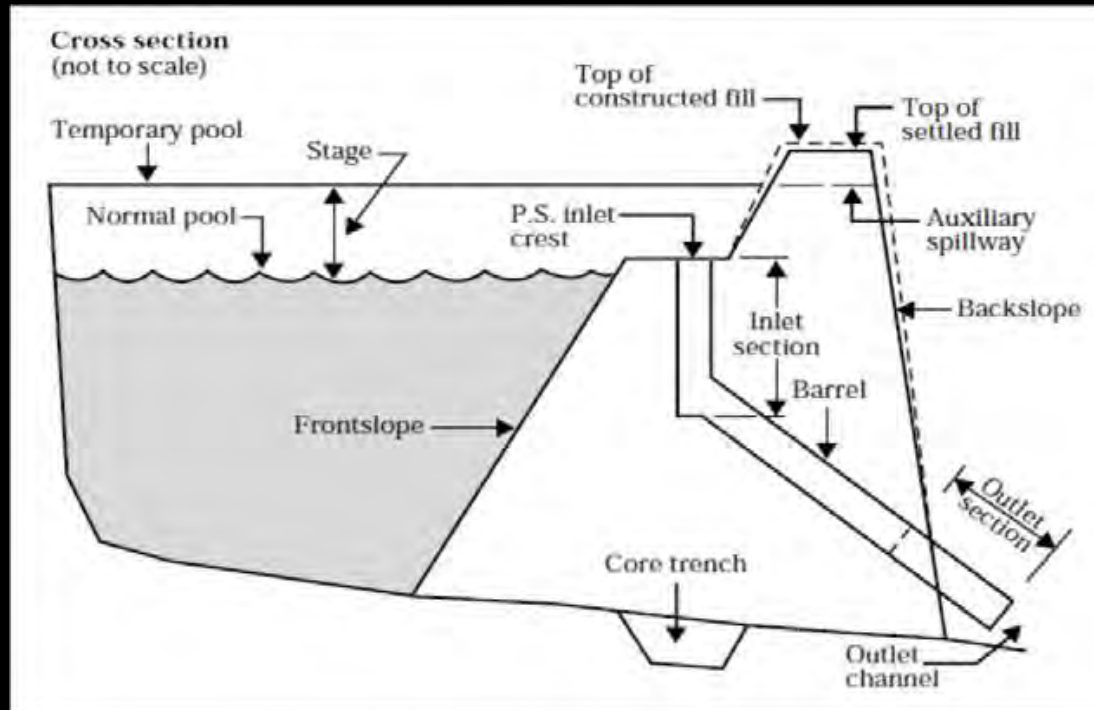
Large watershed ponds can benefit from construction of a small settling pond immediately upstream to reduce turbidity, sedimentation, and help to prevent weed problems in the large pond.



## Typical embankment pond

An embankment pond is made by building an embankment or dam across a stream or other natural watercourse where the stream valley is depressed enough to permit storing 5 feet or more of water. The land slope may range from gentle to steep.

*The image below shows a typical embankment pond system and reservoir cross section.*



## **Embankment ponds - with low risk dam conditions**

Some ponds are built in gently to moderately sloping areas and the capacity is obtained both by excavating and by building a dam.

The criteria and recommendations in this course are for ponds with dams that are less than 35 feet high and located where failure of the structure will not result in loss of life; or damage to homes, commercial or industrial buildings, main highways, or railroads; or in interrupted use of public utilities.



## **Typical excavated pond**

Excavated ponds are made by digging a pit or dugout in a somewhat level area of land. Because the water capacity is obtained almost entirely by digging, excavated ponds are used where only a small supply of water is needed.

Excavation equipment such as that shown in the image above is normally used in the construction process.

## **Chapter Two: Water Needs for Constructing a Pond**



# **Building a Pond for Supplying Water to Livestock**

## Ponds for livestock purposes

A reliable source of clean water in addition to ample vegetation to forage, are equally important in order for livestock to mature to a marketable condition.



## Supply the water near to grazing areas

If stockwater provisions in pasture and range areas are not adequate, then the livestock will tend to graze in concentrations nearer to the water, leaving other areas under-grazed.

This can contribute to a serious loss in livestock and instabilities in the livestock market, thus watering locations need to be properly distributed in relation to available forage.





## **Adding ponds to areas of abundant forage**

Areas of abundant forage may be underused and avoided by livestock, if sufficient water is not made available to livestock grazing those areas.

Installing ponds in these pasture areas encourages more uniform grazing, facilitates pasture improvement practices, mitigates erosion due to overgrazing, and allows farmers to make profitable use of soil-conserving crops and use of erodible, steep areas which are unsuitable for cultivation.

<u>Kind of livestock</u>	<u>Gallons per head per day</u>
Beef cattle and horses	12 to 15
Dairy cows (drinking only)	15
Dairy cows (drinking and barn needs)	35
Hogs	4
Sheep	2

## Estimating livestock water usage

Understanding stockwater requirements helps in planning a pond large enough to meet the needs of the stock using the surrounding grazing area.

(Shown in the table to the right) is a guide for estimating water needs based on the average daily consumption of water by different kinds of livestock.

In calculating the water consumed at a given pond, depends on the average daily consumption per animal species, quantity of livestock drinking at that pond, and the period of time which they are drinking from the pond.

# **Building Ponds for Irrigation Purposes**



## Irrigation

Farm ponds are an important source of water for irrigation, especially in the Eastern states of the country, where there are fewer organized irrigation enterprises than of the West.

Prior to the Second World War, irrigation was not considered necessary in the humid East, unlike present times when many farmers in the East are found irrigating their crops.



### **Irrigation requires a larger water supply than other pond uses**

Water requirements for irrigation are greater than those for the other purposes we will discuss in this course. The area irrigated from a farm pond is limited by the amount of water available throughout the growing season.

Pond capacity must be adequate to meet crop requirements and to overcome unavoidable water losses, and excessive drawdown on the pond (image).



## **Irrigation often reserved for higher value crops**

For example, a 3-inch application of water on 1 acre requires 81,462 gallons. As a result, irrigation from farm ponds is generally limited to use on high-value crops on small acreages, usually less than 50 acres.

*The required storage capacity of a pond used for irrigation depends on these interrelated factors:*

- water requirements of the crops to be irrigated
- effective rainfall expected during the growing season
- application efficiency of the irrigation method
- losses due to evaporation and seepage
- the expected inflow to the pond

# Building Commercial Fisheries



## **Fish production**

Many land users are finding that commercial freshwater fisheries can be a profitable venture. Depending on the species and other variables, a properly built and managed pond can yield from 100 to 300 pounds of fish annually for each acre of water surface.

Freshwater species such as catfish or tilapia are commonly used to stock these ponds. Tilapia (image) is the fourth-most consumed fish in the US, dating back to 2002. The popularity of tilapia came about due to its low price, easy preparation, and mild taste.

Tilapia can become a problematic invasive species in warm-water habitats such as Australia, whether deliberately or accidentally introduced into local waterways. They are generally not as much a threat in more temperate climates due to their inability to survive in cold water.

### **Smaller ponds (Less than 2 acres) easier to manage**

Ponds that have a surface area of a quarter acre to several acres can be managed for good fish production.

Ponds of less than 2 acres are popular because they are less difficult to manage than larger ones. A minimum depth of 8 feet over an area of approximately 1,000 square feet is needed for best management.

# Ponds for Agricultural Spraying

## **Pesticide spraying**

When applying water-based pesticides to crops and orchards, a certain amount of water will be required.

Usually, the amount of water needed for spraying is not considerable, but it still must be available when needed. About 100 gallons per acre for each application is enough for most field crops.

Orchards, however, may require 1,000 gallons or more per acre for each spraying.



## **Conveying water to the spray tank**

The means of conveying the water from the pond to the spray tank requires:

### **In an embankment pond**

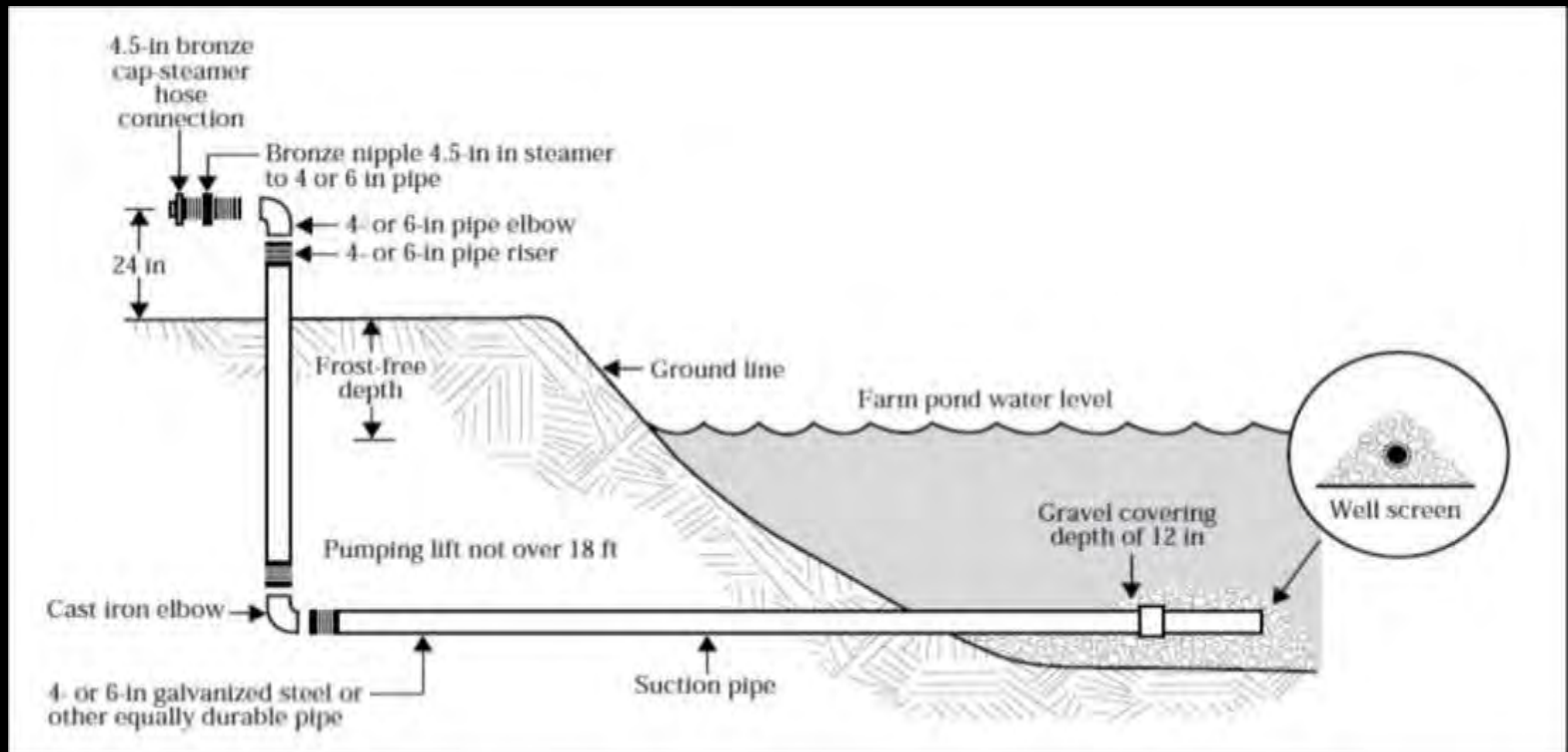
Placing a pipe through the dam and a flexible hose at the downstream end to fill the spray tank by gravity.

### **In an excavated pond**

A small manually-operated, battery-operated, or electrical pump is needed to fill the tank.

# Building a Pond for Fire Protection





## Typical equipment requirements

A dependable source of water will be required for reliable fire-fighting. When the pond is located close to a residence, barn, or other structures, the following equipment is needed:

- a centrifugal pump should be provided
- a small generator or 110v hardwiring
- a hose long enough to reach all sides of all the buildings
- one or more dry hydrants at the pond location (see image)



## Water requirements

Although water-storage requirements for fire protection are not exceptionally large, the withdrawal rate for firefighting is fairly high. A satisfactory fire stream should be at least 250 gpm with a nozzle pressure of at least 50 psi.

Fire nozzles (image) generally are 1 to 1-1/2" diameter, coupled of a good quality rubber-lined firehoses, 2-1/2 to 3" diameter. Preferably, the hose length should not exceed 600 feet in length.

### **Rule of thumb for typical firehose line**

A good fire hose setup will be: 500 ft. of 3" hose with a 1-1/8" smooth nozzle, and a centrifugal pump operating at 63 psi. This arrangement will provide an approximate stream of 265 gpm with a nozzle pressure of 50 psi.

Based on the arrangement above a consistent stream of water should be provided for 5 hours, and will require 1/4 acre-foot of water.

## **Storage and equipment specs**

When located in an area protected by a rural fire fighting organization, provide enough storage to operate several such streams. One acre-foot of storage is enough for four streams.

A local equipment dealer in pumps, engines, and similar equipment can furnish the information needed about pump size, capacity, and engine horsepower. This information is typically supplied online by the equipment manufacturers, as well.

# **Ponds Used for Recreational Purposes**



## **Recreational activity or site aesthetics**

A variety of recreational activities can be centered on a reasonably sized pond, such as swimming, boating, and fishing.

The surrounding area can be turned into an attractive setting for picnicking areas, sports facilities, camping, and other outdoor sources of fun.

Land users can use a pond setting to bring in additional personal income by providing a water scene setting for profitable ventures such as campgrounds, or covered meeting areas for weddings, church groups, company parties, etc.

Aesthetic landscaping features, walkways, trails, and botanical gardens can also add a nice touch.



## **Recreational fishing for a fee**

A good fish pond can provide recreational enjoyment and can be an added source of income should it be opened for public use for a fee.



## For swimming purposes

If a pond is to be used for public recreation, supply enough water to overcome evaporative and seepage losses, in order to maintain a desirable water level.

A pond used for swimming must be free of pollution, excessive algae, pesticides runoff, and harmful types of pond bacteria such as E Coli, which can come from sources such as livestock wastes.

A gently sloping shore is recommended for safety, while sandy beach areas add a nice touch.





## **Recommended facilities**

Minimum facilities for public use and safety are also helpful, including features such as access roads, parking areas, boat ramps or docks, and of course public restrooms.

Also standard park features such as grills, fire pits, campsites, potable water, and picnic tables.



## **Protecting public health and welfare**

Most states have laws and regulatory requirements for water supplies when they are being utilized for swimming and human consumption. Generally, water must be regularly tested and approved prior to public use.

Public sanitary facilities or restrooms (image) need to be built in a manner which protects the pond from inadvertent sewage contamination which can occur from improperly designed mulch pits, or septic leach fields.

# Multi-Purpose Ponds

## **Take care when using a pond for multiple purposes**

The water in a pond can certainly be used for more than one purpose; for example, to provide water for livestock, fish production, and spraying field crops.

When doing so, additional considerations must be weighed. When estimating your water requirements, tally up the amounts needed for each purpose and be sure to provide a supply adequate for all of the intended uses.

## **Verify that the uses are compatible**

Also ensure that the purposes for which the water is to be used are compatible in nature. Some combinations, such as irrigation and recreation, or swimming and livestock watering generally are not compatible.

Reasons being, irrigation would consume much of the water during the irrigation season, making boating or swimming impractical. And allowing livestock around ponds used for swimming or human consumption can be a harmful situation due to potentially harmful bacterial contamination.

## Repurposing a pond

Ponds don't always need to be used as originally intended.

For example a pond which was used temporarily for grade control, or as sediment basin associated with construction sedimentation control measures can be later converted to permanent ponds by cleaning out the sediment, treating the shoreline, and adding landscaping and aquatic vegetation.

If a sediment basin is to be cleaned and reconstructed as a water element, the standards for dam design should be used.



# **Pond Systems for Land Development Enhancement**



## **Incorporating a pond into planned development**

Many a planned urban development and other types of residential subdivision plans have strategically included idyllic pond settings within the home sites.

A property which has a well-designed waterfront view in its backyard has always brought a premium price on the market, and can easily add 30 to 50% to the price of the home site.



### **Ponds used as fill (borrow pits) in areas with high water tables**

In areas such as Florida or coastal Georgia, where the water tables may be high, or considered as lowlands or wetlands, it is common practice to use ponds as borrow pits for bringing in onsite fill.

This saves an enormous amount of money in the purchasing and transporting of good quality fill to a site. This alone compensates for the added cost in excavation and construction of a pond or ponds.

## **Landscaping Scenery in residential planning**

Water adds variety to a residential landscape and enhances its aesthetic quality.

In an ever stressful world, many will pay well to have a home where they can just walk out the back door, and relax, mediate, or entertain around a scenic body of water.

Whether it is set in a rural, suburban, or urban area, a pond helps to conserve or improve the quality of the “homescape”.

### **As wildlife and waterfowl attractions**

Ponds also attract many kinds of interesting-to-watch wildlife like deer, and birds. Migratory waterfowl often use ponds as rest stops within their migrations to and from the northern cold climates.

Ducks will use ponds as breeding places, particularly where the food supply is plentiful; while upland game birds such as pheasant, quail, grouse and dove, use ponds as watering holes.





## **Water views really help to sell real estate**

The return on investment when adding a pond or series of interconnected ponds to a development will typically always balance out in the end.

Regardless of a pond's intended purpose, it can improve a site's appearance when appropriate principles and techniques of design are used.

A pleasing design includes proper consideration of the size, site visibility, relationship to the surrounding landscape and use patterns, and the shoreline configuration.

## **Chapter Three: Site and Design Considerations**

## **General Considerations for Siting of the Pond**



## Selecting a good site for the pond

Selecting a suitable site for a pond is important, and preliminary studies are needed before finalizing the design and construction. Proper site selection should be based on landscape structure and a site relationship to associated ecological functions and values.

When feasible, consider multiple locations, studying each site to decide upon the most ecologically-appropriate, aesthetically-pleasing, and practical site. Take into consideration all of the onsite and offsite consequences and perks of the pond's location.

## **Maximize water storage potential, minimize earthwork**

For economic reasons, locate the pond where the largest storage volume is possible, with the minimal amount of earthwork.

A good site is usually 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.

Such sites also minimize the area of shallow water. Avoid large areas of shallow water because of excessive evaporation and the growth of harmful strains of bacteria and noxious aquatic plant life.



### **Properly space and locate ponds optimally for grazing purposes**

When a farm pond is used for watering livestock, make a pond 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 does 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 locations will encourage more uniform grazing by livestock and promotes better grassland management.



### **Conveyed water**

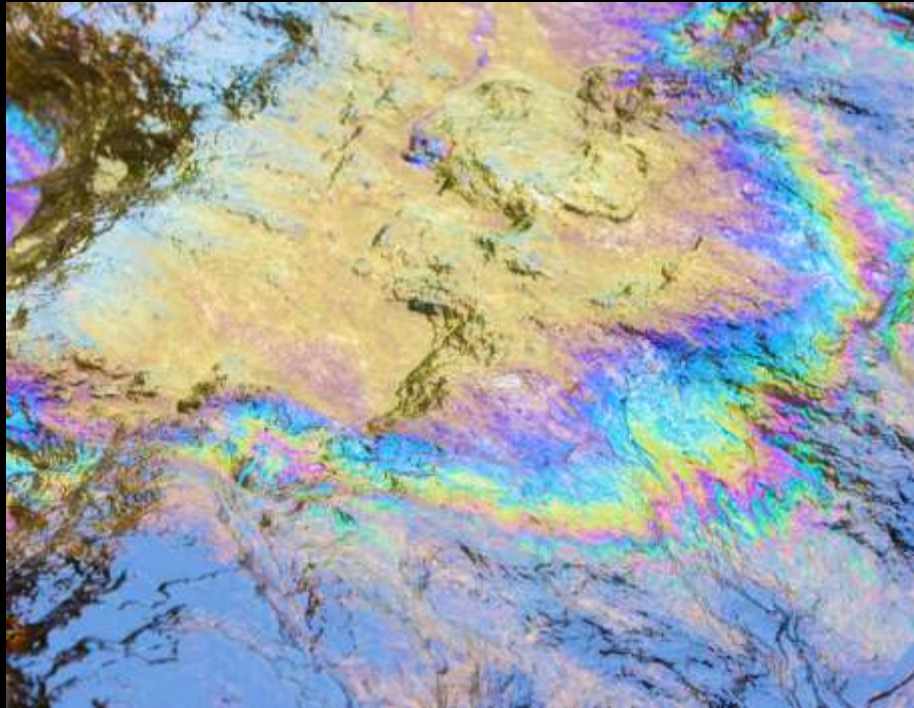
If pond water must be conveyed for use in another location, such as for irrigating crops or protecting a structure from fire, be sure to locate the pond as close to the major water use as is practical.

Conveying water is expensive and, if distance is excessive, the intended use of the water may not be possible without the addition of pump stations.

## **Accessibility for recreational purposes**

Ponds for fishing, boating, swimming, or other forms of recreation must be reached easily by automobile, especially if the general public is charged a fee to use the pond.

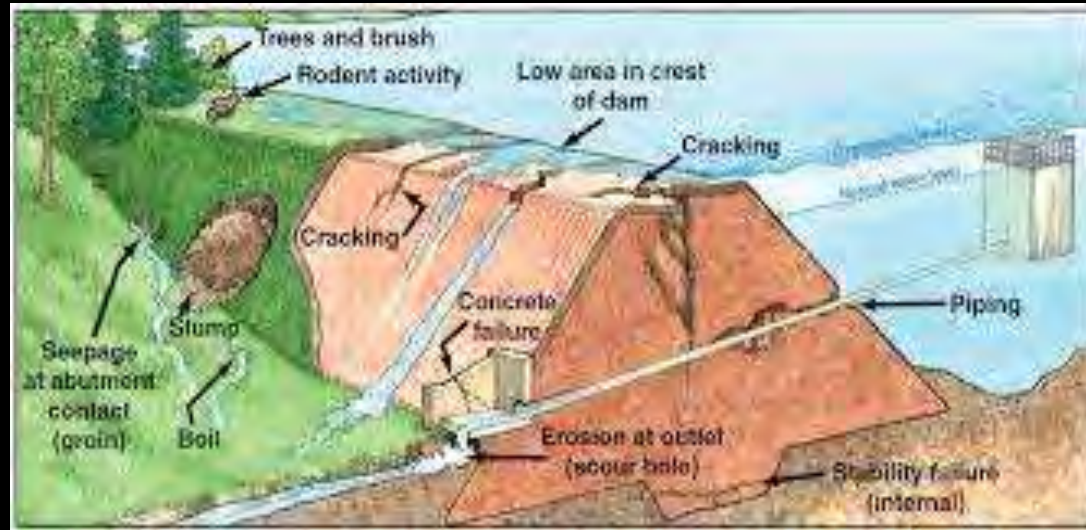
The success of an income-producing recreation enterprise often depends on accessibility. Another consideration is the economic hardship of building long access roads to the site.



## **Avoid pond contamination**

Avoid polluting the pond water by selecting a location where runoff from vehicles, livestock facilities, sewage lines, mining spoils, and similar areas does not drain into the pond.

Redirect any harmful runoff by using permanent or temporary control measures, such as diversions, to channel away contaminated water from these sources to an appropriate outlet or detention basin until the areas can be treated.



## Consider dam failures

One should always consider the possibility of a dam failure and the subsequent damage caused from a sudden release of water.

Avoid locations where failure of the dam could cause loss of life; injury to persons or livestock; damage to homes, industrial buildings, railroads, or highways; or interrupted use of public utilities.

If the only suitable pond site presents one or more of these hazards, look into obtaining a second opinion from another qualified party to investigate other potential sites which may not have occurred to you.



## **Be aware of potential utility hazards**

Be sure that no buried pipelines or cabling 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, notify the utility company prior to beginning the construction and obtain permission clarification of where to excavate.

Overhead hazards should be considered also, avoiding sites which lie beneath power lines, especially for recreational ponds where fishing lines may come into contact with the power lines.

# Drainage Considerations

## **How Adequate is the Area for Proper Drainage?**



## **Considering surface runoff**

For ponds where surface runoff is the primary source of water replenishment, the contributing drainage area must be sufficient in size to maintain water in the pond during times of drought.

However, the drainage area should not be so large that expensive overflow structures are needed to bypass excess runoff during large storm events.

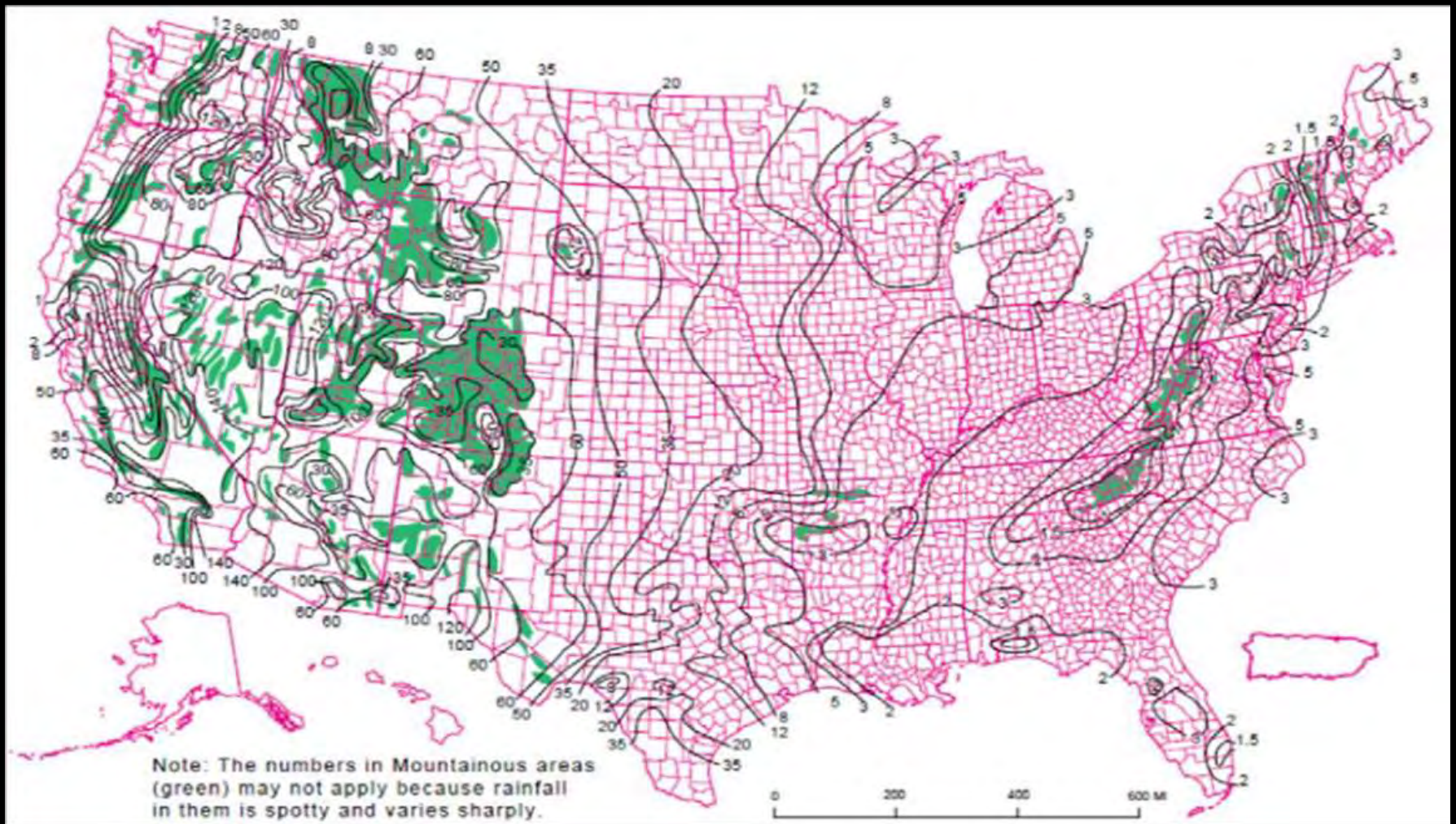
The runoff amount that can be expected annually from a given watershed region depends on so many interrelated factors that no set rule can be applied for its determination.

## **Factors which affect water yield**

Physical characteristics that have a direct affect on the water yield are: ground relief, soil infiltration, amount and types of plant cover, and surface storage.

Storm characteristics which also have an affect on the water yield are: the amount, the intensity, and the duration of the rainfall.

These characteristics vary widely throughout the US, and each must be considered when evaluating the watershed area conditions for a particular pond site.



## Estimating the size of the drainage area

The image above shows a guide for estimating the approximate size of a drainage area (in acres) required for each acre-foot of storage in an embankment or excavated pond.

### **Example (for previous page)**

For example, a pond located in west central Kansas with a capacity of 5 acre-feet requires a drainage area of at least 175 acres under normal conditions.

*When reliable local runoff data is available, this should be used as an alternative to this guide.*

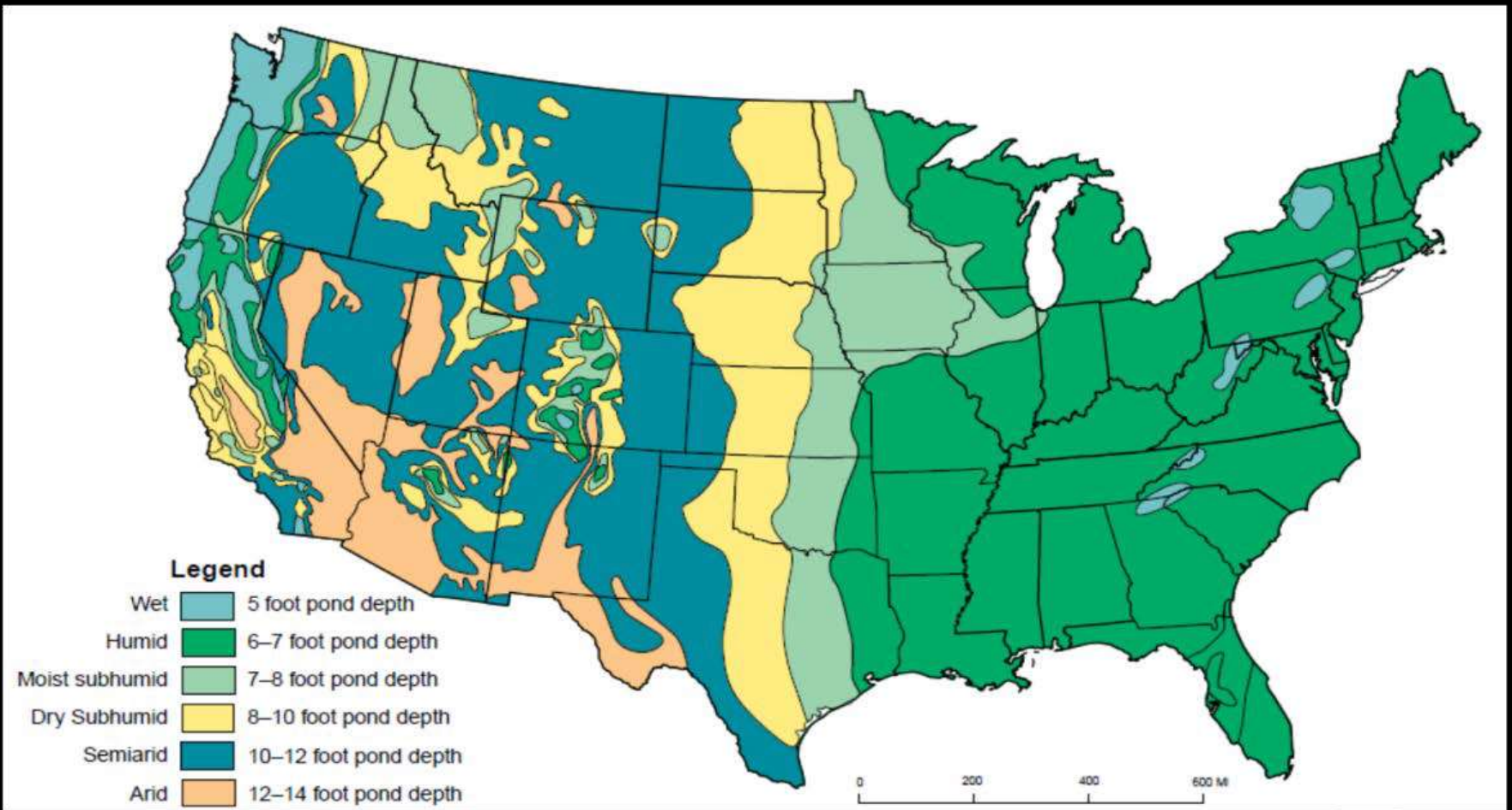
## **Adjustments to runoff for varying physical conditions**

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.

When applying the information obtained in the previous image, some adjustments may be required to meet local conditions. Modify the values in the figure for drainage areas having characteristics other than normal.

Reduce the values by as much as 25 percent for drainage areas having extreme runoff-producing characteristics. Increase them by 50 percent or more for low runoff producing characteristics.

## **Depth and Capacity of the Pond**



## Minimum pond depth

To maintain a consistent water supply, the water level must go deep enough to meet the intended use requirements and to compensate for likely losses due to seepage and evaporation. *The image above shows the recommended minimum depth of water for ponds in the US.*

## **Adjustments for variations**

These will change depending on the region of the country and because of annual variations. The previous image, showed the recommended minimum depth of water for ponds if seepage and evaporation losses are normal.

Deeper ponds are needed where a permanent or year-round water supply is essential or where seepage losses exceed 3 inches per month.



## **Protecting the drainage area**

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.

## **Desirable and undesirable watershed conditions**

*Watershed areas which are most desirable:*

- Land under permanent coverage of trees, grass, or forbs are the most desirable drainage areas
- Cultivated areas protected by conservation practices, such as terraces, conservation tillage, strip-cropping, or conservation cropping systems, are the next best watershed conditions.
- A good watershed will function best with low turbidity, minimal suspended sediment in the water, and infrequent shifts in the water levels

## **Preliminary protection of the drainage area**

If an eroding or inadequately protected watershed must be used to supply pond water, pond construction should be delayed 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.

## Estimating the pond capacity

Estimate pond capacity to be sure that enough water is stored in the pond to satisfy the intended use requirements.

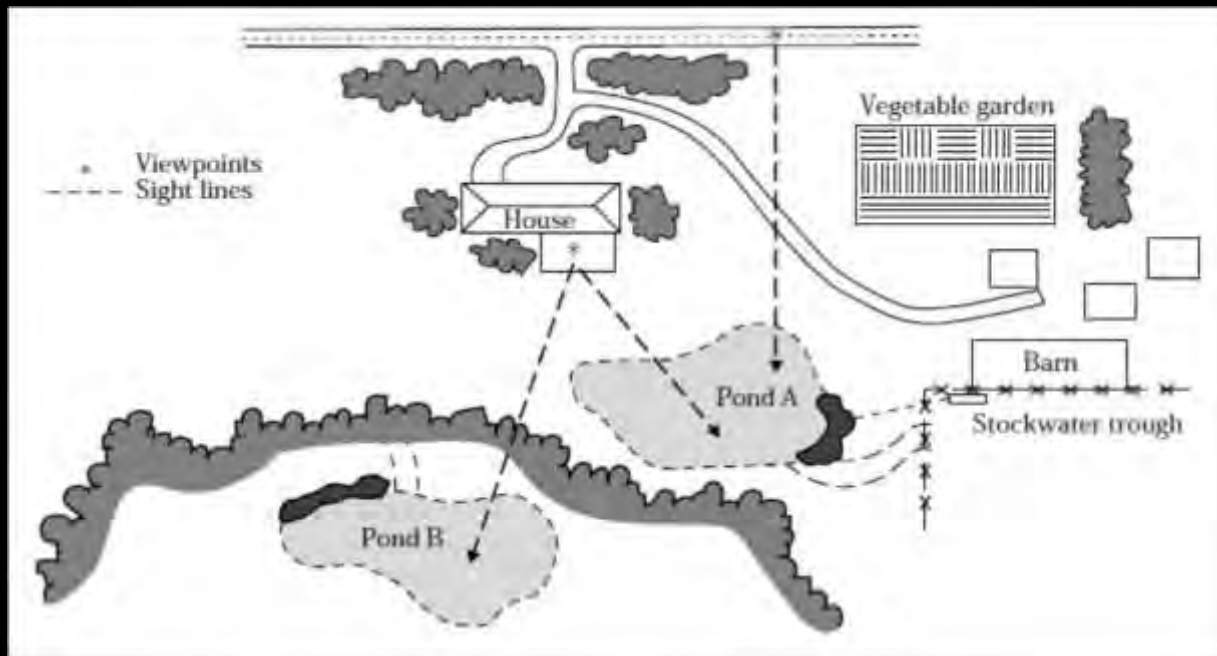
*A simple method to follow:*

- Establish the normal pond-full water elevation and stake the waterline at this elevation.
- 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.
- Multiply the surface area by 0.4 times the maximum water depth in feet measured at the dam.

For example, a pond with a surface area of 3.2 acres and a depth of 12.5 feet at the dam has an approximate capacity of 16 acre-feet  
( $0.4 \times 3.2 \times 12.5 = 16$  acre-feet) [1 acre-foot = 325,651 gallons].

-

## **Landscaping and Point of View Considerations**



## Landscape evaluation

Alternate pond sites should be evaluated for potential visibility and compatibility with surrounding landscape characteristics and use patterns.

Identify major viewpoints (points from which the site is viewed) and draw the important sight lines with cross sections, where needed, to determine visibility.

*The image above shows two potential sites for the pond, (to be used for the purposes of livestock watering, irrigation, and recreation.)*

### **Consider the major line of sight**

If possible, locate the pond so that the major line of sight crosses the longest dimension of water surface.

The pond should be situated so that a person viewing the pond will see the water first before they notice the dam, pipe inlet, or spillway.

### **Consider which outlying features should be most prominent**

Often, minor changes in the dam alignment and spillway location can shift these elements out of view and reduce their prominence. When possible, locate the pond so that existing trees and shrubs remain along part of the shoreline.

Vegetation adds aesthetic value by reflecting on the water, providing shade for hotter days, and helping to blend the pond into the surrounding landscape.

A pond can often be located and designed so that an island is created for recreation, wildlife habitat, or visual interest.





## **Use to rehabilitate poor landscapes**

In addition to the more typical farm and residential sites, ponds can be located on poor quality landscapes to rehabilitate abandoned road borrow areas, dump sites, abandoned rural mines, and other low production areas.

# Site Survey Considerations

## **Performing a pond site survey**

Upon determining the likely location of the pond, a site survey using standard surveying equipment should be conducted to plan and design the dam, spillways, and other features.

A pond survey generally consists of a profile of the centerline of the dam, a profile of the centerline of the earth spillway, and enough measurements to estimate pond capacity.

## Estimating capacity

*To estimate pond capacity:*

- A simple method of estimating pond capacity is described elsewhere in this course.
- For larger and more complex ponds, particularly those used for water supply or irrigation may require a complete topographic survey of the entire pond site and surrounding topography.



## Performing the survey

Run a line of profile level surveys along the centerline of the proposed dam and up both sides of the valley well above the expected elevation of the top of the dam and well beyond the probable location of the auxiliary spillway.

## **The pond's profile**

The profile should show the surface elevation at all significant changes in slope and at intervals of no more than 100 feet. This line of levels establishes the height of the dam and the location and elevation of the earth spillway and the principal spillway. It is also used to compute the volume of earth fill needed to build the dam.

Run a similar line of profile levels along the centerline of the auxiliary spillway. Start from a point of the upstream end that is well below the selected normal water surface elevation and continue to a point on the downstream end where water can be safely discharged without damage to the dam. This line serves as a basis for determining the slope and dimensions of the spillway.



## **Tie the survey to a benchmark**

All surveys made at a pond site should be tied to a reference bench mark.

This may be a large spike driven into a tree, an iron rod driven flush with the ground, a point on the concrete headwall of a culvert, or any object that will remain undisturbed during and after construction of the dam.

## **Chapter Four: Storm Runoff Considerations**





### **Soil types and vegetation which have an effect on runoff**

The quantity of precipitation from rainfall or snow is the source of water that may run off of small watersheds, to replenish a pond's water supply. The kind of soil and the type of vegetation affect the amount of water that runs off.



## **Use of terracing and diversions**

The use of terracing and diversions, along with steepness of grade, and the shape of the watershed area, all affect the rate at which water will run off.



## **Incorporating a spillway into the design**

A spillway should be incorporated into the design, to bypass excess surface runoff after the pond is filled to capacity.

## Estimating peak discharge rates

The tables and charts on this page can be used to estimate the peak discharge rates for the pond's spillway.

They provide a quick and reliable estimate of runoff rates and associated volumes for a range of storm rainfall amounts, soil groups, land use, cover conditions, and watershed slopes.





### Four hydrologic groups

The type of soil in a watershed has a tremendous influence on the runoff rates for that watershed. Depending on the soil type, a given soil mass can have a wide variety of infiltration rates and rates of transmission.

Soil types can be classified into four hydrologic groups according to their infiltration and transmission rates. Group A is highest in infiltration, usually consisting of sandy soils, while Group D has the lowest infiltration rates, consisting of more clay constituents.



## Hydrologic group A

These soils have a high infiltration rate, consisting mainly of deep, well-drained sand or gravel. Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil.

Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.

## **Hydrologic group B**

These soils have a moderate infiltration rate when thoroughly wet, consisting mainly of moderately deep, well-drained soils of moderately fine to moderately coarse texture.

Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures.

Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.

## Hydrologic group C

These soils have a slow infiltration rate when wet, consisting mainly of moderately fine to fine texture soils, having a layer that impedes downward movement of water.

Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted.

Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures.

Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.





## Hydrologic group D

These soils have a very slow infiltration rate, consisting mainly of clay soils that have a high swell potential, soils with a permanent high water table, soils with a claypan at or near the surface, and shallow soils over nearly impervious material. The runoff potential is high, as the water's movement through the soil is very restricted.

Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential.

All soils with a depth to a water impermeable layer less than 20 inches and all soils with a water table within 24 inches of the surface are in this group, although some may have a dual classification, if they can be adequately drained.

## Dual hydrologic groups

Certain wet soils are placed in group D based solely on the presence of a water table within 2 feet of the surface even though the saturated hydraulic conductivity may be favorable for water transmission.

If these soils can be adequately drained, then they are assigned to dual hydrologic soil groups (A/D, B/D, and C/D) based on their saturated hydraulic conductivity and the water table depth when drained.

The first letter applies to the drained condition and the second to the undrained condition. For the purpose of hydrologic soil group, adequately drained means that the seasonal high water table is kept at least 2 feet below the surface in a soil where it would be higher in a natural state.

## Urban runoff CN's

The following tables show numerical runoff ratings for a range of soil-use-cover complexes.

Because these numbers relate to a set of curves developed from the NRCS runoff equation, they are referred to as curve numbers (CN).

The watershed upstream from a farm pond often contains areas represented by different curve numbers.

A weighted curve number can be obtained based on the percentage of area for each curve number.

**Table 1** Runoff curve numbers for urban areas <sup>1/</sup>

Cover description	Average percent impervious area <sup>2/</sup>	Curve numbers for hydrologic soil group			
		A	B	C	D
<b>Fully developed urban areas (vegetation established)</b>					
Open space (lawns, parks, golf courses, cemeteries, etc.) <sup>3/</sup>					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50 to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)					
		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)					
		98	98	98	98
Paved; open ditches (including right-of-way)					
		83	89	92	93
Gravel (including right-of-way)					
		76	85	89	91
Dirt (including right-of-way)					
		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) <sup>4/</sup>					
		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)					
		96	96	96	96
Urban districts:					
Commercial and business					
	85	89	92	94	95
Industrial					
	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)					
	65	77	85	90	92
1/4 acre					
	38	61	75	83	87
1/3 acre					
	30	57	72	81	86
1/2 acre					
	25	54	70	80	85
1 acre					
	20	51	68	79	84
2 acres					
	12	46	65	77	82
<b>Developing urban areas</b>					
Newly graded areas (pervious areas only, no vegetation) <sup>5/</sup>					
		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 3)					

**Table 2** Runoff curve numbers for agricultural lands  $\Delta$ 

Cover type	Cover description		Curve numbers for hydrologic soil group			
	Treatment $\Delta$	Hydrologic condition $\Delta$	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T + CR	Poor	65	73	79	81
Good		61	70	77	80	
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T + CR	Poor	60	71	78	81
Good		58	69	77	80	
Closed-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

## Agricultural lands - runoff CN's

## Other agricultural lands - runoff CN's

**Table 3** Runoff curve numbers for other agricultural lands <sup>1/</sup>

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition <sup>2/</sup>	A	B	C	D
Pasture, grassland, or range—continuous grazing <sup>2/</sup>	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element <sup>2/</sup>	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 <sup>1/</sup>	48	65	73
Woods—grass combination (orchard or tree farm) <sup>2/</sup>	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods <sup>2/</sup>	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 <sup>1/</sup>	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

## Arid and semi-arid rangelands - runoff CN's

**Table 4** Runoff curve numbers for arid and semiarid rangelands <sup>1/</sup>

Cover type	Cover description	Hydrologic condition <sup>2/</sup>	Curve numbers for hydrologic soil group			
			A <sup>2/</sup>	B	C	D
Herbaceous—mixture of grass, forbs, and low-growing brush, with brush the minor element		Poor	—	80	87	93
		Fair	—	71	81	89
		Good	—	62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.		Poor	—	66	74	79
		Fair	—	48	57	63
		Good	—	30	41	48
Pinyon-juniper—pinyon, juniper, or both grass understory		Poor	—	75	85	89
		Fair	—	58	73	80
		Good	—	41	61	71
Sagebrush with grass understory		Poor	—	67	80	85
		Fair	—	51	63	70
		Good	—	35	47	55
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus.		Poor	63	77	85	88
		Fair	55	72	81	86
		Good	49	68	79	84

### **Example using a runoff CN table (use “other agricultural lands” table)**

Assume that the watershed above a pond is three-fourths in good pasture and a soil in hydrologic group B, and the remaining one-fourth is cultivated with conservation treatment on a soil in hydrologic group C.

*A weighted curve number for the total watershed would be:*

$$3/4 \times 61 \text{ (CN from Table 3)} = \mathbf{46} \text{ (approximate)}$$

$$1/4 \times 76 \text{ (CN from Table 3)} = \mathbf{20} \text{ (approximate)}$$

***Weighted CN for the watershed = 66***

## Volume of storm runoff

Often knowing the amount of runoff from a big storm as well as the rate at which it flows is advantageous. Knowing this volume is required for computing the needed storage as well as the peak discharge rate.

The figures in the following table (next page), below are the depth (in inches) at which the storm runoff, if evenly spread, would cover the entire watershed.

Example:

The volume of runoff from a 3-inch rainfall on a 100-acre watershed with the weighted curve number of 66 would be:

- 0.55 inch of runoff depth (interpolated between 0.51 and 0.72 inches; from the runoff depth table, next page)
- 100 acres of watershed x 0.55 inch = 55 acre-inches
- 55 acre-inches/12 = 4.58 acre-feet
- 55 acre-inches x 27,152 gallons per acre-inch = 1.5 million gallons (approximately)



# Runoff depths

**Table 5** Runoff depth, in inches

Rainfall (Inches)	Curve number						
	60	65	70	75	80	85	90
1.0	0	0	0	0.03	0.08	0.17	0.32
1.2	0	0	0.03	0.07	0.15	0.28	0.46
1.4	0	0.02	0.06	0.13	0.24	0.39	0.61
1.6	0.01	0.05	0.11	0.20	0.34	0.52	0.76
1.8	0.03	0.09	0.17	0.29	0.44	0.65	0.93
2.0	0.06	0.14	0.24	0.38	0.56	0.80	1.09
2.5	0.17	0.30	0.46	0.65	0.89	1.18	1.53
3.0	0.33	0.51	0.72	0.96	1.25	1.59	1.98
4.0	0.76	1.03	1.33	1.67	2.04	2.46	2.92
5.0	1.30	1.65	2.04	2.45	2.89	3.37	3.88
6.0	1.92	2.35	2.87	3.28	3.78	4.31	4.85
7.0	2.60	3.10	3.62	4.15	4.69	5.26	5.82
8.0	3.33	3.90	4.47	5.04	5.62	6.22	6.81
9.0	4.10	4.72	5.34	5.95	6.57	7.19	7.79
10.0	4.90	5.57	6.23	6.88	7.52	8.16	8.78
11.0	5.72	6.44	7.13	7.82	8.48	9.14	9.77
12.0	6.56	7.32	8.05	8.76	9.45	10.12	10.76

## **Rainfall amounts and expected frequency**

Maps in U.S. Weather Bureau Technical Paper 4, Rainfall Frequency Atlas of the US, show the amount of rainfall expected in a 24-hour period. These maps have also been reprinted in Hydrology for Small Urban Watershed, Technical Release 55. Contact your local NRCS field office for rainfall amounts on maps.

Designing an ordinary pond spillway to accommodate the peak rate of runoff from the most intense rainstorm ever known or anticipated is not practical. The spillway for an ordinary farm pond generally is designed to pass the runoff from a 25-year frequency storm.

This means a storm with only a 4 percent chance of occurring in any year or the size beyond which larger storms would not occur more often than an average of once in 25 years.

Designing for a 50-year storm frequency is recommended for spillways for larger dams. A 10-year storm frequency may be adequate for sizing the spillway in small ponds.

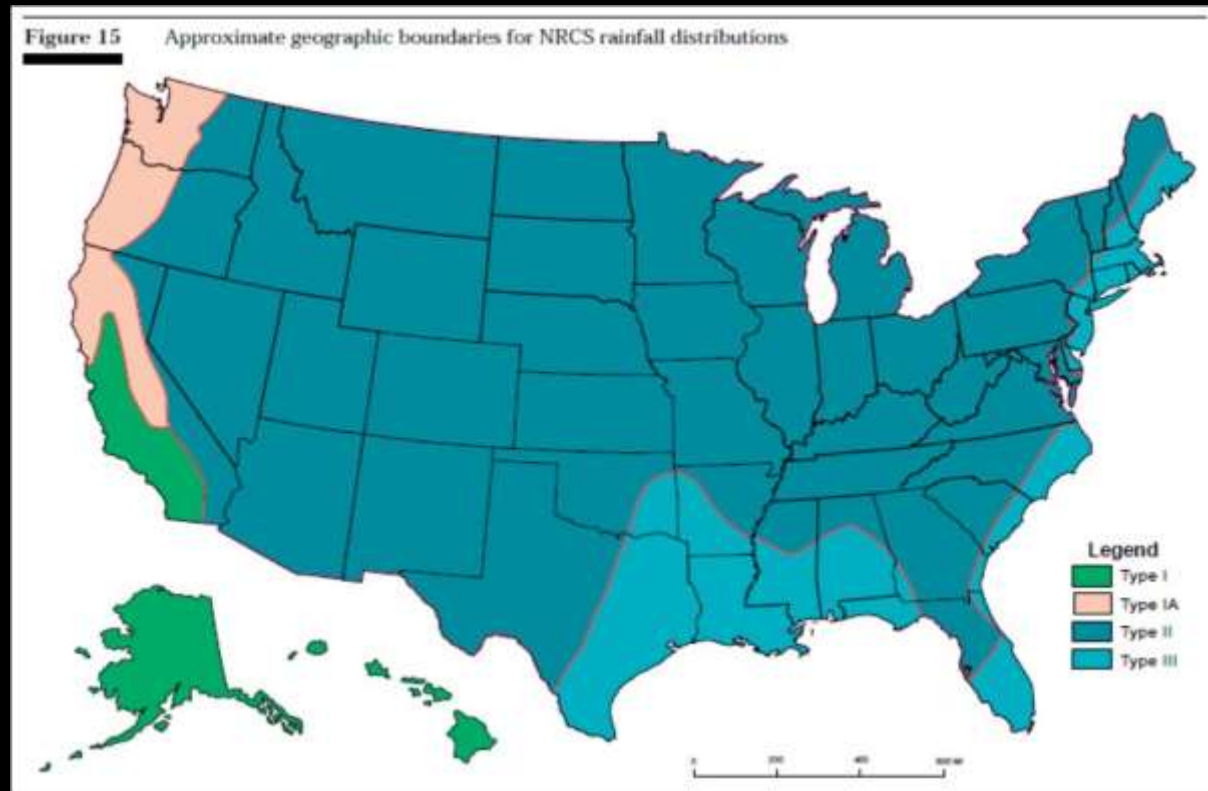
## **Rainfall distribution**

The highest peak discharges from small watersheds are usually caused by intense, brief rainfalls that may occur as part of a longer duration storm. Different rainfall distributions with respect to time have been developed for four geographic areas of the United States.

For each of these areas, a set of synthetic rainfall distributions having nested rainfall intensities were developed. These distributions maximize the rainfall intensities by incorporating selected storm duration intensities within those needed for longer durations at the same probability level.

## Geographic boundaries for NRCS rainfall distribution

In the image below, Type I and IA represent the Pacific maritime climate with wet winters and dry summers. Type III represents Gulf of Mexico and Atlantic coastal areas where tropical storms bring large rainfall amounts. Type II represents the rest of the country.



# Estimating Peak Discharge Rates

## **Peak discharge rate**

The slope of the land above the pond has a significant effect on the peak discharge rate.

The time of concentration along with the runoff curve number, storm rainfall, and rainfall distribution are used to estimate the peak discharge rate. This rate is used to design the auxiliary spillway width and depth of flow.

## Time of concentration

Time of concentration ( $T_c$ ) is the time it takes for runoff to travel from the hydraulically most distant point of the watershed to the outlet.  $T_c$  influences the peak discharge and is a measure of how fast the water runs off the land.

For the same size watershed, the shorter the  $T_c$ , the larger the peak discharge. This means that the peak discharge has an inverse relationship with  $T_c$ .

$T_c$  can be estimated for small rural watersheds using the equation (image) to the right.

$$T_c = \frac{L^{0.8} \left[ \frac{(1000) - 9}{CN} \right]^{0.7}}{1140 Y^{0.5}}$$

where:

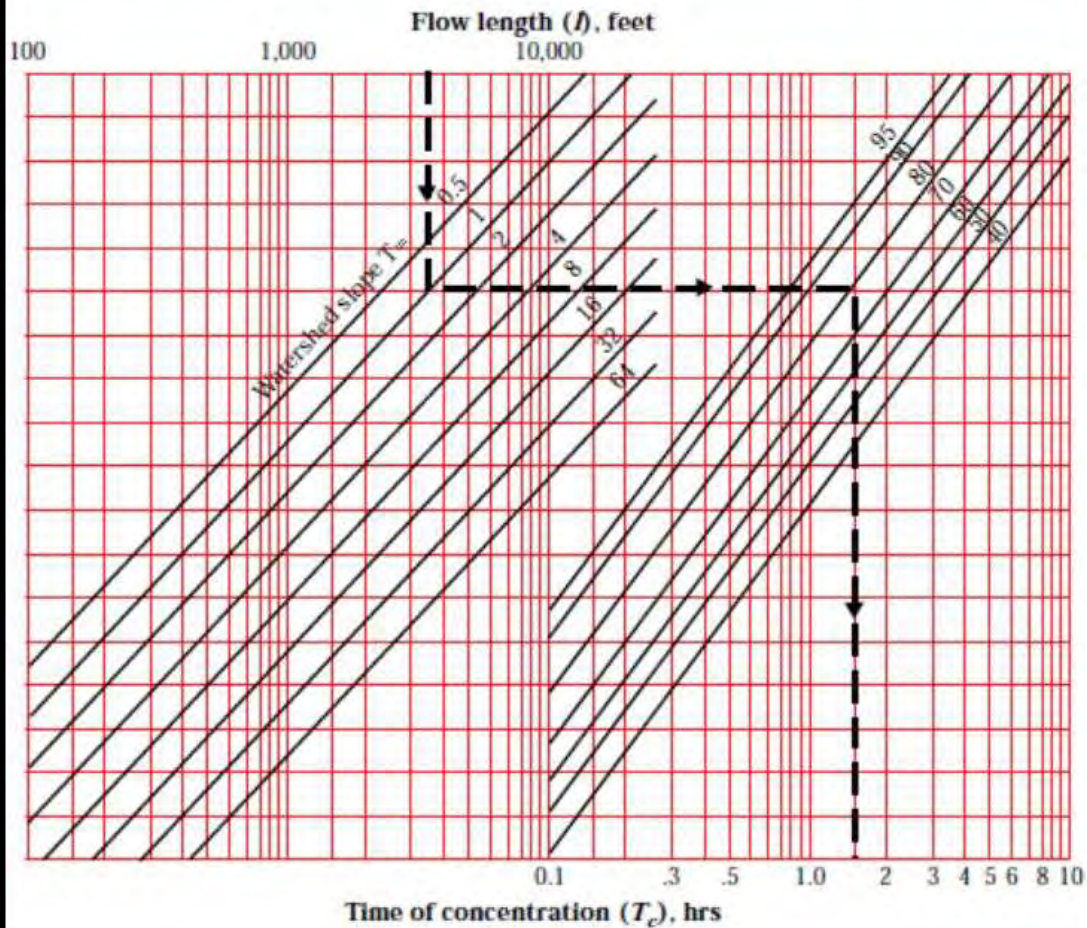
$T_c$  = time of concentration, hr

$L$  = flow length, ft

$CN$  = runoff curve number

$Y$  = average watershed slope, %

**Figure 16** Time of concentration ( $T_c$ ) nomograph



## Time of concentration nomograph

Above is a nomograph for solving the ( $T_c$ ) equation on the previous page.



## Average watershed slope

The average watershed slope ( $Y$ ) is the slope of the land and not the watercourse. It can be determined from soil survey data or topographic maps.

Hillside slopes can be measured with a hand level, lock level, or clinometer in the direction of overland flow. Average watershed slope is an average of individual land slope measurements. The average watershed slope can be determined using the equation to the right (image).

$$Y = \frac{100CI}{A}$$

where:

$Y$  = average slope, %

$C$  = total contour length, ft

$I$  = contour interval, ft

$A$  = drainage area, ft<sup>2</sup>

## **Flow length**

Flow length (l) is the longest flow path in the watershed from the watershed divide to the outlet. It is the total path water travels overland and in small channels on the way to the outlet.

## la /P ratio

The watershed CN is used to determine the initial abstraction (I<sub>a</sub>) from the table to the right.

I<sub>a</sub>/P ratio is a parameter that indicates how much of the total rainfall is needed to satisfy the initial abstraction.

The larger the I<sub>a</sub>/P ratio is, the lower the unit peak discharge (q<sub>u</sub>) for a given T<sub>c</sub>.

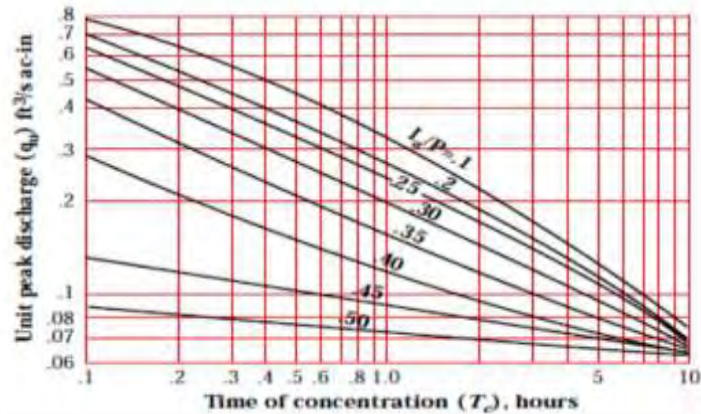
**Table 6** I<sub>a</sub> values for runoff curve numbers

Curve number	I <sub>a</sub> (in)	Curve number	I <sub>a</sub> (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

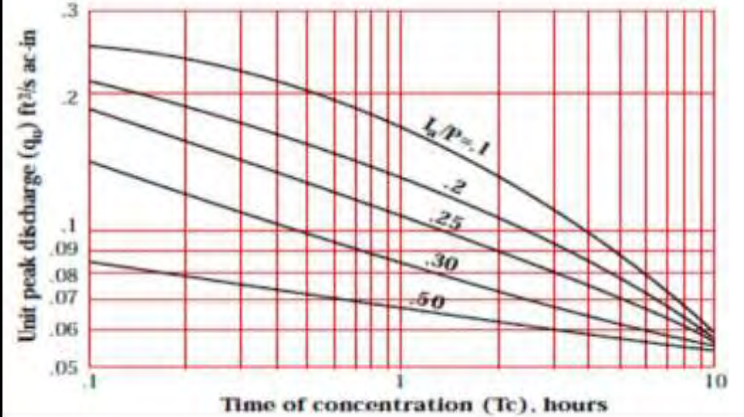
**Step by Step for:  
Estimating the Peak Discharge Rate  
of a Watershed Area**

# Unit peak discharge nomographs

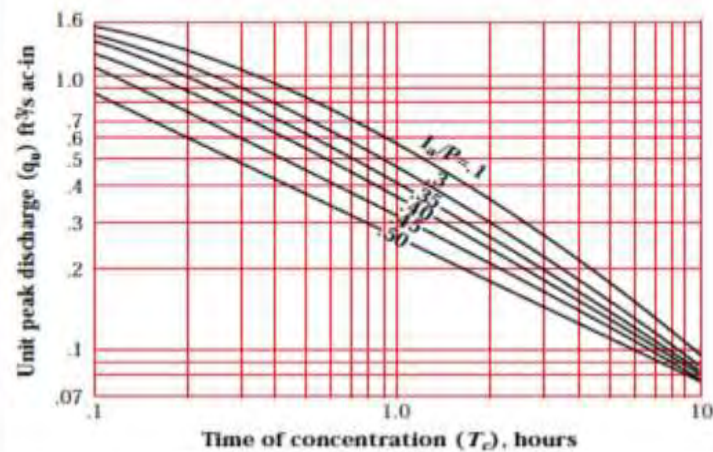
**Figure 17a** Unit peak discharge ( $q_u$ ) for Type I storm distribution



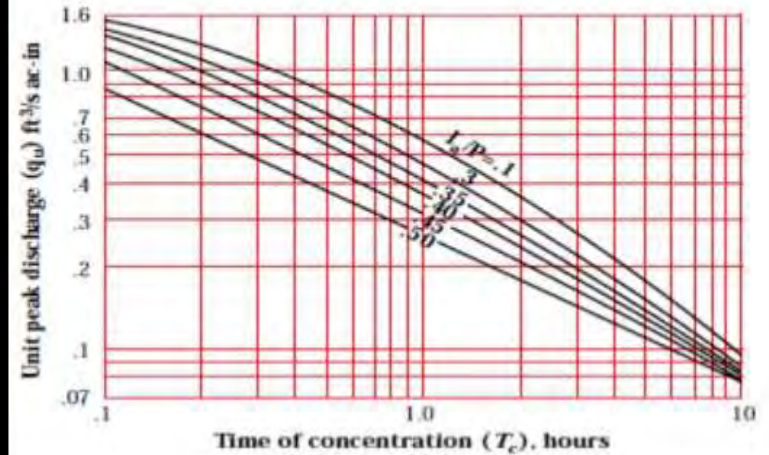
**Figure 17b** Unit peak discharge ( $q_u$ ) for Type IA storm distribution



**Figure 17c** Unit peak discharge ( $q_u$ ) for Type II storm distribution



**Figure 17d** Unit peak discharge ( $q_u$ ) for Type III storm distribution



## Steps for estimating peak discharge rates

- 1) The unit peak discharge ( $q_u$ ) is obtained from the nomographs (on the previous page) depending on the rainfall type.
- 2) The map on page 106 shows the “approximate geographic boundaries” for the four rainfall distributions.
- 3)  $T_c$  and  $I_a/P$  values are needed to obtain a value for  $q_u$  from the exhibit.
- 4) The peak discharge ( $q_p$  in  $\text{ft}^3/\text{s}$ ) is computed as the product of the unit peak discharge ( $q_u$  in  $\text{ft}^3/\text{s}/\text{ac-in}$ ), the drainage area ( $A$  in acres), and the runoff ( $Q$  in inches).

$$q_p = q_u \times A \times Q$$

## Example 1

Known:

Drainage area = 50 acres

Cole County, Missouri

Flow Path 'l' = 1,600 feet

Watershed Slope 'Y' = 4 percent

25-year, 24-hour rainfall = 6 inches

Type II rainfall distribution

Runoff Curve Number = 66

(from example in runoff curve number section)

## Solution to example 1

Solution:

- 1) Find  $T_c$
- 2) Enter figure 16 (on page 110),  $T_c = 0.60$  hours
- 3) Find  $I_a / P$
- 4) Enter table 6 (on page 113), use  $CN = 66$ ,  $I_a = 1.030$
- 5)  $I_a / P = 1.030/6.0$  inches = 0.172
- 6) Find runoff
- 7) Enter table 5 (on page 103), at rainfall = 6.0 inches
- 8) and runoff curve number = 66,
- 9) Read runoff = 2.44 inches.  
*(Note: It was necessary to interpolate between RCN 65 and 70.)*
- 10) Find the peak discharge for spillway design.
- 11) Enter figure 17(c) (on page 115)
  - $q_u = 0.7$
  - $q_p = q_u \times A \times Q$
  - $q_p = 0.7 \times 50 \times 2.44 = \mathbf{85 \text{ ft}^3/\text{s}}$



## **Chapter Five : Construction of an Embankment Pond**

## **Performing Soil Investigations for the Dam and Reservoir (Ponded) Area**

## Soils in the ponded area

The suitability of a pond site depends on the ability of the soil in the reservoir area to retain the water over an extended period of time. The soil should contain a layer of material that is impervious and thick enough to prevent excessive seepage.

Clays and silty clays are excellent for this purpose; while sandy and gravelly clays are usually satisfactory. Coarse-textured sands and sand-gravel mixtures are highly pervious and therefore usually not suitable.

*Generally, soils with these properties do not have excessive seepage when the water depth is less than 10 feet:*

- having at least 20 percent passing the No. 200 sieve;
- having a Plasticity Index of more than 10 percent;
- with an undisturbed thickness of at least 3 feet

## **Treating pervious soils**

The absence of a layer of impervious material over portions of the ponded area does not necessarily mean that the proposed site should be totally abandoned.

Soil treatments can be applied to these areas by one of several methods described later in this course; however these methods can be expensive.

## **Limestone areas**

Some limestone areas are especially problematic as pond sites, having crevices, sinks, or channels that are not visible from the surface potentially lying below the soil mantle.

They can drain the pond in a short period of time. In addition, many soils in these areas are granular.

Because the granules do not break down readily in water, the soils remain highly permeable. All the factors that may make a limestone site undesirable are not easily recognized without extensive investigations and laboratory tests.



## **Obtain soil borings**

The best clue to the suitability of a site is to observe the degree of success others have had with farm ponds in the surrounding areas. Unless you know that the soils are sufficiently impervious and that leakage will not be a problem, you should make soil borings at intervals over the area to be covered with water.

Three or four borings per acre may be sufficient if the soils are uniform, though more may be required if there are significant differences.

# Foundation Materials Beneath Dam

## **Dam foundation materials**

The foundation beneath a dam must ensure stable support for the structure, and resist the seepage of water. Soil borings help to establish the characteristics of the underlying soil.

The depth of the holes should be at least 1-1/2 times the height of the proposed dam.





## **When encountering rock**

Check for steep drop-offs in the rock surface of the foundation beneath the dam, which 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.

## **Coarse textured foundation support materials**

Coarse-textured materials such as gravel, sand, and gravel-sand mixtures, provide good support for a dam, but are highly pervious and do not allow the system to retain water efficiently.

Such materials can be used only if they are sealed to prevent seepage under the dam. You can 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 foundation support materials**

Fine-textured materials such as silts and clays, are relatively impervious, but have a low degree of stability. They are not good foundation material, 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 high organic-matter content from the foundation.

## **Suitable foundation support materials**

These will be materials which can provide both stability and seepage-resistance, and are a proper mixture of both coarse and fine-textured soils.

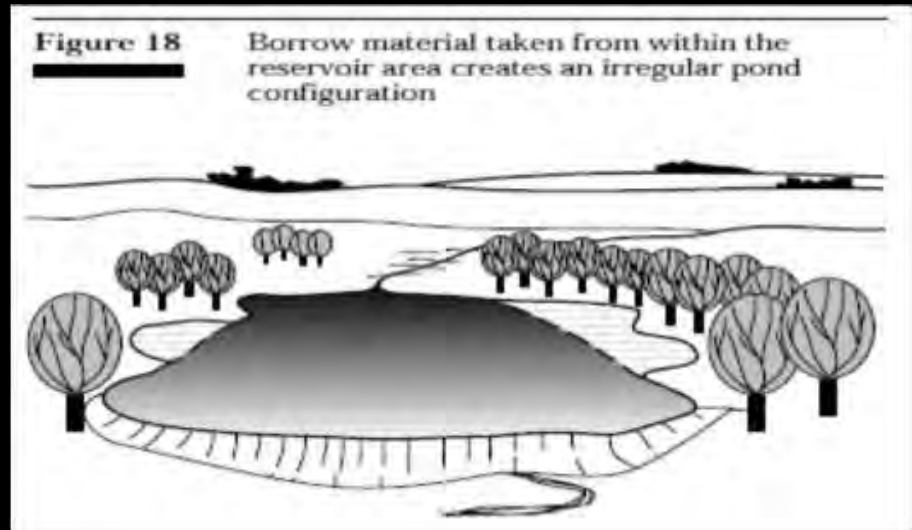
*Some examples of good foundation materials are:*

- gravels and- clay mixtures
- gravel-sand-silt mixtures
- sand clay mixtures
- sand-silt mixtures

*Less desirable but still acceptable foundation materials for ordinary pond dams are:*

- gravelly clays
- sandy clays
- silty clays
- silty and clayey fine sands
- clayey silts that have slight plasticity

## **Fill Materials for the Embankment Dam**



### **Available and suitable materials**

The availability of suitable material for building the dam is a determining factor in selecting a pond site. Enough suitable material should be located close to the site so that placement costs are not excessive. If fill material can be taken from the reservoir area, the surrounding landscape will be left undisturbed and borrow areas will not be visible after the pond has been filled (image).

Materials selected must have enough strength for the dam to remain stable and be tight enough, when properly compacted, to prevent excessive or harmful percolation of water through the dam. Soils described as acceptable for foundation material generally are acceptable for fill material. The exceptions are organic silts and clays.

## **Best materials for earthfill**

The best material for an earthfill contains particles ranging from small gravel or coarse sand to fine sand and clay in the desired proportions. This material should contain about 20 percent, by weight, clay particles.

Though satisfactory earthfills can be built from soils that vary from this ideal, though the greater the variance, the more precautions needed.

### **High gravel or coarse sand content**

Soils containing a high percentage of gravel or coarse sand are pervious and can allow rapid seepage through the dam.

When using these soils, place a core of clay material in the center of the fill and flatten the side slopes to keep the line of seepage from emerging on the downstream slope.







### **High clay content soils**

Fill materials that have a high clay content swells when wet and shrinks when dry. The shrinkage may open dangerous cracks.

If these soils are dispersive, they represent a serious hazard to the safety of the embankment and should be avoided.



## Dispersive Soils

These can be identified by how easily they go into suspension in water, by the presence of a gelatinous cloud around a clod of soil in distilled water, and by the indefinite length of time they stay in suspension in still water.

High sodium soils identified in the soil survey for the planned area of the embankment also indicate dispersive soils.

If any of these indicators are found at the proposed site, a qualified geotechnical engineer should be hired to provide the necessary guidance for sampling, testing, and using these soils for fill.



### **High silt content soils**

For soils consisting mostly of silt, such as the loess areas of western Iowa and along the Mississippi River in Arkansas, Mississippi, and Tennessee, the right degree of moisture must be maintained during construction for thorough compaction.

## Simple test for determining fill materials

To estimate the proportion of sand, silt, and clay in a sample of fill material:

- 1) Obtain a large bottle with straight sides.
- 2) Take a sample of the fill and remove any gravel by passing the material through a 1/4-inch sieve or screen.
- 3) Fill the bottle to about one-third with the sample material and finish filling with water.
- 4) Shake the bottle vigorously for several minutes and then allow the soil material to settle for about 24 hours.





### Results of sedimentation test

The coarse material (sand) settles to the bottom first, and finer material (clay) settles last.

Estimate the proportion of sand, silt, and clay by measuring the thickness of each layer.

# Landscape Planning



## **Ponds that blend with surroundings**

The pond should be located and designed to blend with the existing landform, vegetation, water, and structures with minimum disturbance.

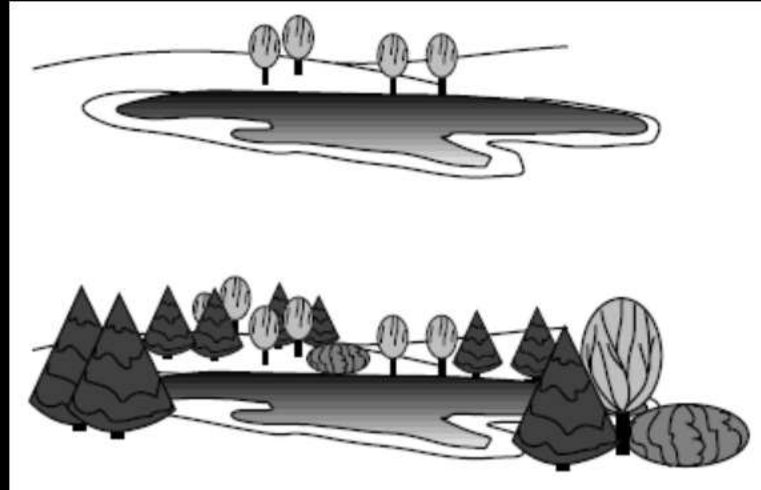
Existing landforms can often form a portion of the impoundment with minimal excavating required. Openings in the vegetation can be used to avoid costly clearing and grubbing.

## **Framing the pond**

Existing structures, such as stone walls and trails, can be retained to control pedestrian and vehicular traffic and minimize disruption of existing use.

In the area where land and water meet, vegetation and landform can provide reflections on the water, draw attention to or from the water, frame the water to emphasize it, and direct passage around the pond.





### **Use of irregular shapes and creative backdrops**

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 (image).

The shape of a pond should complement its surroundings. Irregular shapes with smooth, flowing shorelines generally are more compatible with the patterns and functions found in most landscapes.

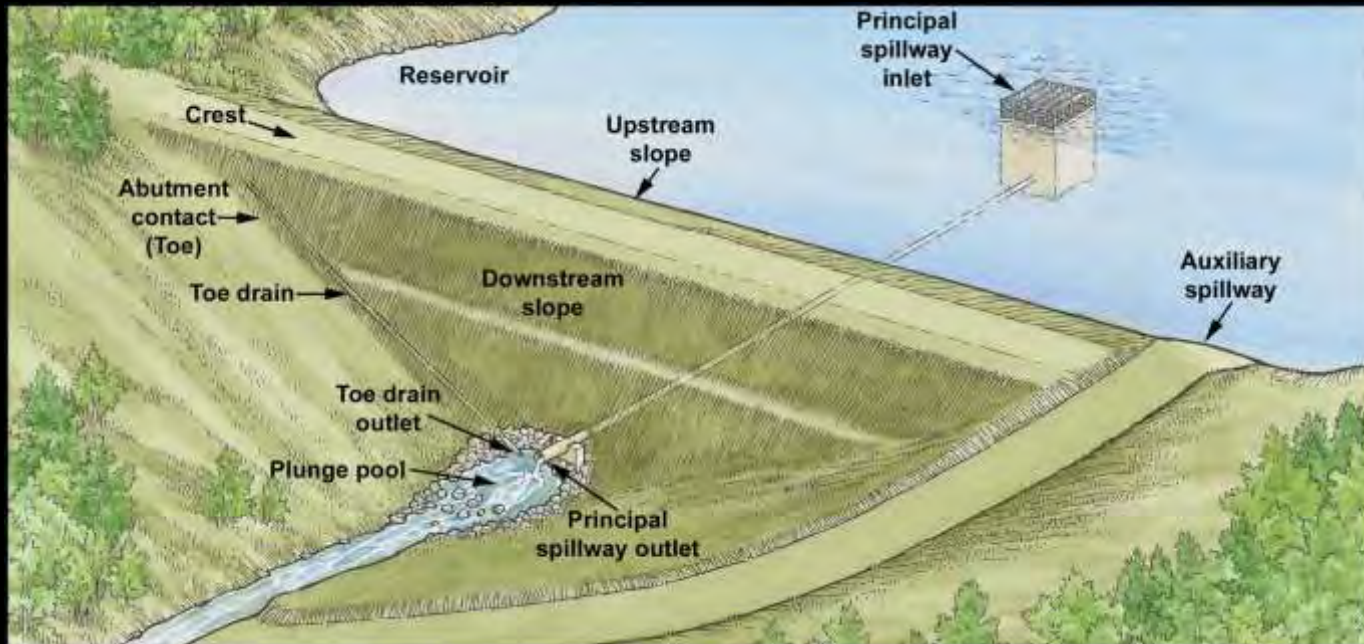


## **Use of peninsulas, islands, inlets**

Irregular shapes with smooth, flowing shorelines generally are more compatible with the patterns and functions found in most landscapes.

# **Chapter Six: Dam and Spillway Requirements**

# Spillways



## Principle spillway

A pipe spillway is often used as well as an earth auxiliary spillway to control the amount of runoff from the watershed. The principal spillway is designed to reduce the frequency of operation of the auxiliary spillway.

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 should be capable of withstanding external loading with yielding, buckling, or cracking. The pipe joints and all appurtenances need to be watertight, while pipe materials may be smooth metal, corrugated metal, or plastic.

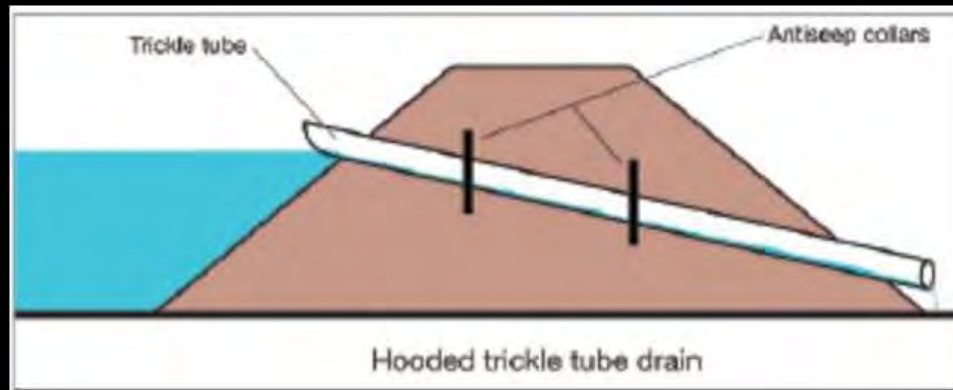
### **For small drainage areas**

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 trickle tube should be installed.

### Small principal spillway pipe (trickle tube)

A small principal spillway pipe, (also known as 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.





### **Hooded or canopy inlets**

This type of inlet is quite common. A disadvantage of this common type of inlet is the larger amount of stage (the head over the inlet crest) needed to make the pipe flow at full capacity.

A drop inlet spillway requires less stage because the size of the inlet may be enlarged to make the barrel flow full. The one shown above has a trash rack attachment to filter out inlet-clogging debris.



## **Earth spillways**

Earth spillways have limitations. Use them only where the soils and topography allow the peak flow to discharge safely at a point well downstream and at a velocity that do not cause appreciable erosion either within the spillway or beyond its outlet.

## **Auxiliary spillway**

The proper functioning of a pond depends on a correctly designed and installed spillway system.

Regardless of the quality of the dam construction, it will likely fail during the first severe storm event if the capacity of the spillway is inadequate.

The function of an auxiliary spillway is to pass excess storm runoff around the dam so that water in the pond does not rise high enough to damage the dam by overtopping.

The spillways must also convey the water safely to the outlet channel below without damaging the downstream slope of the dam.

## **Soil borings required for auxiliary spillway**

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.

**Table 7** Minimum spillway design storm

Drainage area (acre)	Effective height of dam <sup>1/</sup> (ft)	Storage (acre-ft)	Minimum design storm	
			Frequency (yr)	Minimum duration (hr)
20 or less	20 or less	Less than 50	10	24
20 or less	More than 20	Less than 50	25	24
More than 20	20 or less	Less than 50	25	24
All others			50	24

<sup>1/</sup> The effective height of the dam is the difference in elevation between the auxiliary spillway crest and the lowest point in the cross section taken along the centerline of the dam.

## Minimum capacity to discharge peak flow

Auxiliary spillways should have the minimum capacity to discharge the peak flow expected from a storm of the frequency and duration (from table shown in the image above), less any reduction creditable to conduit discharge and detention storage

After the spillway capacity requirements are calculated, the permissible velocity must be determined.

**Table 8** Permissible velocity for vegetated spillways <sup>1/</sup>

Vegetation	Permissible velocity <sup>2/</sup>			
	Erosion-resistant soils <sup>3/</sup>		Easily eroded soils <sup>4/</sup>	
	Slope of exit channel (%)			
	0-5 (ft/s)	5-10 (ft/s)	0-5 (ft/s)	5-10 (ft/s)
Bermudagrass	8	7	6	5
Bahiagrass	8	7	6	5
Buffalograss	7	6	5	4
Kentucky bluegrass	7	6	5	4
Smooth brome	7	6	5	4
Tall fescue	7	6	5	4
Reed canarygrass	7	6	5	4
Sod-forming grass-legume mixtures	5	4	4	3
Lespedeza sericea	3.5	3.5	2.5	2.5
Weeping lovegrass	3.5	3.5	2.5	2.5
Yellow bluestem	3.5	3.5	2.5	2.5
Native grass mixtures	3.5	3.5	2.5	2.5

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 silt and lower plasticity, or nonplastic. Typical soil textures are fine sand, silt, sandy loam, and silty loam.

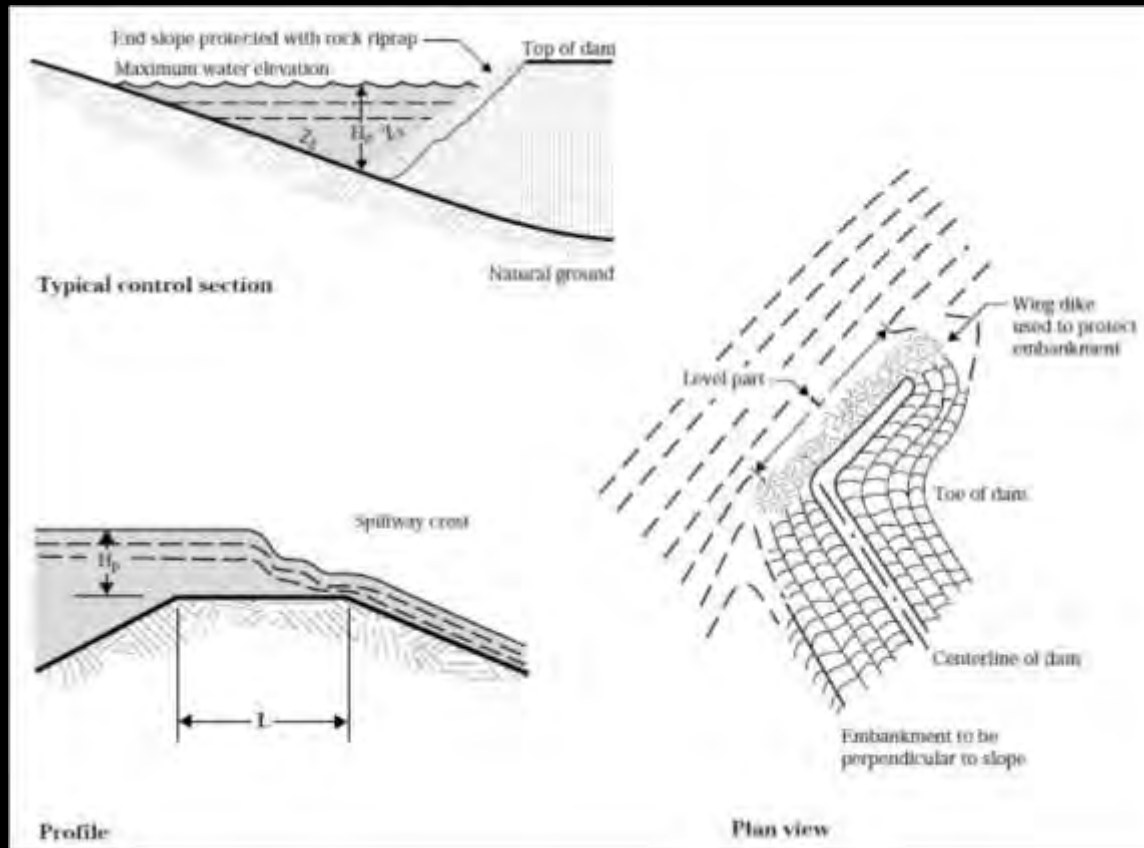
## Permissible velocity for vegetated spillways

The table (Table 8) above shows the recommended allowable velocity for various cover, degree of erosion resistance, and slope of the channel.

Stand	Average height of vegetation (in)	Degree of retardance
Good	Higher than 30	A
	11 to 24	B
	6 to 10	C
	2 to 6	D
	Less than 2	E
Fair	Higher than 30	B
	11 to 24	C
	6 to 10	D
	2 to 6	D
	Less than 2	E

## Degrees of vegetal retardance

The table (Table 9) above shows the retardance factors for the expected height of the vegetation. Both natural and excavated auxiliary spillways are used.



## Natural spillway with vegetation

A natural spillway does not require excavation to provide enough capacity to conduct the pond outflow to a safe point of release (image). The requirements discussed later for excavated spillways do not apply to natural spillways, but the capacity must be adequate.

## Maximum depth of water above the level portion

With the required discharge capacity (Q), the end slope of the embankment (Z1), and the slope of the natural ground (Z2) known, the maximum depth of water above the level portion (Hp) can be obtained (from the table above. )

The depth is added to the elevation of the spillway crest to determine the maximum elevation to which water will rise in the reservoir.

Table 10  $H_p$  discharge and velocities for natural vegetated spillways with 3:1 end slope (Z1)

Natural ground slope Z <sub>2</sub> (%)	$H_p$ (ft)	Retardance										Slope	
		A		B		C		D		E		Min. (%)	Max. (%)
		Q (ft <sup>3</sup> /s)	V (ft/s)	Q (ft <sup>3</sup> /s)	V (ft/s)	Q (ft <sup>3</sup> /s)	V (ft/s)	Q (ft <sup>3</sup> /s)	V (ft/s)	Q (ft <sup>3</sup> /s)	V (ft/s)		
0.5	1.0	19	0.3	28	0.5	47	1.3	68	1.8	130	2.8	0.5	3
	1.1	21	.3	35	.5	76	1.5	108	2.1	154	3.0		
	1.2	29	.4	39	.6	97	1.6	122	2.3	204	3.2		
	1.3	36	.4	53	.6	125	2.0	189	2.5	250	3.4		
	1.5	61	.4	87	1.1	210	2.2	291	2.9	393	3.8		
	1.8	81	.5	187	1.8	384	2.9	454	3.5	651	4.5		
	2.0	110	.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	3
	1.1	13	.4	18	.6	50	2.3	63	2.8	90	3.7		
	1.2	15	.5	21	.8	62	2.5	78	3.1	99	4.0		
	1.3	22	.6	39	1.0	86	2.7	144	3.4	139	4.3		
	1.5	40	.7	75	1.8	133	3.1	186	4.0	218	5.1		
	1.8	56	.8	126	2.3	280	3.8	296	4.5				
	2.0	98	1.1	184	2.8	328	4.3	389	5.0				
2.5	171	2.5	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	3
	1.1	7	.7	14	1.0	29	2.8	39	3.6	50	4.5		
	1.2	9	.8	19	1.1	40	3.1	51	3.9	64	4.9		
	1.3	13	.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	238	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	.8	10	.9	24	3.2	31	4.0	38	5.2		
	1.2	7	.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	1.2	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						



## Example

The following example shows how to use Table 10 (as well as 8 and 9) on the previous pages.

### *Given:*

- Vegetation: good stand of bermudagrass
- Height: 6 to 10 inches
- Slope of natural ground: 1.0 percent

### *Solution:*

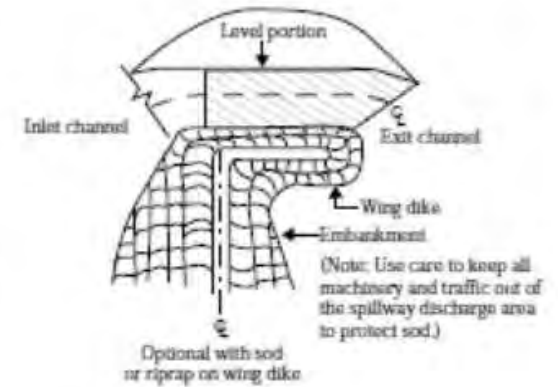
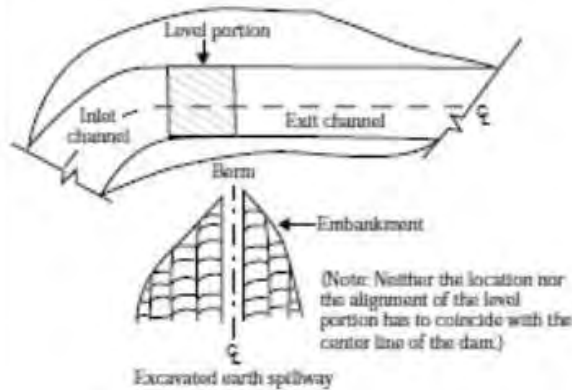
From Table 9, determine a retardance of C. From Table 10, under natural ground slope of 1 percent, and the retardance C column, find:

- $Q = 86$
- $\text{ft}^3/\text{s}$  at  $H_p = 1.3 \text{ ft}$
- $V = 2.7 \text{ ft/s}$

If the freeboard is 1.0 foot, the top of the dam should be constructed 2.3 feet higher than the spillway crest. The velocity is well below the maximum permissible velocity of 6 feet per second given in Table 8.

$H_p$  can be determined by interpolation when necessary. For a  $Q$  greater than that listed in table 10, the spillway should be excavated according to the information on the next page, on excavated auxiliary spillways.

## **Excavated Auxiliary Spillways**

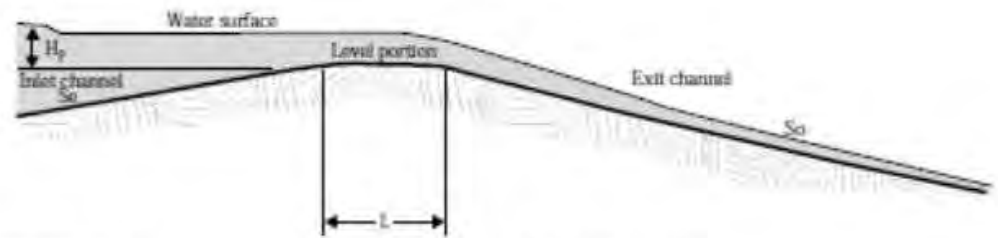


Plan view of earth spillways

## Elements of excavated auxiliary spillways

Excavated spillways consist of the three elements (image). The flow enters the spillway through the inlet channel.

The maximum depth of flow ( $H_p$ ) located upstream from the level part is controlled by the inlet channel, level part, and exit channel.



Profile along centerline

### Definition of terms:

- $H_p$  - depth of water in reservoir above crest
- $L$  - length of level portion min. 25 ft
- $b$  - bottom width of spillway
- $S_0$  - slope for exit channel
- $S_0$  - slope of inlet channel



Cross section of level portion

## **Wing dikes, inlet/exit channels**

Excavation of the inlet channel or the exit channel, or both, can be omitted where the natural slopes meet the minimum slope requirements.

The direction of slope of the exit channel must be such that the discharge does not flow against any part of the dam.

Wing dikes, sometimes called kicker levees or training levees, can be used to direct the outflow to a safe point of release downstream.

## **Excavate for spillway**

The spillway should be excavated into the earth for its full depth. If this is not practical, the end of the dam and any earthfill constructed to confine the flow should be protected by vegetation or riprap.

The entrance to the inlet channel should be widened so it is at least 50 percent greater than the bottom width of the level part.

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 to ensure drainage and low water loss at the inlet.

## Sizing of spillway

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 ( $H_p$ ) can be computed using the figures in Table 11.

This table shows discharge per foot of width. The natural slope of the exit channel should be altered as little as possible.

**Table 11** Depth of flow ( $H_p$ ) and slope range at retardance values for various discharges, velocities, and crest lengths

	Maximum velocity (ft/s)	Discharge (ft <sup>3</sup> /s/ft)	$H_p$ L				Slope	
			25 (ft)	50 (ft)	100 (ft)	200 (ft)	Min. (%)	Max. (%)
Retardance A	3	3	2.3	2.5	2.7	3.1	1	11
	4	4	2.3	2.5	2.8	3.1	1	12
	4	5	2.5	2.6	2.9	3.2	1	7
	5	6	2.6	2.7	3.0	3.3	1	9
	6	7	2.7	2.8	3.1	3.5	1	12
	7	10	3.0	3.2	3.4	3.8	1	9
	8	12.5	3.3	3.5	3.7	4.1	1	10
Retardance B	2	1	1.2	1.4	1.5	1.8	1	12
	2	1.25	1.3	1.4	1.6	1.9	1	7
	3	1.5	1.3	1.5	1.7	1.9	1	12
	3	2	1.4	1.5	1.7	1.9	1	8
	4	3	1.6	1.7	1.9	2.2	1	9
	5	4	1.8	1.9	2.1	2.4	1	8
	6	5	1.9	2.1	2.3	2.5	1	10
	7	6	2.1	2.2	2.4	2.7	1	11
	8	7	2.2	2.4	2.6	2.9	1	12
Retardance C	2	0.5	0.7	0.8	0.9	1.1	1	6
	2	1	0.9	1.0	1.2	1.3	1	3
	3	1.25	0.9	1.0	1.2	1.3	1	6
	4	1.5	1.0	1.1	1.2	1.4	1	12
	4	2	1.1	1.2	1.4	1.6	1	7
	5	3	1.3	1.4	1.6	1.8	1	6
	6	4	1.5	1.6	1.8	2.0	1	12
	8	5	1.7	1.8	2.0	2.2	1	12
	9	6	1.8	2.0	2.1	2.4	1	12
	9	7	2.0	2.1	2.3	2.5	1	10
	10	7.5	2.1	2.2	2.4	2.6	1	12
Retardance D	2	0.5	0.6	0.7	0.8	0.9	1	6
	3	1	0.8	0.9	1.0	1.1	1	6
	3	1.25	0.8	0.9	1.0	1.2	1	4
	4	1.25	0.8	0.9	1.0	1.2	1	10
	4	2	1.0	1.1	1.3	1.4	1	4
	5	1.5	0.9	1.0	1.2	1.3	1	12
	5	2	1.0	1.2	1.3	1.4	1	9
	5	3	1.2	1.3	1.5	1.7	1	4
	6	2.5	1.1	1.2	1.4	1.5	1	11
	6	3	1.2	1.3	1.5	1.7	1	7
	7	3	1.2	1.3	1.5	1.7	1	12
	7	4	1.4	1.5	1.7	1.9	1	7
	8	4	1.4	1.5	1.7	1.9	1	12
	8	5	1.6	1.7	1.9	2.0	1	8
	10	6	1.8	1.9	2.0	2.2	1	12

## **Retardance considerations**

The selection of the degree of retardance for a given auxiliary spillway depends mainly on the height and density of the cover chosen.

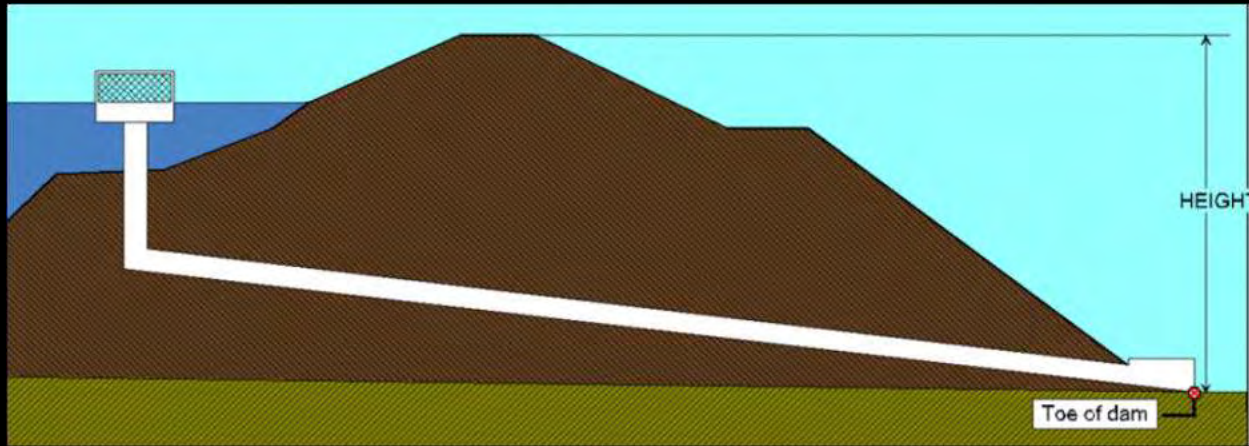
Generally, the retardance for uncut grass or vegetation is the one to use for capacity determination. Because protection and retardance are lower during establishment and after mowing, to use a lower degree of retardance when designing for stability may be advisable.

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

Earth spillway is to be excavated in a highly erodible soil and planted with bahiagrass. After establishment a good stand of 11 to 24 inches is expected.

# Pipe Inlet Spillways





### **Pipes through the dam (pipe spillways )**

Installing a pipe spillway is helpful in protecting the vegetation on earth spillway channels against saturation from spring flow or low flows that may continue for several days following a storm event.

A pipe placed under or through the dam provides this protection, by bypassing the flow of discharge through the dam, and not over it.

## **More considerations**

The crest elevation of the entrance should be 12 inches or more below the top of the control section of the auxiliary spillway.

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.

## Drop-inlet pipe spillway

Drop inlet and hood inlet pipe spillways are commonly used for ponds. The image, shows a drop-inlet type of pipe spillway with an anti-seep collar which helps to prevent wash-out around the pipe's perimeter.

A drop-inlet consists of a pipe barrel located under the dam and a riser connected to the upstream end of the barrel. This riser can also be used to drain the pond if a suitable valve or gate is attached at its upstream end.



### **Drop-inlet pipe spillway**

With the required discharge capacity determined, use Table 12 or Table 13 to select an adequate pipe size for the barrel and riser.

The diameter of the riser must be somewhat larger than the diameter of the barrel if the tube is to flow full.

**Table 12** Discharge values for smooth pipe drop inlets <sup>1/</sup>

Total head (ft)	Ratio of barrel diameter to riser diameter (in)					
	6:8 (ft <sup>3</sup> /s)	8:10 (ft <sup>3</sup> /s)	10:12 (ft <sup>3</sup> /s)	12:15 (ft <sup>3</sup> /s)	15:24 (ft <sup>3</sup> /s)	18:36 (ft <sup>3</sup> /s)
6	1.54	3.1	5.3	8.1	13.6	20.6
8	1.66	3.3	5.7	8.9	14.8	22.5
10	1.76	3.5	6.1	9.6	15.8	24.3
12	1.86	3.7	6.5	10.2	16.8	26.1
14	1.94	3.9	6.8	10.7	17.8	27.8
16	2.00	4.0	7.0	11.1	18.6	29.2
18	2.06	4.1	7.2	11.5	19.3	30.4
20	2.10	4.2	7.4	11.8	19.9	31.3
22	2.14	4.3	7.6	12.1	20.5	32.2
24	2.18	4.4	7.8	12.4	21.0	33.0
26	2.21	4.5	8.0	12.6	21.5	33.8

<sup>1/</sup> Length of pipe barrel used in calculations is based on a dam with a 12-foot top width and 2.5:1 side slopes. Discharge values are based on a minimum head on the riser crest of 12 inches. Pipe flow based on Manning's  $n = 0.012$ .

## Smooth pipe selection for barrel and riser

Table 12 above is used to properly select barrels of smooth pipe.

**Table 13** Discharge values for corrugated metal pipe drop inlets <sup>1/</sup>

Total head (ft)	Ratio of barrel diameter to riser diameter (in)					
	6:8 (ft <sup>3</sup> /s)	8:10 (ft <sup>3</sup> /s)	10:12 (ft <sup>3</sup> /s)	12:15 (ft <sup>3</sup> /s)	15:21 (ft <sup>3</sup> /s)	18:24 (ft <sup>3</sup> /s)
6	0.85	1.73	3.1	5.1	8.8	14.1
8	0.90	1.85	3.3	5.4	9.4	15.0
10	0.94	1.96	3.5	5.7	9.9	15.9
12	0.98	2.07	3.7	6.0	10.4	16.7
14	1.02	2.15	3.8	6.2	10.8	17.5
16	1.05	2.21	3.9	6.4	11.1	18.1
18	1.07	2.26	4.0	6.6	11.4	18.6
20	1.09	2.30	4.1	6.7	11.7	18.9
22	1.11	2.34	4.2	6.8	11.9	19.3
24	1.12	2.37	4.2	6.9	12.1	19.6
26	1.13	2.40	4.3	7.0	12.3	19.9

<sup>1/</sup> Length of pipe barrel used in calculations is based on a dam with a 12-foot top width and 2.5:1 side slopes. Discharge values are based on a minimum head on the riser crest of 12 inches. Pipe flow based on Manning's  $n = 0.012$ .

## Corrugated pipe selection for barrel and riser

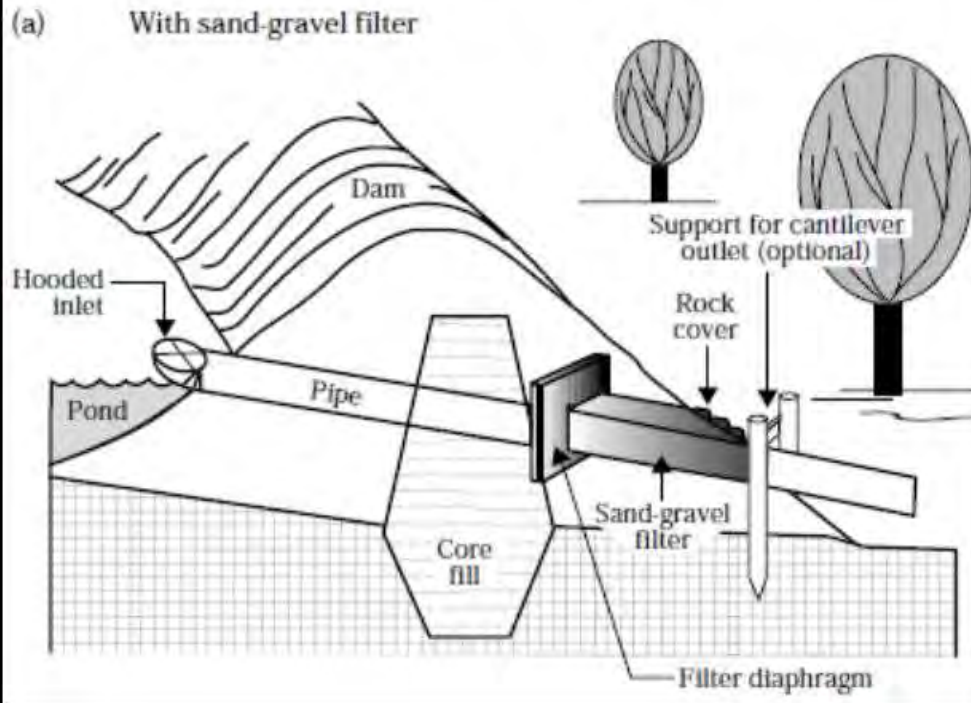
Table 13 above is used for selection of barrels of corrugated pipe.

## **Barrel to riser ratio**

Ratios of barrel diameter to riser diameter are shown in the previous 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.

Because pipes of small diameter are easily clogged by trash and rodents, no pipe smaller than 6 inches in diameter should be used for the barrel.

**Figure 24** Dam with hooded inlet pipe spillway



## Hooded inlet pipe spillway

A hooded inlet consists of a pipe laid in the earthfill (image). The inlet end of the pipe is cut at an angle to form a hood.



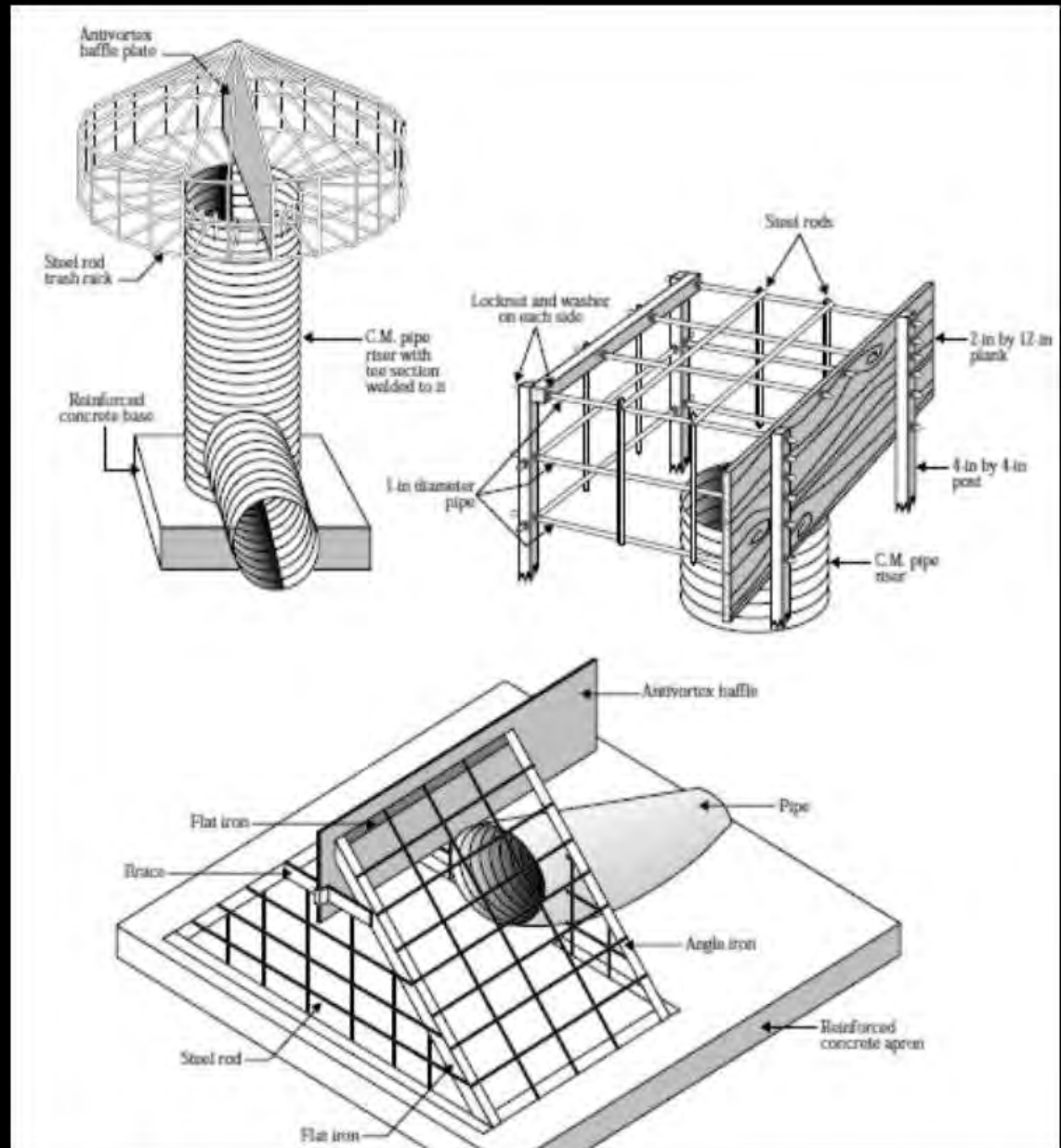
## Hooded inlet pipe spillway

An antivortex device, usually metal, is attached to the entrance of the pipe to increase the hydraulic efficiency of the tube.

Often a hood-inlet can be built at less cost than a drop-inlet because no riser is needed.

The major disadvantage of this kind of pipe spillway is that it cannot be used as a drain.

Typical installations of hood inlets and details of the anti-vortex device are shown (image).



## **Smooth and corrugated pipe tables**

The required diameter for a hood-inlet pipe can be selected from the tables above, after estimating the discharge capacity,  $Q$ , and determining the total head,  $H$ .

The tables shows the minimum head,  $h$  (ft), required above the invert of hood inlets to provide full flow,  $Q$  (ft<sup>3</sup>/s), for various sizes of smooth and corrugated pipe and values of total head,  $H$ .

## **Pipe material and jointing**

Pipes made of cast iron, smooth steel, concrete, plastic, or corrugated metal are suitable for either pipe spillway. For all pipe spillways, use new pipe or pipe so slightly used that it may be considered equivalent to new pipe.

Seal the joints with an approved type of rubber gasket to give them the desired amount of flexibility, and all joints must be watertight.

### **Pipe diaphragms to retard seepage**

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.

One filter and drainage diaphragm should be used around any structure that extends 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 ( $2xDo$ ).

### **Advantages to using a filter and drainage diaphragm:**

Filter and drainage diaphragms provide positive seepage control along structures that extend through the fill, and unlike concrete anti-seep collars, they do not require curing time.

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.

## **Pipe diaphragm considerations**

If bedrock is encountered within the ( $2xDo$ ) 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 ( $1.5 \times Do$ ) that has 1 foot around the pipe being a minimum.

## **Filter and drainage diaphragm material**

In most cases where the embankment core consists of fine-grained materials, such as sandy or gravelly silts and sandy or gravelly clay (15 to 85% - 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 (over 85% - passing No. 200 sieve) core requires special design considerations, and an engineer experienced in filter design should be consulted.

## **Concrete bedding**

Concrete bedding is needed for concrete pipe to ensure a firm foundation and good alignment of the conduit.

When a cradle or bedding is used under the pipe, the vertical downward ( $2xDo$ ) is measured from the bottom of the cradle or bedding.



## **Other Accessories**

## **Anti-seep collars**

Anti-seep collars can be used instead of the filter and drainage diaphragm. Anti-seep 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. If an anti-seep collar is used, it should extend into the fill a minimum of 24 inches perpendicular to the pipe.

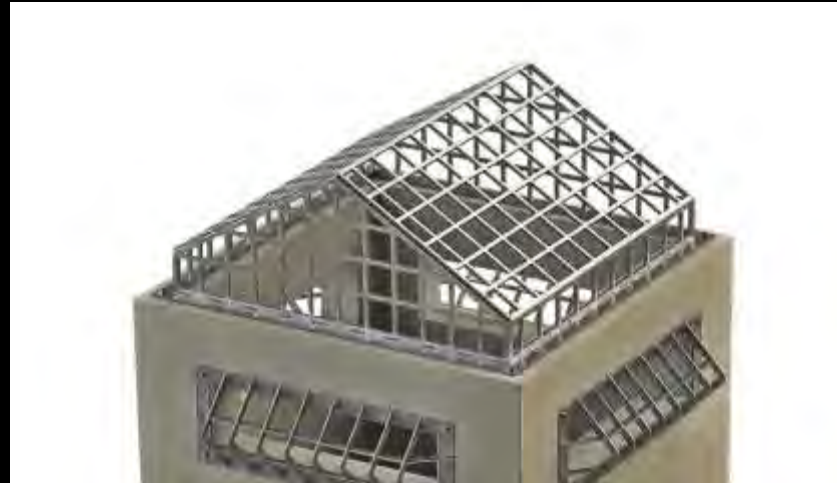


### **Anti-seep collar considerations**

If the dam is less than 15 feet high, one anti-seep collar at the centerline of the fill is usually sufficient.

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 anti-seep collars should be equally spaced between the riser and centerline of the fill.



## Trash racks

Various types of rack pipe covers are useful in deterring clogging of the pipe spillways with trash and debris.

These usually require routine cleaning but are much less trouble, than having to unclog debris from within the pipe.

## **Drainpipes**

Some state regulatory agencies require that provision be made for draining ponds completely or for fluctuations in the water level to eliminate breeding habitats for mosquitoes.

Whether it is mandatory or not, some type of provisions for draining a pond is recommended.

It permits good pond management for fish production and allows maintenance and repair without cutting the fill or using siphons, pumps, or other devices to remove the water.

## **Gates and other flow control devices**

A suitable gate or other control device should be installed and extend the drainpipe to the upstream toe of the dam to drain the pond. Riprap materials, a concrete chute or some other erosion control measure should be used to prevent eroding the toe of the dam.

**Water-supply pipes** Provide a water-supply pipe that runs through the dam if water is to be used at some point below the dam for supplying a stockwater trough, for irrigation, or for filling an orchard spray tank. This pipe is in addition to the principal spillway.

## **Other components in a water supply assembly**

A water-supply pipe assembly should be rigid and have watertight joints, a strainer at its upper end, and a valve at its outlet end.

For a small rate of flow, such as that needed to fill stockwater troughs, use steel or plastic pipe that is 1-1/2 inches in diameter.

For larger flows, such as for irrigation purposes use steel, plastic, or concrete pipe of larger diameter.

Water-supply pipes should also have watertight joints and anti-seep collars or a filter and drainage diaphragm.

# **Chapter Seven: Planning and Building the Earthfill Dam**



# Dam Foundations

## **Dam foundations**

A earthfill dam can be built safely on nearly any type of soil foundation.

A thorough investigation of the underlying soil conditions should be performed, and the foundation's design and construction adapted to conform to those conditions.

However, some foundation conditions require expensive construction measures that cannot be justified for smaller ponds.

## **Optimal conditions**

An ideal foundation consists of soil underlain at a shallow depth by a thick layer of relatively impervious, consolidated clay or sandy clay.

If a suitable layer is at or near the surface, no special measures are needed except the removal of the topsoil and scarifying or disking the remaining soil, to provide a bond with the materials in the dam.

## **Sand or sand-gravel foundations**

If the foundation is sand or a sand-gravel mixture, and there is no impervious clay layer at a depth that can be reached economically with available excavating equipment, an experienced engineer should be brought in to design the dam.

Although such foundations may be stable, corrective measures are needed to prevent excessive seepage and possible failure.

## **Foundation of highly plastic clay or unconsolidated material**

A foundation, consisting of, or underlain by a highly plastic clay or unconsolidated material requires careful investigation and design to obtain stability. If the foundation consists of such materials, again, an experienced engineer should be consulted.

## **Rock foundations**

Water impounded on a bedrock foundation 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 in the foundation, investigate the nature of the rock carefully.



### **Preventing seepage in alluvial soil types**

If the dam's foundation is overlain by alluvial deposits of pervious sands and gravels at or near the surface and rock or clay at a greater depth, seepage in the pervious stratum must be reduced to prevent possible failure of the dam by piping.



## **Preventing seepage with cutoffs**

To prevent excessive seepage in a pervious stratum, you need a cutoff to join the impervious stratum in the foundation with the base of the dam. The most common kind of cutoff is made of compacted clayey material.

A trench is excavated along the centerline of the dam deep enough to extend well into the impervious layer. This trench extends into and up the abutments of the dam as far as there is any pervious material that might allow seepage.

The image above shows a soil-cement-bentonite (SCB) cutoff trench being dug between a roadway and a pond embankment.



## **Dimensions of the cutoff trench**

The bottom of the trench should be no less than 8 feet wide (or the bulldozer blade width, whichever is greater), and the sides no steeper than 1.5:1.

Fill the trench with successive thin layers (9-inch maximum) of clay or sandy clay material. Compact each layer thoroughly at near-optimum moisture conditions before placing the next layer.

## **Top Width and Alignment of Dam**

<u>Height of dam</u> (ft)	<u>Minimum top width</u> (ft)
Under 10	6
11 to 14	8
15 to 19	10
20 to 24	12
25 to 34	14

### **Recommended minimum top width of the dam**

For dams less than 10 feet high, a conservative minimum top width is 6 feet. As the height of the dam increases, the top width increases.



## **Embankments with roads**

If the top of the embankment is to accommodate a road, provide for a shoulder on each side of the roadway to prevent raveling. The top width should be at least 16 feet.

## **Curved dam alignment**

In some situations a curved dam alignment is more desirable than a straight alignment. 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.

## **Side Slopes and Freeboard of the Dam**

## Side slopes

The side slopes of a dam depend primarily on the stability of the fill and on the strength and stability of the foundation material. The more stable the fill material, the steeper the side slopes.

Unstable materials require flatter side slopes. Recommended slopes for the upstream and downstream faces of dams built of various materials are shown in Table 16.

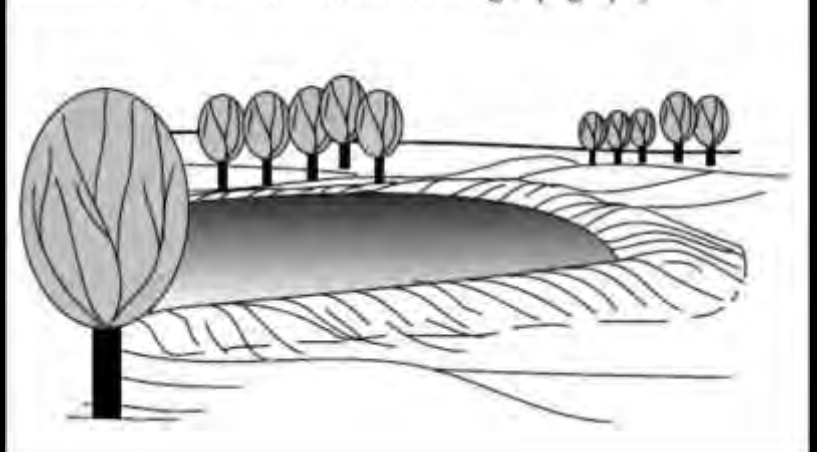
For stability, the slopes should not be steeper than those shown in Table 16, but they can be flatter as long as they provide surface drainage.

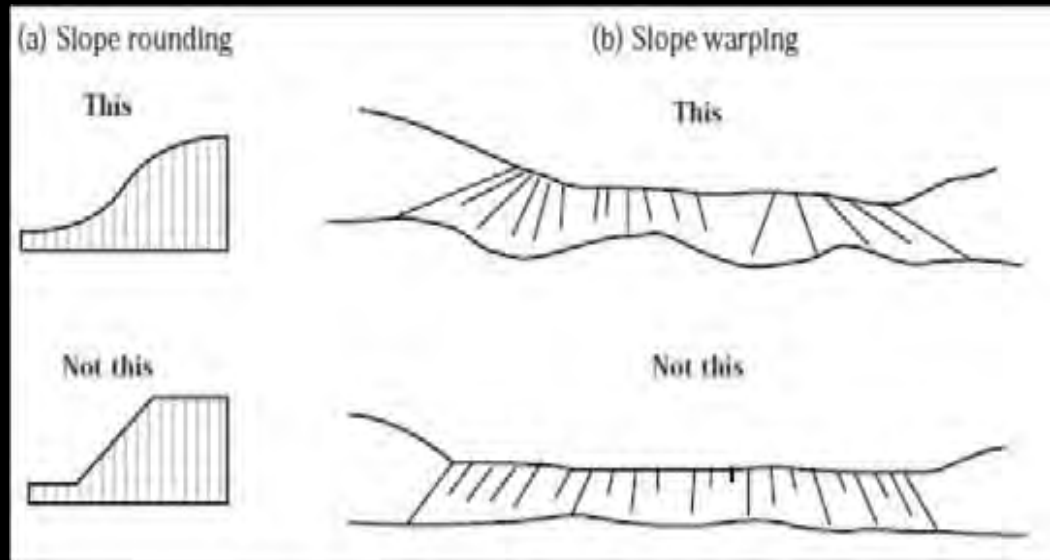
The side slopes need not be uniform, but can be shaped to blend with the surrounding landforms (bottom image).

**Table 16** Recommended side slopes for earth dams

Fill material	Slope	
	Upstream	Downstream
Clayey sand, clayey gravel, sandy clay, silty sand, silty gravel	3:1	2:1
Silty clay, clayey silt	3:1	3:1

**Figure 28** Dam side slopes are curved and shaped to blend with surrounding topography





## Techniques for finish-grading

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 (image).

Additional fill can be placed on the backslope and abutments of the dam, if needed, to achieve this landform transition.



## Freeboard

Freeboard is the additional height of the dam provided as a safety factor to prevent overtopping by wave action or other causes.

It is the vertical distance between the elevations 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 occurred.

The minimum freeboard for a pond:

- is no less than 1 foot (if the pond length is less than 660 feet long)
- is 1.5 feet (for ponds between 660 and 1,320 feet long)
- is 2 feet (for ponds up to a half mile long)
- should be determined by an experienced engineer (for longer ponds)

## Estimating the earthfill volume

After planning is completed, estimate the number of cubic yards of earthfill required to build the dam. Also estimate excavation yardage in foundation stripping, core trench excavation, and any other significant excavations.

This helps predict the cost of the dam and serves as a basis for inviting bids and for awarding a construction contract.

*The estimate of the volume of earthfill should include:*

- volume in the dam itself including the allowance for settlement
- volume required to backfill the cutoff trench
- volume required to backfill stream channels or holes in the foundation area
- any other volume of earthfill the contractor is required to move

## **Dam volume estimation**

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.

# Preparations



## Staking for construction

Each job must be adequately and clearly staked before construction is started, transmitting the information on the drawings to the job site. This information locates the work and provides the lines, grade, and elevations required for construction in accordance with the drawings.

Consider the contractor's needs when staking so that they can make the most effective use of the stakes. The quality and appearance of the completed job are reflected in the care used during the staking stage; taking care to mark each area clearly with an adequate number of stakes.

## Areas to be cleared and staked

### Areas to be cleared:

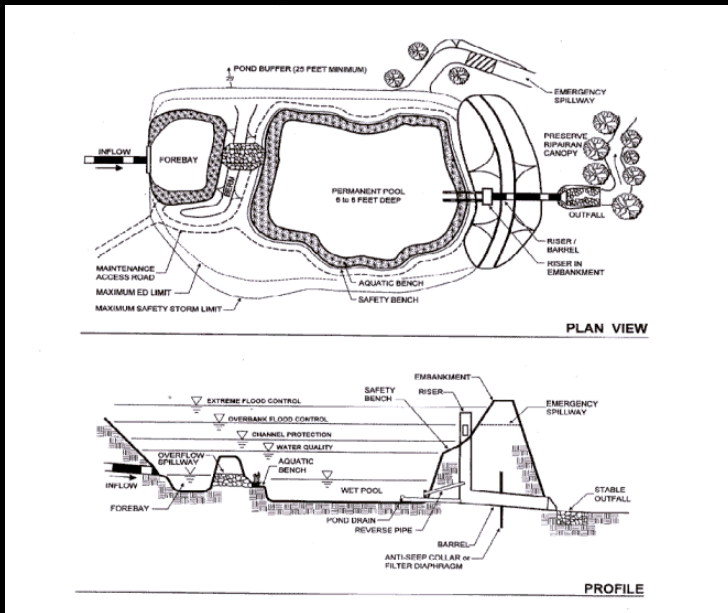
- dam site
- auxiliary spillway site
- borrow area
- pond area (area over which water is to be impounded)

### Areas to be staked:

- **Pond area** - locate the proposed water line; this provides a base line from which clearing limits can be established.
- **Locating the dam** - set stakes along its centerline at intervals of 100 feet or less. (Generally this has been done during the initial planning survey.)
- **Fill and slope stakes** - set the fill and slope stakes upstream and downstream from the centerline stakes to mark the points of intersection of the side slopes with the ground surface and to mark the work area limits of construction. These stakes also establish the height of the dam.

## Areas to be staked (continued)

- **Locating the earth auxiliary spillway** - first stake the centerline and then set cut and slope stakes along the lines of intersection of the spillway side slopes with the natural ground surface.
- **Borrow area** - if fill material must be obtained from a borrow area, this area must be clearly marked. Set cut stakes to indicate the depth to which the contractor can excavate to stay within the limits of suitable material, as indicated by soil borings. This allows the borrow area to drain readily and marks the limits of construction.
- **Principal spillway** - set stakes to show the centerline location of the principal spillway after foundation preparation has reached the point at which the stakes will not be disturbed.
- **Locate the pipe** - where it will rest on a firm foundation. Mark the stakes to show cuts from the top of the stakes to the grade elevation of the pipe.
- **With additional stakes** - mark the location of the riser, drainage gate, filter and drainage diaphragm or anti-seep collars, outlet structures, and other appurtenances.



## Attention to detail during construction

Attention to the details of construction and adhering to the drawings and specifications are as important as proper preliminary investigation and design. Having careless or poor construction principles 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.





## Rules for clearing and grubbing

- **Trees and brush** - Clear foundation area and excavated earth spillway site of trees and brush. In some states this is required by statute, as it can potentially pose a health risk. Cut trees and brush as nearly flush with the ground as practicable and remove them and any other debris from the dam site.
- **Filling the remaining holes** - When uprooting the trees with a bulldozer, 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.
- **Dispose of properly** - 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.

## Rules for clearing and grubbing (continued)

- **Limit vegetation removal when possible** - 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. Removing all vegetation within the construction limits is not always necessary. Selected groupings of desirable plants can be kept.
- **Protecting the remaining plant life** - 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.
- **Clearing limits** – These should be irregular to create a natural appearing edge and open area. 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. Feathering can be accomplished by selective clearing, installation of new plants, or both

## **Preparing the foundation**

This includes treating the surface, then excavating and backfilling the cutoff trench.

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.

Then excavate and backfill existing stream channels.



## Scrap the surface

Remove sod, boulders, and topsoil from the entire area over which the embankment is to be placed, using a tractor-pulled or self-propelled wheeled scraper.

The topsoil can be stockpiled temporarily, until it's needed later for covering the embankment.



## Fill holes

Fill all holes in the foundation area, both natural and those resulting from grubbing operations, with a suitable fill material taken from borrow areas.

Then compact or tamp the holes which have been filled, using either compacting equipment, or hand tampers when necessary.

After filling 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.

## **Trenching the cutoff**

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.

- 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.
- A dragline excavator and a tractor-pulled or self-propelled wheeled scraper are the most satisfactory equipment for excavating cutoff trenches.

### **Prior to the backfilling operations**

Before beginning to backfill, be sure to pump all of the free water from the cutoff trench. Some material which is high in clay content doubles in mass, becoming soggy.

Such clay puddled in the cutoff of a dam may require years to become stable. Also in drying, it will contract and may leave cracks that can produce a roof of the overlying impervious earthfill section and provide passageways for seepage through the dam.

## **Backfilling the cutoff trench**

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.



## **Stream channels**

Deepen, slope back, and widen the 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.

## **Side slopes**

Leave the 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.

## Installing the Pipe Spillway

## Components of dam

The following components of the dam should be installed to the lines and grades as shown in the drawings, and staked out at the site:

- pipe
- riser (if applicable)
- filter and drainage diaphragm
- anti-seep collars
- trash rack
- other mechanical components

## **Installation of the pipes**

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.

Install pipes and filter and drainage diaphragm or anti-seep 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.

## **Earthwork - dam and spillway**

Prior to beginning construction, the dam and spillway areas should be cleared of trees, brush, stumps, boulders, sod, and rubbish.

The sod and topsoil can be stockpiled and used later to cover the dam and spillway. This will help when vegetation is established.

### **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.



## Filling in low areas

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 compact each layer under the same moisture conditions regardless of the placement in or under the embankment.



## **Finding suitable fill material**

Obtain 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. Selected backfill material should be placed in the core trench and around pipes and anti-seep collars, when used.

The material should be compacted by hand tamping or manually directed power tampers around pipes.

## **Placement of fill material**

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.



## **Compaction of fill**

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.

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 sheepfoot rollers, should be used.

## Settlement allowance

Settlement or consolidation depends on the character of the materials in both the dam and the foundation and on the construction method.

- Build higher - to allow for settlement, build earth dams somewhat higher than the design dimensions.
- Foundation settlement - if a 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.
- Yielding foundations - for a compacted fill dam on unyielding foundation, settlement is negligible. Most foundations are yielding, and settlement may range from 1 to 6 percent of the height of the dam, mainly during construction.
- Rolled-fill dams - the settlement allowance for a rolled-fill dam should be about 5 percent of the designed dam height, meaning that the dam should be built 5 percent higher than the designed height. After settlement, the height of the dam will be adequate.
- Dams below 20 feet - Most pond dams less than 20 feet high, are not rolled fill. For these dams the total settlement allowance should be about 10 percent.

# **Chapter Eight: Constructing an Excavated Pond**

## **Reasons to build an excavated pond**

### *Advantages of building an excavated pond:*

- ease with which they can be constructed
- their compactness due to the undisturbed, insitu ground conditions
- can be built to expose a minimum water surface area in proportion to their volume
- their relative safety from flood flow damage
- their low maintenance requirements
- advantageous in places where evaporation losses are high and water is scarce
- Excavated ponds are the simplest to build in relatively flat terrain

## **Limitations with excavated pond systems**

Because their capacity is obtained almost solely by excavation, their practical size is limited, and they are best suited to locations where the demand for water is small

*Excavated ponds are replenished by one of two sources:*

- Some are replenished by surface runoff
- Some are replenished by ground water aquifers; usually layered by sand and gravel
- However, some ponds may be fed from both of these sources

## **Locating the pond to capture water source**

The general location of an excavated pond depends largely on the purpose(s) for which the water is to be used and on other factors we've previously discussed; while the specific location is often influenced by the existing topography.

The water needs to be situated in a way that it can be naturally replenished. This requires either capturing water from the surface (runoff), or water from a groundwater source.



## **Ponds fed by surface runoff**

Excavated ponds fed by surface runoff can be located in almost any type of topography; however most are used in areas of comparatively flat, but well-drained terrain.

A pond can be located in a broad natural drainage way or to one side of a drainage way if the runoff can be diverted into the pond. The low point of a natural depression is often a good location. After the pond is filled, excess runoff escapes through regular drainage ways.

## Requirements for ponds fed by surface runoff

If an excavated pond is to be fed by surface runoff, enough impervious soil at the site is essential to avoid excess seepage losses. The most desirable sites are where fine-textured clay and silty clay extend well below the proposed pond depth. Sites where sandy clay extends to adequate depths generally are satisfactory.

- Avoid sites where the soil is porous or is underlain by strata of coarse-textured sand or sand-gravel mixtures unless you are prepared to bear the expense of an artificial lining.
- Avoid soil underlain by limestone containing crevices, sinks, or channels. The performance of nearby ponds that are fed by runoff and in a similar soil is a good indicator of the suitability of a proposed site.



### **Ponds fed by aquifers (Groundwater)**

Excavated ponds fed by ground water aquifers can be located only in areas of flat or nearly flat topography. If possible, they should be located where the permanent water table is within a few feet of the surface.

If an excavated pond is to be fed from water-bearing sand or a sand-gravel layer, the layer must be at a depth that can be reached practically and economically by the excavating equipment. This depth seldom exceeds 20 feet.

The water-bearing layer must be thick enough and permeable enough to yield water at a rate that satisfies the maximum expected demand for water and overcomes evaporation losses.

## **Perform some pond recon**

Supplement your observations of existing ponds in the surrounding area, by boring enough test holes at intervals over the proposed pond site to determine accurately the kind of material there.

You can get some indication of permeability by filling the test holes with water. The seepage indicates what to expect of a pond excavated in the same kind of material.



## Drill test boreholes

Thoroughly investigate sites proposed for aquifer-fed excavated ponds. Bore test holes at intervals over the site to determine the existence and physical characteristics of the water-bearing material. The water level in the test holes indicates the normal water level in the completed pond.

The vertical distance between this level and the ground surface determines the volume of overburden or excavation needed that does not contribute to the usable pond capacity, but may increase the construction cost considerably.

From an economic standpoint, this vertical distance between water level and ground surface generally should not exceed 6 feet.

## Boring hole observations

*Check the rate at which the water rises in the test holes:*

- **A rapid rate of rise** - indicates a high-yielding aquifer. If water is removed from the pond at a rapid rate, as for irrigation, the water can be expected to return to its normal level within a short time after removal has ceased.
- **A slow rate of rise** - in the test holes indicates a low-yielding aquifer and a slow rate of recovery in the pond. Check the test hole during drier seasons to avoid being misled by a high water table that is only temporary.

# Protection from Erosion, Scour, and Silt

## **Erosion protection for the spillway**

Protection should be provided for the spillway, against erosion, scouring, and silt. Ponds which have been excavated in areas of flat terrain will generally require constructed spillways.

If surface runoff must enter an excavated pond through a channel or ditch rather than through a broad shallow drainage way, the overfall from the ditch bottom to the bottom of the pond can create a serious erosion problem unless the ditch is protected.



## **Scour protection**

Scouring can occur in the side slope of the pond and for a considerable distance upstream in the ditch. The resulting sediment tends to reduce the depth and capacity of the pond.

Protect the slope by placing one or more lengths of rigid pipe in the ditch and extending them over the side slope of the excavation. The extended part of the pipe or pipes can be cantilevered or supported with timbers.

The diameter of the pipes depends on the peak rate of runoff that can be expected from a 10-year frequency storm. If more than one pipe inlet is needed, the combined capacity should equal or exceed the estimated peak rate of runoff.

## **Silt protection**

Silt protection In areas where a considerable amount of silt is carried by the inflowing water, you should provide a desilting area or filter strip in the drainage way immediately above the pond to remove the silt before it enters the pond. This area or strip should be as wide as or somewhat wider than the pond and 100 feet or longer.

After preparing a seedbed, fertilize, and seed the area to an appropriate mix of grasses and forbs. As the water flows through the vegetation, the silt settles out and the water entering the pond is relatively silt free.

# Planning the Pond

## **Pond shape**

Although excavated ponds can be built to almost any shape desired, a rectangle is commonly used in relatively flat terrain.

The rectangular shape is popular because it is simple to build and can be adapted to all kinds of excavating equipment.

Rectangular ponds should not be constructed, however, where the resulting shape would be in sharp contrast to surrounding topography and landscape patterns.

### **Irregular pond shape**

A pond can be excavated in a rectangular form and the edge shaped later with a blade scraper to create an irregular configuration.

The capacity of an excavated pond fed by surface runoff is determined largely by the purpose or purposes for which water is needed and by the amount of inflow that can be expected in a given period.

### **Plans to enlarge in the future**

The required capacity of an excavated pond fed by an underground water-bearing layer is difficult to determine because the rate of inflow into the pond can seldom be estimated accurately. For this reason, the pond should be built so that it can be enlarged if the original capacity proves inadequate.

## Selecting the Pond's Dimensions

## **Dimensions**

The dimensions selected for an excavated pond depend on the required capacity. Of the three dimensions of a pond, the most important is depth.

All excavated ponds should have a depth equal to or greater than the minimum required for the specific location.

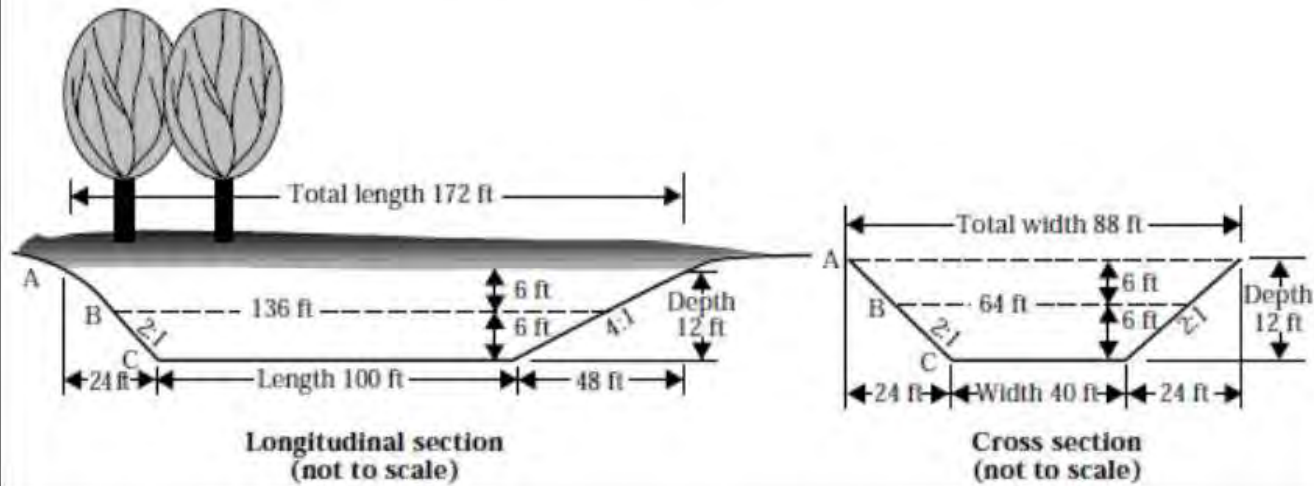


## **Maximum depth**

If an excavated pond is fed from ground water, it should be deep enough to reach well into the water-bearing material. The maximum depth is generally determined by the kind of material excavated and the type of equipment used. The type and size of the excavating equipment can limit the width of an excavated pond.

For example, if a dragline excavator is used, the length of the boom usually determines the maximum width of excavation that can be made with proper placement of the waste material.

Figure 35 Typical sections of an excavated pond



## Minimum length

The minimum length of the pond is determined by the required pond capacity.

To prevent sloughing, the side slopes of the pond are generally no steeper than the natural angle of repose of the material being excavated.

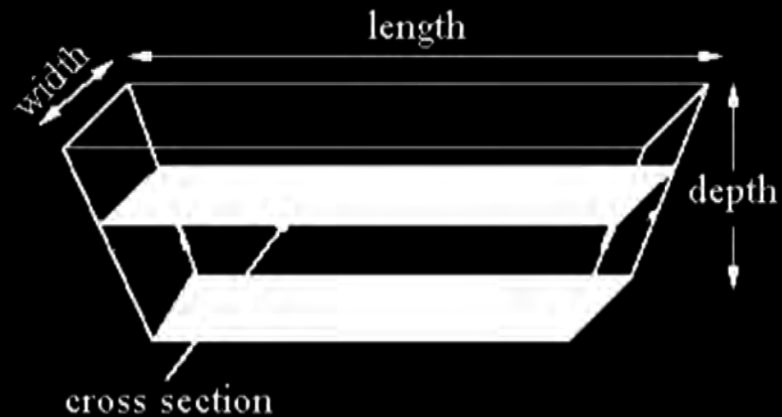
This angle varies with different soils, but for most ponds the side slopes are 1:1 or flatter (image).

## **Need for a flat-sloped sides**

If the pond is to be used for watering livestock, provide a ramp with a flat slope (4:1 or flatter) for access.

Regardless of the intended use of the water, flat slopes are important if certain types of excavating equipment are used.

Tractor-pulled wheeled scrapers and bulldozers require a flat slope to move material from the bottom of the excavation.



## Estimating the volume of excavation

After selecting the pond dimensions and side slopes of the pond, estimate the volume of excavation required. This estimate helps to determine the cost of the pond and is a basis for soliciting construction bids and setting a reasonable price for a contractor.

The volume of excavation required can be estimated with sufficient accuracy by using the prismoidal formula (image). There are various other methods for estimating the volume of an excavated pond as well.

# Handling of Waste Materials

## **Plan out the onsite placement or permanent removal**

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.

## **Where to place the spoils**

If the waste material is not to be removed from the site, it should be placed 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, it should be placed with side slopes which don't exceed the natural angle of repose of the soil.

Waste materials should not be stacked in a geometric mound, but shaped and spread 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.

## Creative use of the spoils

Avoid interrupting the existing horizon line with the top of the waste mound. Waste material can be located and designed to be functional.

Berms and mounds can be arranged to screen undesirable views, buffer out noise sources and wind, or improve the site's suitability for recreation.

In shaping the material, the toe of the fill must be at least 12 feet from the edge of the pond.







## **Other ways to deal with the spoils**

The complete removal of the spoils can be expensive and usually not justified unless the material is needed nearby. Waste material can sometimes be tilled into crop fields, to fill in low-lying areas which may be prone to flooding (image) or as base in building farm roads (sand, gravel, fines).

If state or county highway maintenance crews need such material, you may be able to have them remove it, free of charge, or can advertise or word of mouth, for free fill dirt amongst neighbors can be a good alternative.

# Excavating the Pond

## **Pre-excavation**

To prepare the pond area for excavation, clear the area of all unwanted vegetation, especially ensuring that no stumps will remain when the pond is completed.

Then mark the outer limits of the proposed excavation with cut stakes, indicating on the stakes the depth of cut from the ground surface to the pond bottom.

## **Excavation**

Excavation and placement of the waste material entail the bulk of the workload when building this type pond.

The kind of excavating equipment used depends on the local climate, the physical conditions at the site, and on what equipment is available.

## Equipment to use

- **In low-rainfall areas** - where water is unlikely to accumulate in the excavation, you can use almost any kind of available equipment. Tractor-pulled wheeled scrapers, dragline excavators, and track-type tractors equipped with a bulldozer blade are generally used. Bulldozers can only push the excavated material, not carry it; if the length of push is long, using these machines is expensive.
- **In high-rainfall areas** - and in areas where the water table is within the limits of excavation, a dragline excavator is commonly used because it is the only kind of equipment that operates satisfactorily in any appreciable depth of water. For ponds fed by ground water aquifers, a dragline is normally used to excavate the basic pond.

## **Excavated waste material**

Excavate and place the waste material as close as possible to the lines and grades staked on the site. If you use a dragline excavator, you generally need other kinds of equipment to stack or spread the waste material and shape the edge to an irregular configuration.

Bulldozers are most commonly used. Graders, either tractor-pulled or self-propelled, can be used to good advantage, particularly if the waste material is to be shaped.

## Sealing the Pond

## **Substandard siting**

Excessive seepage in ponds is generally because the site is substandard; usually meaning, one where the soils in the impounding area of the pond are too permeable to retain water.

Choosing a substandard site is often the result of inadequate site investigations and is usually avoidable. In areas where no satisfactory site is available, but the need for water is sufficient to justify using a less-than-satisfactory site, then plans for reducing the seepage by one of several sealing procedures should be considered.



### **Excessive seepage**

In some places excessive removal of the soil mantle during construction, usually to provide material for the embankment, exposes highly pervious material, such as sand, gravel, or rock containing cracks, crevices, or channels. This can be avoided by carefully selecting the source of embankment material.

To prevent excessive seepage, reduce the permeability of the soils to a point at which losses are insignificant or at least tolerable. The method depends largely on the proportions of coarse-grained sand and gravel and of fine-grained clay and silt in the soil.

## **Using Compaction to Seal the Pond**

## **Using compaction alone to seal the pond**

Some pond areas can be made relatively impervious by compaction alone if the material contains a wide range of particle sizes (small gravel or coarse sand to fine sand) and enough clay (10 percent or more) and silt to effectively seal the soil.

This is the least expensive method of those presented in this course. Its use, however, is limited to these soil conditions as well as by the depth of water to be impounded.

## Compaction procedures

The compaction procedure is as follows:

- Clear the pond area of all trees and other vegetation.
- Fill all stump holes, crevices, and similar areas with impervious material.
- Scarify the soil to a depth of 16 to 18 inches with a disk, rototiller, pulverizer, or similar equipment.
- Remove all rocks and tree roots.
- Roll the loosened soil under optimum moisture conditions in a dense, tight layer with four to six passes of a sheepsfoot roller in the same manner as for compacting earth embankments.
- Make the compacted seal no less than 12 inches thick where less than 10 feet of water is to be impounded.
- Because seepage losses vary directly with the depth of water impounded over an area, increase the thickness of the compacted seal proportionately if the depth of water impounded exceeds 10 feet or more.
- The thickness of the compacted seal can be determined using the equation below.

## Compaction example

Assume a pond with a depth,  $H$ , of 12 feet. No soil samples were taken for laboratory testing. Therefore, use the assumed values for  $k$  and  $v$ . Calculate the required minimum thickness of the compacted seal.

If soil samples were taken and permeability tests were performed on the material of the compacted seal at the density it is to be placed, a thickness less than what was calculated may be possible. Without knowing whether the soil underlying the compacted layer will act as a filter for the compacted layer, the minimum thickness should never be less than 12 inches.

Compact the soils in two or more layers not exceeding 9 inches uncompacted over the area. Remove and stockpile the top layer or layers while the bottom layer is being compacted.

## **Reducing Seepage: Clay Blankets and Bentonite**

## **Using clay blankets**

Pond areas containing high percentages of coarse grained soils, but lacking sufficient clay content to prevent excessive seepage, can be sealed by blanketing. Blanket the entire area over which water is to be impounded as well as the upstream slope of the embankment.

The blanket should consist of a well-graded material containing at least 20 percent clay. The requirements for good blanket material are about the same as those described for earth embankments. You can usually obtain material for the blanket from a borrow area close enough to the pond to permit hauling at a reasonable cost.

## **Thickness requirements**

Thickness of the blanket depends on the depth of water to be impounded. The minimum compacted thickness is 12 inches for all depths of water fewer than 10 feet.

Increase this thickness by 2 inches for each foot of water over 10 feet and above. Construction is similar to that for earth embankments.



## **Preparation and application**

Remove all trees and other vegetation and fill all holes and crevices before hauling earth material from the borrow area to the pond site in tractor-pulled wheeled scrapers or similar equipment.

Spread the material uniformly over the area in layers 6 to 8 inches thick. Compact each layer thoroughly, under optimum moisture conditions, by four to six passes of a sheepsfoot roller before placing the next layer.

## **Protecting clay blankets**

Protect clay blankets against cracking that is a result of drying and against rupture caused by freezing and thawing.

Spread a cover of gravel 12 to 16 inches thick over the blanket below the anticipated high water level. Use rock riprap or other suitable material to protect areas where the waterflow into the pond is concentrated.

## **Using bentonite**

Adding bentonite is another method of reducing excessive seepage in soils containing high percentages of coarse-grained particles and not enough clay.

Bentonite is a fine-textured colloidal clay. When wet it absorbs several times its own weight of water and, at complete saturation, swells as much as 8 to 20 times its original volume.

### **Bentonite cracks when dried out**

Mixed in the correct proportions with well-graded coarse-grained material, thoroughly compacted and then saturated, the particles of bentonite swell until they fill the pores to the point that the mixture is nearly impervious to water.

On drying, however, bentonite returns to its original volume leaving cracks. For this reason, sealing with bentonite is typically not recommended for ponds in which the water level is expected to fluctuate widely.

## **Rate of application**

A laboratory analysis of the pond area material to determine the rate of application is essential.

Before selecting this method of sealing a pond, locate the nearest satisfactory source of bentonite and investigate the freight rates. If the source is far from the pond site, the cost may prohibit the use of bentonite.

## **Preparation and application**

As with other methods, clear the pond area of all vegetation. Fill all holes or crevices, and cover and compact areas of exposed gravel with suitable fill material.

The soil moisture level in the area to be treated is important. Investigate it before applying bentonite. The moisture level should be optimum for good compaction. If the area is too wet, postpone sealing until moisture conditions are satisfactory. If it is too dry, add water by sprinkling.

## **Adding bentonite**

Spread the bentonite carefully and uniformly over the area to be treated at the rate determined by the laboratory analysis. This rate usually is 1 to 3 pounds per square foot of area.

Thoroughly mix the bentonite with the surface soil to a depth that will result in a 6-inch compacted layer. This generally is an uncompacted thickness of approximately 8 to 9 inches. A rototiller is best for this operation, but a disk or similar equipment can be used. Then compact the area with four to six passes of a sheepsfoot roller.

## Protection of bentonite application

If considerable time elapses between applying the bentonite and filling the pond, protecting the treated area against drying and cracking may be necessary.

A mulch of straw or hay (image) pinned to the surface by the final passes of the sheepsfoot roller gives this protection.

Use rock riprap or other suitable material to protect areas where water inflow into the treated area is concentrated.





## **Reducing Seepage: Chemical Additives and Waterproof Linings**

### **Chemical additives (dispersing agents)**

Because of the structure or arrangement of the clay particles, seepage is often excessive in fine-grained clay soils. If these particles are arranged at random with end-to-plate or end-to-end contacts, they form an open, porous, or honeycomb structure; the soil is said to be aggregated.

Applying small amounts of chemical dispersing agents to these porous aggregates may result in the collapse of the open structure and rearrangement of the clay particles. This dispersed structure reduces soil permeability.

### **Fine grained soils required**

The soils in the pond area should contain more than 50 percent fine-grained material (silt and clay) and at least 15 percent clay for chemical treatment to be effective.

Chemical treatment is not effective in coarse-grained soils.

## Salts

Although many soluble salts are dispersing agents, sodium polyphosphates and sodium chloride (common salt) are most commonly used.

*Most effective sodium polyphosphates:*

- tetrasodium pyrophosphate
- sodium tripolyphosphate

Sodium polyphosphates generally are applied at a rate of 0.05 to 0.10 pound per square foot, and sodium chloride at a rate of 0.20 to 0.33 pound per square foot.



### **Soda ash (sodium carbonate)**

Soda ash, technical grade 99 to 100 percent sodium carbonate, can also be used.

Historically soda ash was extracted from the ashes of plants growing in sodium-rich soils. Because the ashes of these sodium-rich plants were noticeably different from ashes of wood (once used to produce potash), sodium carbonate became known as "soda ash".

It is produced in large quantities from sodium chloride and limestone by the Solvay process. Soda ash is applied at a rate of 0.10 to 0.20 pound per square foot.

## **Preparation and application of dispersing agents**

A laboratory analysis of the soil in the pond area is essential to determine which dispersing agent will be most effective and to determine the rate at which it should be applied.

## **Application of dispersing agent**

Mix the dispersing agent with the surface soil and then compact it to form a blanket. Thickness of the blanket depends on the depth of water to be impounded.

For water less than 10 feet deep, the compacted blanket should be at least 12 inches thick. For greater depths, the thickness should be increased at the rate of 2 inches per foot of water depth from 10 feet and above.

The soil moisture level in the area to be treated should be near the optimum level for good compaction. If the soil is too wet, postpone treatment. Polyphosphates release water from soil, and the material may become too wet to handle. If the soil is too dry, add water by sprinkling.

## **Preparation**

Clear the area to be treated of all vegetation and trash. Cover rock outcrops and other exposed areas of highly permeable material with 2 to 3 feet of fine grained material. Thoroughly compact this material.

In cavernous limestone areas, the success or failure of the seal may depend on the thickness and compaction of this initial blanket.



## **Application**

Apply the dispersing agent uniformly over the pond area at a rate determined by laboratory analysis. It can be applied with a seeder, drill, fertilizer spreader, or by hand broadcasting.

The dispersant should be finely granular, with at least 95 percent passing a No. 30 sieve and less than 5 percent passing a No. 100 sieve.

## **Mix and protect**

Thoroughly mix the dispersing agent into each 6-inch layer to be treated. You can use a disk, rototiller, pulverizer, or similar equipment.

Operating the mixing equipment in two directions produces best results. Thoroughly compact each chemically treated layer with four to six passes of a sheepfoot roller.

Protect the treated blanket against puncturing by livestock. Cover the area near the high-water line with a 12- to 18-inch blanket of gravel or other suitable material to protect it against erosion.

Use riprap or other suitable material in areas where inflow into the pond is concentrated.

# Reducing Seepage with Waterproof Liners

## Use of waterproof linings

Using waterproof linings is another method of reducing excessive seepage in both coarse-grained and fine grained soils. Polyethylene, vinyl, butyl-rubber membranes, and asphalt-sealed fabric liners are gaining wide acceptance as linings for ponds because they virtually eliminate seepage if properly installed.

Thin films of these materials are structurally weak, but if not broken or punctured they are almost completely watertight.

- **Black polyethylene** -these films are less expensive and have better aging properties than vinyl, and can be joined or patched with a special cement.
- **Vinyl** - is more resistant to impact damage and is readily seamed and patched with a solvent cement.

All plastic membranes should have a cover of earth or earth and gravel not less than 6 inches thick to protect against punctures.

## **Preparation**

Clear the pond area of all undesired vegetation. Fill all holes and remove roots, sharp stones, or other objects that might puncture the film.

When the material is stony or has a coarse texture, it should be covered with a cushion layer of fine-textured material prior to placing the lining.



### **Sterilize, if grass penetration is a concern**

For grasses with high penetration potential, some plants may penetrate both vinyl and polyethylene film. If nutgrass, johnsongrass (shown in image), quackgrass, and other plants having high penetration potential are present, the subgrade (especially the side slopes), should be sterilized.

A number of good chemical sterilizers are available commercially. Sterilization is not required for covered butyl-rubber linings 20 to 30 mils thick.

## **Applying the lining**

Lay the linings in sections or strips, allowing a 6-inch overlap for seaming. Vinyl and butyl-rubber linings should be smooth, but slack.

### **Polyethylene**

**This** should have up to 10 percent slack, using care to avoid punctures. Anchor the top of the lining by burying it in a trench dug completely around the pond at or above the normal water level. The anchor trench should be 8 to 10 inches deep and about 12 inches wide.

### **Butyl-rubber membranes**

**These** need not be covered except in areas travelled by livestock. In these areas a minimum 9-inch cover should be used on all types of flexible membranes. The bottom 3 inches of cover should be no coarser than silty sand.

# Establishing Vegetation





## **Add plant life**

Trees, shrubs, grasses, and forbs (which are flowering, non-grassy herbaceous plants), should be planted during or soon after construction to aid in stabilizing the site.

## Use of upland plants

These are plants that do poorly in the moist and seasonally flooded areas surrounding a pond.

They are good for erosion protection and control, to provide habitats, for watershed filtration, climate control (shading), and as wind breaks to slow evaporation of a pond system.



## **Use of low maintenance and native species of plants**

The vegetation should be able to survive under prevailing conditions with minimum maintenance. Native varieties are preferred for new plantings.

In many areas the exposed surface of the dam, the auxiliary spillway, and the borrow areas as well as their disturbed surfaces can be protected from erosion by establishing a vegetative community of appropriate species.

## **Preparing and seeding**

Prepare a seedbed as soon after construction as practicable. This is generally done by disking or harrowing. Fertilize and seed with mixtures of perennial grasses and forbs appropriate for local soil and climatic conditions.

If construction is completed when the soils are too dry for the seeds to germinate, irrigate the soils to ensure prompt germination and continued growth.

## **Mulching**

Mulching with a thin layer of straw, fodder, old hay, asphalt, or one of several commercially manufactured materials may be desirable.

Mulching not only protects the newly prepared seedbed, seeds, or small plants from rainfall damage, but also conserves moisture and provides conditions favorable for germination and growth.

## **Soil bioengineering**

Soil bioengineering systems should be employed to establish woody vegetation where appropriate on the shorelines of ponds.

The systems best suited to these conditions include live stakes, live fascines, brush mattresses, live siltation, and reed clumps.

## **Flood tolerance and wave resistance**

Trees and shrubs that remain or those planted along the shoreline will be subject to flooding, wave action, or a high water table.

The ability to tolerate such drastic changes varies greatly among species. Flood tolerance and resistance to wave action depend on root density and the ability to regenerate from exposed roots.

A planting plan indicating the species and rate of application of the vegetation can be helpful to visualize and achieve the desired results.

# Protecting the Pond



## **Protect your pond system**

Pond construction is not finalized until protection has been provided against erosion, wave action, trampling by livestock, and other sources of damage. Ponds without protection may be short lived, and the cost of repairing the damage is usually high.

## **Grading and shaping**

Leave any borrow pits in a condition to be planted so that the land can be used for grazing or some other purpose. Grade and shape the banks or side slopes of borrow pits to a slope that permits easy mowing, preferably no steeper than 4:1, and allows the graded area to blend with the landscape.

It is often desirable to establish vegetation to make the borrow area compatible with undisturbed surroundings.

Grade all areas or pits from which borrow material has been obtained so they are well drained and do not permit stagnant water to accumulate as breeding places for mosquitoes.



## Dealing with wave action

Several methods are available to protect the upstream face of a dam from wave action. The choice of method depends on whether the normal pool level remains fairly constant or fluctuates. An irrigation pond is an example of a pond that tends to fluctuate.

In these ponds, water is withdrawn periodically during the growing season and the water level may fluctuate from normal pool level to near pond bottom one or more times each year. The degree of protection required also influences the choice of method.

### **Berms for protecting against wave action**

If the water level in the pond is expected to remain fairly constant, a berm 6 to 10 feet wide located at normal pool level generally provides adequate protection against wave action.

The berm should have a downward slope of about 6 to 12 inches toward the pond. The slope above the berm should be protected by vegetation.

### **Use of log booms for mitigating wave action**

Log booms also break up wave action. A boom consists of a single or double line of logs chained or cabled together and anchored to each end of the dam. Tie the logs end to end as close together as practicable.

Leave enough slack in the line to allow the boom to adjust to fluctuating water levels. When using double rows of logs, frame them together to act as a single unit. For best results place the boom so that it floats about 6 feet upstream from the face of the dam.

## **Anchor posts**

If the dam is built on a curve, you may need anchor posts on the face of the dam as well as at the ends to keep the boom from riding on the slope.

Booms do not give as much protection as some other methods described, but they are inexpensive if timber is readily available. They generally are satisfactory for small structures.



## Riprap

Rock riprap is an effective method of control if a high degree of protection is required or if the water level fluctuates widely. Riprap should extend from the top of the dam down the upstream face to a level at least 3 feet below the lowest anticipated water level.

Riprap is dumped directly from trucks or other vehicles or is placed by hand. Hand placing gives more effective protection and requires less stone, while dumping requires more stone, but is less labor-intensive.

## **Applying riprap**

The layer of stones should be at least 12 inches thick and must be placed on a bed of gravel or crushed stone at least 10 inches thick. This bed keeps the waves from washing out the underlying embankment material that supports the riprap.

If riprap is not continuous to the upstream toe, provide a berm on the upstream face to support the layer of riprap and to keep it from sliding downslope.

When possible, use stones whose color is similar to that in the immediate area. Allow grass and herbs to grow through the riprap to blend with surrounding vegetation, but control woody vegetation.



## **Fencing**

Complete fencing of areas on which embankment ponds are built 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.

## **Fencing with wildlife and livestock in mind**

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.

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. Not all ponds used for watering livestock need to be fenced.

## **Considerations with the use of fencing**

In some situations, the advantages derived from fencing can be offset by the increased cost and maintenance and the fact that fewer animals can water at a given 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.

# **Chapter Nine: Pond Operation, Management, and Maintenance**

# Operating and Maintaining the Pond

## **Proper maintenance recommended**

A pond, no matter how well it is planned and built, must be properly maintained if its intended purposes are to be realized throughout its life expectancy.

Lack of operation and maintenance has caused severe damage to many dams and spillways, with some structures failing completely.

## **Routine inspections and assessment**

It is recommended to inspect and assess a pond periodically, as well as examining it 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. Fill any rills on the side slopes of the dam and any washes in the auxiliary spillway immediately with suitable material and compact it thoroughly.

## Test the water quality

A good pond assessment should include routine testing of the pond water quality. Depending on a pond's intended use, testing of water quality parameters for irregularities are suggested.

*Parameters such as:*

- chemical contamination
- nutrients - nitrogen and phosphorus
- ammonia
- lack of dissolved oxygen (DO)
- turbidity and total suspended solids (TSS)
- coliform bacteria
- pH balance
- protozoan parasites
- metals
- water hardness
- blue-green algae
- high temperature conditions





### **Aquatic plants and algae**

Taking account of the aquatic plants and algae growth (image) in the pond during the summer season is helpful in determining the existing health of the pond and potential future issues.

## **Banks and dam**

The dam and exposed banks should be checked for complete grass coverage and no erosion. Grass, weeds, brush and small trees should be occasionally cut from the dam and banks. Trim vegetation to allow for a visual inspection of the surface to check for leaking or burrowing animals.

Inspect and repair any fencing used to keep livestock from accessing the dam or pond embankments. Large trees should be as they are, as killing large trees may cause leaks to develop around their decaying root systems.

## **Spillway and pipe**

It is especially important to inspect the spillway pipe and remove debris in or around the opening. Obstructions may result in water breaching the dam or continually flowing through the auxiliary spillway (if one exists).

The auxiliary spillway should also be inspected to remove debris and repair any obvious erosion.



## **Pond ingress and egress**

Be sure that the access road to the pond is maintained to allow ready access. This is especially important if a dry hydrant exists to allow access for fire trucks.

To maximize fire protection benefits from a pond, fire trucks must have access to the pond during all seasons of the year and the dry hydrant should be easily accessible from the road.



## Check for signs of leaks

The pond's water level should be routinely monitored for signs of water loss. Most ponds lose some water to underground seepage and evaporation, and ponds with little water inflow might lose several inches each day to evaporation in the summer.

However, water losses in excess of this could be a sign that a significant leak is occurring. This is can sometimes be detected as a soggy or damp area outside the pond, depending on the root cause of the leak.

# Water Quality

## **Unseen hazards from ponds**

Ponds add a tranquil beauty to the landscape and are a haven for all forms of wildlife. While ponds have many functional and aesthetical uses, they can also bring various forms of unseen hazards.

## Hardness

Hardness is a measure of the level of magnesium and calcium in water, and is relative to the source of the pond water.

Ponds in limestone regions usually have water which is harder than those in regions underlain by sandstone or shale.

The hardness of pond water does not have much of an effect on water quality, except when using some copper-based types of aquatic herbicides, (with levels above 50 mg/L reducing the herbicides effectiveness.)





## Temperature

Maintaining a certain temperature range is vital for the survivability of fish and other aquatic life in the pond. Ponds that are fed from underground springs will have colder water in the summer months helping to support cold-water game fish species such as trout and whitefish.

Ornamental fish species such as Koi are also fond of cold-water environments. Ponds should be stocked with game fish species such as crappie, brim, bass, bluegill and perch if the water tends to run warmer.

Temperatures can vary considerably throughout the pond's ecosystem, with surface water affected more by air temperature than the deeper areas, making the top of the pond warmer in the summer and colder in the winter.

## **Altering the temperature of the pond**

There are few solutions available to alter the temperature of pond water. One option is to setup a well nearby, and pump groundwater into the pond to cool the pond during the summer. In most cases, however, it is best to match the types of fish stocked in a pond with the existing environmental temperatures.

Cold-water fish thrive best in water temperatures not exceeding 70°F, while warm-water prefer summer temperatures in the 80s range.

Water temperature is also important when using aquatic herbicides to treat plant or algae growth. Aquatic herbicides are most effective when water temperatures are between 60 and 75°F. Consult the herbicide label for details.

## **Nutrients (nitrogen, phosphorus, ammonia)**

Many ponds suffer from excessive amounts of nitrogen and phosphorous from various runoff sources.

*Sources such as:*

- barnyards and livestock
- crops
- septic systems
- lawn and golf course fertilizing
- waterfowl

## **Ammonia, phosphate, and nitrate**

Nitrogen is usually present in ponds as ammonia or nitrate, while phosphorous occurs as phosphate.

Ammonia usually originates when animal or human wastes directly enter the pond.

It is highly toxic to fish and other aquatic life and any amount of ammonia-nitrogen above 0.1 mg/L can be detrimental to a pond's ecosystem.



### **Good for plants, bad for water quality**

Both nitrogen and phosphorous can be readily used by aquatic plants and algae, which may lead to excessive growth. Long-term control of overabundant plants is best accomplished by reducing or redirecting nutrient sources.

This may be done by reducing fertilizer use near the pond, maintaining, improving or relocating septic systems, directing nutrient laden runoff away from the pond, or maintaining buffer strips around the pond.

When the underlying causes of plant growth are not addressed, the plants must then be controlled with mechanical, biological, or chemical techniques.



## Depletion of dissolved oxygen

The large scale death of aquatic plants or algae, whether by natural causes, or as a result of herbicidal use, will result in the consumption of much of the dissolved oxygen in the pond water and will lead to fish kills.

- Nitrate-nitrogen levels above 3 mg/L are indicative of pollution.
- Phosphate levels as low as 0.01 mg/L may be enough to increase plant and algae growth.
- Excessive amounts of nitrate can also be dangerous for drinking water.
- Dairy cows should not drink water with nitrate concentrations above 23 mg/L measured as nitrate-nitrogen.
- Nitrate and phosphate can be measured with simple water test kits or certified water testing labs.



## **Protozoa parasites**

Whether intentionally drinking from a pond or accidentally ingesting water while swimming or boating, pond water may be extremely dangerous. Just the acts of simply touching one's mouth after touching pond water, or reaching for something to eat, may result in the transmission of parasites.

Because ponds are not treated with chemicals, as a swimming pool would be, their water often contains various protozoa or parasites.

Giardia lamblia and Cryptosporidium which live in human and animal intestinal tracts are protozoa that can occur in any surface water and may cause severe gastrointestinal problems if ingested.

## Coliform bacteria

Ponds can easily become contaminated with various forms of dangerous bacteria. Coliform bacteria are a large group of varying forms of bacteria, some of which can bring about waterborne illnesses.

Some coliform bacteria will occur in all ponds, but dangerously high levels may occur in ponds that receive animal wastes from barnyards or wildlife or human wastes from septic systems (image shows a leaking septic system).

Large populations of waterfowl can increase the bacterial contamination of small ponds.

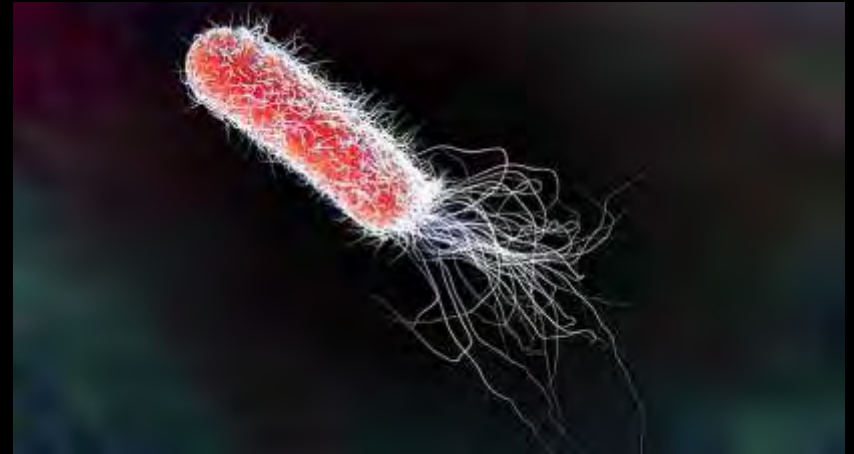


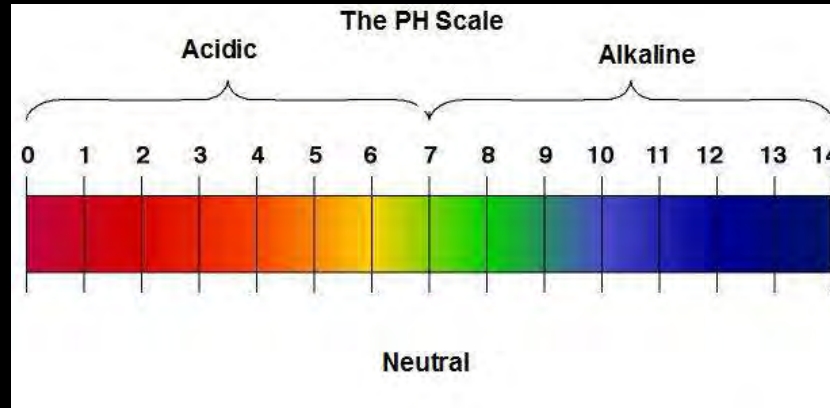


## E Coli

It is recommended that ponds used for swimming contain less than 200 fecal coliform bacteria per 100 mL of water and less than 150 E. coli bacteria per 100 mL of water.

Pond waters used for livestock watering should contain less than 10 fecal coliform bacteria per 100 mL and no E. coli bacteria, especially for calves and other young livestock.





## pH Balance

The pH of a pond is a measure of the acidity of the water. Farm ponds which are located in valleys underlain by limestone will usually have a pH in the range of 7.0 to 8.5. Higher elevation ponds tend to have a lower pH, often less than 7.0. The pH of pond water is important for a number of pond uses.

- Different fish species can tolerate varying pH levels, though most fish function best with a pH near 7.0.
- Ponds with a pH less than 6.0 may result in stunted or reduced fish populations.
- Ponds with a pH less than 5.5 or above 8.5 should not be used for dairy cows.

### **Low pH (acidic) ponds**

Very low pH may be found in ponds in mining areas that are affected by acid mine drainage. In this case, the pH may be too low to support fish life, and the water also may be unusable for livestock watering. Low-pH ponds are often treated by applying limestone.

This is most easily done by broadcasting one to two tons of pulverized limestone over the pond ice during the winter. Repeated applications are often necessary to maintain a high pH in acidic ponds (less than 7.0).

## **Blue-green algae**

Some types of blue-green algae are a water quality issue in ponds used for watering of livestock. Some of these algae can produce toxins that may sicken or kill animals that drink the water.

These toxins are produced during or following excessive algae growth or “blooms,” which usually occur after longer periods of hot summer weather.

Testing for toxic blue-green algae is difficult and not commonly available. Therefore, farmers using a pond to water their livestock should prevent excessive algae growth or limit animal access to these ponds during or right after algae blooms occur.

The common types of filamentous algae that produce long strands or mats are not harmful to animals.



## Chemicals

Many chemicals used within a pond's watershed can wind up flowing into a pond, especially if the pond is fed by surface runoff.

Whether it is pesticides, fungicides, fertilizers, hydrocarbons or any other commonly used household chemical, the water runoff will transport them to the pond, where they usually settle into the muck of the silty pond bottom.

Not only is this a hazard to humans, who may touch or consume the water, but it will also likely result in killing off life forms in the water, such as fish. Unlike algal growth, successfully determining whether a pond is chemically contaminated is nearly impossible without the use of professional testing services.

## Metals

Metals such as iron, manganese, and copper in ponds can create an offensive taste that might affect water consumption by animals. High iron concentrations may also adversely affect the look of a pond by creating an orange coating on the pond bottom, docks, and vegetation.

Iron concentrations above 0.3 mg/L and manganese concentrations above 0.05 mg/L will impart a metallic taste to water and may cause problems with injury to plants being irrigated with the pond water.

Copper concentrations above 1.0 mg/L can cause an offensive metallic taste. High copper concentrations may result from repeated use of copper-based algaecides in the pond.



## **Dissolved oxygen**

The amount of oxygen that is dissolved in pond water is critical for the survivability of fish and other pond life. The amount of oxygen that can be dissolved, is relative to the water temperature. Warmer water holds less dissolved oxygen than colder water, with most pond water retaining about 10 to 12 mg/L of oxygen.

Dissolved oxygen is reduced by the biological decay of organic material such as decaying plants and animals or animal and human wastes. Dissolved oxygen levels below about 6 mg/L can begin to have serious detrimental effects on the types of pond life which require oxygen.



### **Insufficient dissolved oxygen**

A lack of dissolved oxygen is the most common cause of fish kills in ponds. This occurs frequently when aquatic plants and algae die in the summer or when they are treated with aquatic herbicides.

Fish kills due to low oxygen are most common during hot, dry spells when algae grow and then die quickly. The organisms that decompose the dead algae may use so much oxygen that what remains is insufficient for fish. In very deep ponds, the deepest portions of the pond may have very low dissolved oxygen concentrations due to poor aeration.





## **Remediation for dissolved oxygen deficiencies**

Issues with dissolved oxygen can usually be remedied by careful use of aquatic herbicides to limit the excessive plant and algae growth in the pond.

Commercially available, continuous aeration devices are beneficial solutions for ponds that suffer from reduced dissolved oxygen levels.

## **Turbidity**

Turbid or muddy pond water is usually only an aesthetical issue. It is frequently caused by runoff from disturbed areas eroding into the pond or from bottom-dwelling fish.

Muddy water is best solved by eliminating the source of the problem. This might include planting grass or other vegetation on exposed areas, putting a layer of rocks over exposed banks, or removing muskrats or bottom-dwelling fish.

Persistent muddy water problems can be treated with additions of ground limestone, hydrated lime, gypsum, or alum.

## **Turbid water due to zooplankton**

Ponds that are only turbid or coloured during the summer are probably experiencing zooplankton blooms. Zooplankton are small animals that serve as a food source for fish and other aquatic life.

## Zooplankton

Zooplankton can be distinguished from sediment in water by holding a clear glass of pond water up to a bright light. If most of the particles in the water move erratically, the pond is experiencing a zooplankton bloom. If the particles do not move, sediment is the cause of the water discoloration.

Zooplankton blooms can be eliminated with copper sulphate, but in most cases the health of the pond is best served if they are left untreated.

Muddy water is common in new ponds and usually subsides as vegetation grows around the pond. In established ponds, muddy water can almost always be traced to a preventable source.

## Secchi disk measurements

Secchi disk sediment or turbidity in pond water can be measured using a simple device called a Secchi disk.

This black and white weight is lowered into the water until it is barely visible and the depth of water is recorded.



# Pond Sedimentation

## **Excessive pond sediment**

A common problem among older ponds is excessive sedimentation. Depending on the source of water, ponds tend to fill up over time with sediment.

As sediment fills in the pond, growth of aquatic plants and algae will generally increase, due to increased sunlight penetrating the ever shallower water.

When sediment levels in a pond become noticeable, steps should be taken to reduce the sediment from entering the pond. Inspect the pond water source to determine if exposed banks or upstream activities are causing increased sedimentation intrusion.

## **Settling basins**

If the pond receives excessive amounts of silt, erosion control practices should be implemented in the watershed. When the upstream land is owned by others, a small settling basin just upstream from a pond could be built to intercept the incoming sedimentation.





## **Dredging to remove sediment**

Sediment can be removed from the pond through dredging but this process has drawbacks, and is destructive to the pond's ecosystem.

Mechanical dredging operations are more effective when the pond has been completely drained and the bottom sediments have had time to dry out. This means all aquatic life must either be relocated or killed off.

## **Dredging causes damage to the pond's ecosystem**

When dredging wet, as soon as the dredge equipment touches the sediment, the fine particles expand into the water releasing toxic gases and nutrients.

This kills off much of the existing aquatic life and leaves the pond with a black, mucky mess. Once the dredging is finished, the sediments then settle back to the bottom of the pond, and much of the dredging benefits are lost.

Heavy equipment can cause extensive damage to the landscape and is hindered by houses, power lines, telephone poles, and trees. The cost in some cases is prohibitive and some mechanical dredgers will not consider working on smaller ponds

## **Removing sediment with suction pumps**

High-volume suction pumps can also be used to remove sediment buildup in ponds. They basically descend to the bottom of the pond, and move through the sediment, vacuuming it up. This not only removes the sediments, but also the toxic gases and nutrients.

The process can also remove loose clay, rocks, and sand, and free up covered features such as springs, pipe spillways, irrigation systems, and culverts.

# Muck



## **Yuck, it's muck!**

As a pond ages over time, dead plant growth will accumulate at the bottom of the pond eventually turning into muck.

Those naturally-occurring microorganisms and bacteria which are found in a well-established pond may not be enough to deal with ponds which have excessive muck buildup.

## **Muck-digesting bacteria**

This may require the addition of commercially-available products, which consist of a specialized blend of muck-digesting bacteria. These bacteria are effective in eliminating muck, thus improving water clarity and eliminating the associated noxious odors.

Muck can also be removed by commercial suctioning pumps, like those mentioned in the previous page on sedimentation.

*Muck is caused by various sources of accumulated, decaying organic matter such as:*

- fish and animal fecal matter
- decaying algae
- weeds
- woody materials
- aquatic, and mowed grasses
- leaves

## **Prevention of organics into the pond system**

It is always advisable to prevent organics from entering the pond and remove as much as possible. Over time, as the layers of organic matter build up, the sludge can become several inches thick.

Muck is a natural food source containing high levels of nutrients that feed algae and aquatic weeds. As the muck layer grows, so will your problems with these aquatic nuisances. Muck can also be a breeding ground for insects such as leeches which burrow in the muck.

## **Muck's noxious odor**

Muck tends to have a rotten egg smell; an odor common in ponds that are not aerated, particularly during certain times of the year.

In the summer and winter, non-aerated ponds stratify into layers of water with distinct temperature differences.

While the water is stratified, the oxygen in the lower portion of the pond is consumed quickly.





## **Transition from aerobic to anaerobic state**

This causes it to transition from an aerobic environment (oxygen-rich) to an anaerobic environment (low-oxygen); which is ideal for slow-moving anaerobic bacteria that use enzymes to ferment and digest the decaying muck on the bottom.

Those microorganisms ultimately produce waste products, including carbon dioxide and hydrogen sulfide, which creates the rotten egg odor.

In the spring and during strong weather events, the water column turns over; the anaerobic layers on the bottom rise to the top, bringing with it the foul-smelling odors. In northern states, the melting ice releases gas all at once, bringing out the noxious odor.

## **How muck fits in to a pond's life cycle**

Understanding a pond's life cycle will help to better explain how muck fits in, studying the condition of a freshly constructed pond, as opposed to the later years, as the pond begins to mature.



### **The early stage of a pond (first 3-5 years)**

A freshly constructed pond will be free of weeds and debris caused by wildlife, waste, plant decay and other organic material.

The water is generally clean and clear and there is minimal algae and weed growth.

## **The 2nd stage of a pond**

As organic debris accumulates and the pond becomes overabundant with nutrients, these excess nutrients become an effective plant fertilizer, causing weeds and algae to proliferate.

Weeds such as cattails and shoreline grasses begin to emerge along the shoreline and a foul smell emanates from the water. Pond owners tend to use treatments like aquatic herbicides and algaecides during this stage to kill the existing growth.

These treatments provide a quick-fix to weed and algae control, but when left in the pond, the decaying plant material turns into nutrient-rich pond muck that continues to fuel weed and algae growth.

## Eutrophic stage of a pond

The pond then enters a vicious cycle of reactive treatments, leaving the pond owner to use chemicals to control growth.

A pond at this point is said to be eutrophic, or teeming with enough excess debris to support algae and weed growth.



# Classifying Weeds



## **Weeds classification**

As a pond matures, the weeds will increasingly tend to proliferate. In addition to being annoying and unsightly, they can choke the life out of the pond's ecosystem.

Most algaecides and herbicides will treat a variety of weeds and algae so it is not always necessary to identify the exact type of weed but to just determine the classification of weed it belongs in.



## Algae

This is a cellular plant that is a common nuisance with no distinguishable leaves or root system. Referred to as string algae or pond scum is algae that floats on top of the water in clusters, turn the water green and is often treated by a liquid algaecide.

Chara (shown in image) is algae that looks like a submerged weed, but is easy to rake out and has a musky odor with a crunchy texture when handled.





## **Submerged plants**

Submerged plants require water to stand and have a strong root system that is difficult to pull from the water without breaking the soft stems.

The majority of the plant will be submerged in the water, however the plant may grow to the surface and spread.



## Floating plants

These are generally found in shallower water, floating plants can spread and completely cover the surface cutting off light and oxygen to the fish below.

They can be divided in two groups:

- Those which are free floating
- Those which are rooted

A free-floating plant have roots underneath the plant to absorb nutrients from the pond's water, but never touches the bottom, while rooted floating plants often have showy flowers and large leafed foliage that sits on top of the water.



## **Emergent plants**

These are rooted plants like cattails, grow along the shoreline and stand above the surface or in shallow areas.

Emergent plants may have some of their root system (up to 6-8 inches) in water, however all the leaves will be above water due to the stiff or firm stem.



## Shoreland plants

These are aquatic plants that thrive on the shore, but can tolerate being in moist and seasonally flooded areas.

Examples include: blue flag iris, some shrubs and trees

# Pond Safety

## **Pond hazards**

Ponds of all kinds will tend to attract people, bringing the possibility of injury or drowning. Whether a pond is built for watering livestock, irrigation, or any of the other purpose, it will likely have people that congregate around it, for recreational and other purposes.

A pond owner needs to take some of the following steps to prevent injuries or drownings, and to protect against litigation situations.

## Potential liability issues

Find out what the local laws are regarding liability in case of injury or death resulting from use of the pond, regardless of authorized use or unauthorized use. This is particularly important when the intent is to open a pond to the public and charge a fee for its use.

It's likely that there will be a need for insurance to protect against litigation. Deciding how the water is going to be used helps in planning the needed safety measures before construction starts.

For example, if the water is to be used for swimming, guards over conduits are required. Also beaches and diving facilities might be provided; the latter require a minimum depth of about 10 feet of water.

## **Safety measures**

Safety measures should be taken during a pond's construction. Remove undesirable trees, stumps, brush and debris that might be a hazard to boaters and swimmers.

Maintain a gradual and consistent slope in the pond, eliminating sudden dropoffs and deep holes, which can cause unpredictable conditions for swimmers. 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.



# Chapter Ten: Pond Aesthetics

# Pond Aeration

## Use of a pond aeration system

There are many benefits to installing a bottom diffused aeration system into a pond.

Aeration is vital in the summer months for increasing the availability of dissolved oxygen for the pond's ecosystem.



## **Aeration reduces pond muck**

As a pond ages, organic matter and nutrients accumulate at the bottom of the pond and become muck.

Aeration is important in reducing the effects of muck and other detritus on pond life by increasing the dissolved oxygen and circulating the water.

This pond water aeration encourages the colonization of beneficial aerobic bacteria that consume the nutrients, thus reducing existing muck build-up and preventing its future accumulation.

## **Aerate to reduce the bad stuff**

Nutrients will accumulate at the bottom of a pond, becoming muck. They will also become suspended solids in the water column causing the pond to take on a murky appearance.

By reducing the muck and excess nutrients, and increasing dissolved oxygen, this will in turn bring upon an improvement in the water's quality and clarity.

Additionally, pond water aeration will aid in the reduction of algae and weeds because of the reduced nutrient levels.

### **Higher DO levels = more aerobic bacteria**

Higher DO levels are needed from pond water aeration to sustain the fish population, but it is also needed to vitalize the growth of beneficial bacteria. Without oxygen, a pond will go into an anaerobic state.

Anaerobic bacteria are not as efficient at breaking down organic material as aerobic bacteria. Also, an anaerobic bacterium produces carbon dioxide and hydrogen sulfide when digesting organic matter, giving the pond the sulfuric, rotten egg odor.



### **Good aerobic bacteria**

A beneficial colony of aerobic bacterium will produce a harmless gas when breaking down muck and debris.

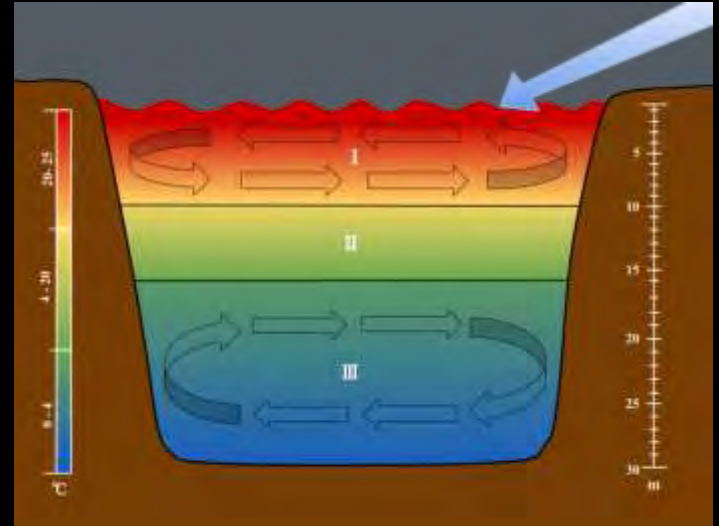
Incorporating aeration into the pond increases the amount of DO in the water, thus keeping it smelling better, and functioning as a healthy aerobic system.

## **Aeration eliminates the thermocline**

The thermocline is the boundary between the warmer, aerobic surface environment and the colder, bottom anaerobic environment.

Aeration eliminates these stratified layers by blending the cooler oxygen-starved water at the bottom with the pond's warmer surface water, so it can become infused with oxygen.

The oxygen-rich water then mixes with the bottom stratum of water to revitalize the beneficial bacterial activity.





## **Aeration reduces hypoxia**

Fish kills are most frequently caused by pollution from agricultural runoff or biotoxins, which cause hypoxia (oxygen depletion).

The hypoxic event may be brought on by factors such as excessive organic decay, algae blooms, drought, or high temperatures.

Aeration is vital in remediating a hypoxic event by continually pumping fresh oxygen into the pond.

## **Seasonal turnover events**

In the spring and fall, turnover events due to stratified water can cause a fish kill.

During a turnover event, a stratified pond rapidly mixes, depleting the oxygen from the surface water as it combines with the bottom oxygen-starved water.

Pond water aeration will eliminate the thermocline and prevent these spring and fall turnovers.

## Use of Pond Dyes

## Pond dyes

Excessive sunlight can have a negative effect on water quality. Adding pond dyes will improve the look of a pond and improve water quality by providing a natural pond shade, effectively reducing the amount of sunlight which reaches the algae and weeds in the pond water.

This helps in managing the growth of the algae and weeds.

It can be used in the pond throughout the year because it has no water or temperature restrictions.





## Dye colors

Pond dyes come in various colors such as black (shown in image), green, light or deep blue tint or a natural mirror like reflective surface. Adding blue pond dye does more than just change the color of the water.

They serve several other purposes as well: controlling algae, protecting fish and masking a murky pond.

## **Staining due to dye applications**

After 24 hours of being applied, the dye will not cause staining. However, when in concentrated form, it will cause serious staining, thus it is recommended to wear gloves and be cautious when adding dye to the pond.

Once mixed into the water, pond dye is safe for agriculture and irrigation purposes. Immediately after treatment, the pond can be used for recreation, fishing and other activities. It's safe for swimming ponds, as well as watering animals.



## Benefits to fish life

Using dye in ponds can be beneficial to fish by hiding them from the sight of predatory birds. Also as temperatures rise, dissolved oxygen levels in the pond are reduced, helping to keep the water cooler in summer months.

## Use of Pond Fountains





## **Pond fountains**

Pond fountains are an excellent way to enhance the visual quality of the pond setting, and create a focal point. In addition to this aesthetic appeal, fountains also oxygenate the water as the spray droplets make contact with the air and fall back into the pond.

Using pond water fountains alone may provide enough aeration to the pond ecosystem to meet all of its DO needs, if it is fairly shallow.

## **The six-foot depth rule**

If the depth of the pond is in excess of 6 feet, then a fountain will likely not provide a sufficient amount of aeration. Proper pond aeration is achieved when the entire body of water circulates at the same time.

Fountains draw water from the top of the water column only, so the water that is deeper than the 6-foot mark remains untouched and does not become properly oxygenated.

## Subsurface aeration systems

Subsurface aeration systems, are typically recommended for deeper ponds, to provide whole-pond circulation.

With these units, pressurized air is forced through the diffuser plates positioned at the bottom of the pond.

As the air bubbles rise, oxygenated water from the surface moves to the bottom, creating a healthy aerobic pond ecosystem.



### **For irregularly shaped ponds**

For ponds less than 6' deep with a uniform shape, one fountain may be enough to aerate the pond.

If the shape is irregular, one may not suffice. A pond shape with a curvy design adds a unique and stylish look to the pond, but it can also restrict proper whole-pond circulation; thus the oxygenated water created by a fountain may not reach the isolated corners of the pond.

This may require additional pond water fountains or a combination of a fountain and aeration system in order to fully aerate the pond. It's not likely that the pond would ever suffer from over-aeration, but under-aeration is a possibility, which would lead to more weed and algae growth in the areas that aren't receiving enough oxygen.



### **Correct spray pattern for the fountain**

The most effective shape for pond aeration is the simple and effective v-shaped pattern.

The more decorative the spray pattern, the less likely it is to adequately aerate the pond, as more energy is being spent on creating the patterns than on moving the water.



### **Fountain pump horsepower rating**

When choosing a fountain for aerating a pond, a good rule of thumb is to use one 1.5 HP pump motor per acre.

When using the fountain for decorative purposes only, a 1 HP pump motor per acre would work.

## **Conclusion**

As we have discussed in this course, a pond is much more than a hole in the ground that retains water. There is a complex system of components at work, keeping the pond in balance, maintaining water levels, and providing functionality to this mini ecosystem.

## Course bibliography

- Much of this course is based on the USDA technical publication, “Ponds – Planning, Design, Construction, Agricultural Handbook Part 590”
- Additional materials were found at The Pond Guy, Learning Center at [www.thepondguy.com](http://www.thepondguy.com)
- Various Wikipedia articles were also contributions to this course
- USDA NRCS’s “Part 630 Hydrology National Engineering Handbook- Ch. 7 Hydrologic Soil Groups”



This concludes our course on “A Guide to Excavated and Embankment Pond Systems”.  
You may now proceed to the final exam.

**Thank you for taking this Flashcard course!**

*A Guide to Excavated and Embankment Pond Systems, 2019 Edition  
First Printing: March, 2019  
Copyright © 2019 by Don Parnell, PE and D. Allen Hughes, PE*

*All rights reserved. No part of this courseware may be reproduced or distributed, or transmitted in any form or by any means, including, without limitation, electronic, optical, or mechanical means (by way of example and not limitation, photocopying, or recording by or in an information storage retrieval system) without express written permission of the above mentioned courseware developers.*