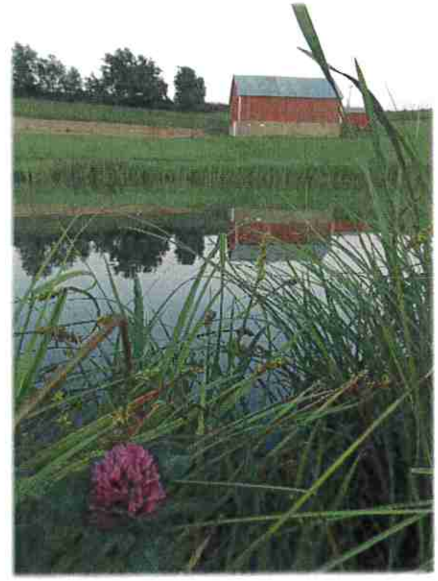
Westmoreland Conservation District

A Guide to Building Dams and Ponds

This is a guide containing information on the preparation and construction of a dam and backyard pond.

Date Modified: October 2023

Are you considering building a pond, but you don't know where to start or what kind of permits are required or needed? Or maybe you have an existing waterbody on your property and you want to install a boat dock or launch? This publication will answer the most common questions and provide you with the basic requirements and resources to successfully install and maintain a man-made water body (pond or dam). But before we dive in, let's review some basic definitions.



DAMS- A dam is any artificial barrier, such as an earthen embankment or concrete structure, built for the purpose of impounding or storing water or another fluid or semi-fluid.

PONDS- A pond is a small body of open water. An artificial pond may not have an embankment.

When do I Need a Permit? (25 Pa. Code Chapter 105)

- **A PA Department of Environmental Protection's (DEP) Division of Dam Safety Permit is required if (1 of 3 criteria are met with a dam on a watercourse)(contact DEP at 412-442-4018):**
  1. The dam is located across a watercourse and the contributory drainage area (watershed) to the dam exceeds 100 acres.
  2. The dam is located across a watercourse and/or the maximum depth of water, measured from the upstream toe of the dam to the top of the dam at maximum storage elevation, is greater than 15 feet.
  3. The dam is located across a watercourse and the impounding capacity (storage volume) at maximum storage elevation is greater than 50 acre-feet. (e.g. 3.5 acres x 15 feet deep = 52 acre-feet)
- **Exceptions for when a dam permit is not required**:

  An embankment on a watercourse does not exceed three feet in height or 50 feet in width, (except wild trout streams designated by the Fish and Boat Commission). In this case a permit is not required, but an Environmental Assessment (EA) must be conducted. The Environmental Assessment Information Sheet must be filled out and sent to DEP for review if the proposed dam is located in a wetland or waterway with an exceptional value designation, and where water quality certification is required under section 401 of the Clean Water Act.

****Keep in mind that after an impoundment or pond is constructed, it becomes a regulated body of water. This means additional permits may be needed if you want to install docks, boat ramps, or any water encroachment structures.

Additional Permit Requirements (25 Pa. Code Chapter 105)

- Confirm with DEP that the proposed pond location is not on or near a wetland. If it is a wetland, a consultant should be hired to ensure no negative impacts will result from pond construction. If there are wetland impacts during construction, a Department of Environmental Protection (DEP) Chapter 105 Water Obstruction and Encroachment Permit (Joint Permit) and Federal Section 404 permit will be required. (Contact DEP)
- If a pond will have an intake structure (for off-stream ponds): a DEP General Permit - 4 is required, unless the drainage area of the stream to the intake point is less than 100 acre drainage area. (Contact WCD)
- To install a boat dock or launch: a DEP General Permit - 2 is required. (Contact WCD)

Maintenance and Permit Requirements

- A draw-down permit may be required by the PA Fish & Boat Commission if you plan on draining a pond that is one acre or larger after construction. (More info under "Permits to Draw Off Impounded Waters")
- A permit is not required for the following, but an <u>approved erosion and sediment control plan may be needed:</u>
    1. Replacing a failing outlet structure.
    2. To repair and/or excavate a dam embankment.
    3. To stabilize an eroding shoreline and embankment using vegetation or rip-rap.
    4. Maintenance dredging: removal of accumulated sediment.

*1, 2, and 4 may need a permit if they meet the requirements under "When do I need a permit?"

Erosion Control (25 Pa. Code Chapter 102)

- An Erosion and Sediment Control Plan is required under Chapter 102 if 5,000 square feet or more of land is to be disturbed. This plan must be on-site during the construction activity. (Contact WCD for assistance)
- Projects that generate one acre or more of earth disturbance must obtain a federal National Pollutant Discharge Elimination System (NPDES) permit from County Conservation Districts.
- It is recommended to prepare an Erosion and Sediment Control Plan for earth disturbances under 5,000 square feet when working near bodies of water.
- Permanent trees/grass coverage within the pond's drainage area protects against erosion. Trees are not recommended on embankments.

Site Selection

- If surface runoff is the main source of water for your pond, an ideal site would be where an earthen dam could be constructed between two moderately steep slopes. Check surrounding area for potential pollution sources to pond water (i.e. septic systems, agriculture activity, and waste sites).
- Avoid areas of excessive erosion. This will fill your pond with sediment in a short period of time.
- Do not locate a pond where failure of the dam could cause loss of life or damage of property.
- Do not locate a pond in a wetland.

Before Construction

- Check soil types – Clay and silty clays are excellent for reservoirs and embankments. You may dig soil pits for testing or consult web soil survey (nrcs.usda.gov/resources/data-and-reports/web-soil-survey).
- Confirm with your neighbors that there is not a septic system or well located at the proposed pond location.
- Notify your municipality.
- Check local safety and building ordinances to see if fence installation is required.
- Complete a PA 1 Call to locate any utilities at the proposed pond location. (Call 811)
- Install erosion and sediment controls (for example, filter compost sock). Under resources, there is a link to DEP website explaining erosion and sediment controls.

What type of pond do I want?

Embankment Pond- "An embankment pond is made by building an embankment or dam across a stream or watercourse where the stream valley is depressed enough to allow storing five feet or more of water. The land slope may range from gentle to steep" (USDA, "Ponds- Planning, Design, Construction").

Excavated Pond- "An excavated pond is made by digging a pit or dugout in a nearly level area. Because the water capacity is obtained almost entirely by digging, excavated ponds are used where only a small supply of water is needed. Some ponds are built in gently to moderately sloping areas and the capacity is obtained both by excavating and building a dam/embankment" (USDA, "Ponds- Planning, Design, Construction").

Design Considerations

- Depth and top width of the pond or dam is essential to the design.
- The water must be deep enough to offset any seepage or evaporation loss. A depth of at least 6-7 foot is recommended for most of Western Pennsylvania (USDA, "Ponds- Planning, Design, Construction").
- Top width for dams should follow the table specifications below (Butler Soil & Water Conservation District, "New Pond Construction").

Height of Dam (ft)	Minimum Top Width (ft) of Embankment Berm
Under 15	8
15-19.9	10
20-24.9	12
25-34.9	14
35-40	15

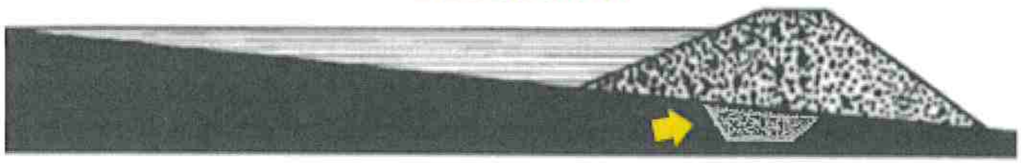
- Any dam height over 15 feet will need a Dam Safety Permit (page 2).
- Freeboard should be considered when designing the pond or dam. "Freeboard is the vertical distance between the elevation of the water surface in the pond when the spillway is discharging at designed depth and the elevation of the top of the dam after all settlement" (USDA, "Ponds- Planning, Design, Construction").
- Generally, a minimum of 24 inches of freeboard is required above the elevation of the water. (DEP, "Erosion and Sediment Pollution Control Program Manual").
- Side slopes should follow a 3:1 ratio. Slopes should never be steeper than 2:1.

Construction of Embankment Ponds

Some design considerations should be noted before the construction of an embankment pond. Considerations include determining what soils are present at the proposed pond location and knowing spillway requirements to prevent design failures. The construction sequence should go as follows:

1. Install erosion and sediment controls (for example, filter compost sock)
2. Clearing and Grubbing- clear foundation area of trees and brush
3. Foundation Preparation- treating the surface, excavating and backfilling both the cutoff trench and existing stream channels
4. Installing Pipe Spillway- installation of pipe, riser, trash rack, etc.
5. Excavating the Earth Spillway- should conform to drawings/specifications
6. Build Dam

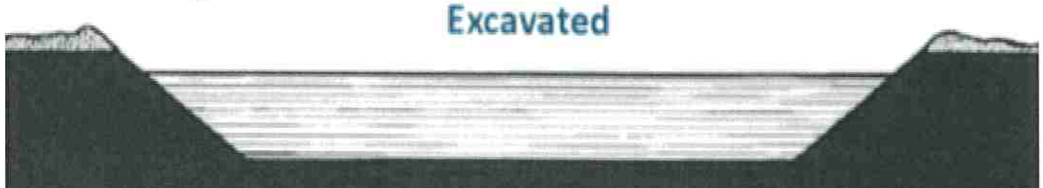
Please consult this pdf for more information before constructing your pond. "Ponds- Planning, Design, Construction"



The Cutoff Trench or Keyway is beneath the dam and needs to be excavated into firm original ground.

Construction of Excavated Ponds

- There are two types of excavated ponds fed either by surface water or ground water aquifers. Ponds fed by surface water are most commonly placed in flat, well drained locations. Ponds fed by groundwater aquifers should be located where the permanent water table is within a few feet of the surface. Like the embankment pond, the excavated pond should follow the same design considerations. Considerations include determining what soils are present at the proposed pond location and knowing spillway requirements to prevent design failures. The construction sequence should go as follows:
    1. Install erosion and sediment controls (for example, filter compost sock).
    2. Clearing and grubbing- remove undesired vegetation and outline of the pond
    3. Excavation and sealing- determine what equipment and soil material to use
    4. Placement of waste material- grade to match natural contours
    5. Establish vegetation



Please consult "Ponds- Planning, Design, Construction" for more information before constructing your pond.

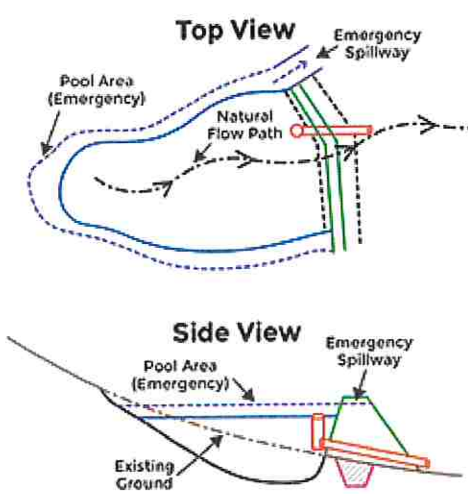
Sealing a Pond

- Inadequate soil and site investigations can lead to a poorly chosen site where excessive seepage may occur. Several methods can be employed to prevent seepage. These methods include soil compaction, clay blankets, bentonite, chemical additives, and waterproof linings.

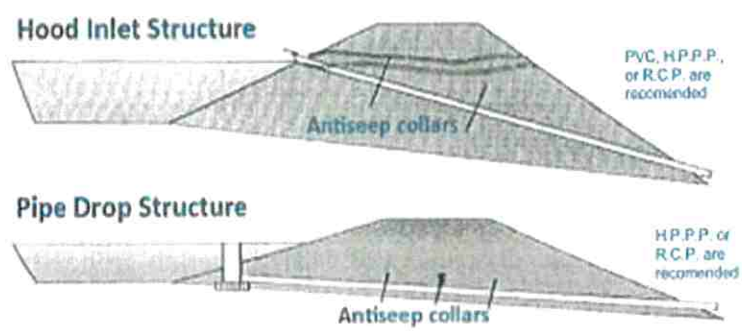
Spillway Considerations

- Excavated and Embankment ponds should have principal and emergency spillways implemented into the design.
- A spillway is a safety addition to a pond or dam that allows water to leave the pond whenever the water level gets too high.
- A principal spillway is usually composed of a pipe that allows water to exit the pond or dam.
- An emergency spillway or earthen spillway is a small excavated part of the embankment that is lower in elevation than the embankment, and allows excess stormwater to move freely over the bypass and not cause erosion or flooding. Emergency spillways should be designed to handle 25, 50, or 100 year storms. Grass should be well rooted in the emergency spillway before adding water into the pond.
- Types of principal spillways include a hooded inlet or drop inlet.
- A hooded inlet consists of a PVC or corrugated metal pipe running through the fill from the upstream toe water line to the downstream toe of the pond or dam embankment. This is more prone to become loose and start to leak due to freeze and thaw.
- A drop inlet consists of a pipe located at the bottom of a riser or outlet structure that runs through the embankment and discharges to a safe location. Westmoreland Conservation District **recommends** the drop inlet or "riser barrel" type of spillway because it is more resistant to freeze and thaw.
- Antiseep collars around outlet pipes should be implemented into the design to prevent leaks, seeps, and failures.
- The pipes should be made from High Performance Polypropylene Pipe (H.P.P.P.) or Reinforced Concrete Pipe (R.C.P.).

Emergency Spillway



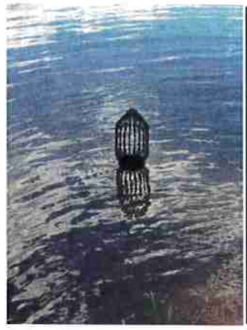
Principal Spillway

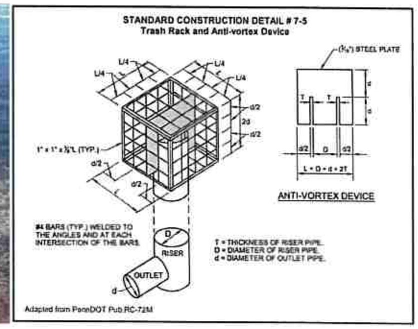


Please consult this pdf for more information on spillways. "New Pond Construction"

<u>Examples of Trash Racks:</u>

Hooded inlet





Drop inlet

Permits to Draw Off Impounded Waters

(58 Pa. Code Chapter 51)

- <u>Draw Down Permits</u> are for **after** construction. This permit is to drain or release water from an existing pond. The "Application to Draw Off Water From Impoundments" permit is required from the PA Fish and Boat Commission when releasing water from:
    - Ponds that require a Dam Safety Permit or Water Obstruction and Encroachment Permit
    - Ponds that have surface area greater than 1 acre
- The form for this permit is at the end of this document.

Operation and Maintenance

- Inspect pond regularly especially after large rain events and snow melts.
- Maintain protective plant cover.
- Keep structures free of trash and pond water unpolluted.
- Stock predatory fish species (i.e. bass, bluegill, and catfish), aerate the water, and keep pond edges free of decaying debris to prevent mosquito breeding.
- Consider installing fence, and safe swimming signs for safety reasons.
- Maintain all vegetation including removing trees, tree roots, shrubs, and weeds on embankment of dams.

SAMPLE
Erosion and Sedimentation Control Plan For Pond/ Dam Construction

1. Maps and Plans:
   - Maps show the location of the project with respect to area of disturbance (limits of disturbance 5,000 sq.ft. to 0.99 acre), access roads, existing structures, and other landmarks
   - Work plans show detailed drawings of the specific work sites.
2. Perimeter controls (ex. silt fence or compost filter sock) will be installed on the down slope side of the earth disturbance.
3. All work will be done during low or no-flow conditions, avoiding periods during or immediately following heavy precipitation.
4. If work must occur with flow in the stream, all attempts must be made to keep the work area dry, by pumping the stream around.
5. If water accumulates in the work area, this sediment laden water must be pumped to a sediment filter bag and not directly back into the surface water.
6. All disturbed areas will be immediately stabilized with rock, seeded, and mulched. Newly vegetated areas will be inspected and repaired as needed until grass is established.
7. Grass seed mixtures used will be a shade, conservation, or slope variety depending upon that site's requirements. All seed mixtures shall have heavy annual rye content. Seed will be hand broadcasted at a minimum rate of six pounds per 1000 sq. feet.
8. Straw or hay mulch will be placed by hand to produce a loose layer three-fourths to one inch deep (2.5 T/A)
9. Only clean, nonpolluting materials will be used as fill. Stone size will be selected according to specific stream and conditions.
10. Any materials excavated during the construction will be deposited at an approved site by the Westmoreland Conservation District (if 5,000 square feet or greater in earth disturbance) and away from areas affected by flood waters or wetlands, and stabilized within 24 hours.

Agencies who can provide technical assistance or guidance for the construction of a pond

- Natural Resources Conservation Service, (NRCS)
- United States Army Corps of Engineers, (USACE)
- Pennsylvania Department of Environmental Protection, (DEP)
- PA Fish and Boat Commission (PAFBC)
- Westmoreland Conservation District (WCD)

References

Berks County Conservation District, "Pond Information"
http://berkscd.com/water-encroachments/pond-construction-maintenance/

Bucks County Conservation District, "Pond Construction and Maintenance Permit Guide"
http://www.bucksccd.org/assets/Watershed-Programs/Brochures/Pond-Permit-Fact-Sheet-N131405.pdf

Clean Water Academy, Josh Fair, "Ponds, Impoundments, and why People Call About Them"
https://pacleanwateracademy.remote-learner.net/
DEC NY, Department of Environmental Conservation of New York State
https://www.dec.ny.gov/docs/fish_marine_pdf/pdconstruction.pdf

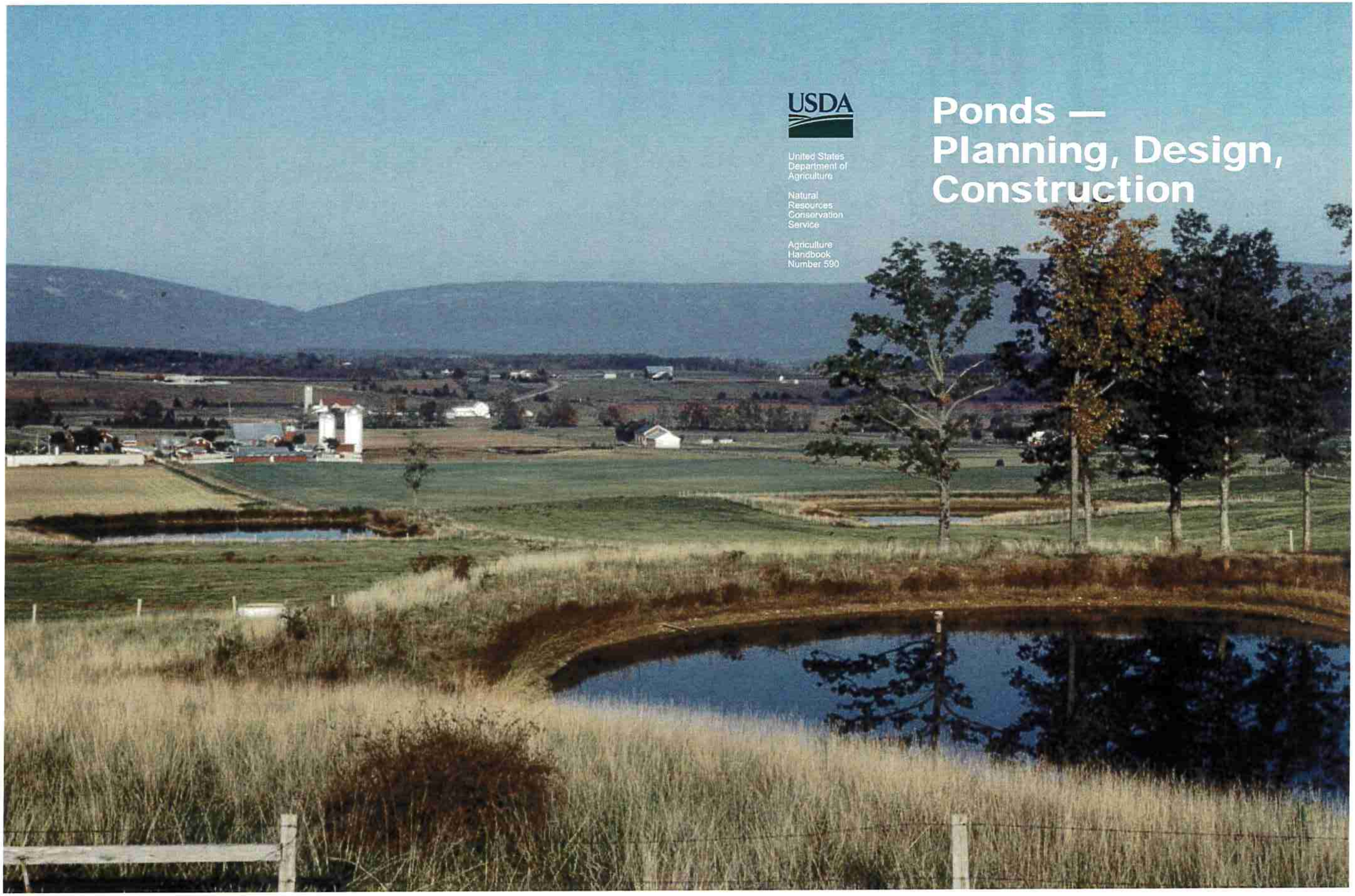
Penn State Extension, "Pond Agencies and Permits in Pennsylvania"
https://extension.psu.edu/pond-agencies-and-permits-in-pennsylvania

Richland Soil and Water Conservation District, "Spillway"
https://richlandswcd.net/services/water/ponds/pond-components/spillway

USDA, Natural Resources Conservation Service, "Backyard Conservation"
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/newsroom/features/?cid=nrcs143_023574

USDA, "Ponds- Planning, Design, Construction"
https://nrcspad.sc.egov.usda.gov/distributionCenter/pdf.aspx?productID=115

Westmoreland Conservation District, "Quick Links"
https://westmorelandconservation.org/



USDA

United States
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Natural
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Conservation
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Agriculture
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Ponds — Planning, Design, Construction

Preface

This handbook describes the requirements for building a pond. It is useful to the landowner for general information and serves as a reference for the engineer, technician, and contractor.

In fulfilling their obligation to protect the lives and property of citizens, most states and many other government entities have laws, rules, and regulations governing the installation of ponds. Those responsible for planning and designing ponds must comply with all such laws and regulations. The owner is responsible for obtaining permits, performing necessary maintenance, and having the required safety inspections made.

Acknowledgments

The first version of this handbook was prepared under the guidance of Ronald W. Tuttle, national landscape architect for the USDA, Natural Resources Conservation Service (NRCS), and Gene Highfill, national agricultural engineer (retired), NRCS, Washington, DC.

This version of the handbook was prepared by Clifton Deal, soil mechanic engineer, NRCS Portland, Oregon; Jerry Edwards, hydraulic engineer (retired), NRCS, Columbia, Missouri; Neil Pellmann, agricultural engineer, NRCS, Columbia, Missouri; Ronald W. Tuttle; and under the guidance of Donald Woodward, national hydrologist, NRCS, Washington, DC.

The appendixes material was originally prepared for Landscape Architecture Note 2—Landscape Design: Ponds by Gary Wells, landscape architect, NRCS, Lincoln, Nebraska.

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Ponds — Planning, Design, Construction

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Ponds — Planning, Design, Construction

Introduction

For many years farmers and ranchers have been building ponds for livestock water and for irrigation. By 1980 more than 2.1 million ponds had been built in the United States by land users on privately owned land. More will be needed in the future.

The demand for water has increased tremendously in recent years, and ponds are one of the most reliable and economical sources of water. Ponds are now serving a 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 handbook describes embankment and excavated ponds and outlines the requirements for building each. The information comes from the field experience and observation of land users, engineers, conservationists, and other specialists.

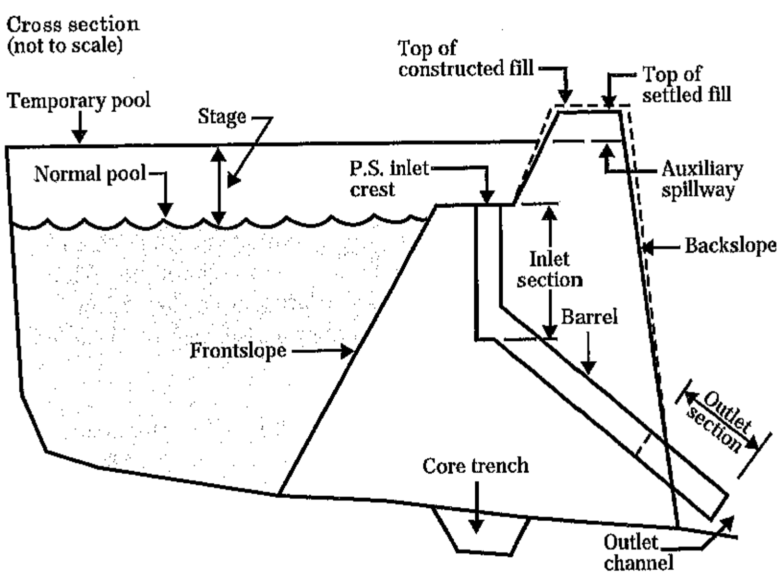
An embankment pond (fig. 1) is made by building an embankment or dam across a stream or watercourse where the stream valley is depressed enough to permit storing 5 feet or more of water. The land slope may range from gentle to steep.

An excavated pond is made by digging a pit or dugout in a nearly level area. Because the water capacity is obtained almost entirely by digging, excavated ponds are used where only a small supply of water is needed. 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 are for dams that are less than 35 feet high and located where failure of the structure will not result in loss of life; in damage to homes, commercial or industrial buildings, main highways, or railroads; or in interrupted use of public utilities.

Local information is essential, and land users are encouraged to consult with specialists experienced in planning and building ponds.

Figure 1 Typical embankment and reservoir



Water needs

Livestock

Clean water and ample forage are equally essential for livestock to be finished out in a marketable condition. If stockwater provisions in pasture and range areas are inadequate, grazing will be concentrated near the water and other areas will be undergrazed. This can contribute to serious livestock losses and instability in the livestock industry.

Watering places must also be properly distributed in relation to the available forage. Areas of abundant forage may be underused if water is not accessible to livestock grazing on any part of that area (fig. 2).

Providing enough watering places in pastures encourages more uniform grazing, facilitates pasture improvement practices, retards erosion, and enables farmers to make profitable use of soil-conserving crops and erodible, steep areas unfit for cultivation.

An understanding of stockwater requirements helps in planning a pond large enough to meet the needs of the stock using the surrounding grazing area. The average daily consumption of water by different kinds of livestock shown here is a guide for estimating water needs.

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

The amount of water consumed at one pond depends on the average daily consumption per animal, number of livestock served, and period over which they are served.

Figure 2 This pond supplies water to a stockwater trough used by cattle in nearby grazing area

Irrigation

Farm ponds are now an important source of irrigation water (fig. 3), particularly in the East, which does not have the organized irrigation enterprises of the West. Before World War II irrigation was not considered necessary in the humid East. Now many farmers in the East are irrigating their crops.

Water requirements for irrigation are greater than those for any other purpose discussed in this handbook. 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. For example, a 3-inch application of water on 1 acre requires 81,462 gallons. Consequently, irrigation from farm ponds generally is limited to 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, and the expected inflow to the pond. Your local NRCS conservationist can help you estimate the required capacity of your irrigation pond.

Fish production

Many land users are finding that fish production is profitable. A properly built and managed pond can yield from 100 to 300 pounds of fish annually for each acre of water surface. A good fish pond can also provide recreation (fig. 4) and can be an added source of income should you wish to open it to people in the community for a fee.

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.

Figure 3 Water is pumped out of this pond for irrigation

Field and orchard spraying

You may wish to provide water for applying pesticides to your field and orchard crops. Generally, the amount of water needed for spraying is small, but it 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.

Provide a means of conveying water from the pond to the spray tank. In an embankment pond, place 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 pump is needed to fill the tank.

Fire protection

A dependable water supply is needed for fighting fire. If your pond is located close to your house, barn, or other buildings, provide a centrifugal pump with a power unit and a hose long enough to reach all sides of all the buildings. Also provide for one or more dry hydrants (figs. 5 and 6).

Although water-storage requirements for fire protection are not large, the withdrawal rate for fire fighting is high. A satisfactory fire stream should be at least 250 gallons per minute with pressure at the nozzle of at least 50 pounds per square inch. Fire nozzles generally are 1 inch to 1-1/2 inches in diameter. Use good quality rubber-lined firehoses, 2-1/2 to 3 inches in diameter. Preferably, the hose should be no more than 600 feet long.

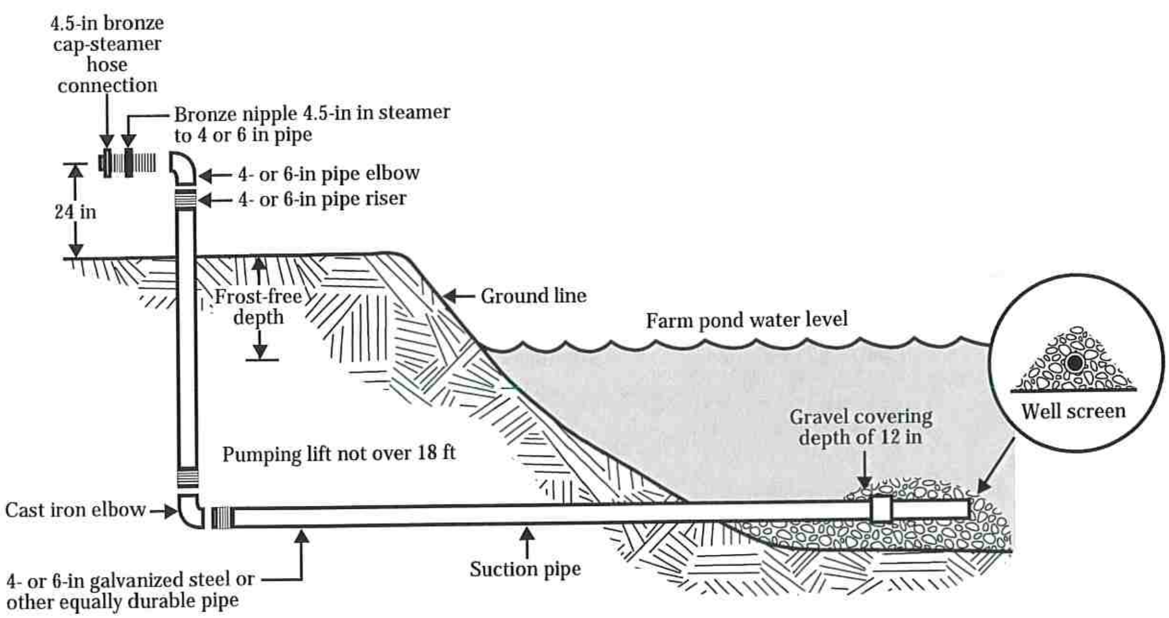
A typical firehose line consists of 500 feet of 3-inch hose and a 1-1/8 inch smooth nozzle. A centrifugal pump operating at 63 pounds per square inch provides a stream of 265 gallons per minute with a nozzle pressure of 50 pounds per square inch. Such a stream running for 5 hours requires 1/4 acre-foot of water. If you live 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.

Your local dealer in pumps, engines, and similar equipment can furnish the information you need about pump size, capacity, and engine horsepower.

Figure 4 A pond stocked with fish can provide recreation as well as profit

Figure 5 A dry hydrant is needed when a pond is close enough to a home or barn to furnish water for fire fighting

Figure 6 Details of a dry hydrant installation



Not to scale

Recreation

A pond can provide many pleasant hours of swimming, boating, and fishing. The surrounding area can be made into an attractive place for picnics and games (fig. 7).

Many land users realize additional income by providing water for public recreation. If the public is invited to use a pond for a fee, the area must be large enough to accommodate several parties engaged in whatever recreation activities are provided.

If a pond is to be used for public recreation, supply enough water to overcome evaporation and seepage losses and to maintain a desirable water level. A pond used for swimming must be free of pollution and have an adequate depth of water near a gently sloping shore. Minimum facilities for public use and safety are also needed. These facilities include access roads, parking areas, boat ramps or docks, fireplaces, picnic tables, drinking water, and sanitary facilities.

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

Waterfowl and other wildlife

Ponds attract many kinds of wildlife. Migratory waterfowl often use ponds as resting places in their flights to and from the North. Ducks often use northern ponds as breeding places, particularly where the food supply is ample (fig. 8). Upland game birds use ponds as watering places.

Landscape quality

Water adds variety to a landscape and further enhances its quality. Reflections in water attract the eye and help to create a contrast or focal point in the landscape (fig. 9). A pond visible from a home, patio, or entrance road increases the attractiveness of the landscape and often increases land value. Ponds in rural, suburban, and urban areas help to conserve or improve landscape quality.

Figure 7 Ponds are often used for private as well as public recreation

Figure 8 Waterfowl use ponds as breeding, feeding, watering places, and as resting places during migration

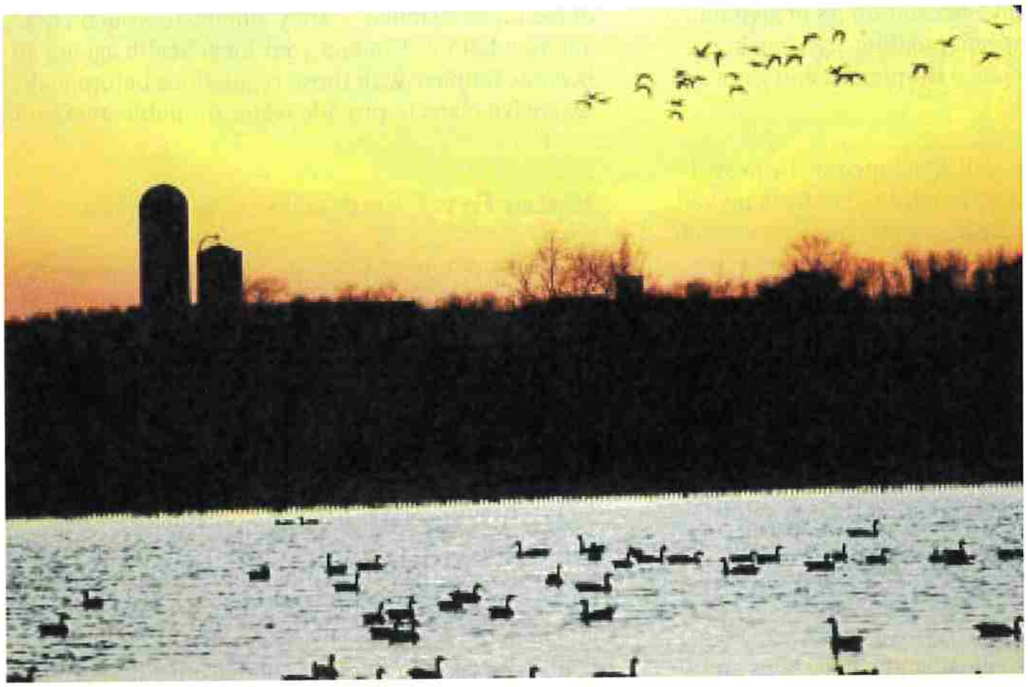


Figure 9 The shoreline of a well-designed pond is protected from erosion by the addition of stone. Such a pond, reflecting nearby trees, increases the value of the surrounding land

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

Your local NRCS conservationist can help you apply the basic principles and design techniques. Consult a landscape architect for additional information and special designs.

Multiple purposes

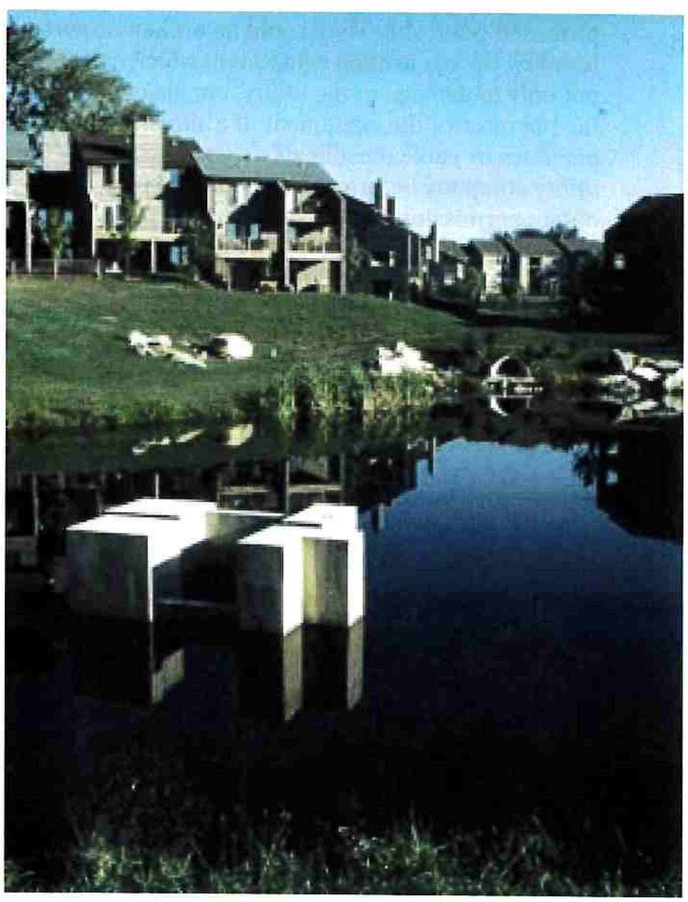
You may wish to use the water in your pond for more than one purpose; for example, to provide water for livestock, fish production, and spraying field crops. If so, two additional factors must be considered.

First, in estimating your water requirements you must total the amounts needed for each purpose and be sure that you provide a supply adequate for all the intended uses.

Second, make sure that the purposes for which the water is to be used are compatible. Some combinations, such as irrigation and recreation, generally are not compatible. You would probably use most of the water during the irrigation season, making boating and swimming impractical.

Ponds used temporarily for grade control or as sediment basins associated with construction sites can be converted later into permanent ponds by cleaning out the sediment, treating the shoreline, and adding landscape measures (fig. 10). If a sediment basin is to be cleaned and reconstructed as a water element, the standards for dam design should be used.

Figure 10 This pond, which served as a sediment basin while homes in the background were being constructed, now adds variety and value to the community



Preliminary investigations

General considerations

Selecting a suitable site for your pond is important, and preliminary studies are needed before final design and construction. Analysis and selection of pond sites should be based on landscape structure and associated ecological functions and values. Relationship of the site to other ecological features within the landscape is critical to achieving planned objectives. If possible, consider more than one location and study each one to select the most ecologically appropriate, esthetic, and practical site. Weighing both onsite and offsite effects of constructing a pond is essential in site selection. Refer to figure 1 and the glossary to become familiar with the components of a pond and associated dam.

For economy, locate the pond where the largest storage volume can be obtained with the least amount of earthfill. A good site generally is one where a dam can be built across a narrow section of a valley, the side slopes are steep, and the slope of the valley floor permits a large area to be flooded. Such sites also minimize the area of shallow water. Avoid large areas of shallow water because of excessive evaporation and the growth of noxious aquatic plants.

If farm ponds are 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 places encourage uniform grazing and facilitate grassland management.

If pond water must be conveyed for use elsewhere, such as for irrigation or fire protection, locate the pond as close to the major water use as practicable. Conveying water is expensive and, if distance is excessive, the intended use of the water may not be practical.

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.

Avoid pollution of pond water by selecting a location where drainage from farmsteads, feedlots, corrals, sewage lines, mine dumps, and similar areas does not reach the pond. Use permanent or temporary measures, such as diversions, to redirect runoff from these sources to an appropriate outlet until the areas can be treated.

Do not overlook the possibility of failure of the dam and the resulting damage from sudden release of water. Do not locate your pond 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, hire a qualified person to investigate other potential sites to reduce the possibility of failure from improper design or construction.

Be sure that no buried pipelines or cables cross a proposed pond site. They could be broken or punctured by the excavating equipment, which can result not only in damage to the utility, but also in injury to the operator of the equipment. If a site crossed by pipelines or cable must be used, you must notify the utility company before starting construction and obtain permission to excavate.

Avoid sites under powerlines. The wires may be within reach of a fishing rod held by someone fishing from the top of the dam.

Area adequacy of the drainage

For ponds where surface runoff is the main source of water, the contributing drainage area must be large enough to maintain water in the pond during droughts. However, the drainage area should not be so large that expensive overflow structures are needed to bypass excess runoff during large storms.

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

Figure 11 is a general guide for estimating the approximate size of drainage area needed for a desired water-storage capacity. 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. If reliable local runoff information is available, use it in preference to the guide.

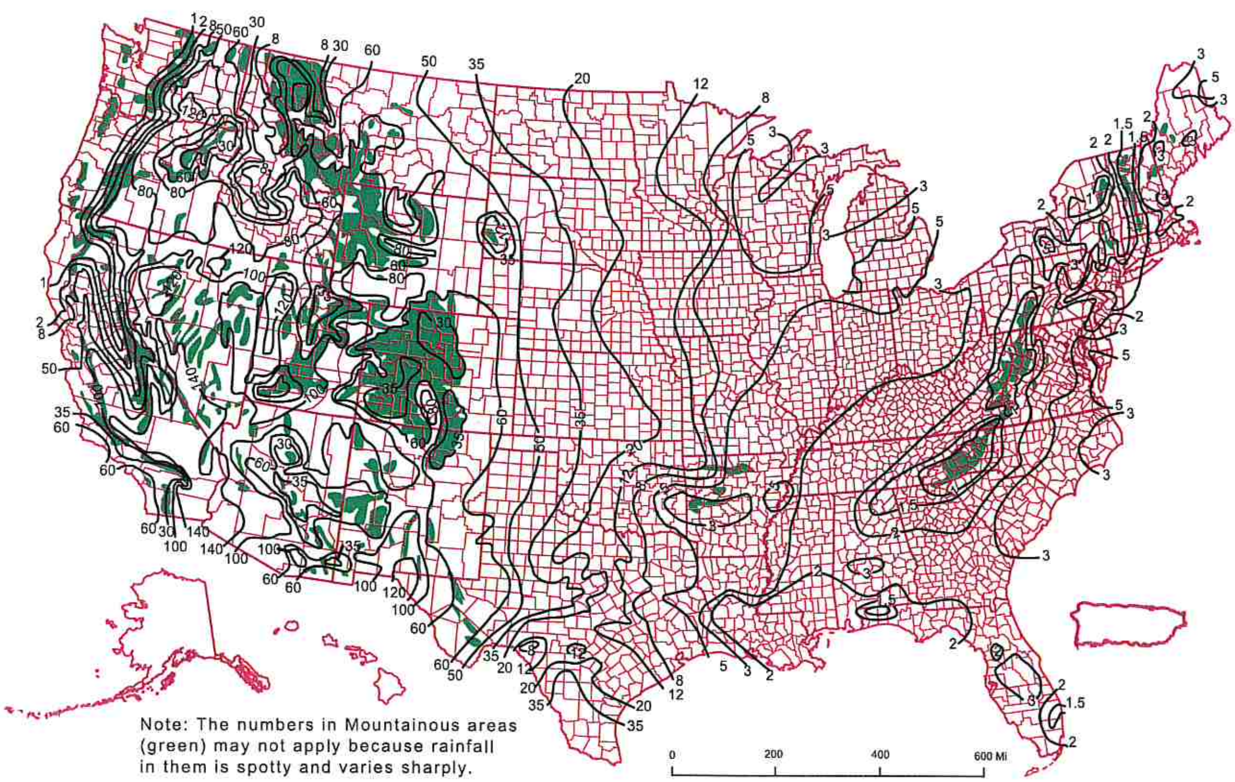
Average physical conditions in the area are assumed to be the normal runoff-producing characteristics for a drainage area, such as moderate slopes, normal soil infiltration, fair to good plant cover, and normal surface storage.

To apply the information given in figure 11, some adjustments may be necessary 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.

Minimum pond depth

To ensure a permanent water supply, the water must be deep enough to meet the intended use requirements and to offset probable seepage and evaporation losses. These vary in different sections of the country and from year to year in any one section. Figure 12 shows 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.

Figure 11 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



Drainage area protection

To maintain the required depth and capacity of a pond, the inflow must be reasonably free of silt from an eroding watershed. The best protection is adequate application and maintenance of erosion control practices on the contributing drainage area. Land under permanent cover of trees, grass, or forbs is the most desirable drainage area (fig. 13). Cultivated areas protected by conservation practices, such as terraces, conservation tillage, stripcropping, or conservation cropping systems, are the next best watershed conditions.

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

Figure 13 Land with permanent vegetation makes the most desirable drainage area

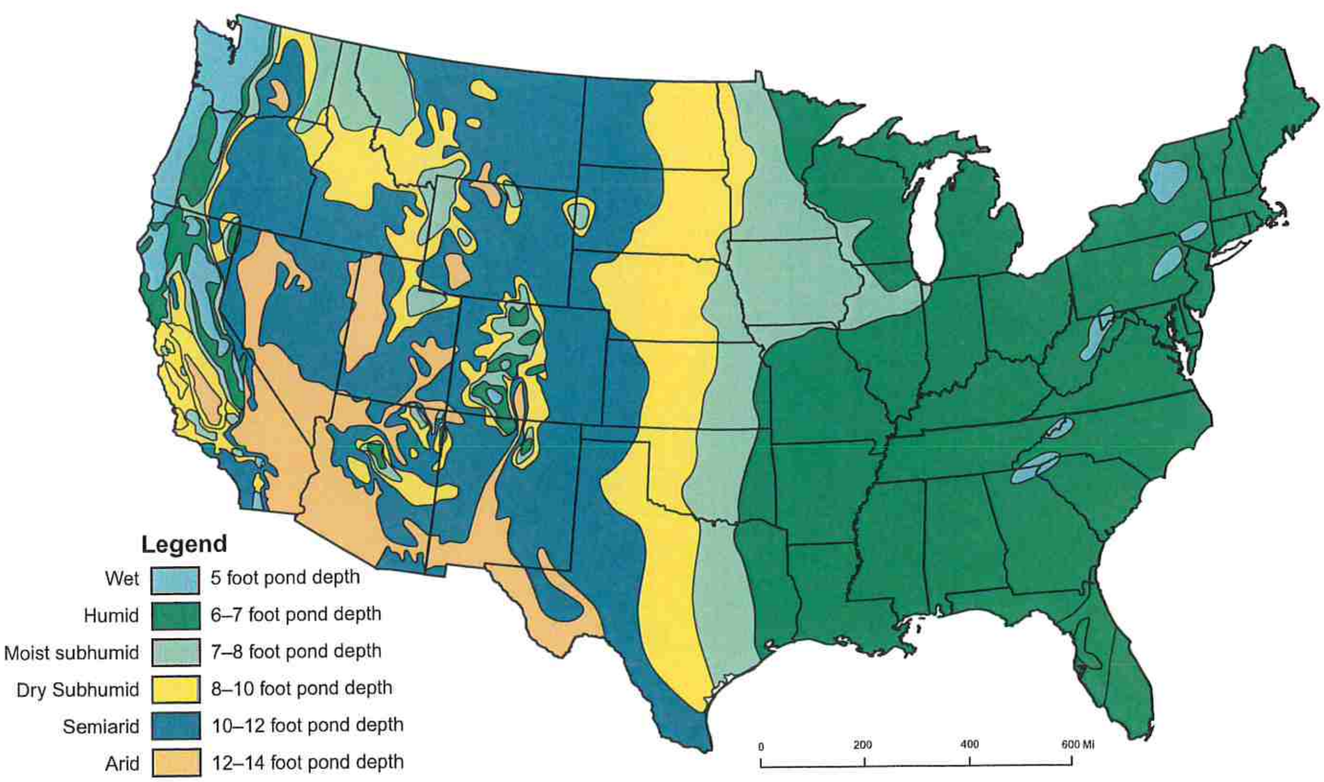


Figure 12 Recommended minimum depth of water for ponds in the United States

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 follows:

- 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 x 3.2 x 12.5 = 16 acre-feet) [1 acre-foot = 325,651 gallons].

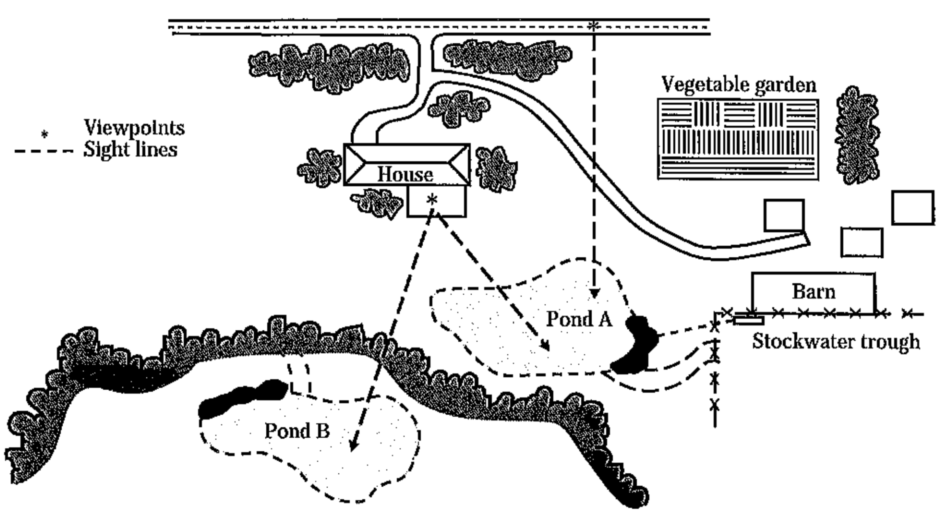
Landscape evaluation

Alternative pond sites should be evaluated for potential visibility and compatibility with surrounding landscape characteristics and use patterns (fig. 14). Identify major viewpoints (points from which the site is viewed) and draw the important sight lines with cross sections, where needed, to determine visibility. If feasible, locate the pond so that the major sight line crosses the longest dimension of water surface. The pond should be placed so that a viewer will see the water first before noticing the dam, pipe inlet, or spillway. Often, minor changes in the dam alignment and spillway location can shift these elements out of view and reduce their prominence.

If possible, locate your pond so that some existing trees and shrubs remain along part of the shoreline. Vegetation adds aesthetic value by casting reflections on the water, provides shade on summer days, and helps 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.

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

Figure 14 A preliminary study of two alternative sites for a pond to be used for livestock water, irrigation, and recreation



Estimating storm runoff

The amount of precipitation, whether it occurs as rain or snow, is the potential source of water that may run off small watersheds. The kind of soil and the type of vegetation affect the amount of water that runs off. Terraces and diversions, along with steepness and shape of a watershed, affect the rate at which water runs off.

A spillway is provided to bypass surface runoff after the pond is filled. The tables and charts in the following sections should be used to estimate the peak discharge rates for the 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.

Hydrologic groupings of soils

Soils are classified in four hydrologic groups according to infiltration and transmission rates:

A—These soils have a high infiltration rate. They are chiefly deep, well-drained sand or gravel. The runoff potential is low.

B—These soils have a moderate infiltration rate when thoroughly wet. They are chiefly moderately deep, well-drained soils of moderately fine to moderately coarse texture.

C—These soils have a slow infiltration rate when wet. These moderately fine to fine texture soils have a layer that impedes downward movement of water.

D—These soils have a very slow infiltration rate. They are chiefly clay soils that have a high swelling 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.

The NRCS district conservationist or your county extension agent can help you classify the soils for a given pond site in one of the four hydrologic groups.

Runoff curve numbers

Tables 1 through 4 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) in these tables.

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. For example, assume that the watershed above a pond is mainly (three-fourths) in good pasture and a soil in hydrologic group B. The remainder is cultivated with conservation treatment on a soil in hydrologic group C.

A weighted curve number for the total watershed would be:

3/4 x 61	=	46 (approximately)
1/4 x 76	=	20 (approximately)
Weighted	=	66

Table 1 Runoff curve numbers for urban areas 1/

Cover description	Average percent impervious area 2/	Curve numbers for hydrologic soil group A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) 3/					
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) 4/		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
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) 5/		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 3)					

1/ Average runoff condition, and $I_a = 0.2S$.

2/ The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4 in NRCS Technical Release 55, Urban Hydrology for Small Watersheds.

3/ CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

4/ Composite CN's for natural desert landscaping should be computed using figure 2-3 or 2-4 in Technical Release 55, based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

5/ Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 in Technical Release 55, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 2 Runoff curve numbers for agricultural lands 1/

Cover description			Curve numbers for hydrologic soil group			
Cover type	Treatment 2/	Hydrologic condition 3/	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

1/ Average runoff condition, and $I_a = 0.2S$.

2/ Crop residue cover applies only if residue is on at least 5 percent of the surface throughout the year.

3/ Hydrologic condition is based on combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes in rotations, (d) percentage of residue cover on the land surface (good > 20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table 3 Runoff curve numbers for other agricultural lands 1/

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition 3/	A	B	C	D
Pasture, grassland, or range—continuous grazing 2/	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 3/	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 4/	48	65	73
Woods—grass combination (orchard or tree farm) 5/	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods 6/	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 4/	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1/ Average runoff condition, and $I_a = 0.2S$.
2/ Poor: <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.
3/ Poor: <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
4/ Actual curve number is less than 30; use CN = 30 for runoff computations.
5/ CN's shown were computed for areas with 50% woods and 505 grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
6/ Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table 4 Runoff curve numbers for arid and semiarid rangelands 1/

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition 2/	A 3/	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

1/ Average runoff condition, and $I_a = 0.2S$. For range in humid regions, use table 3.
2/ Poor: <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good: >70% ground cover.
3/ Curve numbers for group A have been developed only for desert shrub.

Volume of storm runoff

Often knowing how much water runs off from a big storm as well as the rate at which it flows is good. The volume is needed to compute needed storage as well as the peak discharge rate.

The figures in table 5 are the depth (in inches) at which the storm runoff, if spread evenly, would cover the entire watershed. For 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 (interpolated between 0.51 and 0.72 inches)
100 acres x 0.55 inch = 55 acre-inches
55 acre-inches ÷12 = 4.55 acre-feet
55 acre-inches x 27,152 gallons per acre-inch = 1.5 million gallons (approximately)

Table 5 Runoff depth, in inches

Rainfall	Curve number						
(inches)	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 40 (USWP-TP-40), Rainfall Frequency Atlas of the United States, 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.

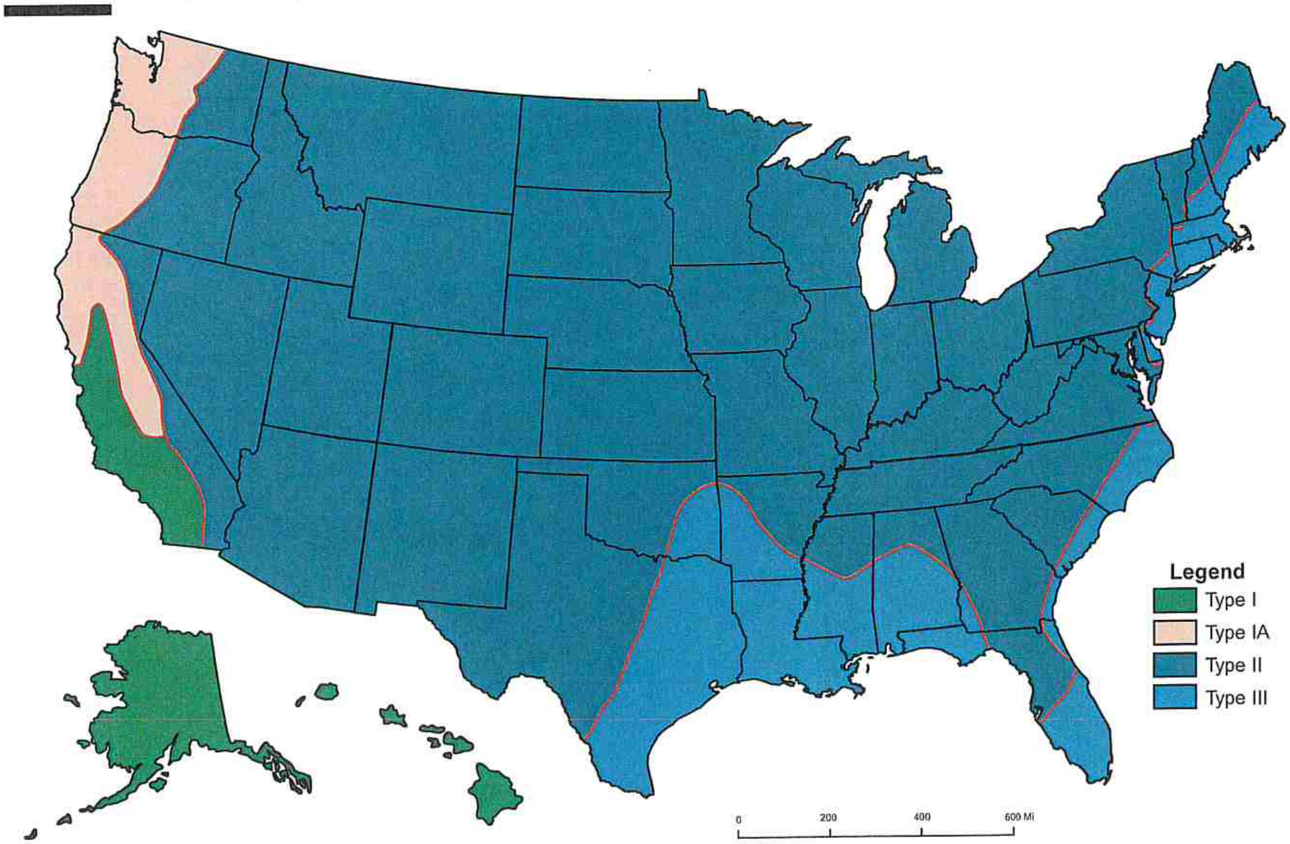
Designing an ordinary pond spillway to accommodate the peak rate of runoff from the most intense rainstorm ever known or anticipated is not practical. The spillway for an ordinary farm pond generally is designed to pass the runoff from a 25-year frequency storm. This means a storm with only a 4 percent 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.

In figure 15, 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.

Figure 15 Approximate geographic boundaries for NRCS rainfall distributions



Peak discharge rate

The slope of the land above the pond affects the peak discharge rate significantly. 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

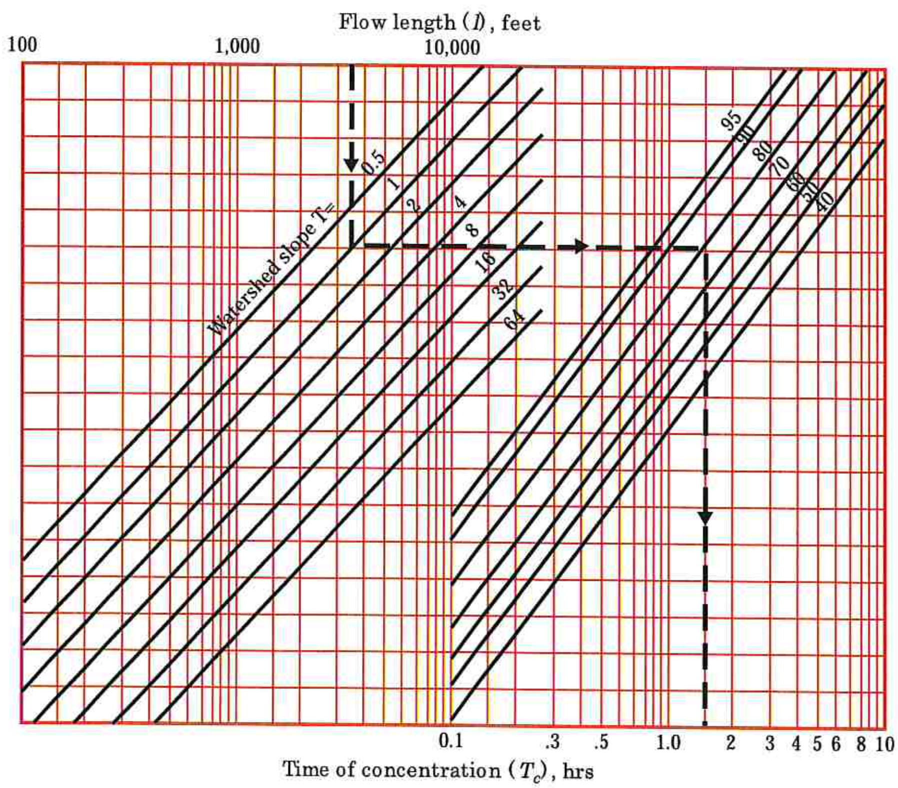
Time of concentration (T_c) is the time it takes for runoff to travel from the hydraulically most distant point of the watershed to the outlet. T_c influences the peak discharge and is a measure of how fast the water runs off the land. For the same size watershed, the shorter the T_c, the larger the 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 equation 1. Figure 16 is a nomograph for solving this equation.

$$T_c = \frac{l^{0.8}\left[\frac{(1000)-9}{CN}\right]^{0.7}}{1140\, Y^{0.5}} \qquad \text{[Eq. 1]}$$

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



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 equation 2:

$$Y = \frac{100CI}{A} \qquad \text{[Eq. 2]}$$

where:

Y = average slope, %
C = total contour length, ft
I = contour interval, ft
A = drainage area, ft^2

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. The flow length can be determined using a map wheel, or it can be marked along the edge of a paper and converted to feet.

I_a/P ratio

The watershed CN is used to determine the initial abstraction (I_a) from table 6. I_a/P ratio is a parameter that indicates how much of the total rainfall is needed to satisfy the initial abstraction. The larger the I_a/P ratio, the lower the unit peak discharge (q_u) for a given T_c.

Table 6 I_a values for runoff curve numbers

Curve number	I_a (in)	Curve number	I_a (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		

Estimating peak discharge rates

The unit peak discharge (q_u) is obtained from figure 17 depending on the rainfall type. Figure 15 shows the approximate geographic boundaries for the four rainfall distributions. T_c and I_a/P values are needed to obtain a value for q_u from the exhibit. The peak discharge (q_p in ft^3/s) is computed as the product of the unit peak discharge (q_u in ft^3/s/ac-in), the drainage area (A in acres), and the runoff (Q in inches).

$$q_p = q_u \times A \times Q \qquad \text{[Eq. 3]}$$

Example 1 Estimating peak discharge rates

Known:

Drainage area = 50 acres
Cole County, Missouri
Flow Path 'I' = 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:

Find T_c
Enter figure 16, T_c = 0.60 hours

Find I_a/P
Enter table 6, use CN = 66, I_a = 1.030
I_a/P = 1.030/6.0 inches = 0.172

Find runoff
Enter table 5, at rainfall = 6.0 inches
and runoff curve number = 66,
Read runoff = 2.44 inches. (Note: It was necessary to interpolate between RCN 65 and 70.)

Find the peak discharge for spillway design.
Enter figure 17(c):
q_u = 0.7
$q_p = q_u \times A \times Q$
q_p = 0.7 x 50 x 2.44 = 85 ft^3/s

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

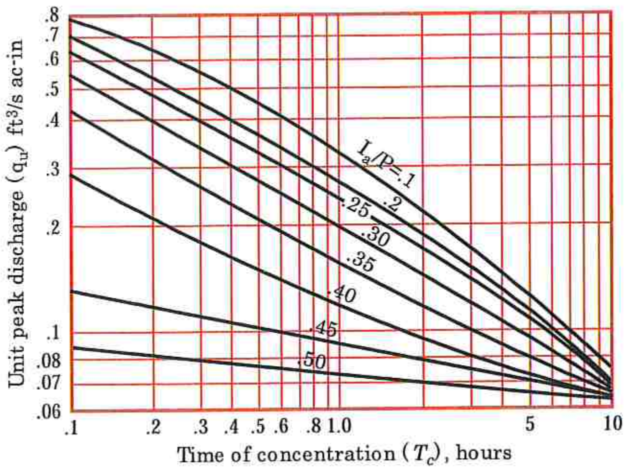


Figure 17c Unit peak discharge (q_u) for Type II storm distribution

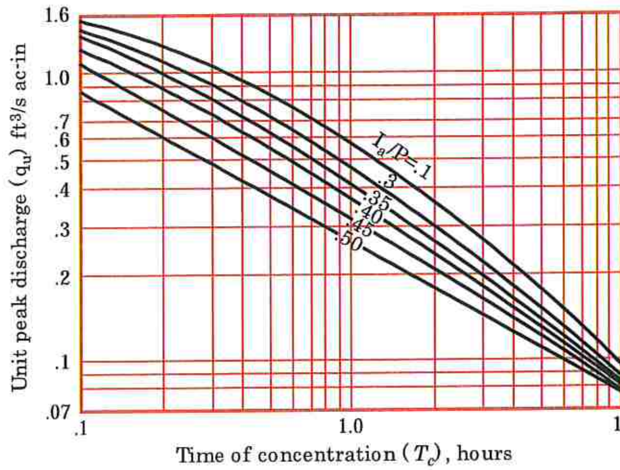


Figure 17b Unit peak discharge (q_u) for Type IA storm distribution

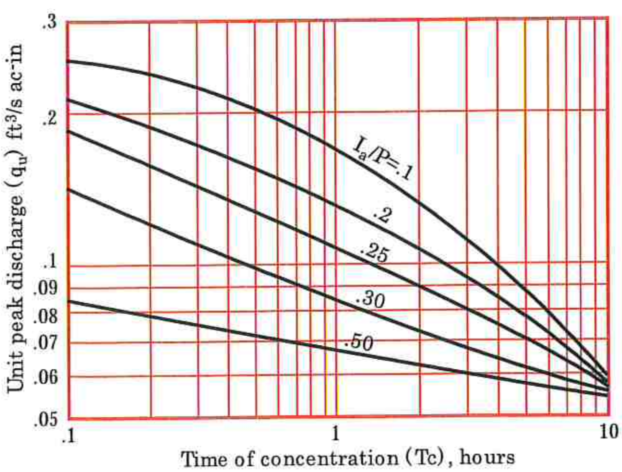
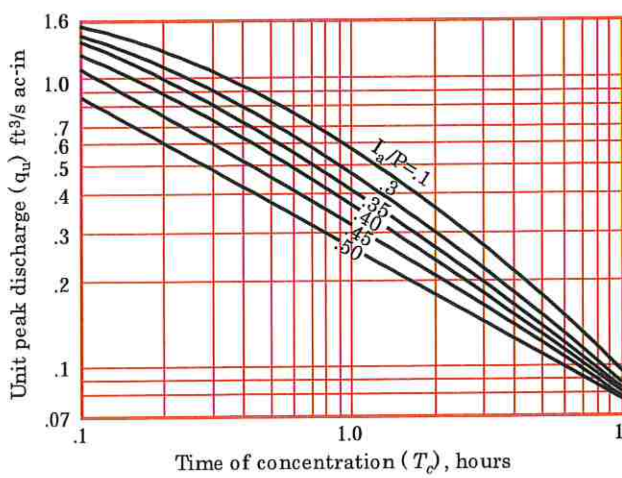


Figure 17d Unit peak discharge (q_u) for Type III storm distribution



Site surveys

Once you determine the probable location of the pond, conduct a site survey to plan and design the dam, spillways, and other features. Those unfamiliar with the use of surveying instruments should employ a licensed surveyor or other qualified professional.

Pond surveys generally consist 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. A simple method of estimating pond capacity is described on page 12. For larger and more complex ponds, particularly those used for water supply or irrigation, you may need a complete topographic survey of the entire pond site.

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 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 earthfill needed to build the dam.

Run a similar line of profile levels along the centerline of the auxiliary spillway. Start from a point on 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.

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

Embankment ponds

Detailed soils investigation

Soils in the ponded area—Suitability of a pond site depends on the ability of the soils in the reservoir area to hold water. 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; sandy and gravelly clays are usually satisfactory. Generally, soils with at least 20 percent passing the No. 200 sieve, a Plasticity Index of more than 10 percent, and an undisturbed thickness of at least 3 feet do not have excessive seepage when the water depth is less than 10 feet. Coarse-textured sands and sand-gravel mixtures are highly pervious and therefore usually unsuitable. The absence of a layer of impervious material over part of the ponded area does not necessarily mean that you must abandon the proposed site. You can treat these parts of the area by one of several methods described later in this handbook. Any of these methods can be expensive.

Some limestone areas are especially hazardous as pond sites. Crevices, sinks, or channels that are not visible from the surface may be in the limestone below the soil mantle. They may empty the pond in a short 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. The best clue to the suitability of a site in one of these areas is the degree of success others have had with farm ponds in the immediate vicinity.

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 enough if the soils are uniform. More may be required if there are significant differences.

Foundation conditions—The foundation under a dam must ensure stable support for the structure and provide the necessary resistance to the passage of water.

Soil borings help to investigate thoroughly the foundation conditions under the proposed dam site. The depth of the holes should be at least 1-1/2 times the height of the proposed dam. Ensure there are not any steep dropoffs in the rock surface of the foundation under the dam. Steep dropoffs in the rock surface can result in cracking of the embankment. Study the natural banks (abutments) at the ends of the dam as well as the supporting materials under the dam. If the dam is to be placed on rock, the rock must be examined for thickness and for fissures and seams through which water might pass.

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

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

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

Fill material—The availability of suitable material for building a 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 (fig. 18).

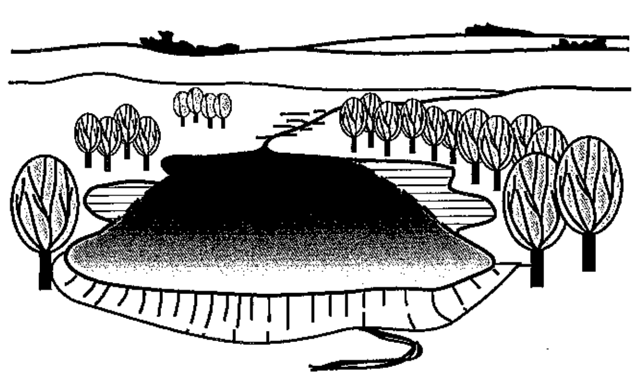
Materials selected must have enough strength for the dam to remain stable and be tight enough, when properly compacted, to prevent excessive or harmful percolation of water through the dam. Soils described as acceptable for foundation material generally are acceptable for fill material. The exceptions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

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 the ideal, the greater the variance, the more precautions needed.

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.

Fill material that has 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 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

Figure 18 Borrow material taken from within the reservoir area creates an irregular pond configuration



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, an engineer should be hired to provide the necessary guidance for sampling, testing, and using these soils for fill. 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.

To estimate the proportion of sand, silt, and clay in a sample of fill material, first obtain a large bottle with straight sides. Take a representative sample of the fill material and remove any gravel by passing the material through a 1/4-inch sieve or screen. Fill the bottle to about one-third with the sample material and finish filling with water. Shake the bottle vigorously for several minutes and then allow the soil material to settle for about 24 hours. 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 the different layers with a ruler.

Landscape planning—The pond should be located and designed to blend with the existing landform, vegetation, water, and structures with minimum disturbance. Landforms can often form the impoundment with minimum excavation. Openings in the vegetation can be used to avoid costly clearing and grubbing. 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 interesting reflections on the water's surface, guide attention to or from the water, frame the water to emphasize it, and direct passage around the pond.

A pond's apparent size is not always the same as its actual size. For example, the more sky reflected on the water surface, the larger a pond appears. A pond surrounded by trees will appear smaller than a pond the same size without trees or with some shoreline trees (fig. 19). 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. Peninsulas, inlets, or islands can be constructed to create diversity in the water's edge.

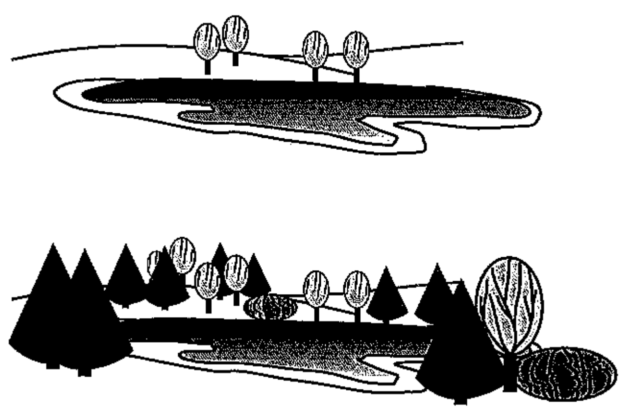
Spillway requirements

A pipe spillway often is used as well as an earth auxiliary spillway to control 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 shall be capable of withstanding external loading with yielding, buckling, or cracking. The pipe joints and all appurtenances need to be watertight. Pipe materials may be smooth metal, corrugated metal, or plastic. Design limitations exist with all materials.

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

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

Figure 19 The apparent size of the pond is influenced by surrounding vegetation



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 shall be installed.

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 does not cause appreciable erosion either within the spillway or beyond its outlet.

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.

No matter how well a dam has been built, it will probably be destroyed during the first severe storm 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. The proper functioning of a pond depends on a correctly designed and installed spillway system.

Auxiliary spillways should have the minimum capacity to discharge the peak flow expected from a storm of the frequency and duration shown in table 7 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 shows the recommended allowable velocity for various cover, degree of erosion resistance, and slope of the channel. Table 9 gives the retardance factors for the expected height of the vegetation.

Both natural and excavated auxiliary spillways are used. A natural spillway does not require excavation to provide enough capacity to conduct the pond outflow to a safe point of release (fig. 20). The requirements discussed later for excavated spillways do not apply to natural spillways, but the capacity must be adequate.

With the required discharge capacity (Q), the end slope of the embankment (Z_1), and the slope of the natural ground (Z_2) known, the maximum depth of water above the level portion (H_p) can be obtained from table 10. 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 7 Minimum spillway design storm

Drainage area (acre)	Effective height of dam 1/ (ft)	Storage (acre-ft)	Minimum design storm: Frequency (yr)	Minimum design storm: 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

1/ 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.

Table 8 Permissible velocity for vegetated spillways 1/

Vegetation	Permissible velocity 2/			
	Erosion-resistant soils 3/		Easily eroded soils 4/	
	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.

Table 9 Guide to selection of vegetal retardance

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

Figure 20 Plan, profile, and cross section of a natural spillway with vegetation

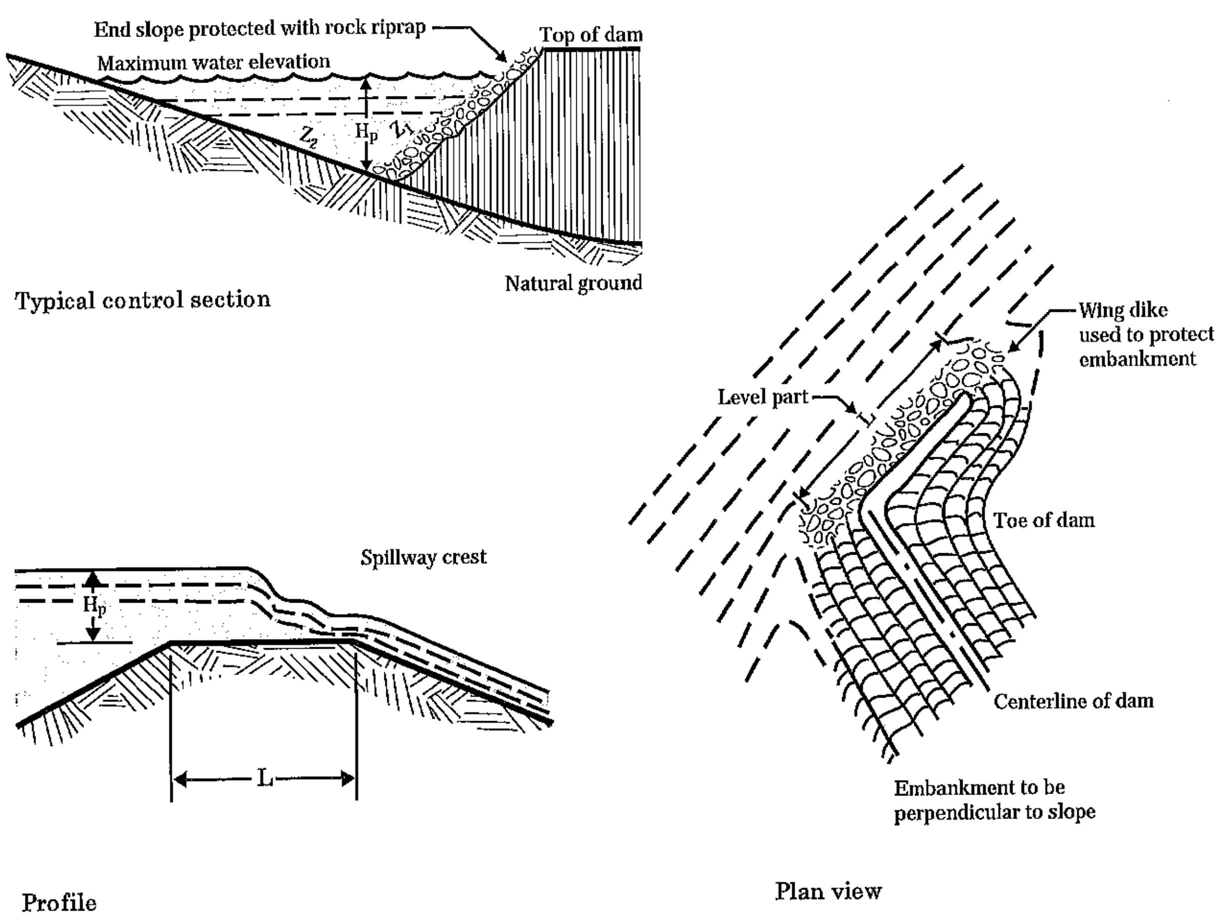


Table 10 H_p discharge and velocities for natural vegetated spillways with 3:1 end slope (Z_1)

Natural ground slope Z_2 (%)	H_p (ft)	Retardance A Q (ft³/s)	A V (ft/s)	B Q (ft³/s)	B V (ft/s)	C Q (ft³/s)	C V (ft/s)	D Q (ft³/s)	D V (ft/s)	E Q (ft³/s)	E V (ft/s)	Slope Min. (%)	Slope Max. (%)
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						

The following example shows how to use table 10:

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 1 percent and retardance C column, find Q = 88 ft³/s at H_p = 1.3 ft, and V = 2.7 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 in the next section, Excavated auxiliary spillways.

Excavated auxiliary spillways—Excavated spillways consist of the three elements shown in figure 21. 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.

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 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.

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.

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.

The selection of the degree of retardance for a given auxiliary spillway depends mainly on the height and density of the cover chosen (table 9). 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 following examples show the use of the information in table 11:

Example 1 where only one retardance is used for capacity and stability:

Given:
Q = 87 ft³/s (total design capacity)
So = 4 percent (slope of exit channel determined from profile, or to be excavated)
L = 50 ft

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.

Required:
Permissible velocity (V)
Width of spillway (b)
Depth of water in the reservoir above the crest (H_p).

Solution:
From table 8 for sod-forming grass-legume mixtures, read permissible velocity V = 5 ft/s.

From table 9 for average height of vegetation of 6 to 10 inches, determine retardance C.

For retardance C, enter table 11 from left at maximum velocity $V = 5$ ft/s. A 4 percent slope is in the slope range of 1–6 with Q of 3 $ft^3/s/ft$.

H_p for L of 50 ft = 1.4 ft.

If the freeboard is 1 foot, the spillway should be constructed 29 feet wide and 2.4 feet deep.

For retardance C, enter table 11 from left at maximum velocity $V = 5$ ft/s. A 4 percent slope is in the slope range of 1–6 with Q of 3 $ft^3/s/ft$.

H_p for L of 50 ft = 1.4 ft.

If the freeboard is 1 foot, the spillway should be constructed 29 feet wide and 2.4 feet deep.

Example 2 where one retardance is used for stability and another is used for capacity:

Given:

So = 4 percent (slope of exit channel determined from profile or to be excavated)
L = 50 ft

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.

Required:

Permissible velocity (V)
Width of spillway (b)
Depth of water in reservoir above the crest (Hp).

Solution:

From table 8 determine permissible velocity for bahiagrass in a highly erodible soil that has 8 percent slope $V = 5$ ft/s.

From table 9, select retardants to be used for stability during an establishment period that has a good stand of vegetation of 2 to 6 inches (retardance D).

Select retardance to be used for capacity for good stand of vegetation that has a length of 11 to 24 inches (retardance B).

From table 11, enter from left at maximum velocity $V = 5$ ft/s. A slope of 6 percent is in the range for $Q = 2$ $ft^3/s/ft$.

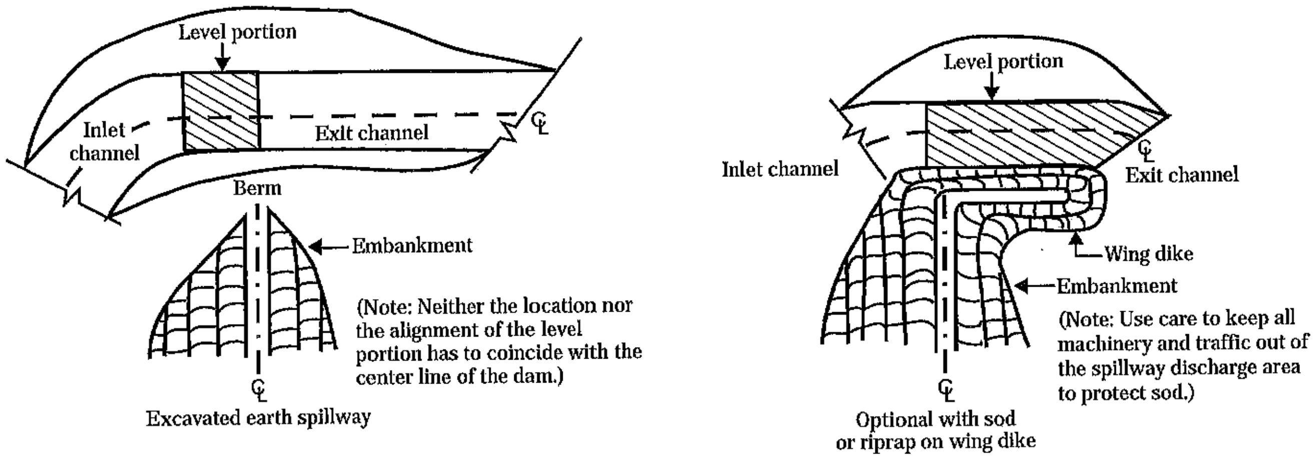
Then

From table 11, enter $q = 2$ $ft^3/s/ft$ under retardance B and find H_p for L of 25 ft = 1.4 ft.

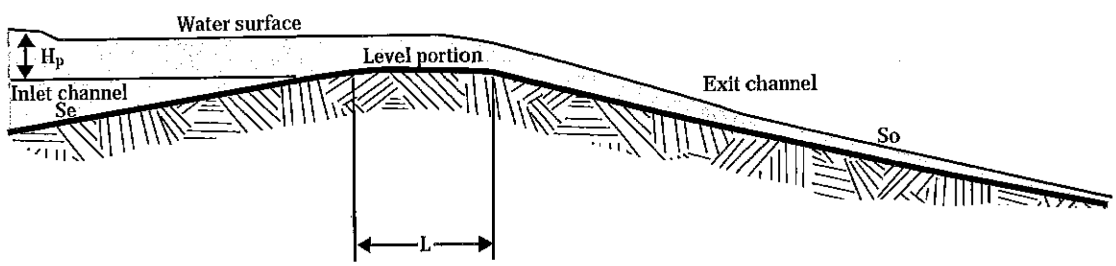
If the freeboard is 1 foot, the spillway should be constructed 50 feet wide and 2.4 feet deep.

Protection against erosion—Protect auxiliary spillways against erosion by establishing good plant cover if the soil and climate permit. As soon after construction as practicable, prepare the auxiliary spillway area for seeding or sodding by applying fertilizer or manure. Sow adapted perennial grasses and protect the seedlings to establish a good stand. Mulching is necessary on the slopes. Irrigation is often needed to ensure good germination and growth, particularly if seeding must be done during dry periods. If the added cost is justified, sprigging or sodding suitable grasses, such as bermudagrass, gives quick protection.

Figure 21 Excavated earth spillway

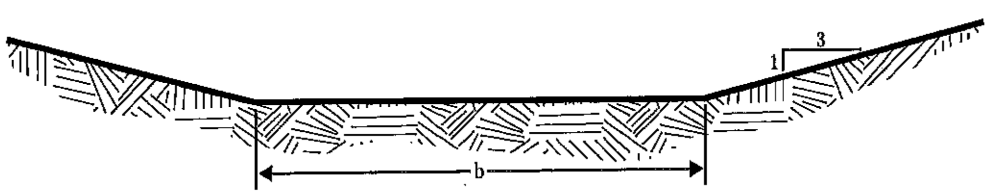


Plan view of earth spillways



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
- So = slope for exit channel
- Se = slope of inlet channel



Cross section of level portion

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

	Maximum velocity	Discharge	H_p				Slope	
			L				Min.	Max.
			25	50	100	200		
	(ft/s)	(ft³/s/ft)	(ft)	(ft)	(ft)	(ft)	(%)	(%)
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

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

	Maximum velocity	Discharge	H_p				Slope	
			L				Min.	Max.
			25	50	100	200		
	(ft/s)	(ft³/s/ft)	(ft)	(ft)	(ft)	(ft)	(%)	(%)
Retardance E	2	0.5	0.5	0.5	0.6	0.7	1	2
	3	0.5	0.5	0.5	0.6	0.7	1	9
	3	1	0.7	0.7	0.8	0.9	1	3
	4	1	0.7	0.7	0.8	0.9	1	6
	4	1.25	0.7	0.8	0.9	1.0	1	5
	5	1	0.7	0.7	0.8	0.9	1	12
	5	2	0.9	1.0	1.1	1.2	1	4
	6	1.5	0.8	0.9	1.0	1.1	1	12
	6	2	0.9	1.0	1.1	1.2	1	7
	6	3	1.2	1.2	1.3	1.5	1	4
	7	2	0.9	1.0	1.1	1.2	1	12
	7	3	1.2	1.2	1.3	1.5	1	7
	8	3	1.2	1.2	1.3	1.5	1	10
	8	4	1.4	1.4	1.5	1.7	1	6
	10	4	1.4	1.4	1.5	1.7	1	12

Pipes through the dam

Pipe spillways—Protect the vegetation in earth spillway channels against saturation from spring flow or low flows that may continue for several days after a storm. A pipe placed under or through the dam provides this protection. 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 and hood inlet pipe spillways are commonly used for ponds.

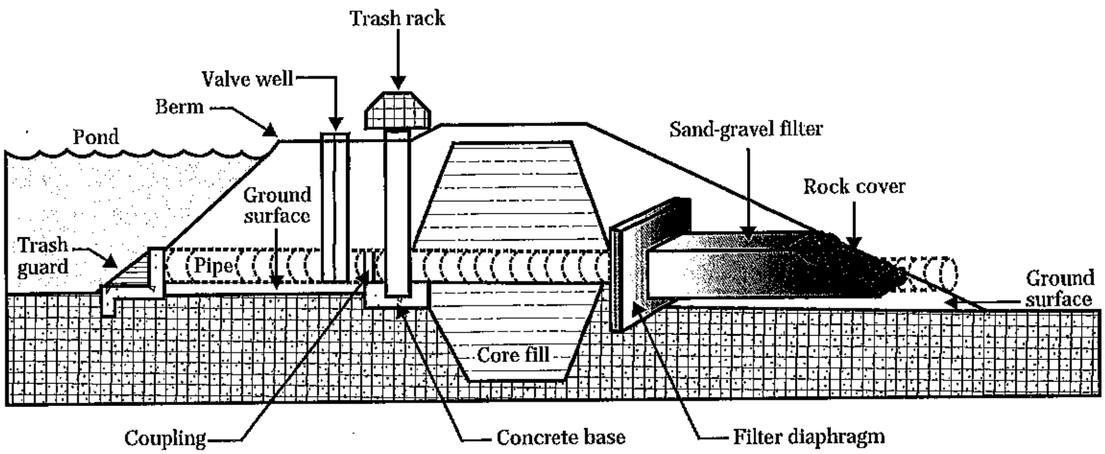
Drop-inlet pipe spillway—A drop-inlet consists of a pipe barrel (fig. 22) located under the dam and a riser connected to the upstream end of the barrel. This riser can also be used to drain the pond if a suitable valve or gate is attached at its upstream end (fig. 23).

With the required discharge capacity determined, use table 12 or 13 to select an adequate pipe size for the barrel and riser. Table 12 is for barrels of smooth pipe, and table 13 is for barrels of corrugated metal pipe. The diameter of the riser must be somewhat larger than the diameter of the barrel if the tube is to flow full. Recommended combinations of barrel and riser diameters are shown in the tables. In these tables the total head is the vertical distance between a point 1 foot above the riser crest and the centerline of the barrel at its outlet end. 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 22 Drop-inlet pipe spillway with antiseep collar

Figure 23 Drop-inlet pipe spillways

(a) With sand-gravel filter



(b) With antiseep collar

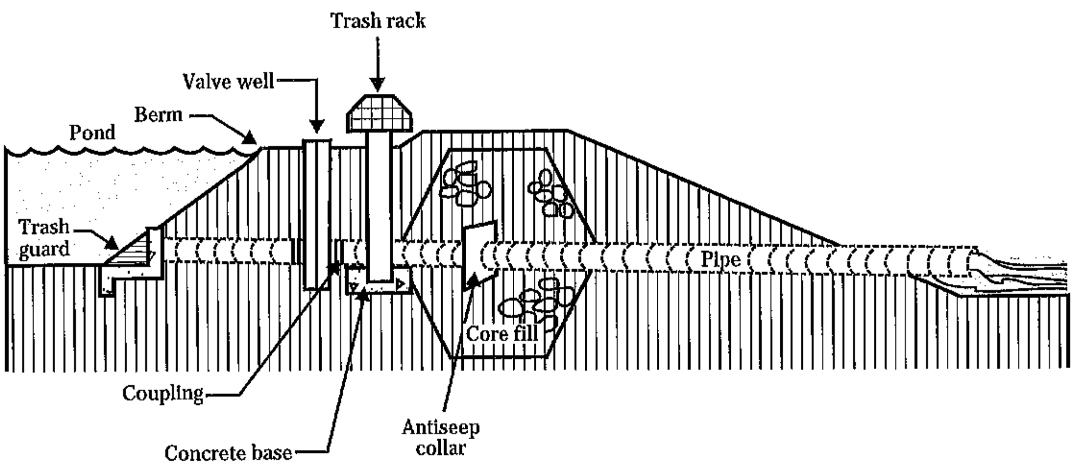


Table 12 Discharge values for smooth pipe drop inlets 1/

Total head	Ratio of barrel diameter to riser diameter (in)					
	6:8	8:10	10:12	12:15	15:24	18:36
(ft)	(ft^3/s)	(ft^3/s)	(ft^3/s)	(ft^3/s)	(ft^3/s)	(ft^3/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

1/ 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 $n = 0.012$.

Table 13 Discharge values for corrugated metal pipe drop inlets 1/

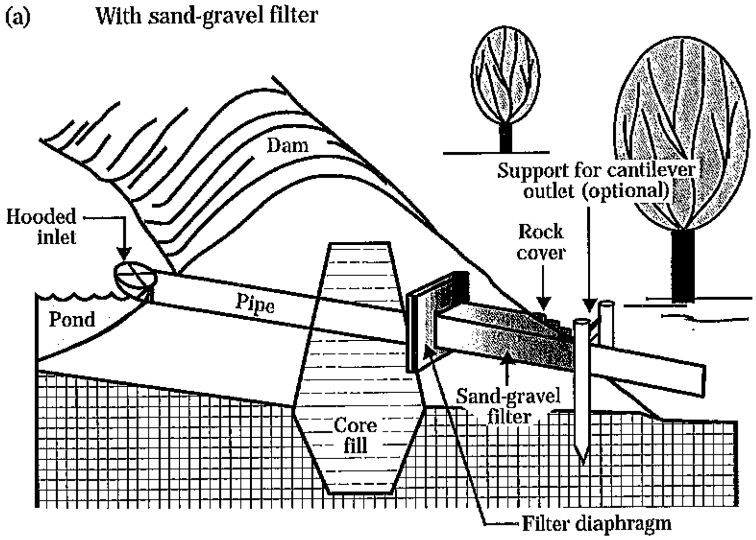
Total head	Ratio of barrel diameter to riser diameter (in)					
	6:8	8:10	10:12	12:15	15:21	18:24
(ft)	(ft^3/s)	(ft^3/s)	(ft^3/s)	(ft^3/s)	(ft^3/s)	(ft^3/s)
6	0.85	1.73	3.1	5.1	8.8	14.1
8	0.90	1.85	3.3	5.4	9.4	15.0
10	0.94	1.96	3.5	5.7	9.9	15.9
12	0.98	2.07	3.7	6.0	10.4	16.7
14	1.02	2.15	3.8	6.2	10.8	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

1/ 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 $n = 0.012$.

Hood-inlet pipe spillway—A hood-inlet consists of a pipe laid in the earthfill (fig. 24). The inlet end of the pipe is cut at an angle to form a hood. An antivortex device, usually metal, is attached to the entrance of the pipe to increase the hydraulic efficiency of the tube. Typical installations of hood inlets and details of the antivortex device are shown in figure 25. 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.

Figure 24 Dam with hooded inlet pipe spillway

(a) With sand-gravel filter



(b) With antiseep collar

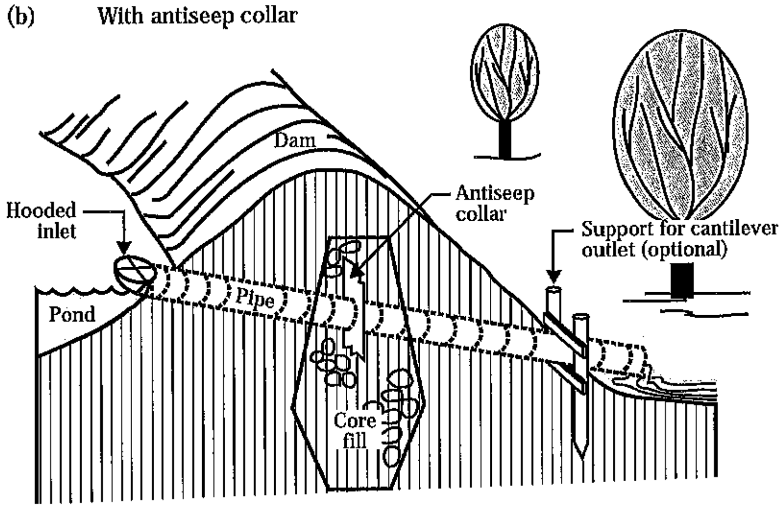
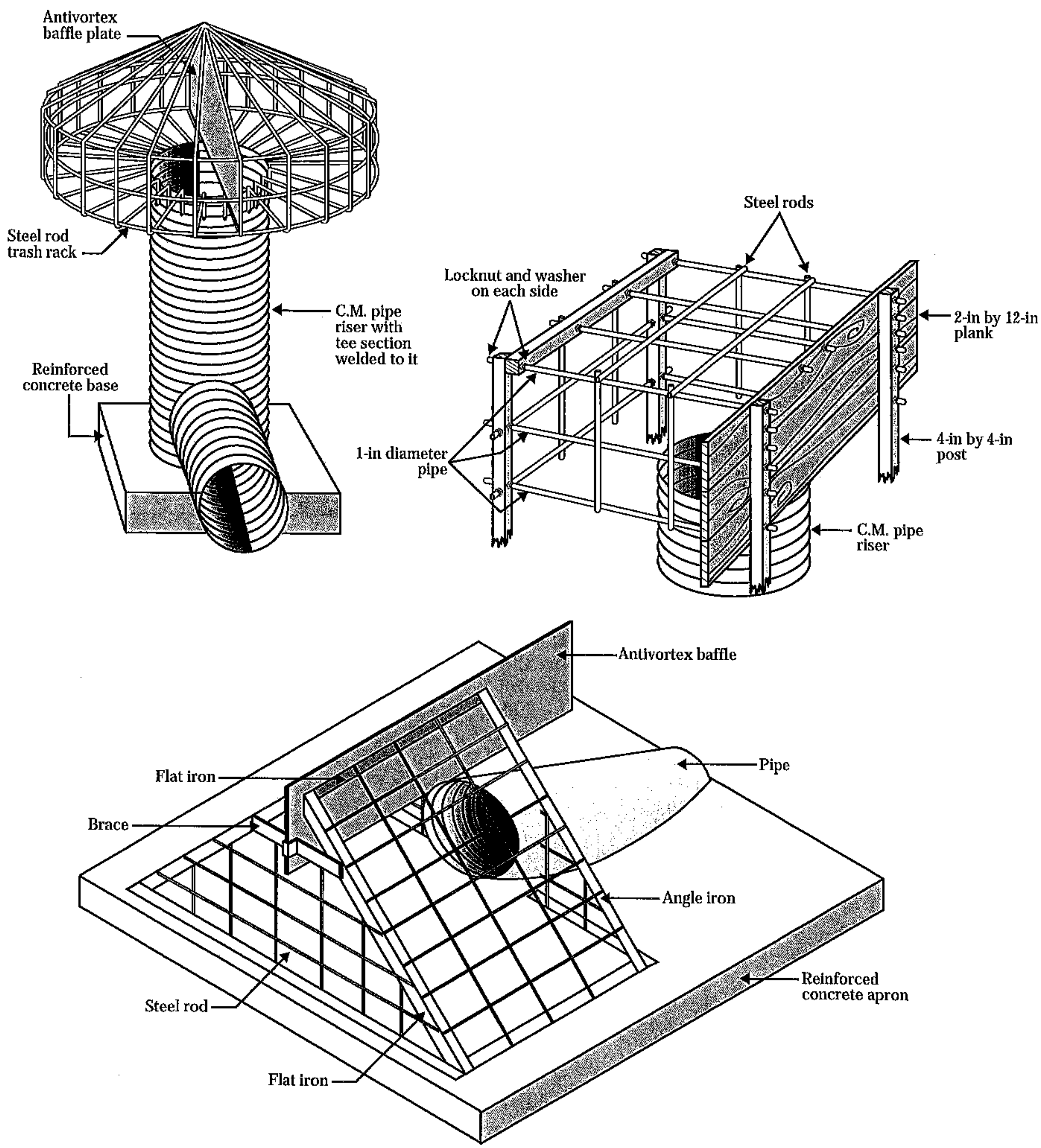


Figure 25 Pipe inlet spillways that have trash rack and antivortex baffle



The required diameter for a hood-inlet pipe can be selected from table 14 or 15 after estimating the discharge capacity, *Q*, and determining the total head, *H*. The tables also show the minimum head, *h*, required above the invert or crest elevation of the pipe entrance. Unless you provide this minimum head, the pipe will not flow full.

Pipe made of cast iron, smooth steel, concrete, plastic, or corrugated metal is suitable for either kind of pipe spillway. All joints must be watertight. A concrete cradle or bedding is needed for concrete pipe to ensure a firm foundation and good alignment of the conduit. Seal the joints of concrete pipe with an approved type of rubber gasket to give them the desired amount of flexibility. For all pipe spillways, use new pipe or pipe so slightly used that it may be considered equivalent to new pipe.

To retard seepage through the embankment along the outside surface of the pipe, compact the fill around the pipe and use a filter and drainage diaphragm around the pipe like that shown in figure 24.

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 ($2D_o$). When a cradle or bedding is used under the pipe, the vertical downward $2D_o$ is measured from the bottom of the cradle or bedding. If bedrock is encountered within the $2D_o$ measurement, the diaphragm should terminate at the bedrock surface. The location

Table 14 Minimum head, *h* (ft), required above the invert of hood inlets to provide full flow, *Q* (ft^3/s), for various sizes of smooth pipe and values of total head, *H* 1/

Total head (ft)	Diameter of pipe in inches: 6	8	10	12	15	18
6	h = 0.63 Q = 1.63	h = 0.85 Q = 3.0	h = 1.04 Q = 5.3	h = 1.23 Q = 8.5	h = 1.54 Q = 14.0	h = 1.82 Q = 21.2
8	h = 0.65 Q = 1.78	h = 0.86 Q = 3.5	h = 1.06 Q = 6.0	h = 1.27 Q = 9.3	h = 1.57 Q = 15.5	h = 1.87 Q = 23.3
10	h = 0.66 Q = 1.93	h = 0.87 Q = 3.8	h = 1.08 Q = 6.6	h = 1.30 Q = 10.2	h = 1.60 Q = 17.0	h = 1.91 Q = 25.4
12	h = 0.67 Q = 2.06	h = 0.88 Q = 4.1	h = 1.09 Q = 7.1	h = 1.32 Q = 10.9	h = 1.63 Q = 18.3	h = 1.94 Q = 27.5
14	h = 0.67 Q = 2.18	h = 0.89 Q = 4.3	h = 1.11 Q = 7.5	h = 1.33 Q = 11.6	h = 1.65 Q = 19.5	h = 1.96 Q = 29.4
16	h = 0.68 Q = 2.28	h = 0.90 Q = 4.5	h = 1.13 Q = 7.8	h = 1.35 Q = 12.2	h = 1.67 Q = 20.5	h = 1.98 Q = 31.0
18	h = 0.69 Q = 2.36	h = 0.91 Q = 4.7	h = 1.14 Q = 8.1	h = 1.36 Q = 12.7	h = 1.69 Q = 21.4	h = 2.00 Q = 32.5
20	h = 0.69 Q = 2.43	h = 0.92 Q = 4.9	h = 1.15 Q = 8.4	h = 1.37 Q = 13.2	h = 1.70 Q = 22.2	h = 2.02 Q = 33.9
22	h = 0.70 Q = 2.50	h = 0.93 Q = 5.0	h = 1.16 Q = 8.7	h = 1.38 Q = 13.6	h = 1.71 Q = 23.0	h = 2.04 Q = 35.1
24	h = 0.70 Q = 2.56	h = 0.93 Q = 5.1	h = 1.16 Q = 9.0	h = 1.39 Q = 14.0	h = 1.72 Q = 23.7	h = 2.05 Q = 36.3
26	h = 0.71 Q = 2.60	h = 0.94 Q = 5.2	h = 1.17 Q = 9.3	h = 1.40 Q = 14.4	h = 1.73 Q = 24.4	h = 2.07 Q = 37.5

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

of the diaphragm should never result in a minimum soil cover over a portion of the diaphragm measured normal to the nearest embankment surface of less than 2 feet. If this requirement is exceeded, the filter and drainage diaphragm should be moved upstream until the 2-foot minimum is reached. The outlet for the filter and drainage diaphragm should extend around the pipe surface a minimum of 1.5 times the outside diameter of the pipe ($1.5Do$) that has 1 foot around the pipe being a minimum.

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

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

- They provide positive seepage control along structures that extend through the fill.
- Unlike concrete antiseep 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.

Antiseep collars can be used instead of the filter and drainage diaphragm. Antiseep collars have been used

Table 15 Minimum head, h (ft), required above the invert of hood inlets to provide full flow, Q (ft^3/s), for various sizes of corrugated pipe and values of total head, H[1/]

Total head	Diameter of pipe in inches					
(ft)	6	8	10	12	15	18
6	h = 0.59	h = 0.78	h = 0.97	h = 1.17	h = 1.46	h = 1.75
	Q = 0.92	Q = 1.9	Q = 3.3	Q = 5.3	Q = 9.1	Q = 14.5
8	h = 0.59	h = 0.79	h = 0.98	h = 1.18	h = 1.48	h = 1.77
	Q = 1.00	Q = 2.1	Q = 3.6	Q = 5.8	Q = 10.0	Q = 16.0
10	h = 0.60	h = 0.79	h = 0.99	h = 1.19	h = 1.49	h = 1.79
	Q = 1.06	Q = 2.2	Q = 3.9	Q = 6.3	Q = 10.9	Q = 17.3
12	h = 0.60	h = 0.80	h = 1.00	h = 1.20	h = 1.50	h = 1.80
	Q = 1.12	Q = 2.3	Q = 4.2	Q = 6.7	Q = 11.6	Q = 18.5
14	h = 0.61	h = 0.81	h = 1.01	h = 1.21	h = 1.51	h = 1.82
	Q = 1.18	Q = 2.4	Q = 4.4	Q = 7.1	Q = 12.2	Q = 19.6
16	h = 0.61	h = 0.81	h = 1.01	h = 1.21	h = 1.52	h = 1.82
	Q = 1.22	Q = 2.5	Q = 4.6	Q = 7.4	Q = 12.7	Q = 20.5
18	h = 0.61	h = 0.81	h = 1.02	h = 1.22	h = 1.53	h = 1.83
	Q = 1.26	Q = 2.6	Q = 4.8	Q = 7.6	Q = 13.2	Q = 21.3
20	h = 0.62	h = 0.82	h = 1.03	h = 1.23	h = 1.54	h = 1.85
	Q = 1.30	Q = 2.7	Q = 4.9	Q = 7.8	Q = 13.7	Q = 21.9
22	h = 0.62	h = 0.83	h = 1.03	h = 1.24	h = 1.55	h = 1.86
	Q = 1.33	Q = 2.8	Q = 5.0	Q = 8.0	Q = 14.1	Q = 22.5
24	h = 0.63	h = 0.83	h = 1.04	h = 1.25	h = 1.56	h = 1.88
	Q = 1.35	Q = 2.8	Q = 5.1	Q = 8.2	Q = 14.5	Q = 23.0
26	h = 0.63	h = 0.84	h = 1.05	h = 1.26	h = 1.58	h = 1.89
	Q = 1.37	Q = 2.9	Q = 5.2	Q = 8.3	Q = 14.7	Q = 23.4

1/ Length of pipe used in calculations is based on a dam with a 12-foot top width and 2.5:1 side slopes. Pipe flow based on Manning's $n = 0.025$.

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

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

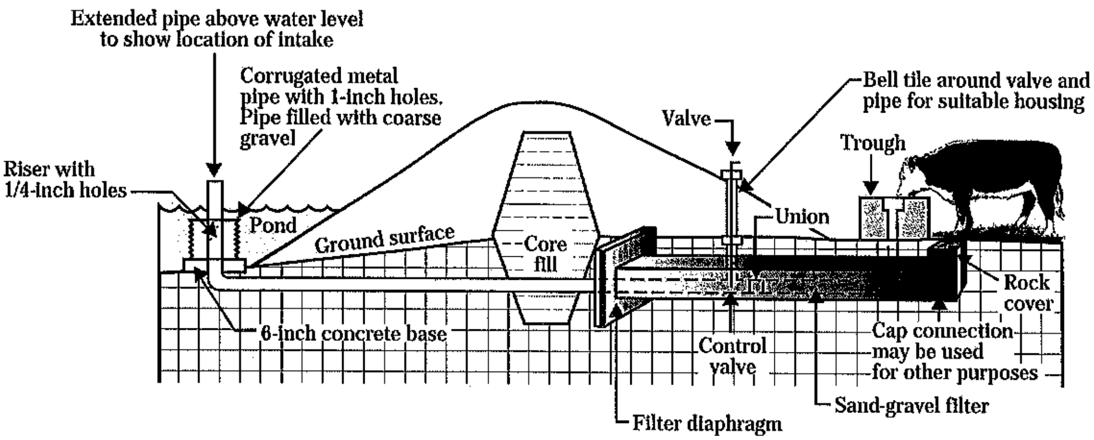
Extend the pipe 6 to 10 feet beyond the downstream toe of the dam to prevent damage by the flow of water from the pipe. For larger pipes, support the extension with a timber brace.

Drainpipes—Some state regulatory agencies require that provision be made for draining ponds completely or for fluctuating the water level to eliminate breeding places for mosquitoes. Whether compulsory or not, provision for draining a pond is desirable and 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. Install a suitable gate or other control device and extend the drainpipe to the upstream toe of the dam to drain the pond.

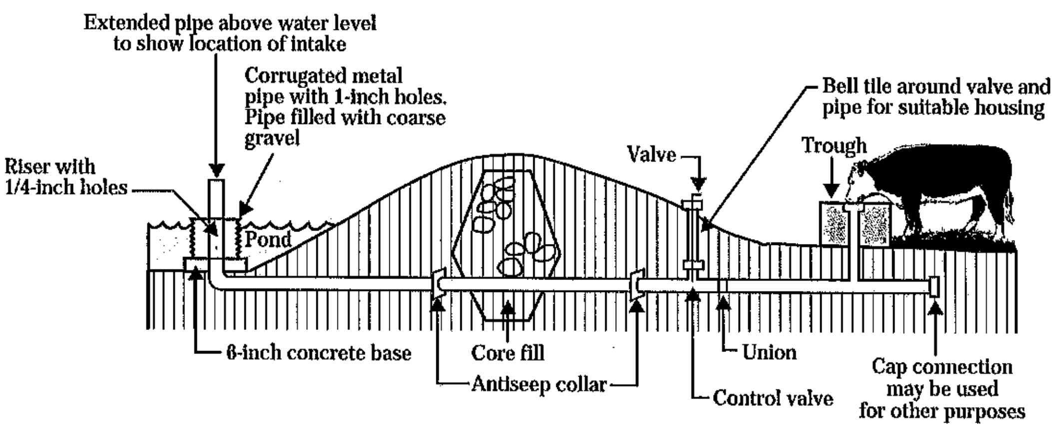
Water-supply pipes—Provide a water-supply pipe that runs through the dam if water is to be used at some point below the dam for supplying a stockwater trough, for irrigation, or for filling an orchard spray tank (fig. 26). This pipe is in addition to the principal spillway. A water-supply pipe should 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 a larger rate of flow, such as that needed for irrigation, use steel, plastic, or concrete pipe of larger diameter. Water-supply pipes also should have watertight joints and antiseep collars or a filter and drainage diaphragm.

Figure 26 Water is piped through the dam's drainpipe to a stockwater trough

(a) Pipe with sand-gravel filter



(b) Pipe with antiseep collars



Planning an earthfill dam

Foundations—You can build a safe earthfill dam on almost any foundation if you thoroughly investigate the foundation and adapt the design and construction to the conditions. Some foundation conditions require expensive construction measures that cannot be justified for small ponds.

The most satisfactory 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 removing the topsoil and scarifying or disking to provide a bond with the material in the dam.

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 engineer should design the dam. Although such foundations may be stable, corrective measures are needed to prevent excessive seepage and possible failure. 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, consult an engineer.

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.

Cutoffs—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. To prevent excessive seepage, 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 (fig. 27). This trench extends into and up the abutments of the dam as far as there is any pervious material that might allow seepage. 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. 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.

Top width and alignment—For dams less than 10 feet high, a conservative minimum top width is 6 feet. As the height of the dam increases, increase the top width. The recommended minimum top width for earth embankments of various heights is:

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

If the top of the embankment is to be used for a roadway, provide for a shoulder on each side of the roadway to prevent raveling. The top width should be at least 16 feet. In some situations a curved dam align-

Figure 27 A core trench is cut on the centerline of a dam

ment 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—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 (fig. 28).

Finish-grading techniques used to achieve a smooth landform transition include slope rounding and slope warping. Slope rounding is used at the top and bottom of cuts or fills and on side slope intersections. Slope warping is used to create variety in the horizontal and vertical pitch of finished slopes (fig. 29). 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 elevation of the water surface in the pond when the spillway is discharging at designed depth and the elevation of the top of the dam after all settlement. If your pond is less than 660 feet long, provide a freeboard of no less than l foot. The minimum freeboard is 1.5 feet for ponds between 660 and 1,320 feet long, and is 2 feet for ponds up to a half mile long. For longer ponds an engineer should determine the freeboard.

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

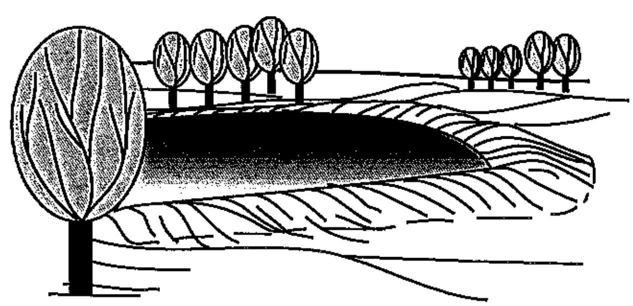
Most foundations are yielding, and settlement may range from l to 6 percent of the height of the dam, mainly during construction. The settlement allowance for a rolled-fill dam should be about 5 percent of the designed dam height. In other words, the dam is built 5 percent higher than the designed height.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

Estimating the volume of the earthfill—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

Table 16 Recommended side slopes for earth dams

Fill material	Slope Upstream	Slope 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



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, and
- any other volume of earthfill the contractor is required to move.

Volume estimates for dams generally are made of the required number of cubic yards of earthfill in place. Probably the most efficient method of estimating the volume of earthfill is the sum-of-end-area method. The ground surface elevations at all points along the centerline of the dam where the slope changes significantly are established by the centerline profile. With the settled top elevation of the dam established, you can obtain the settle fill height at each of these points by subtracting the ground surface elevation from the settle top elevation. With the fill heights, side slopes, and top width established, find the end areas at each of these stations along the centerline in table 17.

For example, assume that a dam has slopes of 3:1 on both upstream and downstream sides and a top width of 12 feet. For a point along the centerline where the fill is 15 feet high, the table shows that the end area at that point is 675 plus 180, or 855 square feet. The number of cubic yards of fill between two points on the centerline of the dam is equal to the sum of the end areas at those two points multiplied by the distance between these points and divided by 54. The total volume of earthfill in the dam is the sum of all such segments. A sample volume estimate illustrating the use of the sum-of-end-areas method is shown in table 18.

Figure 29 Finished grading techniques

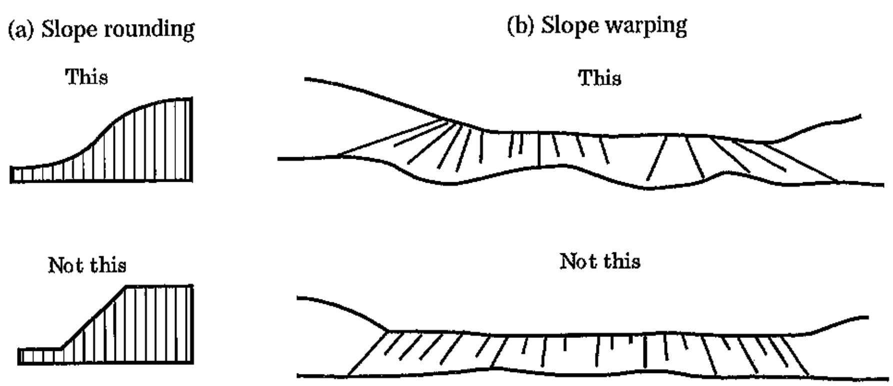


Table 17 End areas in square feet of embankment sections for different side slopes and top widths 1/

Fill height (ft)	Side slopes					Top width (ft)				
	2.5:1 2.5:1	2.5:1 3:1	3:1 3:1	3.5:1 3.5:1	4:1 4:1	8	10	12	14	16
	2:1 3:1	2:1 3.5:1	2.5:1 3.5:1	3:1 4:1	3:1 5:1					
1.0	3	3	3	4	4	8	10	12	14	16
1.2	4	4	4	5	6	10	12	14	17	19
1.4	5	5	6	7	8	11	14	17	20	22
1.6	6	7	8	9	10	13	16	19	22	26
1.8	8	9	10	11	13	14	18	22	25	29
2.0	10	11	12	14	16	16	20	24	28	32
2.2	12	13	15	17	19	18	22	27	31	35
2.4	14	16	17	20	23	19	24	29	34	39
2.6	17	19	20	24	27	21	26	31	36	42
2.8	20	22	23	27	31	22	28	34	39	45
3.0	22	25	27	32	36	24	30	36	42	48
3.2	26	28	31	36	41	26	32	38	45	51
3.4	29	32	35	40	46	27	34	41	47	55
3.6	32	36	39	45	52	29	36	43	50	58
3.8	36	40	43	50	58	30	38	46	53	61
4.0	40	44	48	56	64	32	40	48	56	64
4.2	44	49	53	62	71	34	42	50	59	67
4.4	48	53	58	68	77	35	44	53	61	71
4.6	53	58	63	74	85	37	46	55	64	74
4.8	57	63	69	81	92	38	48	57	67	77
5.0	62	69	75	87	100	40	50	60	70	80
5.2	67	74	81	94	108	42	52	62	73	83
5.4	73	80	87	102	117	43	54	65	75	87
5.6	78	86	94	110	125	45	56	67	78	90
5.8	84	93	101	118	135	46	58	69	81	93
6.0	90	99	108	126	144	48	60	72	84	96
6.2	96	106	115	135	154	50	62	74	87	99
6.4	102	113	123	143	164	51	64	77	89	103
6.6	109	120	131	152	174	53	66	79	92	106
6.8	116	128	139	162	185	54	68	81	95	109
7.0	123	135	147	172	196	56	70	84	98	112
7.2	130	143	156	182	207	58	72	86	101	115
7.4	138	152	165	193	219	59	74	89	103	119
7.6	145	159	174	203	231	61	76	91	106	122
7.8	153	168	183	214	243	62	78	93	109	125
8.0	160	176	192	224	256	64	80	96	112	128
8.2	169	185	202	235	269	66	82	98	115	131
8.4	177	194	212	247	282	67	84	101	117	135
8.6	186	204	222	259	296	69	86	103	120	138
8.8	194	213	232	271	310	70	88	105	123	141

See footnote at end of table.

Table 17 End areas in square feet of embankment sections for different side slopes and top widths 1/—Continued.

Fill height	Side slopes					Top width (ft)				
	2.5:1	2.5:1	3:1	3.5:1	4:1					
	2.5:1	3:1	3:1	3.5:1	4:1	8	10	12	14	16
(ft)	2:1	2:1	2.5:1	3:1	3:1					
	3:1	3.5:1	3.5:1	4:1	5:1					
9.0	203	223	243	283	324	72	90	108	126	144
9.2	212	233	254	296	339	74	92	110	129	147
9.4	222	244	266	310	353	75	94	113	131	151
9.6	231	254	277	323	369	77	96	115	134	154
9.8	241	265	289	337	384	78	98	117	137	157
10.0	250	275	300	350	400	80	100	120	140	160
10.2	260	286	313	364	416		102	122	143	163
10.4	271	298	325	379	433		104	125	145	167
10.6	281	309	338	394	449		106	127	148	170
10.8	292	321	350	409	467		108	129	151	173
11.0	302	333	363	424	484		110	132	154	176
11.2	313	344	376	440	502		112	134	157	179
11.4	325	357	390	456	520		114	137	159	183
11.6	336	370	404	472	538		116	139	162	186
11.8	348	383	418	488	557		118	141	165	189
12.0	360	396	432	504	576		120	144	168	192
12.2	372	409	447	522	595		122	146	171	195
12.4	385	424	462	539	615		124	149	173	199
12.6	397	437	477	557	635		126	151	176	202
12.8	410	451	492	574	655		128	153	179	205
13.0	422	465	507	592	676		130	156	182	208
13.2	436	479	523	610	697		132	158	185	211
13.4	449	494	539	629	718		134	161	187	215
13.6	463	509	555	648	740		136	163	190	218
13.8	476	523	571	667	762		138	166	193	221
14.0	490	539	588	686	784		140	168	196	224
14.2	505	555	605	706	807		142	170	199	227
14.4	519	570	622	726	829		144	173	202	230
14.6	534	586	639	746	853		146	175	204	234
14.8	548	602	657	767	876		148	178	207	237
15.0	563	619	675	788	900		150	180	210	240
15.2	578	635	693	809	924		152	182	213	243
15.4	594	653	711	830	949		154	185	216	246
15.6	609	669	730	852	973		156	187	218	250
15.8	625	687	749	874	999		158	190	221	253
16.0	640	704	768	896	1,024		160	192	224	256
16.2	656	722	787	919	1,050			194	227	259
16.4	673	740	807	942	1,076			197	230	262
16.6	689	758	827	965	1,102			199	232	266
16.8	706	776	847	988	1,129			202	235	269
17.0	723	795	867	1,012	1,156			204	238	272

See footnote at end of table.

Table 17 End areas in square feet of embankment sections for different side slopes and top widths 1/—Continued.

Fill height (ft)	2.5:1 2.5:1 / 2:1 3:1	2.5:1 3:1 / 2:1 3.5:1	3:1 3:1 / 2.5:1 3.5:1	3.5:1 3.5:1 / 3:1 4:1	4:1 4:1 / 3:1 5:1	Top width 8	Top width 10	Top width 12	Top width 14	Top width 16
17.2	740	814	888	1,036	1,183			206	241	275
17.4	757	833	909	1,060	1,211			209	244	278
17.6	774	852	930	1,084	1,239			211	246	282
17.8	792	871	951	1,109	1,267			214	249	285
18.0	810	891	972	1,134	1,296			216	252	288
18.2	828	911	994	1,160	1,325			218	255	291
18.4	846	931	1,016	1,186	1,354			221	258	294
18.6	865	951	1,038	1,212	1,384			223	260	298
18.8	884	972	1,060	1,238	1,414			226	263	301
19.0	903	993	1,083	1,264	1,444			228	266	304
19.2	922	1,014	1,106	1,291	1,475			230	269	307
19.4	941	1,035	1,129	1,318	1,505			233	272	310
19.6	960	1,056	1,152	1,345	1,537			235	274	314
19.8	980	1,078	1,176	1,372	1,568			238	277	317
20.0	1,000	1,100	1,200	1,400	1,600			240	280	320
20.2	1,020	1,122	1,224	1,428	1,632			242	283	323
20.4	1,040	1,144	1,248	1,457	1,665			245	286	326
20.6	1,061	1,167	1,273	1,486	1,697			247	288	330
20.8	1,082	1,190	1,298	1,515	1,731			250	291	333
21.0	1,103	1,213	1,323	1,544	1,764			252	294	336
21.2	1,124	1,236	1,348	1,574	1,798			254	297	339
21.4	1,145	1,254	1,374	1,604	1,832			257	300	342
21.6	1,166	1,283	1,400	1,634	1,866			259	302	346
21.8	1,188	1,307	1,426	1,664	1,901			262	305	349
22.0	1,210	1,331	1,452	1,694	1,936			264	308	352
22.2	1,232	1,356	1,479	1,725	1,971			266	311	355
22.4	1,254	1,380	1,506	1,756	2,007			269	314	358
22.6	1,277	1,405	1,533	1,788	2,043			271	316	362
22.8	1,300	1,430	1,560	1,820	2,079			274	319	365
23.0	1,323	1,455	1,587	1,852	2,116			276	322	368

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

Table 18 Volume of material needed for the earthfill

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

1/ Elevation of top of dam without allowance for settlement.
2/ End areas based on 12-foot top width and 3:1 slopes on both sides.
3/ Divide double volume in cubic feet by 54 to obtain volume in cubic yards; for example,

$$\frac{379{,}548}{54} = 7{,}029\ yd^3$$

Allowance for settlement (10%) = 703 yd^3

Total volume = 7,732 yd^3

The sample volume estimate of 7,732 cubic yards includes only the volume of earth required to complete the dam itself. Estimate the volume of earth required to backfill the core trench, old stream channels, and other required excavation and add it to the estimate for the dam. Also include an estimate of additional fill to be placed on the backslope and abutments. For example, assume that, in addition to the volume shown in table 18, there is a cutoff trench to be backfilled. The dimensions of the trench are:

Average depth = 4.0 ft
Bottom width = 8.0 ft
Side slopes = 1.5:1
Length = 177 ft

Compute the volume of backfill as follows:

$$\text{End area} = \left[w + \left(z \times d \right) \right] d \qquad \text{[Eq. 4]}$$

$$\text{Volume} = \frac{\left(\text{End area} \times l \right)}{27} \qquad \text{[Eq. 5]}$$

where:
d = average depth
w = bottom width
l = length
z = side slopes

$$\text{End area} = [8 + (1.5 \times 4)]4 = 56 \text{ ft}^2$$

$$\text{Volume} = \frac{56 \times 177}{27} = 367 \text{ yd}^3$$

Add this to the volume required for the dam and the total volume is 7,732 plus 367, or 8,099 cubic yards. This 8,099 cubic yards represents the required compacted volume. To account for shrinkage resulting from compaction, a minimum of 1.5 times this amount is generally necessary to have available in the borrow areas and required excavations. In this example you need a minimum of 12,148 cubic yards available to construct the dam.

Drawings and specifications—Record on the engineering drawings all planning information that would affect the construction of the dam. These drawings should show all elevations and dimensions of the dam, the dimensions and extent of the cutoff trench and other areas requiring backfill, the location and dimensions of the principal spillway and other planned appurtenances, and any other pertinent information. The drawings should also include a list of the estimated quantity and kind of building materials required. The construction and material specifications state the extent and type of work, site specific details, material quality, and requirements for prefabricated materials.

Observe all land disturbance laws by including temporary protective measures during construction to minimize soil erosion and sedimentation.

Unless you have all the necessary equipment, you will need to employ a contractor to build the pond. You may wish to receive bids from several contractors to be sure that you are getting the job done at the lowest possible cost. A set of drawings and specifications shows what is to be done. This provides a basis for contractors to bid on the proposed work, allows fair competition among bidders, and states the conditions under which the work is to be done. The specifications should

- give all the information not shown on the drawings that is necessary to define what is to be done,
- prescribe how the work is to be done if such direction is required,
- specify the quality of material and workmanship required, and
- define the method of measurement and the unit of payment for the various items of work that constitute the whole job.

Construction work of the quality and standards desired will not result unless there is a clear understanding of these requirements between the owner and the contractor. For these reasons specifications should be prepared for all ponds for which the owners award the construction contracts.

Assistance in preparing drawings and specifications is available from your local soil conservation district, NRCS specialists, or private consultants.

Staking for construction

Each job must be adequately and clearly staked before construction is started. Staking transmits 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 wishes in staking so that he can make the most effective use of the stakes. The quality and appearance of the completed job reflect the care used in staking. The staking should be done by an engineer or other qualified person.

The areas to be cleared generally consist of the dam site, the auxiliary spillway site, the borrow area, and the area over which water is to be impounded. Mark each area clearly with an adequate number of stakes. In the pond area, locate the proposed water line with a level and surveying rod. This provides a base line from which clearing limits can be established.

To locate the dam, set stakes along its centerline at intervals of 100 feet or less. (Generally this has been done during the initial planning survey.) Then 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.

To locate 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.

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.

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 antiseep collars, outlet structures, and other appurtenances.

Building the pond

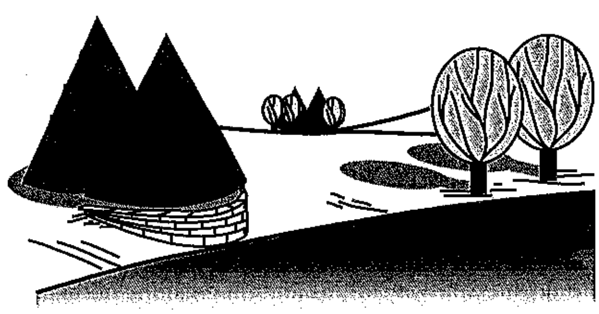
Attention to the details of construction and adherence to the drawings and specifications are as important as adequate investigation and design. Careless and shoddy construction can make an entirely safe and adequate design worthless and cause failure of the dam. Adherence to specifications and prescribed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

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

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.

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.

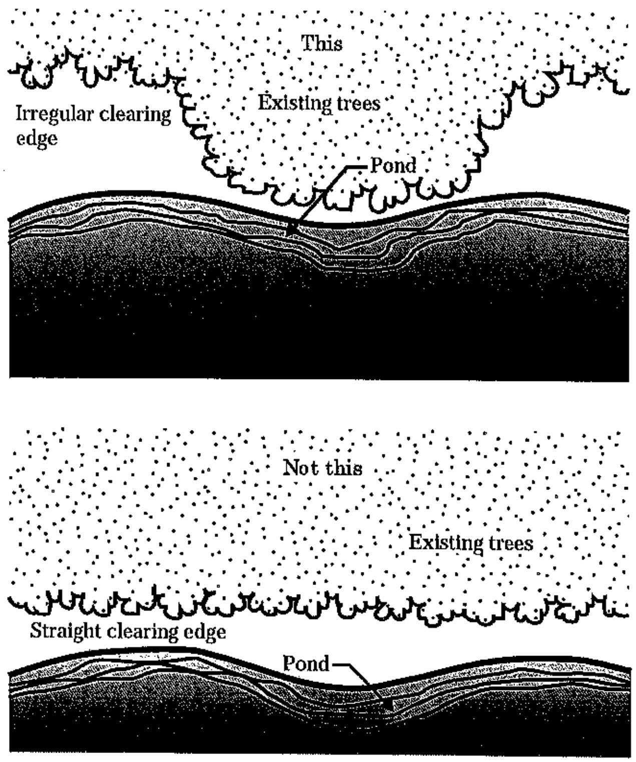
Figure 30 A tree well preserves vegetation



Removing all vegetation within the construction limits is not always necessary. Selected groupings of desirable plants can be kept. Trees and shrubs can often survive a 1- to 2-foot layer of graded fill over their root systems or they can be root-pruned in excavated areas. Tree wells and raised beds can also be used to retain vegetation (fig. 30).

Clearing limits should be irregular to create a natural-appearing edge and open area (fig. 31). Further transition with vegetated surroundings can be accomplished by feathering clearing edges. Density and height of vegetation can be increased progressively from the water's edge to the undisturbed vegetation (fig. 32). Feathering can be accomplished by selective clearing, installation of new plants, or both.

Figure 31 Irregular clearing around the pond helps create a natural appearing edge

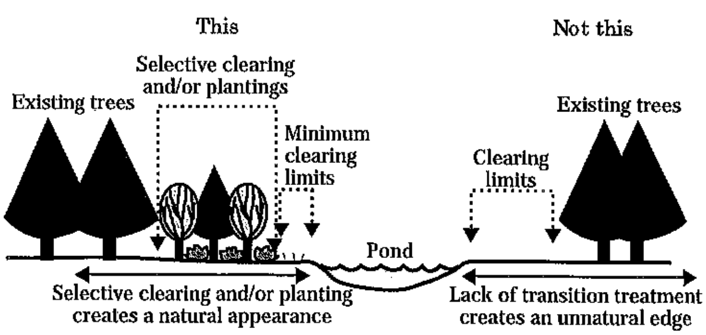


Preparing the foundation—Preparing the foundation includes treating the surface, excavating and backfilling the cutoff trench, and excavating and backfilling existing stream channels. If the foundation has an adequate layer of impervious material at the surface or if it must be blanketed by such a layer,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

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

After filling the holes, thoroughly break the ground surface and turn it to a depth of 6 inches. Roughly level the surface with a disk harrow and then compact it so that the surface materials of the foundation are as well compacted as the subsequent layers of the fill. Dig the cutoff trench to the depth, bottom width, and side slopes shown on the drawings. Often the depths shown on the drawings are only approximate; you

Figure 32 Feathering vegetation at the pond's edge makes a natural transition with existing vegetation



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. Before backfilling operations are attempted, pump all free water from the cutoff trench. Some material high in clay content takes up more than twice its own weight of water and becomes a soggy mass. Such clay puddled in the cutoff of a dam may require many years to become stable. Also, in drying it contracts and may leave cracks that can produce a roof of the overlying impervious earthfill section and provide passageways for seepage through the dam.

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.

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

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

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

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

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

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

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

Figure 33 The sod and topsoil in a pond construction area can be stockpiled for later use

Excavated ponds

Excavated ponds are the simplest to build in relatively flat terrain. Because their capacity is obtained almost solely by excavation, their practical size is limited. They are best suited to locations where the demand for water is small. Because excavated ponds can be built to expose a minimum water surface area in proportion to their volume, they are advantageous in places where evaporation losses are high and water is scarce. The ease with which they can be constructed, their compactness, their relative safety from flood-flow damage, and their low maintenance requirements make them popular in many sections of the country.

Two kinds of excavated ponds are possible. One is fed by surface runoff and the other is fed by ground water aquifers, usually layers of sand and gravel. Some ponds may be fed from both of these sources.

The general location of an excavated pond depends largely on the purpose or purposes for which the water is to be used and on other factors discussed previously in this handbook. The specific location is often influenced by topography. Excavated ponds fed by surface runoff can be located in almost any kind of topography. They are, however, most satisfactory and most commonly used in areas of comparatively flat, but well-drained terrain. A pond can be located in a broad natural drainageway or to one side of a drainageway if the runoff can be diverted into the pond. The low point of a natural depression is often a good location. After the pond is filled, excess runoff escapes through regular drainageways.

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.

Soils

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. Supplement such observations of existing ponds 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.

If an excavated pond is to be fed from a 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.

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.

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.

Spillway and inlet requirements

If you locate an excavated pond fed by surface runoff on sloping terrain, you can use a part of the excavated material for a small low dam around the lower end and sides of the pond to increase its capacity. You need an auxiliary spillway to pass excess storm runoff around the small dam. Follow the procedures for planning the spillway and provide protection against erosion as discussed in the *Excavating the earth spillway* section.

Ponds excavated in areas of flat terrain generally require constructed spillways. If surface runoff must enter an excavated pond through a channel or ditch rather than through a broad shallow drainageway, the overfall from the ditch bottom to the bottom of the pond can create a serious erosion problem unless the ditch is protected. 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 you need more than one pipe inlet, the combined capacity should equal or exceed the estimated peak rate of runoff.

Pipe diameter 1/ (in)	Pond inflow Q (ft^3/s)
15	0 to 6
18	6 to 9
21	9 to 13
24	13 to 18
30	18 to 30
36	30 to 46
42	46 to 67
48	67 to 92
54	92 to 122
60	122 to 157

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

In areas where a considerable amount of silt is carried by the inflowing water, you should provide a desilting area or filterstrip in the drainageway 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 more long. After you prepare 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.

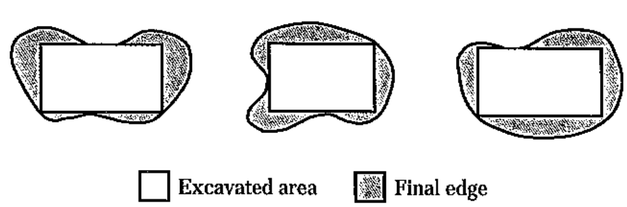
Planning the pond

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. A pond can be excavated in a rectangular form and the edge shaped later with a blade scraper to create an irregular configuration (fig. 34).

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. The required capacity of an excavated pond fed by an underground waterbearing 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.

Figure 34 Geometric excavation graded to create more natural configuration



Selecting the 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. If an excavated pond is fed from ground water, it should be deep enough to reach well into the waterbearing 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.

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 (fig. 35).

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, these flat slopes are necessary 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—After you have selected the dimensions and side slopes of the pond, estimate the volume of excavation required. This estimate determines the cost of the pond and is a basis for inviting bids and for making payment if the work is to be done by a contractor.

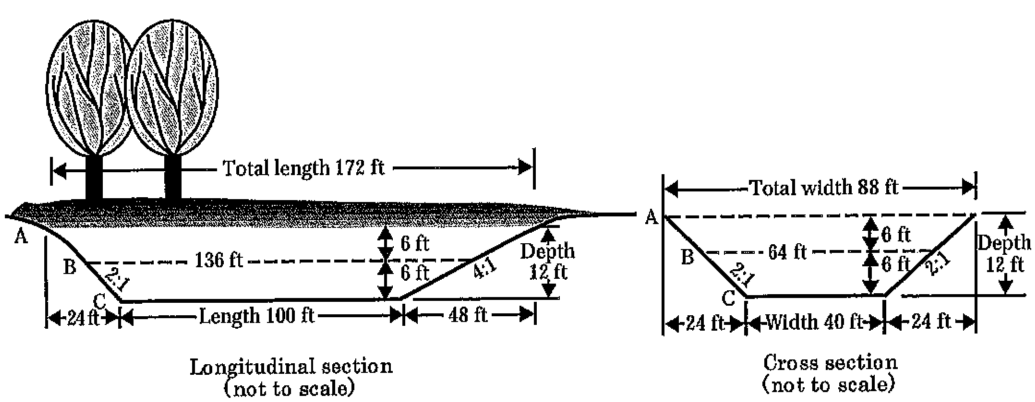
The volume of excavation required can be estimated with enough accuracy by using the prismoidal formula:

$$V = \frac{(A + 4B + C)}{6} \times \frac{D}{27} \qquad \text{[Eq. 6]}$$

where:

- V = volume of excavation (yd³)
- A = area of the excavation at the ground surface (ft²)
- B = area of the excavation at the mid-depth (1/2 D) point (ft²)
- C = area of the excavation at the bottom of the pond (ft²)
- D = average depth of the pond (ft²)
- 27 = factor converting cubic feet to cubic yards

Figure 35 Typical sections of an excavated pond



As an example, assume a pond with a depth, *D*, of 12 feet, a bottom width, *W*, of 40 feet, and a bottom length, *L*, of 100 feet as shown in figure 35. The side slope at the ramp end is 4:1, and the remaining slopes are 2:1. The volume of excavation, *V*, is computed as follows:

$$A = 88 \times 172 = 15{,}136$$
$$4B = 4(64 \times 136) = 34{,}816$$
$$C = 40 \times 100 = 4{,}000$$
$$(A + 4B + C) = 53{,}952$$

Then

$$V = \frac{53{,}952}{6} \times \frac{12}{27} = 3{,}996 \text{ yd}^3$$

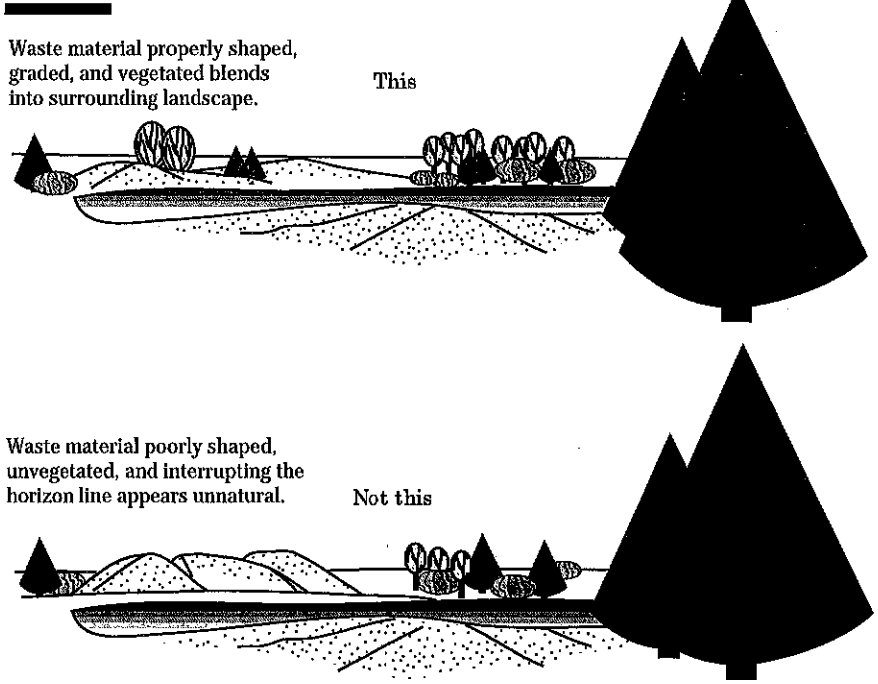
If the normal water level in the pond is at the ground surface, the volume of water that can be stored in the pond is 3,996 cubic yards times 0.00061963, or 2.48 acre-feet. To convert to gallons, 3,996 cubic yards multiplied by 201.97 equals 807,072 gallons. The sample procedure is used to compute the volume of water that can be stored in the pond if the normal water level is below the ground surface. The value assigned to the depth D is the actual depth of the water in the pond rather than depth of excavation.

A summary of methods for estimating the volume of an excavated pond is provided in appendix A. This summary information is reprinted from NRCS (formerly SCS) Landscape Architecture Note No. 2, Landscape Design: Ponds, September 2, 1988.

Waste material—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.

If you do not remove the waste material from the site, place it so that its weight does not endanger the stability of the side slopes and rainfall does not wash the material back into the pond. If you stack the material, place it with side slopes no steeper than the natural angle of repose of the soil. Do not stack waste material in a geometric mound, but shape and spread it to blend with natural landforms in the area. Because many excavated ponds are in flat terrain, the waste material may be the most conspicuous feature in the landscape. Avoid interrupting the existing horizon line with the top of the waste mound (fig. 36).

Figure 36 Correct disposal of waste material



Waste material can also be located and designed to be functional. It can screen undesirable views, buffer noise and wind, or improve the site's suitability for recreation (fig. 37). In shaping the material, the toe of the fill must be at least 12 feet from the edge of the pond. In the Great Plains you can place the waste material on the windward side of the pond to serve as a snow fence for collecting drifts in the pond. These banks can also reduce evaporation losses by breaking the force of prevailing winds across the pond.

Perhaps the most satisfactory method of handling waste material is to remove it from the site. Complete removal, however, is expensive and can seldom be justified unless the material is needed nearby. Waste material can sometimes be used advantageously for filling nearby low areas in a field or in building farm roads. If state or county highway maintenance crews need such material, you may be able to have them remove it.

Building the pond

Clear the pond area of all undesired vegetation. Mark the outside limits of the proposed excavation with stakes. On the stakes indicate the depth of cut from the ground surface to the pond bottom.

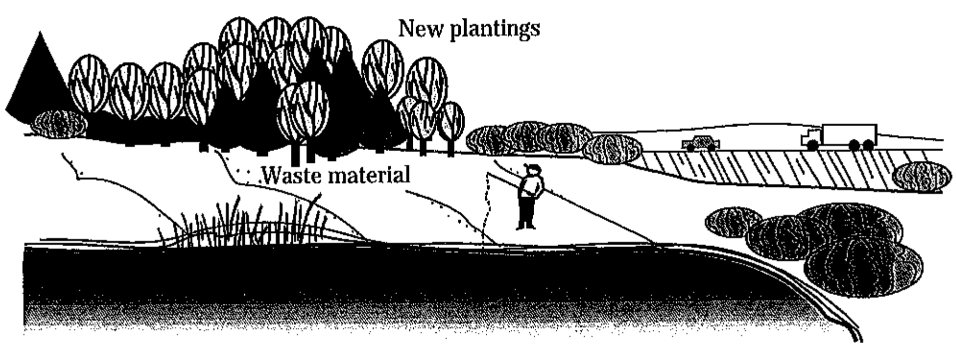
Excavation and placement of the waste material are the principal items of work in building this type pond. The kind of excavating equipment used depends on the climatic and physical conditions at the site and on what equipment is available.

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.

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.

Figure 37 Waste material and plantings separate the pond from a major highway



Sealing the pond

Excessive seepage in ponds is generally because the site is poor; that is, one where the soils in the impounding area are too permeable to hold water. Selecting a poor site is often the result of inadequate site investigations and could have been avoided. In some places no satisfactory site is available, but the need for water is great enough to justify using a site that is somewhat less than satisfactory. In this case the original pond design must include plans for reducing seepage by sealing (fig. 38). 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.

Compaction

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

The procedure is simple. 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

Figure 38 Disking in chemical additive to seal a pond

water impounded exceeds 10 feet or more. The thickness of the compacted seal can be determined using equation 7.

$$d = \frac{k \times H}{(v - k)} \qquad \text{[Eq. 7]}$$

where:

d = thickness of compacted seal
k = coefficient of permeability of compacted seal, which is assumed to be 0.003 fpd unless testing is done
H = water depth
v = allowable specific discharge which is assumed to be 0.028 fpd unless otherwise specified

As an 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. Using the preceding equation:

$$d = \frac{0.003\ fpd \times 12\ ft}{0.028\ fpd - 0.003\ fpd}$$
$$= 1.4 \text{ ft}$$

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.

Clay blankets

Pond areas containing high percentages of coarse-grained soils, but lacking enough clay 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 of the blanket depends on the depth of water to be impounded. The minimum compacted thickness is 12 inches for all depths of water under 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. 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.

Protect clay blankets against cracking that results from 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.

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. 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 usually is not recommended for ponds in which the water level is expected to fluctuate widely. 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.

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.

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.

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 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.

Chemical additives

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 certain chemicals to these porous aggregates may result in collapse of the open structure and rearrangement of the clay particles. This dispersed structure reduces soil permeability. The chemicals used are called dispersing agents.

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.

Although many soluble salts are dispersing agents, sodium polyphosphates and sodium chloride (common salt) are most commonly used. Of the sodium polyphosphates, tetrasodium pyrophosphate and sodium tripolyphosphate are most effective. Soda ash, technical grade 99 to 100 percent sodium carbonate, can also be used. 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 is applied at a rate of 0.10 to 0.20 pound per square foot. 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.

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.

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.

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.

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 sheepsfoot 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.

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 films are less expensive and have better aging properties than vinyl. Vinyl, on the other hand, is more resistant to impact damage and is readily seamed and patched with a solvent cement. Polyethylene can be joined or patched with a special cement.

All plastic membranes should have a cover of earth or earth and gravel not less than 6 inches thick to protect against punctures. Butyl-rubber membranes need not be covered except in areas traveled 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.

Clear the pond area of all undesired vegetation. Fill all holes and remove roots, sharp stones, or other objects that might puncture the film. If the material is stony or of very coarse texture, cover it with a cushion layer of fine-textured material before placing the lining.

Some plants may penetrate both vinyl and polyethylene film. If nutgrass, johnsongrass, quackgrass, and other plants having high penetration are present, the subgrade, especially the side slopes, should be sterilized. Several good chemical sterilizers are available commercially. Sterilization is not required for covered butyl-rubber linings 20 to 30 mils thick.

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 should have up to 10 percent slack. Be extremely careful 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.

Establishing vegetation

Trees, shrubs, grasses, and forbs should be planted during or soon after construction. Their functions include erosion control, screening, space definition, climate control, and wildlife habitat. 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 other disturbed surfaces can be protected from erosion by establishing a vegetative community of appropriate species. 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 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 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, brushmattresses, live siltation, and reed clumps. Additional information about these and other soil bioengineering systems is in Part 650, Engineering Field Handbook, chapters 16 and 18.

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 in achieving the desired results. For information on recommended plants and grass mixtures, rates of fertilization, and mulching procedures, contact the local representatives of the Natural Resources Conservation Service or the county agent.

Protecting the pond

Construction of the pond is not complete until you have provided protection against erosion, wave action, trampling by livestock, and any other source of damage. Ponds without this protection may be short lived, and the cost of maintenance is usually high.

Leave borrow pits in 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.

Wave action

Several methods are available to protect the upstream face of a dam against 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 the latter. 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—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.

Booms—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. If you use double rows of logs, frame them together to act as a unit. For best results place the boom so that it floats about 6 feet upstream from the face of the dam. 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. Dumping requires more stone, but less labor. 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. If 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.

Livestock

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. 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. On some western and midwestern ranges, the advantages derived from fencing are more than offset by the increased cost and maintenance and the fact that fewer animals can water at one time. A rancher with many widely scattered ponds and extensive holdings must have simple installations that require minimum upkeep and inspection. Fencing critical parts of livestock watering ponds, particularly the earthfill and the auxiliary spillway, is usually advantageous even if complete fencing is impractical.

Operating and maintaining the pond

A pond, no matter how well planned and built, must be adequately maintained if its intended purposes are to be realized throughout its expected life. Lack of operation and maintenance has caused severe damage to many dams and spillways. Some structures have failed completely. For these reasons you must be fully aware of the need for adequate operation and maintenance, and you should carry out all measures required.

Inspect your pond periodically. Be sure to examine 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. Fertilize as needed and reseed or resod these areas. If the upstream face of the earthfill shows signs of serious washing or sloughing because of wave action, install protective devices, such as booms or riprap. If seepage through or under the dam is evident, consult an engineer at once so that you can take proper corrective measures before serious damage occurs.

To maintain the protective plant cover on the dam and on the auxiliary spillway, mow it frequently and fertilize when needed. Mowing prevents the growth of woody plants where undesirable and helps develop a cover and root system more resistant to runoff. If the plant cover is protected by fencing, keep the fences in good repair.

Keep pipes, trash racks, outlet structures, valves, and watering troughs free of trash at all times.

In some localities burrowing animals such as badgers, gophers, beaver, and prairie dogs cause severe damage to dams or spillways. If this damage is not repaired, it may lead to failure of the dam. Using a submerged inlet or locating the inlet in deeper water discourages beavers from the pipe inlets. A heavy layer of sand or gravel on the fill discourages burrowing to some extent. Poultry netting can be used, but in time it rusts out and needs to be replaced.

Keep the water in your pond as clean and unpolluted as possible. Do not permit unnecessary trampling by livestock, particularly hogs. If fencing is not practical, pave the approaches to the pond with small rocks or gravel. Divert drainage from barn lots, feeding yards, bedding grounds, or any other source of contamination away from the pond. Clean water is especially important in ponds used for wildlife, recreation, and water supply.

In areas where surface water encourages mosquito breeding, stock the pond with topfeeding fish. Gambusia minnows are particularly effective in controlling mosquitoes. In malaria areas, do not keep any aquatic growth or shoreline vegetation and take special precautions in planning, building, and operating and maintaining the pond. Most states in malaria areas have health regulations covering these precautions. These regulations should be followed.

In some areas, algae and other forms of plant life may become objectionable. They can cause disagreeable tastes or odors, encourage bacterial development, and produce an unsightly appearance.

Pond safety

Ponds, like any body of water, attract people so that there is always a chance of injury or drowning. You may be planning to build a pond for watering livestock, irrigation, or any of the other purposes discussed in this handbook. However, your family and friends may picnic beside the pond or use it for fishing, swimming, boating, or ice skating, and you can never tell what a small child passing by may do.

Your pond can become a source of pleasure as well as profit, but only if it is safe. You can take some of the following steps to prevent injuries or drownings and to protect yourself financially.

Before construction

Almost all states have laws on impounding water and on the design, construction, and operation and maintenance of ponds. In many states small farm ponds are exempt from any such laws. You should become familiar with those that apply in your state and be sure that you and your engineer comply with them.

Find out what your community or state laws are regarding your liability in case of injury or death resulting from use of your pond, whether you authorize such use or not. This is particularly important if you intend to open your pond to the public and charge a fee for its use. You may find that you need to protect yourself with insurance.

You should decide how the water is going to be used so that you can plan the needed safety measures before construction starts. For example, if the water is to be used for swimming, guards over conduits are required. You may wish to provide for beaches and diving facilities; the latter require a minimum depth of about 10 feet of water.

During construction

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

After completion

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

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Glossary

abutment	A portion of a valley cross section higher in elevation than the valley floor. The slope above the valley floor.
antiseep collar	A constructed barrier installed perpendicular to a pipe or conduit and usually made of the same material as the pipe or conduit. Its purpose is to intercept the flow of seepage along the pipe or conduit and to make the seepage path longer.
appurtenance	Interrelated elements or components of a designed system, or structure.
auxiliary spillway	The spillway designed to convey excess water through, over, or around a dam.
backslope	The downstream slope of an embankment.
bench mark	Point of known elevation for a survey. May be in relation to National Geodetic Vertical Datum (NGVD) or assumed for a given project.
berm	A strip of earth, usually level, in a dam cross section. It may be located in either the upstream side slope, downstream side slope, or both.
boom	A floating barrier extending across a reservoir area, just upstream from the dam, to protect the side slope from erosion.
borrow area	An area from which earthfill materials can be taken to construct the dam.
bottom width	A flat, level cross section element normally in an open channel, spillway, or trench.
coefficient of permeability	The rate of flow of a fluid through a unit cross section of a porous mass under a unit hydraulic gradient.
compaction	The process by which the soil grains are rearranged to decrease void space and bring them into closer contact with one another, thereby increasing the weight of solid material per cubic foot.
conduit (pipe)	Any channel intended for the conveyance of water, whether open or closed.
control section	A part of an open channel spillway where accelerated flow passes through critical depth.
core trench (excavation) of a trench)	The trench in the foundation material under an earth embankment or dam in which special material is placed to reduce seepage.
critical depth	Depth of flow in a channel at which specific energy is a minimum for a given discharge.
cross section	A section formed by a plane cutting an area, usually at right angles to an axis.

dam (earth dam)	A constructed barrier, together with any associated spillways and appurtenant works, across a watercourse or natural drainage area, which permanently impounds and stores water, traps sediment, and/or controls flood water.
design elevation	The height above a defined datum describing the required elevation of pool that will provide the required temporary storage.
diaphragm	See Antiseep collar.
drain	An appurtenance installed in the dam and/or its foundation to safely collect and discharge seepage water.
drawings	A graphical representation of the planned details of the work of improvements.
drop inlet	A vertical entrance joined to a barrel section of a principal spillway system.
earthfill	Soil, sand, gravel, or rock construction materials used to build a dam and its components.
effective fill height	The difference in elevation in feet between the lowest auxiliary spillway crest and the lowest point in the original cross section on the centerline of the dam. If there is no auxiliary spillway, the top of the dam becomes the upper limit.
embankment	A structure of earth, gravel, or similar material raised to form a dam.
excavated pond	A reservoir constructed mainly by excavation in flat terrain. A relatively short embankment section on the downstream watercourse side may be necessary for desired storage amount.
exit channel (of an open channel spillway)	The portion downstream from the control section that conducts the flow to a point where it may be released without jeopardizing the dam.
fill height	The difference in elevation between the existing ground line and the proposed top of dam elevation, including allowance for settlement.
filter and drainage diaphragm	A soil piping and water seepage control device installed perpendicular to a pipe or conduit, consisting of a single, or multizones of, aggregate. Its purpose is to intercept the water flow along pipes or conduits and prevent the movement of soil particles that makeup the embankment.
flow depth	The depth of water in the auxiliary spillway or any other channel.
foundation	The surface upon which a dam is constructed.
freeboard	The difference in elevation between the minimum settled elevation of the top of dam and the highest elevation of expected depth of flow through the auxiliary spillway.

hooded or canopy inlet	A fabricated assembly attached to the principal spillway pipe to improve the hydraulic efficiency of the overall pipe system.
inlet section (of an open channel spillway)	The portion upstream from the control section.
mulch	A natural or artificial layer of plant residue or other material, such as grain straw or paper, on the soil surface.
outlet channel	A section of open channel downstream from all works of improvement.
outlet section	The downstream portion of an open channel or of a principal spillway.
peak discharge	The maximum flow rate at which runoff from a drainage area discharges past a specific point.
pond	A still body of water of limited size either naturally or artificially confined and usually smaller than a lake.
pool area	The location for storing water upstream from the dam.
principal spillway	The lowest ungated spillway designed to convey water from the reservoir at predetermined release rates.
profile	A representation of an object or structure seen from the side along its length.
propped outlet	A structural support to protect the outlet section of a pipe principal spillway.
riprap	A loose assemblage of broken stones commonly placed on the earth surface to protect it from the erosive forces of moving water or wave action.
riser	The vertical portion of a drop inlet.
sealing	The process used to close openings in soil materials and prevent seepage of water.
sediment	Solid material, both mineral and organic, that is being transported in suspension, or has been moved from its site of origin by water, air, gravity, or ice and has come to rest on the Earth's surface either above or below the principal spillway crest.
settlement	Movement of an embankment or structure during the application of loads.
side slope (ratio)	The ratio of horizontal to vertical distance measured along the slope, either on an open channel bank or on the face of an embankment, usually expressed in "n":1; e.g., 2:1 (meaning two units horizontal to one unit vertical).
site investigation	Site visit to evaluate physical features of a proposed project or watershed including soils data and characteristics of the watershed.

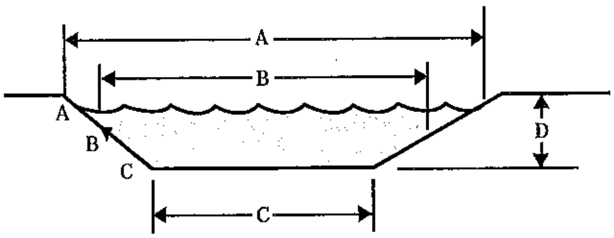
specifications	Detailed statements prescribing standards, materials, dimensions, and workmanship for works of improvement.
specific discharge	The theorical flow rate through the full flow cross sectional area of a porous media.
spillway	An open or closed channel, conduit or drop structure used to convey water from a reservoir. It may contain gates, either manually or automatically controlled, to regulate the discharge of water.
stage	The elevation of a water surface above its minimum plane or datum of reference.
storage volume	The total volume available from the bottom of the reservoir to the top of dam.
temporary storage	The volume from the crest of the principal spillway to the top of dam.
top width	The horizontal dimension (planned or existing) across the top of dam, perpendicular to the centerline.
valley floor	Part of a valley cross section that is level or gently sloping.
vegetative retardance	The amount of hindrance to flow caused by the type, density, and height of vegetation.
visual focus	An element in the landscape upon which the eyes automatically focus because of the element's size, form, color, or texture contrast with its surroundings.

Appendix A

Estimating the Volume of an Excavated Pond

The volume of a pond can be estimated by using the prismoidal formula:

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



V = volume of excavation (yd^3)
A = area of excavation at ground level (ft^2)
B = area of excavation at the middle depth of the pond (ft^2)
C = area of excavation at the bottom of the pond (ft^2)
D = average depth of the pond in (ft)
27 = factor converting cubic feet to cubic yards

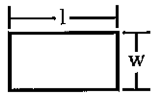
Note: When using meters for area and depth, 27 is not needed. The formula would then be:

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

where:
V = volume of excavation (m^3)

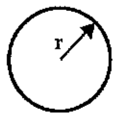
This formula can be used for ponds of any shape. The area of excavation can be determined either by planimetering the shape on the plans or by using geometric formulas for areas. The following formulas give the area of some common shapes.

Rectangle:



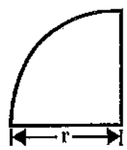
Rectangle A = wl

Circle:



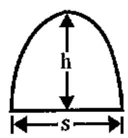
Circle A = πr^2 or $3.14 r^2$

Quadrant:



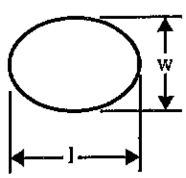
Quadrant A = $\frac{\pi}{4} r\left(r^2 \text{ or } 0.7854 r^2\right)$

Parabola:



Parabola A = $0.67\, sh$

Ellipse:

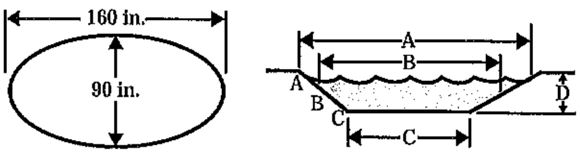


Ellipse A = $\frac{\pi}{4} wl$ or $0.7854\, wl$

Example A–1 Determing the volume of an elliptical pond

As an example, determine the volume of an elliptical pond with a major axis (l) of 160 ft, a minor axis (w) of 90 ft at the surface, a depth (D) of 8 ft, and 2:1 side slopes. Use the prismoidal formula:

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



Step 1: Calculate the area of the surface (A) using the formula,

$$\text{Area}=\frac{(\pi)}{4}\,wl \text{ for an ellipse}$$

$$A=\frac{3.14}{4}(90\times160)$$

$$A=11,304\ ft^2$$

Step 2: Determine the dimensions of the bottom (C). Since the side slopes are 2:1 and depth is 8 feet, the bottom will be 16 feet narrower than the surface. The bottom dimensions would then be 58 feet (w) by 128 feet (l).

Step 3: Calculate the area of the bottom (C) using

$$C=\frac{3.14}{4}(58\times128)$$

$$C=5,828\ ft^2$$

Step 4: Determine the dimensions of the middle depth (B). Since the middle depth lies equally between the surface and the bottom, the dimensions can be determined by adding the surface and bottom dimensions together and dividing by 2.

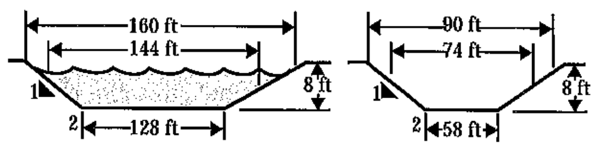
$$\frac{160+128}{2}=144 \text{ (major axis)}$$

$$\frac{90+58}{2}=74 \text{ (minor axis)}$$

Step 5: Calculate the area of the middle depth (B) using Area = (pi) wl.

$$B=\frac{3.14}{4}(74\times144)$$

$$B=8,365\ ft^2$$



Step 6: Determine the volume in cubic yards.

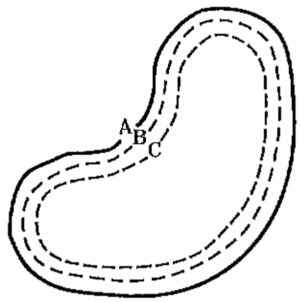
$$V=\frac{[11,304+(4\times8,365)+5,828]}{6}\times\frac{8}{27}$$

$$V=\frac{50,592}{6}\times\frac{8}{27}$$

$$V=2,498 \text{ or approx. } 2,500\ yd^3$$

Example A–2 Determining area of the surface, the middle depth, and bottom

The area of the surface, the middle depth, and bottom can also be determined by using a planimeter. In this example, the pond was drawn at a 1 inch = 40 feet scale and has a depth of 8 feet.



Scale: 1 inch = 40 feet

Step 1: Measure the surface area (A) using a planimeter. Convert the measurement from square inches into square feet. (A factor of 1,600 is used to convert square inches into square feet for a scale of 1 inch = 40 feet.)

$$A = 10.0\ in^2 \times 1,600 = 16,000\ ft^2$$

Step 2: Measure the middle depth (B) area and convert to square feet.

$$B = 7.7\ in^2 \times 1,600 = 12,320\ ft^2$$

Step 3: Measure the bottom (C) and convert to square feet.

$$C = 5.5\ in^2 \times 1,600 = 8,800\ ft^2$$

Step 4: Use the prismoidal formula to estimate volume of excavation in cubic yards.

$$V = \frac{(A + 4B + C)}{6} \times \frac{8}{27}$$

$$V = \frac{[16,000 + (4 \times 12,320) + 8,800]}{6} \times \frac{8}{27}$$

$$V = \frac{74,080}{6} \times \frac{8}{27}$$

$$V = 3,658\ yd^3$$

Appendix B Flood-Tolerant Native Trees and Shrubs

Flooding creates several conditions that are unfavorable to most woody species. The most critical condition appears to be the depletion of soil oxygen that is critical to plants. The lack of oxygen favors anaerobic bacteria, which can lead to the development of toxic organic and inorganic byproducts. A plant's ability to survive flooding is dependent on many factors; among them are flood depth, flood duration, flood timing, plant age and size, wave action, and substrata composition.

The plant lists in tables B–1 through B–4 were taken from the Corps of Engineers Technical Report E-79-2, Flood Tolerance of Plants: A State-of-the-Art Review. The ratings used are intended only to be a relative classification. Tolerance will vary with local conditions. The plants are divided into four groups: very tolerant, tolerant, somewhat tolerant, and intolerant. Each plant was also given a range coinciding with the plant growth regions, figure B–1, developed from USDA Miscellaneous Publication 303, Native Woody Plants of the United States, by William R. Van Dersal.

Figure B–1 Plant growth regions

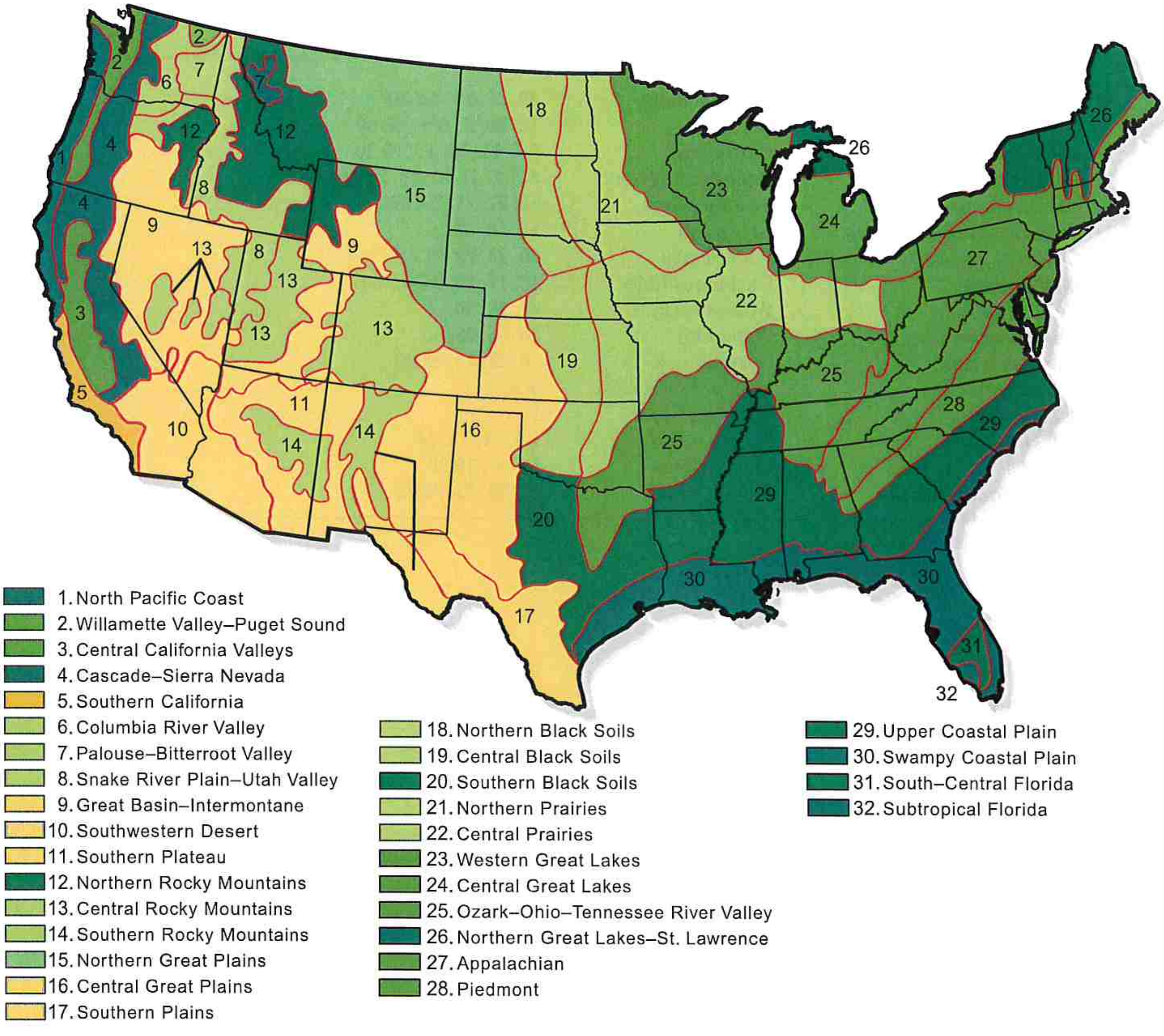


Table B–1 Flood tolerance of very tolerant native plants

[These plants are able to survive deep, prolonged flooding for more than 1 year.]

Scientific name	Common name	Range
Carya aquatica	Water hickory	20, 25, 28, 29, 30
C. illinoensis	Pecan	16, 20, 22, 25, 29, 30
Cephalanthus occidentalis	Buttonbush	3-5, 11, 16, 17, 19-30
Cornus stolonifera	Redosier dogwood	4, 7-9, 11-15, 18, 21 -28
Forestiera acuminata	Swamp privet	20, 22, 25, 29, 30
Fraxinus pennsylvanica	Green ash	15, 18, 20-30
Gleditsia aquatica	Waterlocust	20, 25, 28-30
Illex decidua	Deciduous holly	16, 17, 20, 25, 28-30
Nyssa aquatica	Water tupelo	25, 29, 30
Planera aquatica	Water elm	20, 25, 29, 30
Quercus lyrata	Overcup oak	20, 22, 25, 28-30
Salix exigua	Narrow leaf willow	4-16
S. hookeriana	Hooker willow	1
S. lasiandra	Pacific willow	1-5, 11, 13, 14
S. nigra	Black willow	16, 17, 19-30
Taxodium distichum	Baldcypress	17, 20, 25, 28-32

Table B–2 Flood tolerance of tolerant native plants

[These plants are able to survive deep flooding for one growing season, with significant mortality occurring if flooding is repeated the following year.]

Scientific name	Common name	Range
Acer negundo	Boxelder	17-30
A. rubrum	Red maple	19-30
A. saccharinum	Silver maple	18-30
Alnus glutinosa	Black alder	26-27
Amorpha fruticosa	False indigo	5, 10, 11, 15-29
Betula nigra	River birch	20, 22, 23, 25-29
Celtis occidentalis	Hackberry	15, 16, 18, 20-30
Diospyros virginiana	Persimmon	20, 22, 25, 27-31
Kalmia polifolia	Bog laurel	4, 12, 23, 24, 26, 27
Ledum groenlandicum	Labrador tea	4, 12, 23, 24, 26, 27
Liquidambar styraciflua	Sweetgum	20, 22, 25, 27-30
Nyssa sylvatica	Blackgum	20, 22, 24-30
Pinus contorta	Lodgepole pine	2, 4, 10, 12-15
Platanus occidentalis	Sycamore	16, 20-22, 24-30
Populus trichocarpa	Black cottonwood	1-8, 12, 13
Quercus lyrata	Overcup oak	20, 22, 25, 28-30
Q. palustris	Pin oak	21-25, 27, 29
Sambucus callicarpa	Pacific red elder	1,2,4
Spirea douglasii	Hardhack	1-4
Tamarix gallica	French tamarisk	3, 4, 9-11, 13, 16, 19, 22, 25, 29, 30
Thuja plicata	Western redcedar	1, 2, 4, 6, 7, 12
Ulmus americana	American elm	15, 16, 18-23, 25-30
Vaccinium uliginosum	Blueberry	1, 4, 12-14, 23, 24, 26, 27

Table B–3 Flood tolerance of somewhat tolerant native plants

[These plants are able to survive flooding or saturated soils for 30 consecutive days during the growing season.]

Scientific name	Common name	Range
Alnus rugosa	Hazel alder	20, 22-29
Carpinus caroliniana	Ironwood	20-30
Celtis laevigata	Sugarberry	11, 16, 17, 20, 22, 25, 29, 30
Cornus nuttallii	Pacific dogwood	1-5
Crataegus mollis	Downy hawthorn	
Fraxinum americana	White ash	20, 22-25, 27-30
Gleditsia triacanthos	Honeylocust	16, 20, 22-27, 29, 30
Ilex opaca	American holly	20, 25, 27-30
Juglans nigra	Black walnut	18-30
Juniperus virginiana	Eastern redcedar	18, 20-29
Malus spp.	Apple	
Morus rubra	Red mulberry	16-25, 27-30
Ostrya virginiana	Eastern hophornbeam	15, 18, 20-25, 27-30
Picea stichensis	Sitka spruce	1
Pinus echinata	Shortleaf pine	20, 25, 27-30
P. ponderosa	Ponderosa pine	4
Populus grandidentata	Bigtooth aspen	21-23, 25-28
Quercus alba	White oak	20, 22-30
Q. bicolor	Swamp white oak	21-28
Q. imbricaria	Shingle oak	22-25, 27, 28
Q. macrocarpa	Bur oak	15, 16, 18-30
Q. nigra	Water oak	17, 20, 25, 28-30
Q. phellos	Willow oak	20, 25, 27-30
Q. rubra	Northern red oak	21 -27
Rhus glabra	Smooth sumac	6-9, 11, 14, 15, 17-31
Tilia americana	American basswood	20-27
Tsuga heterophylla	Western hemlock	1 , 2, 4, 6, 12
Ulmus alata	Winged elm	17, 20, 25, 28-30
U. rubra	Red elm	25, 27, 29
Viburnum prunifolium	Blackhaw	20, 22-25, 27-30

Table B–4 Flood tolerance of intolerant native plants

[These plants are unable to survive more than a few days of flooding during the growing season without significant mortality.]

Scientific name	Common name	Range
Acer macrophyllum	Bigleaf maple	1-5
A. saccharum	Sugar maple	15, 18, 21-29
Alnus rubra	Red alder	1 , 2, 5, 6
A. sinuata	Sitka alder	2, 4, 6, 7, 12
Betula lutea	Yellow birch	21-28
B. papyrifera	Paper birch	12, 13, 15, 18, 21-24, 26, 27
B. populifolia	White birch	24, 26-28
Buxus sempervirens	Boxwood	
Carya cordiformis	Bitternut hickory	20, 22-30
C. laciniosa	Shellbark hickory	22, 24, 25, 27, 28, 29
C. ovata	Shagbark hickory	21-30
C. tomentosa	Mockernut hickory	20, 22, 24, 25, 27-30
Cercis canadensis	Eastern redbud	22-25, 27-30
Cornus florida	Flowering dogwood	20, 22-25, 27-30
Corylus avellana	Filbert	
C. rostrata	Hazel	15, 18, 21-29
Cotoneaster spp.	Cotoneaster	
Fagus grandifolia	American beech	20, 22-30
Gymnocladus dioica	Kentucky coffeetree	19, 21-25, 27
Ilex aquifolium	Holly	
Philadelphus gordonianus	Mock orange	4, 6-8, 12
Picea abies	Norway spruce	
P. pungens	Colorado spruce	9, 12, 13, 14
P. rubens	Red spruce	27
Pinus strobus	Eastern white pine	21-24, 27
P. taeda	Loblolly pine	19, 20, 22, 25, 28-30
Populus tremuloides	Quaking aspen	1, 2, 4, 6-9, 11, 15, 18, 21-27
Prunus americana	Wild plum	12-25, 27-30
P. emarginata	Bitter cherry	1, 2, 4, 6, 8-14
P. laurocerasus	Cherry-laurel	
P. serotina	Black cherry	11, 18-30
Psuedotsuga menziesii	Douglas fir	
Pyrus rivularis	Wild apple	1, 2, 4
Q. marilandica	Blackjack oak	16,19, 20, 22, 24, 25, 27-30
Q. muehlenbergii	Chinquapin oak	11, 16, 20-30
Q. shumardii	Texas oak	16, 20, 22, 24, 25, 27-29
Q. stellata	Post oak	19, 20, 22, 25, 27-30
Q. velutina	Black oak	20, 22-30
Rhamnus purshinana	Cascara	1-4, 6, 7, 9, 11, 12
Rubus procerus	Blackberry	

Table B-4 Flood tolerance of intolerant native plants—Continued.

[These plants are unable to survive more than a few days of flooding during the growing season without significant mortality.]

Scientific name	Common name	Range
Sassafras albidum	Sassafras	20, 22-30
Sorbus aucuparia	Rowan tree	21, 22, 27
Symphoricarpos occidentalis	Snowberry	15, 18, 21-24
Syringa vulgans	Lilac	
Thuja occidentalis	American arborvitae	22-24, 26, 27
Tsuga canadensis	Eastern hemlock	22-25, 27, 28

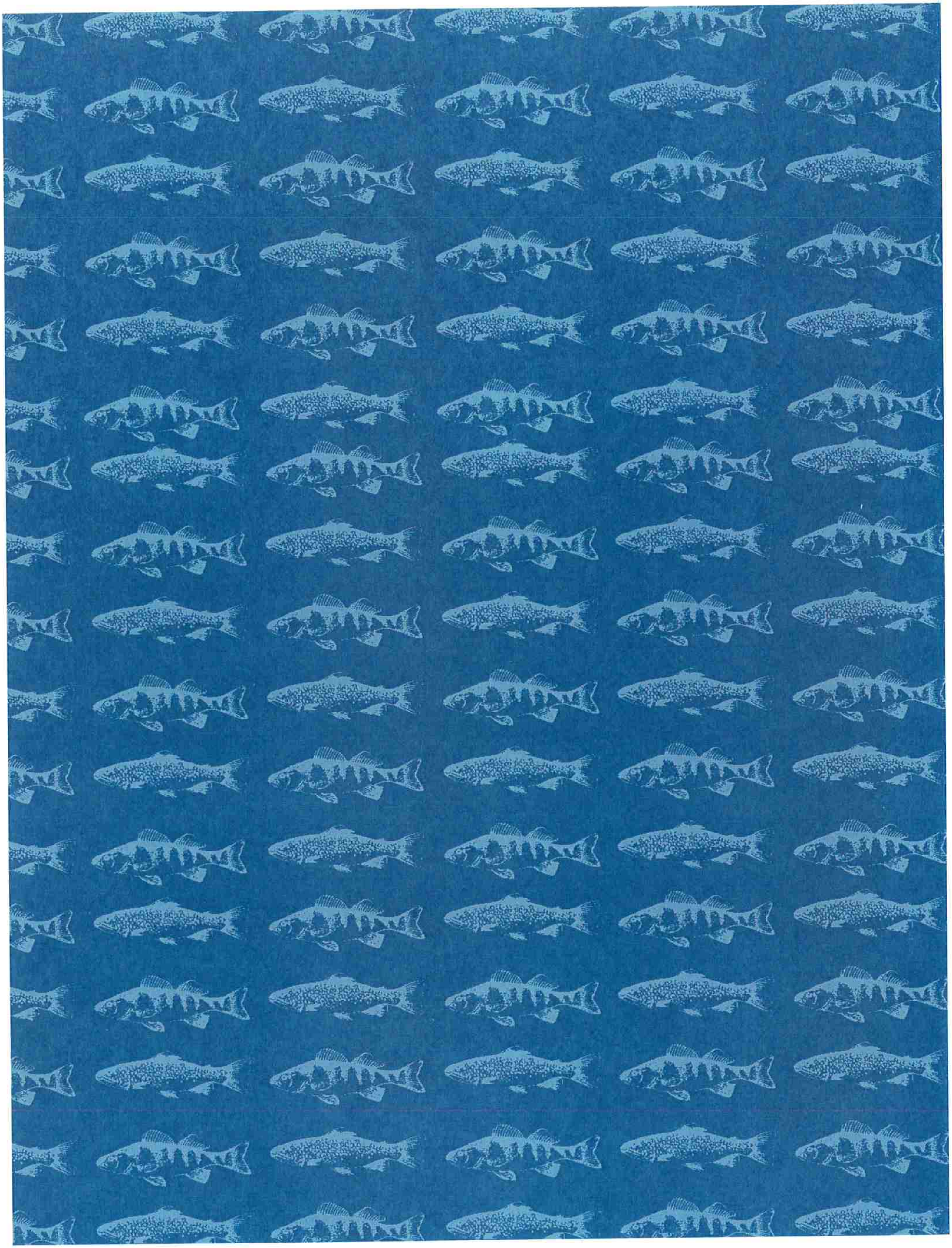
Penn State **Extension**

Management of Fish Ponds in Pennsylvania

PENNSTATE

Cooperative Extension

College of Agricultural Sciences



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About This Publication

Ponds are a common feature of Pennsylvania's landscape. Although they occur naturally in some parts of the state, thousands also have been constructed for a variety of purposes. Many were built under the technical supervision of the United States Natural Resources Conservation Service (formerly the Soil Conservation Service), largely to assist farming operations. In more recent years, the recreational uses of ponds have become more important to pond owners.

Regardless of a pond's intended use, its management can be difficult and complex. Even with careful planning, many ponds do not meet the objectives of their owners or serve their intended purposes. Fortunately, management techniques are available to help you deal with almost any pond problem.

The purpose of this publication is to provide general information about a wide variety of pond management principles applicable to Pennsylvania. It is not intended to be a complete or exhaustive guide. References are given in the text to more comprehensive publications and web pages where they are available.

Although some generalizations can be applied to pond management, each pond is unique and may require specific treatment to achieve a desired result. When the general recommendations of this publication appear to be inadequate, you are encouraged to seek additional professional assistance.

Where to Get Help with Pond Management

Assistance with pond management is available from a variety of sources. In addition to local extension offices, local offices of the Natural Resources Conservation Service (NRCS), Pennsylvania Fish and Boat Commission (PFBC), and Pennsylvania Department of Environmental Protection (DEP) may be able to advise pond owners. Often, consultants are hired to implement major pond management practices. The agencies listed below or your local Yellow Pages may be able to direct you to local pond consultants.

Sources of Assistance

PA Fish and Boat Commission
Phone: 717-705-7800
Check phone book for local number.
www.fish.state.pa.us

PA Department of Environmental Protection
Phone: 717-783-2300
Check phone book for regional office.
www.dep.state.pa.us

Natural Resources Conservation Service
Phone: 717-237-2200 (Pennsylvania office)
Check phone book for local office.
www.nrcs.usda.gov

Penn State Extension
Check phone book for local office.
extension.psu.edu/water/ponds

Developing Objectives for Your Pond

You may have a wide variety of reasons for building or owning a pond. The first and most important step of proper pond management is choosing your primary objective or use for your pond and understanding the limitations this will place on other uses of the pond. For example, small ponds today are commonly used to aesthetically enhance the landscape, but their relatively simple construction may not provide the best facilities for other activities like swimming, boating, and fishing. The importance of establishing objectives for the projected uses of a given pond cannot be overemphasized. Careful consideration of use compatibility and use priorities is essential in planning a new pond.

In dealing with an existing pond, you will need a slightly different approach. Make an appraisal, or have one made, that describes the existing pond and its potential for management. For example, if the water quality is unacceptable for trout, it would be pointless to spend a great deal of time developing a plan with a trout fishery as the objective. Recognize the limitations of the resources available, then develop objectives and plans that fall within these limitations. This will make management of the pond easier, less costly, and more satisfying and rewarding.

Ponds are frequently used in several ways to satisfy more than one objective. For example, having water available in the pond for fire protection usually does not conflict with other objectives such as swimming or fishing. Multiple-use ponds are fine as long as the uses are compatible. When conflicting or incompatible uses are desired, you must assign priorities to your objectives. For example, the objective of providing for swimming may conflict directly with the objective of having water available for irrigation. Irrigation needs may lower the water level to a point where swimming is impossible, at a time when it is most wanted. If this occurs, you must decide which objective is most important. Sometimes planning and management can eliminate or at least reduce these conflicts. This is one reason for listing and prioritizing specific objectives.

Table 1. The most common primary uses of ponds, from a survey of 557 pond owners throughout Pennsylvania.

Pond Use	Percent of Respondents
Aesthetic Beauty	45
Fishing	21
Wildlife Habitat	11
Swimming	7
Animal Drinking Water	6
Fire Protection	6
Irrigation	1
Other	3

Planning a New Pond

When deciding where to locate a new pond on your property, you should consider several critical factors. These include topography, land use, soil texture, and water supply. In some cases, these factors may limit the pond location to one site. Where these factors are equally satisfactory at several locations, appearance and convenience will play a role in site selection.

For example, a pond located near a house, where it can be observed frequently and conveniently, is safer and more desirable for family recreation. It can be used as a source of water for fire protection or for irrigating a small garden. Road access to the pond is important if it is to be used for fire protection, so fire trucks can drive to within 15 feet of the water.

The size of the pond will be determined by the site characteristics and money you want to spend on construction and maintenance. Keep in mind that small ponds are not easy to manage for fish. Normally, ponds of less than ¼ acre in surface area are too small for effective management of warmwater fish. Ponds as small as $\frac{1}{10}$ acre in surface area may be suitable for trout, however, if they have appropriate water quality.

The Pond Watershed

The area of land surrounding the pond that contributes water to it is known as the pond watershed. Understanding the pond watershed is important, because anything that occurs within this area can affect the pond. Locating a pond in an undisturbed area or minimizing disturbance and land use changes within the pond watershed are important components of managing a pond.

The ideal topography for a pond watershed is a natural depression or a broad drainage with a narrow neck at its lower end where only a short dam will be needed. The most economical site is one that will require the smallest dam and the least amount of work for the size of the pond created. Small ponds collecting runoff from large drainage areas require expensive overflow and spillway systems to handle water safely.

Soil texture must be considered when selecting the pond site. The bottom of the pond, the banks, and the earth fill placed in the dam must contain enough clay or silt to prevent seepage and make the reservoir hold water. Normally, areas that include exposed bedrock or beds of sand or gravel are not satisfactory. Anyone who is considering building a pond should have the soils and geological conditions in the area checked by a professional consultant knowledgeable and competent in making site investigations.

Water Supply

Springs, seeps, and small streams are typically the best sources of water for ponds. They usually provide cool and relatively clean water suitable for most pond uses. If an obvious water supply is not available, direct surface runoff from the surrounding land can be the primary source of water to maintain the level of a pond. The drainage area should be large enough to ensure that the combined surface runoff and subsurface seepage are adequate during even the driest years. Normally, a drainage area of 10 to 20 acres yields sufficient water for a one-acre pond in Pennsylvania.

Land use around the water supply is critical in determining the water quality of the pond. All sources of water contributing to the pond should be free of sediment, pesticides, and other forms of pollution. It is generally a good idea to establish a buffer strip of vegetation around the pond to trap sediment and keep it out of the water. Ponds also commonly suffer from excessive amounts of nitrogen and other nutrients. These nutrients often originate from animal or human waste or fertilizers from nearby barnyards, crop fields, and septic systems. Drainage from these areas should be diverted away from the pond, since too much nitrogen and other nutrients will cause excessive growth of weeds and algae.

Construction Permits

Permits for the construction of ponds or dams may be required, depending on the size of the drainage area, the height of the dam, and the capacity of the impoundment. A permit is required for the construction of any dam that impounds the runoff from a drainage area that exceeds 100 acres or provides a maximum storage capacity of 50 acre-feet of water (about 16.3 million gallons). A permit also is required for any pond with a dam more than 15 feet high, even if the pond's only source of water is a spring, a well, or a small pipeline from a stream. Permits are not required for ponds that do not exceed these specifications.

Contact your local Pennsylvania DEP office for more information and to obtain the necessary permit application. The office telephone number and location can be found in the state government pages of your local phone book.

Safety and Liability Concerns

Safety and liability are legitimate concerns of all landowners, and ponds create an additional reason for concern. Ponds may pose a downstream threat, and consequently the aforementioned permits are required to ensure proper construction.

Ponds, like any body of water, attract people. When the two come together, accidents sometimes can occur. Consider safety features when planning your pond. Remove trees, stumps, and brush that may be a hazard to swimmers. Keep the pond and banks free of rubbish, wire, cans, bottles, and other debris. After the pond is built and filled with water, mark the swimming area and post safety rules for all permitted water uses. Place warning signs at all known danger spots. If boating and swimming are permitted, consider building a dock or pier. Place lifesaving devices such as ring buoys, ropes, or long poles near swimming areas.

Although many pond owners willingly allow use of their land and water areas for varied recreational purposes, liability for accidents is a justifiable concern. To address this issue, Pennsylvania enacted a law that has as its purpose "encouraging landowners to make land and water areas available to the public for recreational purposes by limiting liability in connection therewith, and repealing certain acts." This law generally limits landowner liability, except for "willful or malicious failure to guard or warn against a dangerous condition, use, structure, or activity." Liability also is not limited when fees are assessed for recreational uses such as fishing, regulated shooting, campsite rentals, and other for-fee activities.

In addition to the protection offered by this law, most landowners carry comprehensive liability insurance on their property. Some pond owners also choose to restrict access to their pond by posting signs prohibiting tresspassing. You should consult with an attorney and an insurance agent for proper legal interpretation and protection for the specific circumstances involved with your pond.

Design

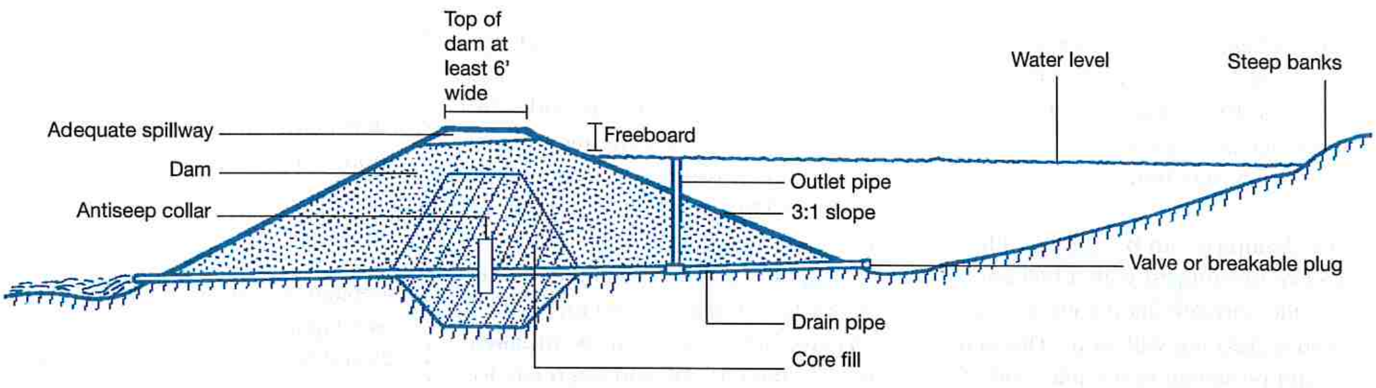
Ponds designed and constructed according to recommended standards are relatively safe, easy to manage, and fairly economical to build. Ponds constructed haphazardly are unsatisfactory and difficult to maintain. It pays to obtain information and expert advice before you start construction. This section briefly discusses the basic components of a well-designed pond.

For More Information on Pond Design, Construction, and Maintenance

Look in the U.S. Government pages of your phone book for your local Natural Resources Conservation Service office. Request Agriculture Handbook Number 590, *Ponds—Planning, Design, Construction.* This 85-page color publication gives detailed information on proper pond design and construction, including detailed illustrations.

This publication is also available online at the Penn State Extension pond website, **extension .psu.edu/water/ponds**.

Figure 1. Pond construction.



Top Width and Side Slopes of Dam

The top width of the dam depends on the height of the structure. In most cases, the dam should be wide enough to permit limited use as a roadway for vehicles. The minimum top width should be 6 feet if the dam is less than 10 feet tall. The minimum top width increases to 14 feet for a dam that is over 25 feet tall.

All earth dams should be constructed with side slopes stable enough to prevent erosion and keep the earth fill in place. In most instances, a slope of 3 feet horizontal to 1 foot vertical (3:1) on both the upstream and downstream faces of the dam will be satisfactory. Under no circumstance should either face of the dam or any excavated slope be steeper than 2:1. Proper slope is especially important in the shallow edges of the pond. Water should be at least 3 feet deep at a point 6 feet out from the shoreline to discourage growth of algae and aquatic weeds. Experience indicates that it is best to slope the banks properly at the time of construction.

Emergency Spillway

An emergency spillway is necessary to provide a safe overflow outlet for floodwater. Be sure that your pond has one. The spillway should be constructed in the undisturbed bank at one end of the dam. It should have a flat-bottomed channel large enough to handle the overflow caused by a 10- to 50-year rainstorm, depending on the size and watershed area. Pennsylvania DEP requirements must be met for dams that are large enough to require a permit (see permit section).

The spillway, including the side slopes and channel bottom, should be planted with a mixture of grass seed that will produce a thick, tough sod. Good sod prevents rushing floodwater from scouring deep ruts in the channel. The pond should not be filled with water until the sod becomes well established and the spillway is ready for use.

Freeboard

The crest, or top, of all earth dams must be higher than the normal water level to keep waves and high water from breaking over the top and cutting channels through the structure. After settling, the top of the dam for a one-acre or smaller pond should be at least 1.5 feet above the high water level or the elevation of water designed to flow through the emergency spillway (see above). The interval between the water level and the top of the dam is called the freeboard. The freeboard interval is maintained by the emergency spillway and the outlet pipe.

Outlet Pipe

A drop- or hood-inlet pipe should be installed through the dam to provide an outlet for the normal flow of water. The pipe, which governs the depth of water in the pond, should be positioned at a level about 12 inches below the bottom of the emergency spillway. The pipe should be large enough to drain the full pond down to normal water level within 24 hours after the flow through the emergency spillway ends. These pipe sizes vary with drainage area and pond storage characteristics and should be determined by an engineering professional.

Drain

A combination outlet pipe and drainpipe is highly desirable for pond management. It can be used to drain the pond for various fish management practices, pond repairs, or emergency situations.

The drainpipe can be closed with a valve or plugged with a bell-end clay tile partially filled with cement. Even a glass jug will work. The plug should be sealed in the inlet end of the pipe with asphalt cement or cement mortar. If a breakable plug is used, the pond can be drained whenever it becomes necessary, but it will be difficult to stop the flow without draining the pond completely.

Antiseep collars or drainage diaphragms should be placed around the drainpipe to prevent water from seeping along the outside of the pipe and eroding a channel through the dam. When steel pipe is used, the collars should be metal plates welded to the pipe. Prefabricated drains with antiseep collars and drain valves may be available where culverts and large corrugated pipes are sold. A drainage diaphragm consists of sand and gravel surrounding the downstream sections of the outlet pipe.

Dry Hydrants

A dry hydrant is a nonpressurized, low-cost pipe system installed along the bank of the pond at a location accessible by fire trucks to provide easy access to pond water during an emergency. It is constructed from 6-inch or larger PVC pipe that extends from at least 2 feet below the water surface through the pond embankment and above the ground next to the pond. Dry hydrants usually can be installed for less than $1,000 and often pay for themselves over time in insurance premium savings.

Dry hydrant

Construction

The construction site should be cleared of all large rocks, trees, brush, roots, and other debris. The topsoil should be removed and stockpiled for later use.

Most earth dams should have an antiseepage core built into the structure. (See Figure 1.) A trench for this core should be dug along the centerline of the dam and then refilled and packed with the best fine-grain soil available. This trench should extend the full length of the dam and be at least 3 feet deep, preferably deeper. The core is necessary to prevent seepage and to establish a good bond with the undisturbed foundation.

Pond construction

The earth fill used in the dam should be free of boulders, stumps, roots, tree limbs, and decaying vegetation. Organic material buried in the dam will eventually decay and leave channels through which water can seep and cause the dam to fail. Earth fill should be spread in 6- to 8-inch layers and compacted with a heavy roller. The top of the dam should be built about 10 percent higher than the designed height, to allow for settling.

The emergency spillway and exposed faces of the dam should be planted with a grass mixture to make the pond attractive and to prevent erosion. Trees should not be planted on the dam, because their root growth may cause leakage from the pond.

Precautionary measures at the time of construction may avoid some management problems that commonly occur after the pond is completed. Riprap should be applied to the upstream face of the dam to control wave erosion and discourage muskrats. If livestock are nearby, a fence should be constructed to keep them from tramping along the banks and polluting the water.

Selecting a Contractor

Attention to the details of construction and adherence to specifications are as important as adequate investigation and design. Careless and shoddy construction can make an otherwise safe and adequate design worthless and can cause failure of the dam. Adherence to specifications and prescribed construction methods are the responsibility of the contractor, who should have a reputation for high standards of workmanship. Your local NRCS office may be able to provide you with a partial list of local contractors experienced in pond construction. Additional contractors may be found in the telephone directory. It may prove worthwhile to go to several ponds the contractor has constructed to see if the work completed appears satisfactory and the pond owner is satisfied with the work.

The type of equipment to be used is also important. With proper construction equipment, the cost can be reduced and a safer dam constructed. The contractor should have a backhoe to conduct soils investigations at the proposed dam site and borrow area. A bulldozer can be used to clear and grub the area. If the borrow area is immediately adjacent to the dam site, a bulldozer is also satisfactory for excavating, backfilling, and placing the fill. For dams over 20 feet high, special equipment such as a sheepsfoot roller may be needed for fill compaction. As with all construction, the landowner should understand the type of work that is to be performed and regularly inspect the construction to help ensure that the contractor is doing a good job.

Construction Costs

The cost of building a pond is highly variable, depending on site conditions and specific features of the desired pond. Costs can range from several thousand dollars per acre to over $30,000 per acre for a more unique design. Although cheaper contractors may seem appealing at first, many cheaply built ponds end up costing their owners more in the long run after costly repairs are made.

Maintenance

A popular misconception is that a completed pond provides immediate benefits to the owner that last forever with little maintenance. Nothing could be farther from the truth. A pond certainly requires as much or more attention than does any comparably sized piece of land.

Many older ponds, or those that were not constructed properly, may have fallen into disrepair. They may be partially silted in, develop leaks, or have unsafe dams with trees growing on them. Repairs to ponds are possible, but you should obtain professional assistance. Consult your local NRCS office or a consulting engineer for help. If pond renovation is going to involve modifying or enlarging any dam covered under a permit issued by the Pennsylvania DEP, a written permit is required to make these changes.

Inspection

Routine inspection and frequent maintenance protects a pond, keeps it attractive, and extends its useful life. Lack of inspection and prompt repair of problems may cause more severe damage that is either irreparable or more expensive to fix.

The dam structure should be checked to ensure it has complete grass cover and has not eroded. Soil should be added and re-seeded at the first sign of erosion. Cut the grass and keep weeds, brush, and trees from growing on the dam. Trees growing away from the dam and pond embankments are usually acceptable. Check for signs of minor leaks along the dam so they can be repaired before they become more serious.

Remove floating debris that can clog the overflow pipe and emergency spillway. Also, check the overflow inlet and outlet to ensure that flow is unrestricted. Check for and repair any erosion in the spillway. Inspect and repair any fences that are used to keep livestock from accessing the dam embankment.

Be sure that any roads provided for fire trucks are maintained for the passage of heavy vehicles and are plowed following a heavy snowfall. To maximize fire protection benefits from a pond, you must ensure that fire trucks have access to the pond during all seasons of the year and that the dry hydrant is readily accessible.

Muskrat Damage

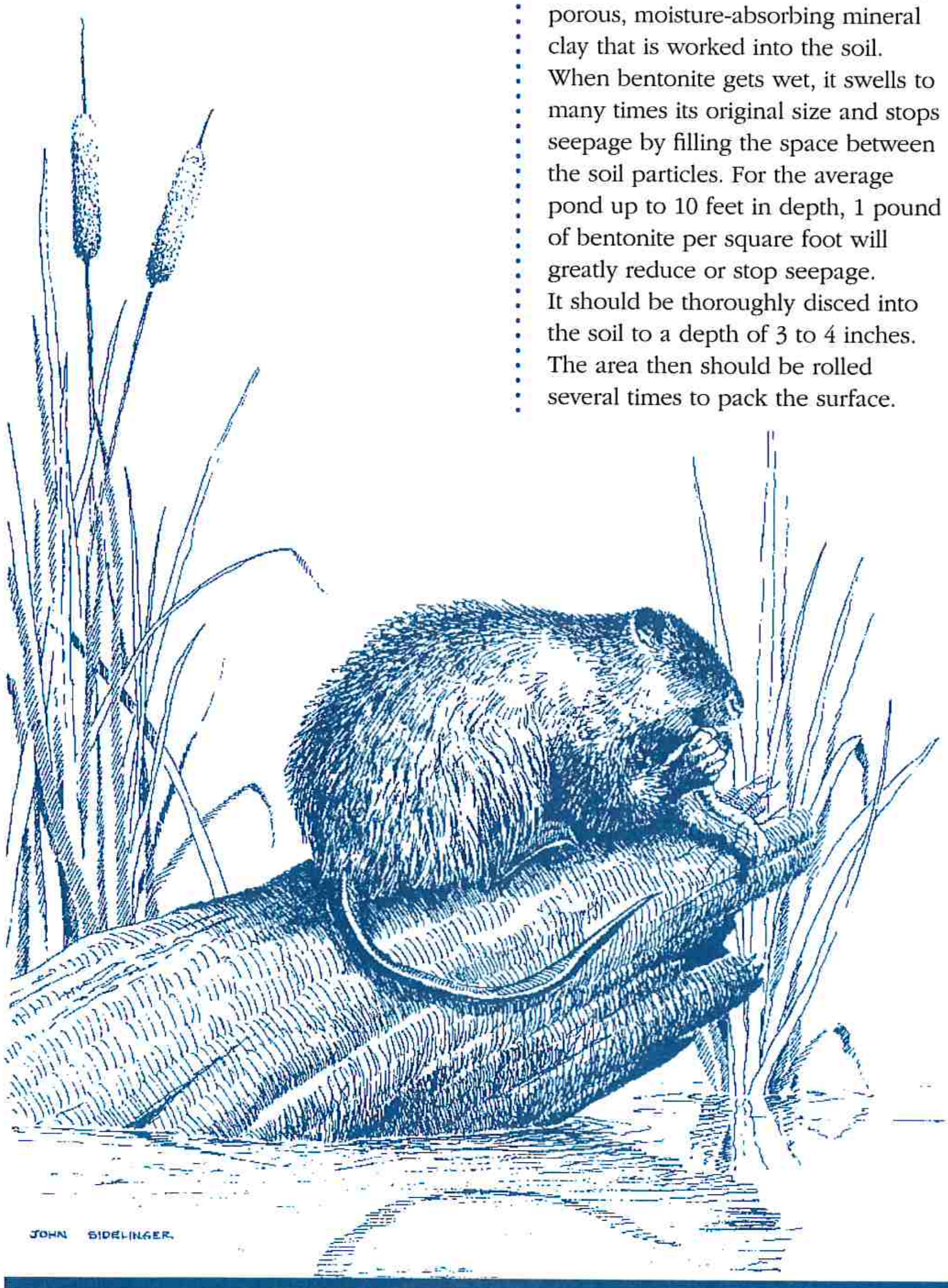
Muskrats may damage a pond by building dens in the banks. They begin burrowing 6 to 18 inches below the waterline and angle up into the bank, where they construct living quarters in dry soil above the water line.

The best defense against muskrat damage is a properly designed pond. A wide top and sufficient freeboard will make a dam relatively safe from damage. There is little danger of leaks in dams with adequate top widths, because muskrats usually will not burrow completely through. If sufficient freeboard is provided, the den usually will have enough ground cover over it to prevent a cave-in.

Despite construction precautions, muskrats are likely to take up housekeeping in even the best-designed ponds. They are especially attracted to areas of emergent and submergent vegetation such as cattails. Removal of this vegetation is one way to reduce muskrat activity in the pond.

Burrowing can be stopped by riprapping the shoreline with large gravel or small stones. These materials should be placed in a layer at least 6 inches thick, and should extend from at least 1 foot above the normal water level to at least 3 feet below it. Riprapping also protects the shore from erosion caused by waves.

Muskrats are furbearers that can be trapped legally during parts of the year. The Pennsylvania Game Law further provides that any person may kill or capture alive, at any time, any furbearing animal (except beaver) in the act of destroying personal property. Poisons legally may not be used in muskrat control, but various repellents may be used. Contact your local Wildlife Conservation Officer for further details.



Fixing Leaks

Seepage is less likely when precautions are taken at the time of construction. If leaks develop after the pond has been filled, it will be necessary to drain the pond, let the bottom dry, then apply a sealant. Leaks usually cannot be fixed without draining the pond. Before attempting any sealing, consult a soils professional to ensure that the treatment is suited to the pond conditions.

Several products are used for sealing pond leaks. One is bentonite, a soft, porous, moisture-absorbing mineral clay that is worked into the soil. When bentonite gets wet, it swells to many times its original size and stops seepage by filling the space between the soil particles. For the average pond up to 10 feet in depth, 1 pound of bentonite per square foot will greatly reduce or stop seepage. It should be thoroughly disced into the soil to a depth of 3 to 4 inches. The area then should be rolled several times to pack the surface.

Sodium polyphosphate is the name of a group of chemicals used to seal pond leaks. The chemicals are similar to some household detergents and usually are obtained in a white, granular form. Treated lumpy soils break down into fine particles that pack together and hold water better. Small channels and voids in the untreated soil fill with these dispersed particles. The result is a relatively stable, impermeable blanket over the treated area.

Ten pounds of granulated sodium polyphosphate will adequately treat 200 square feet of pond bottom. Thoroughly mix the soil to a depth of 8 inches. Apply the polyphosphate by broadcasting or drilling. Compact the treated area with a rubber-tired roller or a steel roller before filling the pond. Do not use a sheepsfoot roller.

Sodium polyphosphate works best in a limestone soil with a high silt and clay content. It does not work as well with coarse-textured soils. Bentonite works well on coarse-textured sods, but is not effective on highly acidic soils.

Leaks in an established pond sometimes may be eliminated by applying a 6-inch blanket of clay to the pond bottom. If clay is not available at the pond site, it may be transported from a nearby area. The clay should be compacted and the water should be returned to the pond as quickly as possible to prevent the clay from cracking because of excessive drying.

Dredging Pond Sediment

Ponds that are filled with sediment can be renovated, but the process is expensive. The least expensive method is to drain, pump, or siphon the water from the pond and use a bulldozer to remove the sediment. The more expensive but quicker method is to remove the sediment with a dragline. If the pond is small enough, a backhoe may be used.

A pond with a high inflow and without a drain may require a cut through the dam at a depth lower than the pond bottom to drain the water from the sediment. Drain the pond before cutting through the embankment. After removing the sediment, you may want to consider constructing a bottom drain through the cut and then repairing the dam.

Sediment removed from the pond, or "spoil," should be spread to promote drying. To prevent silt from washing into the pond or stream, place the spoil away from water bodies and establish a vegetative buffer or sediment trap between the spoil and the water's edge. Once the spoil dries, it can be permanently seeded.

If the pond receives excessive amounts of silt, implement erosion control practices in the watershed. If you do not own upstream land, a small settling basin just upstream from your pond could be built to intercept silt or debris.

Water Quality

Water quality is critical to the beneficial use of ponds, but the parameters and levels of concern will vary depending on the intended use of the pond. For example, water quality criteria are much different in ponds used for animal watering or human drinking water compared to ponds used for irrigation or fishing. Water quality also plays a critical role in determining the types and number of fish species that can live in all ponds, as well as their growth and survival rates.

Water quality is complicated by the fact that many parameters will vary seasonally and from year to year and by differences in water quality between the source and the pond. Changes in water quality are normal and acceptable provided that drastic changes do not occur in a very short time period, changes do not exceed extreme limits, and changes are not caused by pollutants that are directly or indirectly problematic.

Most ponds have not been tested for water quality, and most pond owners are unaware of the important water quality parameters for which they should be testing. This section discusses some of the most important water quality parameters for typical pond uses and describes how water testing might be accomplished.

Physical Water Quality

Temperature and dissolved oxygen

Temperature and dissolved oxygen are the most important physical water quality concerns for pond fishes. It is desirable to check these water quality parameters when they are likely to be least satisfactory (usually July through September).

Trout require cool water and high levels of dissolved oxygen to survive. They grow and survive best when water temperatures are between 55 and 60°F and can withstand only short time periods when temperatures exceed 75°F. Trout also require water that is high in oxygen content; 5 parts per million (equivalent to 5 milligrams per liter) is considered the safe minimum.

Warmwater fish, like bass and bluegill, prefer water temperatures in the 70s and 80s. They reproduce and grow well if the temperature remains in the low 70s for several weeks during early summer. The dissolved oxygen concentrations should be at least 3 parts per million (3 milligrams per liter) for warmwater fish.

Temperature and dissolved oxygen measurements must be made before deciding which fish species will be stocked in a pond. It is difficult or impossible to change the physical characteristics of pond water to make it more suitable for the types of fish you prefer.

Fish kills from a lack of dissolved oxygen or excessive water temperature occur occasionally in Pennsylvania ponds. Refer to the "Miscellaneous Troubles and Treatments" section on page 29 of this publication for more details about this problem and other causes of fish kills in your pond.

Muddy water

Muddy or cloudy water is perhaps the most common pond water quality problem. Newly constructed ponds nearly always have muddy water until grass is established around the pond. In older ponds, muddy water is aesthetically undesirable, makes swimming displeasing, reduces fish growth, and interferes with fish reproduction. It may be caused by erosion from a cultivated or unprotected watershed, by livestock wading in the pond, by wave action eroding the banks, and by the feeding action of some bottom-dwelling fish. Attempts should be made to determine the cause of the muddy water before resorting to treatment.

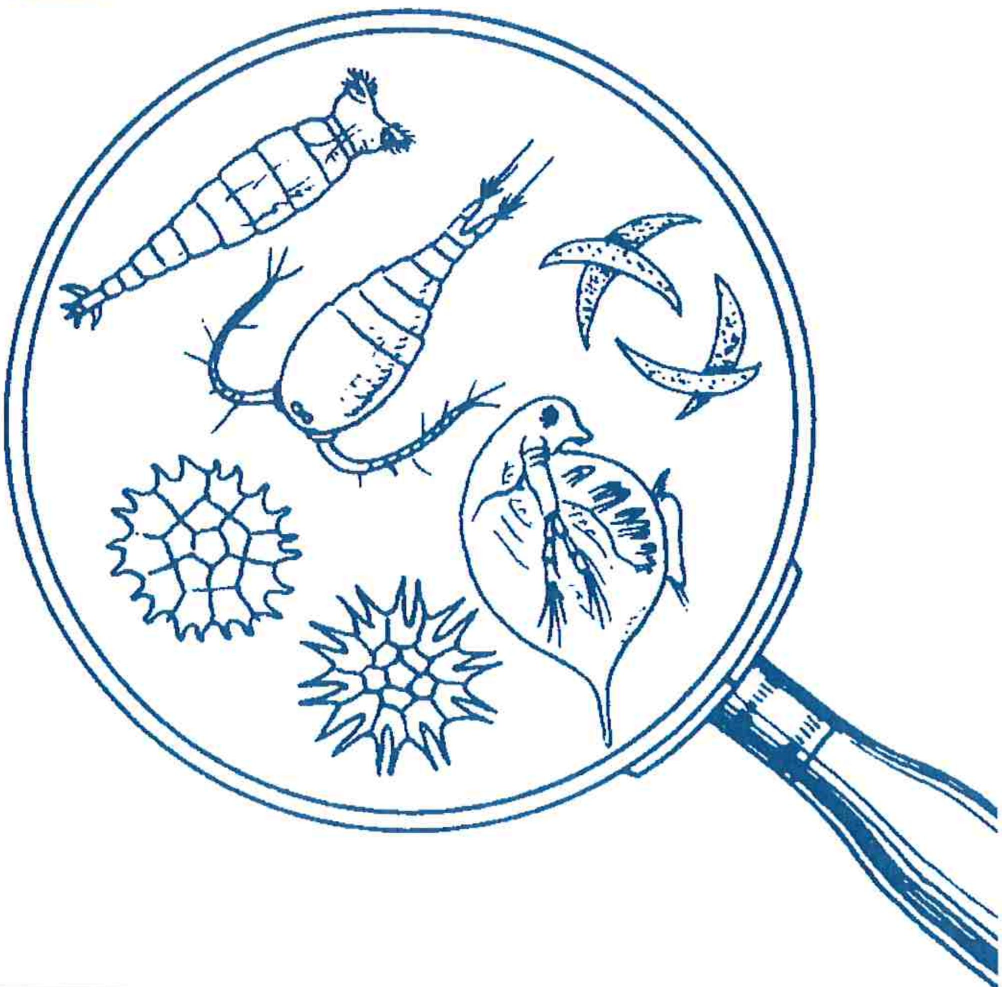
Correcting the problem may be as simple as diverting muddy surface runoff away from the pond. Muddy water from bank erosion can be corrected by adding 3 to 4 inches of stone or gravel riprap to exposed banks. Occasionally, muddy water will result from an overabundance of bottom-dwelling fish such as catfish. In this case, take steps to reduce their population through fishing, trapping, or draining the pond.

When muddy water results from the action of waves stirring up the bottom sediments, the situation may be corrected by spreading a layer of hay or straw over the bottom of the pond from the edge to a few feet from shore. This measure will have the greatest beneficial effect in shallow areas or where wave action is especially heavy. The mat prevents the waves from picking up fine sediments and provides food and cover for aquatic organisms. Introducing too much hay or straw, however, could cause oxygen depletion that could result in a fish kill.

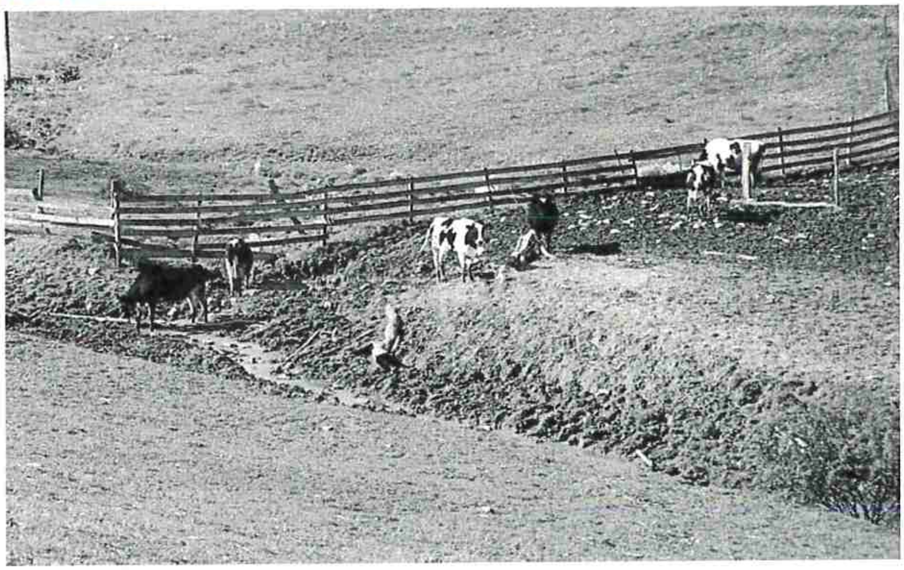
Sometimes the problem of clearing muddy water is not easy to solve, especially when colloidal particles become suspended in the water and must be precipitated by chemical action. In these cases, one of the following chemical additions may be effective in clearing the water: (1) Broadcast 1,000 pounds of ground agricultural limestone (calcium carbonate) or 740 pounds of hydrated lime per surface acre of water. This treatment should clear a pond and keep it clear for two years or more. Do not use burned lime or quicklime (calcium oxide), because it may kill the fish. (2) Broadcast 1,000 pounds of agricultural gypsum per surface acre of water. It may be necessary to repeat this treatment several times a year to keep the pond clean. (3) Broadcast 250 pounds of aluminum sulfate (commercial alum) per surface acre. Apply treatments weekly until the water clears. Both gypsum and alum treatments will lower the pH of water and may reduce yields of fish.

In some cases, cloudy water is actually caused by growth of microscopic organisms called plankton. This can be easily determined by holding a glass of pond water up to a strong light. Plankton can be observed moving around the glass of water. Plankton blooms can be reduced using chemical applications (see "Chemical Controls" section), but these treatments may reduce the overall productivity of the pond.

Plankton



Nutrient runoff



Chemical Water Quality

Chemical water quality in ponds is important not only for fish but also for other pond uses like animal watering and swimming. Changes in chemical water quality also are usually responsible for excessive growth of aquatic plants and algae. Brief descriptions of some of the most important parameters are given below.

pH

The pH of a pond is a measure of the water acidity. The pH scale runs from 0 to 14, with values less than 7 indicating acidic water and values greater than 7 indicating alkaline water. Most fish species prefer a pH in the range of 6 to 9, although values as low as 5 may be suitable for brook trout. Ponds with a pH less than 6 are common in northern Pennsylvania and may result in stunted or reduced fish populations. Ponds used for animal watering also should have a pH between 6 and 9.

Nutrients

Excessive nutrients such as nitrogen and phosphorus are a common problem in Pennsylvania ponds. These nutrients usually originate from fertilizers or animal wastes applied within the pond watershed. They cause excessive growth of aquatic plants and algae that plague many ponds during summer months. Nutrient levels in pond water can be measured by testing for ammonia, nitrate, and phosphate. Measurable amounts of ammonia or phosphate may be problematic. Nitrate levels in excess of 100 mg/L may be dangerous for animal watering.

Nutrient management techniques and best management practices such as vegetated buffer strips and limited use of fertilizers and manures near ponds are necessary to reduce nutrient levels and restore the pond ecosystem.

Hardness

Hardness is a measure of the mineral content of water, especially calcium and magnesium. Ponds with hard water have a high mineral content and are usually more fertile. These ponds are more likely to support a dense growth of aquatic plants and algae. Soft water has a low mineral content, which results in low fertility. Ponds or lakes containing soft water often have sparse vegetation and clearer water.

Hardness measures are especially important for the use of some aquatic herbicides, especially the copper compounds used for algae control. Hardness concentrations above 50 mg/L as $CaCO_3$ can interfere with the effectiveness of some of these chemicals, requiring increased dosage.

Hardness also may cause a buildup of a whitish solid known as scale in pipes, watering troughs, and plumbing that use pond water. This is an aesthetic problem that will not harm animals drinking the water.

Pesticides

Ponds that are located near farm fields, golf courses, or yards may be susceptible to pesticide pollution from surface runoff or drift during application. Many pesticides, especially insecticides, are highly toxic to all forms of aquatic life and could also be dangerous for ponds used for animal watering. Pond owners should be especially cautious about using pesticides near ponds or streams. A fish kill from pesticides may be difficult to detect, and minute amounts of a pesticide can cause losses over a long period. Read and follow pesticide labels carefully and apply them as far away from ponds as possible. Since fish are generally much more susceptible to pesticides than livestock are, fish kills are often apparent before problems occur with animals.

Aquatic herbicides

A variety of herbicides are registered for use in Pennsylvania ponds to reduce or eliminate aquatic plants and algae. The use of aquatic herbicides is generally compatible with other uses of the pond, but limiting certain uses for specific time periods may be recommended. *Always read and carefully follow product labels.* Warnings regarding other uses of the water should be taken seriously. Some herbicides, especially the copper-based algaecides, are highly toxic to fish and other aquatic life if applied in doses higher than those indicated. Others may require that swimmers or animals be denied access to the water for some period of time to allow the herbicide to break down naturally. The repeated use of copper-based algaecides also may lead to excessive concentrations of copper in pond sediments.

Acid mine drainage

Ponds in western Pennsylvania also are susceptible to pollution from acid mine drainage. Runoff from mined areas can carry high concentrations of iron, manganese, aluminum, and sulfate. Metals like iron and manganese impart an objectionable taste to water that may cause intake problems for livestock. Iron concentrations above 0.3 milligrams per liter and manganese levels above 0.05 milligrams per liter may be sufficient to reduce water palatability to livestock. Iron is also toxic to fish at low concentrations. Aluminum is toxic to fish species, especially trout, when the concentration exceeds about 0.2 milligrams per liter.

Biological Water Quality

Coliform bacteria

Coliform bacteria are a large group of many species of bacteria that can originate from animals, plants, and soil. A subgroup, fecal coliform bacteria, represent species that originate from animals, including humans. Many of the bacteria in this group are harmless, but their presence indicates the potential for disease-causing bacteria also to be present.

Some coliform bacteria are present in all ponds, but bacteria levels are highest in ponds that receive runoff containing animal or human waste. Ponds located near barnyards or septic systems are most vulnerable. High densities of waterfowl also can contribute to excessive bacteria levels. Pond water cannot be treated efficiently to reduce excessive bacteria numbers. Rather, reduction must be accomplished by removing the source of the bacteria, whether by diversion of polluted runoff or reducing direct access by animals and waterfowl.

The acceptable levels of bacteria will depend on the intended use of the pond. Ponds used for swimming should contain fewer than 2,000 total coliform bacteria and 200 fecal coliform bacteria per 100 milliliters of water. Adult livestock should not drink pond water with fecal coliform bacteria above 10 per 100 milliliters, and calves should have water free of fecal coliform bacteria.

Toxic algae

Algae growth is common in many ponds when nutrient and temperature conditions are favorable. Algae growth normally occurs between May and October, with a peak in late summer. At least six species of blue-green algae that occur in Pennsylvania may produce toxins that are harmful to animals.

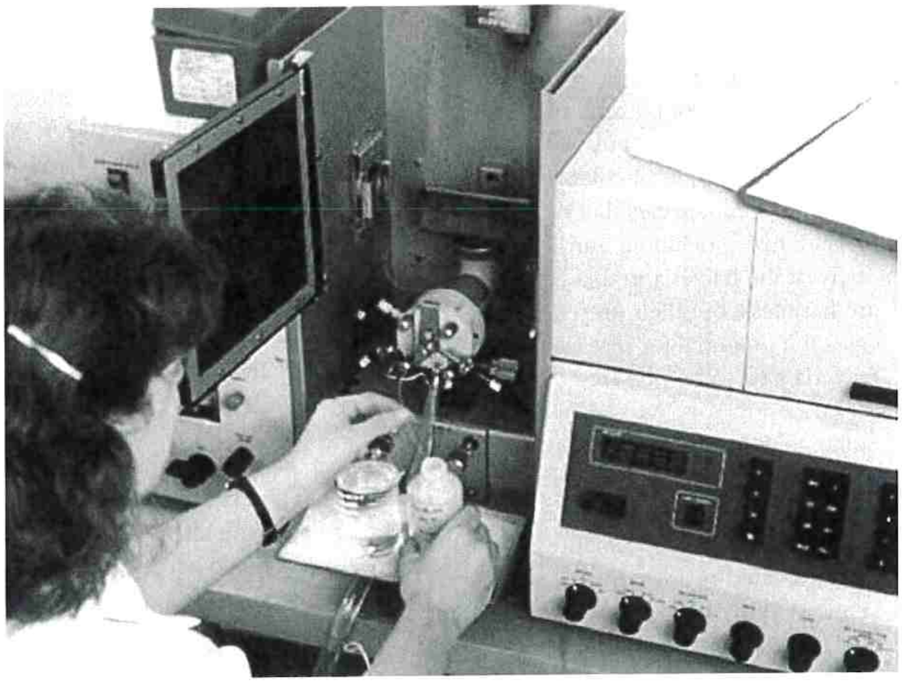
Toxic algae poisoning of livestock and pets is rare in Pennsylvania. Symptoms include muscle tremors, diarrhea, lack of coordination, collapse, labored breathing, and death. If these symptoms appear, animals should be denied access to algae-contaminated water.

Toxic algae blooms can be treated using applications of copper sulfate as described later in this publication. Again, this is a rare problem in Pennsylvania, but it should not be overlooked if symptoms appear in animals with access to a pond with algae.

Parasites

The most common parasite problem in ponds is swimmer's itch. It is caused by a small, free-swimming parasite that burrows under skin, where it dies. This causes an itching that lasts for about a week. A brisk rubdown with a towel immediately after the swimmer emerges from the water will minimize the irritation caused by this parasite. The most practical way to control these parasites is to control the snails that serve as their intermediate hosts, by draining the pond and letting it dry for several months. Stocking of redear sunfish also may be effective, since they are a natural predator of snails. No chemicals are registered for controlling snails.

Water testing



Testing Your Pond Water Quality

Your pond water can be tested easily and inexpensively for many of the parameters listed above. Temperature, dissolved oxygen, pH, ammonia, hardness, and various other water quality parameters can be tested using kits available at most local pet stores for less than $10 each.

Measurement of total coliform bacteria, fecal coliform bacteria, pesticides and metals, and identification of toxic algae would require more sophisticated testing by certified laboratories. Tests for total and fecal coliform bacteria normally cost $10 to $30 each at a certified lab. A list of certified labs by county is available from your local Penn State Extension office.

Routine water testing for pollutants that are important for your pond will help identify problems before they become too serious. The following guidelines provide some testing recommendations for the most common pond uses in Pennsylvania. They indicate only the most common pollutants that should be tested for. When doing additional testing, pond owners should evaluate the symptoms of their pond, keeping in mind the other special water quality problems described above.

Fishing—test the water frequently, especially during the summer, for temperature, dissolved oxygen, and pH. Test kits from a local pet store are adequate.

Animal drinking—test the water annually for pH, nitrate, and fecal coliform bacteria at a certified water-testing laboratory.

Swimming—test the water annually for total and fecal coliform bacteria at a certified water-testing laboratory.

Penn State recently developed a pond and lake water testing program. Contact your local Penn State Extension office to obtain a pond and lake water testing kit. Costs for testing range from $42 to $70.

Pond Fisheries Management

Whether for fishing or for aesthetic enjoyment, most pond owners are interested in developing and managing a pond fishery. The success of fish in a pond depends on the water quality, the pond's construction, and the management of the fish populations. The following sections give some guidelines for the stocking and management of some common fish species in Pennsylvania ponds.

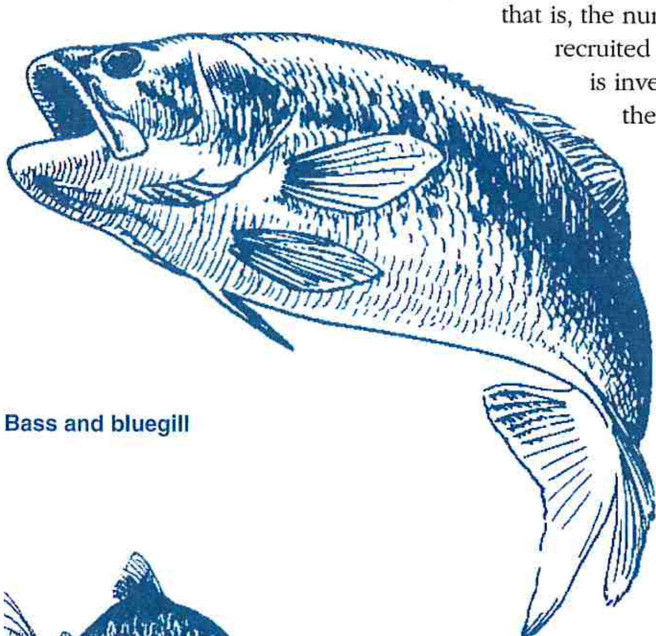
Warmwater Versus Coldwater

Ponds may be stocked with warmwater fish such as largemouth bass and bluegills, or with coldwater fish such as trout. The decision of which type of fish to stock is determined primarily by the temperature regime of the pond and the desire of the pond owner. Other water quality factors such as pH may be important to fish survival and reproduction. Consult the water quality section of this publication for more information about other water quality concerns for fish.

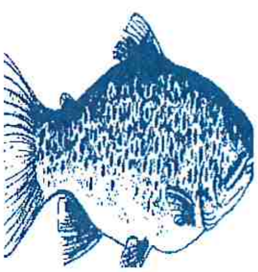
Coldwater fish like trout grow and survive best when water temperatures are 55 to 60°F. Trout may be able to withstand temperatures of 80°F for a few hours, but long periods with temperatures exceeding 75°F will cause death. Many ponds get too warm during the summer months to support trout, but they may still support a put-and-take trout fishery during cooler months. Most ponds in Pennsylvania are better suited to the temperature requirements of warmwater species like bass and bluegill. These species will grow well when water temperatures remain above 80°F for several weeks in the summer.

Warmwater Pond Management

Many fish species combinations have been tried in small artificial ponds, but largemouth bass and bluegills have been the most successful in all parts of the country. Pennsylvania experiences with largemouth bass and bluegill sunfish range from outstanding successes to complete failures. The difference is in the management. Recent investigations at Mansfield University of Pennsylvania have confirmed that this species combination is capable of providing excellent sportfishing in Pennsylvania.



Bass and bluegill



Basic ecology

Largemouth bass spawn the first spring that they reach 9–10 inches in length and the water temperature reaches 60°F. Bluegills spawn at a younger age than bass, but not until later in the summer when the water temperature reaches 67 to 80°F. Unlike bass, bluegills may spawn several times during the summer in fertile ponds if they are not too crowded.

Bass feed effectively on bluegills as large as one-third their own body length. Although bass guard their eggs and fry, bluegills prey upon them in a density-dependent manner; that is, the number of young bass recruited into the population is inversely proportional to the number of bluegills present. Thus, bass and bluegills control each other by their predatory habits. If bluegills are too numerous, they can totally eliminate bass reproduction, resulting in elimination of bass from the pond. In the absence of bass predation, bluegills become overcrowded and stunted. When bass are able to spawn successfully, bluegills will be adequately controlled. When bass become too dominant, very few bluegills survive their predation and the bass become crowded and stunted.

Population structures

Bass are often stocked alone in farm ponds in Pennsylvania. The result is a self-sustaining population of small bass. In bass-only ponds, the fish stop growing, regardless of age, at lengths from 9 to 12 inches, depending on the fertility of the pond. Very few small bass and no large bass are present in bass-only ponds.

A population that contains about 3 pounds of bluegills for every pound of bass is bass-crowded and results in relatively slow-growing bass but very large bluegills. The adult bass in this situation will be larger than in the bass-only pond because of the forage provided by the bluegills when they spawn, but still rather small because nearly all the young bluegills produced will be eaten soon after they hatch. The few bluegills that survive predation will grow very rapidly because the invertebrate food supply will be divided among relatively few individuals. The bass-crowded condition provides excellent bluegill fishing. Many bass will be caught, but few will be larger than 2 pounds.

A community containing about 8 pounds of bluegills per pound of bass has relatively few large bass present, but a more equal representation of different size classes than in the bass-crowded situation. The bluegills are crowded, and few will exceed 6 inches in length. This condition provides a great deal of bass forage and allows them to achieve their maximum growth potential. Bass in Pennsylvania ponds like this often grow a pound per year, resulting in real trophy fishing.

Table 2. Average bass and bluegill size in ponds.

	Years after stocking				
	1	2	3	4	5
Bass					
Length (inches)	8	10	12	14	15
Weight (ounces)	5	10	15	20	24
Bluegill					
Length (inches)	5	6	7	8	8
Weight (ounces)	2	4	6	7	8

Stocking bass-bluegill ponds

When small bass and bluegills of the same age were stocked simultaneously in Alabama, balanced populations always resulted. When this stocking strategy was followed in the North, the result nearly always was a stunted bluegill population and a bass population unable to spawn successfully. Research at Cornell University showed that to achieve successful bass-bluegill populations in northern states, the initial stocking must consist of bass that are at least 1 year older than the bluegills. This can be achieved by stocking yearling bass 1 year ahead of yearling bluegills or combining 2-year-old bass (over 6 inches) with yearling bluegills less than 2 inches long. Researchers currently believe that the proper number of fingerling fish to stock is 100 bass and 200 to 500 bluegills per surface acre. This stocking strategy has been shown to be successful in Pennsylvania ponds.

Bass and bluegill fingerlings usually grow quickly during the first few years after stocking (Table 2). Actual growth rates will vary considerably depending on food availability, population structure, and many other pond characteristics. The numbers in the table above are given only as broad averages and should not be expected in any given pond.

Pond owners in Pennsylvania commonly stock their ponds with adult fish obtained from other ponds. At least 6 bass over 10 inches and 100 bluegills over 5 inches should be stocked per pond, or per acre in ponds larger than 1 acre. This stocking strategy has been very successful. Properly stocked ponds should result in balanced populations that will become bass-crowded if the ponds are not fished. Removal of bass (and their predation on the bluegill population) allows the bluegill population to increase. Excess harvest of bass by angling will shift the population toward the bluegill-crowded condition. In this case, bluegills eventually become so numerous that the few remaining bass are unable to spawn successfully and the abundant bluegill are stunted in their growth.

Determining the bass harvest

Little was written about the possibility of bass overharvest before 1970, possibly because of the slowly changing notion that fisheries must be consumptive to be successful. Today, nearly all biologists working with largemouth bass recognize overharvest as a chief reason for unsuccessful bass-bluegill ponds. Regulation of bass harvest is applied to maintain an adequate bass population which, in turn, regulates the abundance of small bluegills. The remaining bluegills then grow to a harvestable size while converting forage biomass in smaller bluegills to valuable bass flesh. In most small ponds under private ownership, the fishing can be closely monitored. As a result, a pond manager can easily implement a quota to regulate numbers of bass removed from the pond and stop bass harvest when the quota is reached. A 15-inch size limit, in addition to a quota, appears to be necessary to protect bass in small ponds. Since enforcing a quota on public lakes with uncontrolled access is very difficult, if not impossible, the bass harvest is controlled with a size limit.

Based on research from other states, it appears that a proper quota for bass harvest in Pennsylvania is about 30 percent of the adult bass per year. If this figure is exceeded, the population shifts toward crowded bluegills, and if the harvest is less than 30 percent, the population shifts toward crowded bass. If the bass harvest exceeds 50 percent per year, irreversible bluegill crowding is likely to occur.

Bass-bluegill ponds in Pennsylvania will contain 50 to 300 pounds of fish per acre, depending on the fertility. Suppose a 30 percent quota of bass is sought for a pond of average fertility containing 250 pounds of fish per acre. The ratio of bass to bluegills is defined by the population structure. A pond containing small bass and large bluegills would contain approximately ¼ bass and ¾ bluegills, by weight.

Therefore, the total weight of bass in the pond would be: 250 x 0.25 = 62.5 pounds. The average size of the adult bass in this bass-crowded pond would be about 1.5 pounds. Thus, the annual bass quota would be: 62.5 pounds of bass ÷ 1.5 pounds each x 30 percent = 13 bass per acre of pond per year.

In a bluegill-crowded pond, the proportion might be $1/9$ bass to $8/9$ bluegills, or only 28 pounds of bass in our example of 250 pounds of fish. The average adult bass is probably 3 pounds. The annual harvest quota is then calculated as: 28 pounds of bass ÷ 3 pounds each x 30 percent = 3 fish per acre per year.

Calculating these harvest rates reveals the importance of carefully monitoring the number of bass removed from farm ponds, especially small ponds. Catch-and-release fishing for bass and fishing bluegills for an occasional meal of fresh fish is appropriate management for small warmwater ponds. It should be remembered that even with catch-and-release fishing, some of the released bass may die. Those fish must also be counted in any harvest quota for bass.

The pond manager can fine-tune the fish populations by regulating the bass harvest to provide the desired type of fishing. Increasing the bass quota will make the bluegills more numerous, but smaller, and the bass fewer, but larger. Decreasing the quota will provide larger bluegills and smaller bass. Satisfactory fishing is defined differently by different people. Catching many small bass rather than occasional large ones may be desirable for one angler but not another. Bass-only ponds do not provide satisfactory fishing for most anglers because of the small size of the fish caught. Research at Mansfield University has shown that stocking of adult bluegills in these ponds can successfully establish bluegill populations. Bluegill-only populations and ponds that are irreversibly bluegill-crowded are generally drained to remove all the fish and then restocked. It may be possible, however, to obtain enough adult bass from another pond to establish bass in bluegill-only populations, especially in very small ponds.

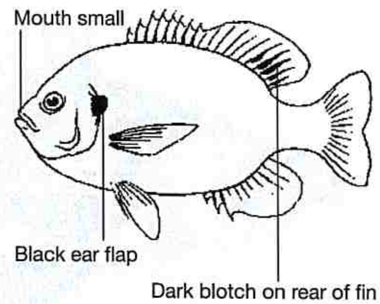
Other fish species for warmwater ponds

Many pond owners stock several species of fish in their ponds; in fact, some people stock every fish they can get their hands on. This practice is undesirable, because the resulting species interactions make management much more difficult and unreliable. However, some other fish show promise as candidates for pond management. Many ponds in Pennsylvania contain bullheads. While they do not seem to interfere or compete with bass or bluegills, bullheads can become stunted and overcrowded in ponds containing few bass. In some bass-crowded ponds, bullheads have been eliminated by bass predation. If bullheads are desired, they should be stocked.

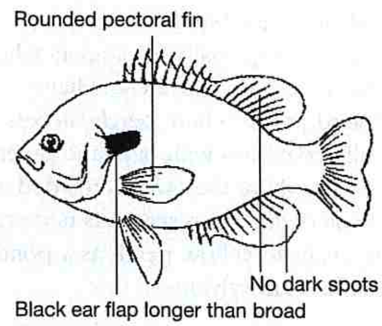
Some biologists recommend stocking golden shiners or fathead minnows with bass. These forage species give bass a good start in a pond, but experience has shown that such forage fish are soon eliminated by bass predation. The forage fish never grow large enough to avoid being consumed by the bass, and eventually the population of these fish declines to a very low level.

Other sunfish species are not as satisfactory as bluegills for pond stocking. The common and colorful pumpkinseed does not grow as large as the bluegill, and the redear, popular in the South, cannot reliably survive Pennsylvania winters. Green sunfish should be avoided.

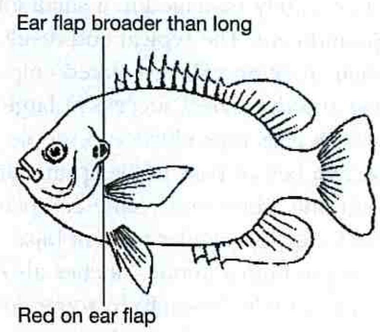
Bluegill



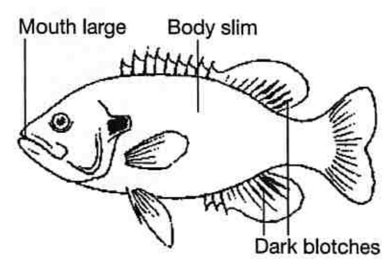
Redbreast sunfish



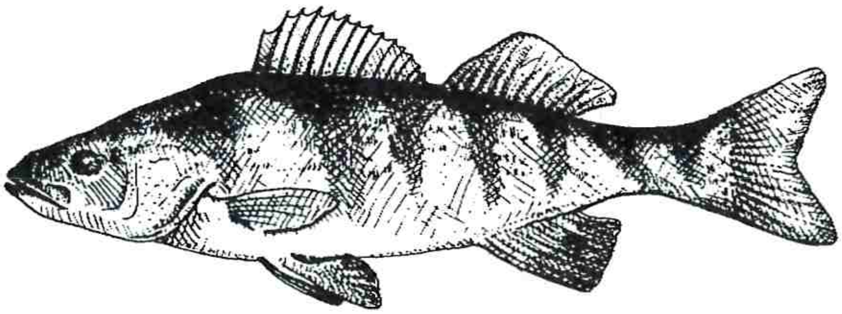
Pumpkinseed sunfish



Green sunfish



Yellow perch



Yellow perch may be a suitable substitute for bluegills as a forage for bass, especially for anglers who like to icefish. Researchers have found ponds where perch successfully coexisted with bass and other ponds where they were crowded and stunted. Further research is necessary to evaluate yellow perch as a pond fish in Pennsylvania.

Although both white and black crappie are often of interest to pond owners, these species seldom are successfully managed in a small impoundment. The typical end result of their stocking will be stunted crappie and decreased success of largemouth bass reproduction. Crappie spawn before bass in the spring, and both the adults and young compete for food with similar sizes of bass. Crappie below about 7 inches also compete with bluegills to some degree. Because of these characteristics, introducing crappie into farm ponds is discouraged.

For several reasons, it is generally more economical to manage ponds for warmwater species than for coldwater species.

- Warmwater species are not as exacting in their water quality requirements as trout. All ponds that will support fish life permanently will support warmwater species, but not necessarily trout.
- Most properly managed warmwater species develop a self-sustaining population. Trout usually must be maintained through periodic restocking.
- Warmwater species are generally more tolerant of herbicides for aquatic vegetation control when the herbicides are used correctly. Trout are very sensitive to copper sulfate, a herbicide often used for algae control, and may be killed by the chemical.

Nevertheless, many pond owners are still interested in managing their pond as either a seasonal or annual trout fishery. Tips for managing trout in ponds are discussed in the next section.

Management of Trout Ponds

Trout occupy a highly favored position among Pennsylvania game fishes. They are generally easy to catch, making them an outstanding sportfish, and they make great table fare. Water temperature constraints normally determine whether a pond owner desiring trout should implement put-and-take versus year-round trout management.

Put-and-take versus year-round

In Pennsylvania, most ponds are able to support trout in spring and fall, and some pond owners may choose a put-and-take trout program. This is not necessarily efficient, economical, or recommended for most ponds, but it is discussed here for completeness. Such a program is governed more by economics than by biology. The pond owner acquires trout of an acceptable catchable size, stocks them in the pond, and begins to fish for them immediately. The number of fish stocked should not exceed the number needed to provide the desired level of sportfishing until the water temperature is no longer suitable for trout (usually sometime in June). Under such a program, it is desirable to harvest as many of the stocked trout as possible if they cannot survive through the summer.

The pond owner should bear in mind that adult trout will compete for food with other insect-eating fish (including young bass) present in the pond. This is true even though the trout will be present for a relatively short period of time. Artificial feeding of trout may alleviate the competition for natural food, but care must be exercised so that artificial feeding is not overdone. Excessive amounts of feed could result in water quality deterioration. Minnows should not be stocked as a food source for trout.

Some ponds in Pennsylvania can support a year-round trout fishery. These ponds may be supplied by a groundwater spring that supplies cool groundwater even during the summer months or may be small and shaded during most of the day. When free from competition with other species, trout thrive in an insect-rich pond that remains cool during the summer.

Species of trout

Brook trout and rainbow trout are best suited for small lakes or ponds. This is especially true if the pond owner wants to establish a permanent fishery of trout only, but also true if occasional put-and-take trout fishing is an objective.

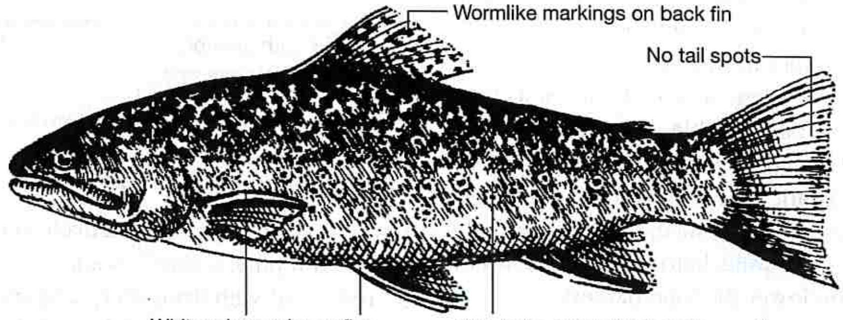
Brook trout are easier to "fish out," making them a good option for a put-and-take trout pond. Rainbow trout are generally considered to be more spectacular fighters. A mixture of these two kinds of trout can be stocked in a pond to provide variety in fishing. If both species are stocked, they should be about the same size so one group will not prey heavily upon the other. Brown trout are generally more difficult to catch than brook or rainbow trout.

Stocking year-round trout ponds

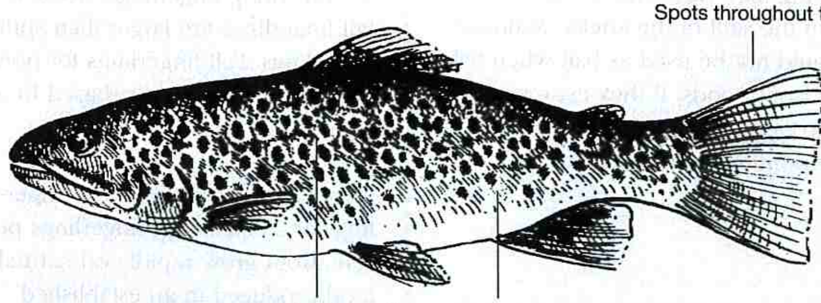
Either spring fingerlings (2 to 3 inches long, 2 to 3 months old) or fall fingerlings (5 to 6 inches long, 7 to 8 months old) may be used in stocking trout ponds. Both types reach catchable size about the same time; that is, in the spring following stocking. However, results with spring fingerlings are much more variable and unpredictable than with fall fingerlings.

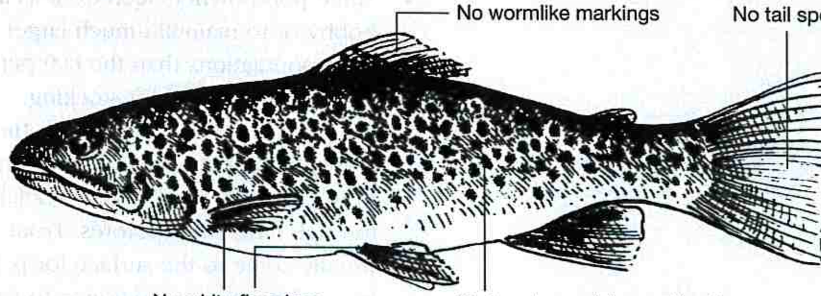
When trout are obtained from commercial hatcheries, fall fingerlings usually provide considerably more catchable-sized trout per dollar than spring fingerlings. It is economically unwise to purchase trout longer than about 6 inches for pond stocking, unless they are to be fished out within a year.

Brook trout



Rainbow trout





A stocking rate of 600 fall fingerlings (or 2,000 spring fingerlings) per surface acre of pond should produce the best yield and satisfactory growth. Highly productive trout ponds on limestone soils may accommodate 700 fall fingerlings per acre, while ponds located on more acidic soils probably will support fewer fall fingerlings per acre.

To minimize losses, stock trout only in the cool or cold weather of spring and fall. If the weather is warm, ice should be packed around the transporting tank to keep the water below 55°F. Do not put ice made from chlorinated water in with the fish, because chlorine is toxic to fish. Oxygen-producing tablets, available in sport or bait shops, may be used when transporting trout. Do not release the fingerlings near the overflow structure of your pond.

Fishing trout ponds

Natural losses of trout will reduce the population of unfished ponds by 90 percent in two years. For this reason, pond owners should harvest as many trout as possible during this period. The time interval between stocking and initial harvest is a matter of owner preference, but the longer the owner waits before harvesting trout, the lower the total harvest.

Pond trout generally are much easier to catch in spring and fall than in the summer. Successful methods of fishing may vary with the season and with the skill of the angler. Minnows should not be used as bait when fishing trout ponds. If they escape and reproduce, they may eventually ruin the pond for trout production.

Table 3. Average trout size in ponds after stocking as fall fingerlings (5–6 inches).

	After 1 year	After 2 years	After 3 years
Length (inches)	10	12	14
Weight (ounces)	8	14	22

Restocking and feeding trout

Because trout have a relatively short survival time, a pond should be restocked with trout every 2 years to maintain adequate fishing. Fall fingerlings should always be used for restocking. "Holdover" trout are less likely to prey on them than they are on spring fingerlings, because fall fingerlings are larger than spring fingerlings. Fall fingerlings for pond restocking must be purchased from commercial sources.

At stocking rates of 600 fall fingerlings or 2,000 spring fingerlings per acre, trout grow rapidly on natural food produced in an established pond. Supplemental feeding may increase the growth rate an inch or two per year, but it is expensive.

Some pond owners feed trout as a hobby or to maintain much larger trout populations than the 600 per acre recommended for stocking. Feeding is one way to increase the fishing potential, especially in a small pond. Pelleted trout food is available through farm supply stores. Trout usually come to the surface for pellets and become conditioned to feeding at the same area of the pond.

Use only as much food as the trout will eat immediately. Excess food will settle to the bottom and decompose, removing dissolved oxygen from the water and possibly causing fish kills. Feeding should be done only in ponds that have a year-round supply of good water.

Growth, survival, and spawning

Brook and rainbow trout in ponds grow at about the same rate, although growth may vary considerably from one pond to another. Growth generally slows as fish become older, and usually is faster in summer than in winter. Growth may be slower in newly constructed ponds, since aquatic insect life may be limited, and in soft (acid) water. Table 3 illustrates average growth rates.

In general, it is best not to fertilize trout ponds. A single application of 10-10-10 fertilizer at 300 pounds per acre may hasten the establishment of a natural food supply in newly constructed ponds. Heavier fertilization may harm the trout and cause summer or winter fish kills.

Pond trout survival rates depend on the size of fingerlings stocked and many environmental factors. Survival rates may vary considerably from pond to pond and from year to year. Larger fish generally have better chances for survival. During the summer immediately following stocking, the survival rate of spring fingerlings in ponds averages 30 percent. In each subsequent year, the rate averages about 50 percent. At the end of the second year, only 5 to 10 percent of the original number remain. Few trout remain in a stocked pond after 3 years. Fish death from natural causes is a gradual and continuous process, even though dead fish seldom are seen.

Total poundage of trout in a pond at any time following stocking depends on two opposing processes: growth, which increases poundage, and death or fish losses, which reduce the poundage. Total poundage rises rapidly the first year after stocking, then decreases. In an unfished 1-acre pond stocked with 600 fall fingerlings or 2,000 spring fingerlings, an average of 230 trout will remain after 1 year. They will weigh a total of about 110 pounds. Two years later, only 45 trout will remain and they will weigh a total of about 41 pounds.

Most ponds lack suitable spawning sites, so trout rarely reproduce in Pennsylvania ponds; however, they may go through the act of spawning. A suitable spawning site for trout is a gravel area through which well-oxygenated water circulates during the incubation period. In ponds with exceptionally large, heavily flowing springs, limited trout reproduction may occur naturally or may be achieved by development of gravel beds in suitable locations. Reproduction is usually limited to brook trout because rainbow and brown trout require tributary streams for spawning. So far, no economical method has been developed to achieve adequate natural reproduction in the average spring-fed pond.

Sources of Fish for Stocking Ponds

Ponds may be successfully stocked with fish caught from other water. If this is done, it must be in accordance with all state regulations. Both warmwater and coldwater fish species also can be purchased from dozens of private commercial hatcheries throughout Pennsylvania. A list of licensed private fish hatcheries showing the addresses and the species each has available can be obtained from the Pennsylvania Department of Agriculture. Hatcheries should be contacted directly for other specific details.

For a list of commercial fish hatcheries, visit the Penn State Extension pond website at **extension.psu.edu/water/ponds**.

Once the pond, either warmwater or coldwater, and its fish populations are established, it is important to regulate activities involving the pond. Regulations probably constitute the pond owner's most valuable management tool.

Regulations and Laws Affecting Fish Ponds

The Pennsylvania Fish and Boat Commission has the chief regulatory and legal responsibility for fishery resources of all waters in the state. For the most part, anglers over the age of 16 are required to have a valid Pennsylvania fishing license to fish in any Commonwealth water, including privately owned ponds. The Fish and Boat Code does contain a provision allowing landowners and their families to fish in private ponds on their own lands without a license. This license exemption does not apply to guests, employees, temporary residents, or tenants on the land.

A separate statute applies to "farm fish ponds," which are defined as artificial ponds on a farm holding "water, the source of which is wholly within the limits of the farm." On farm fish ponds, the resident owner or lessee of the farm, members of his or her family, and persons who are regularly employed on the farm, all of whom must permanently reside there, are exempt from license requirements and other fishing regulations (including season, size, and creel limits) when fishing in the farm fish pond.

In addition to existing state regulations, pond owners should carefully manage the harvesting of fish from their pond. Ponds have a finite capacity to produce fish biomass. The amount that can be harvested by anglers is controlled and determined by the amount of fish production in the pond, and the two processes must be in balance. The need for pond owners to regulate harvest cannot be overemphasized. State regulations provide pond owners with a framework for effectively managing the harvest of the pond's fish resources, but owners may establish their own regulations and restrictions on fishing, as long as they are not more liberal than the state laws. Enforcement of personal regulations is the responsibility of the pond owner. Pond owners especially might want to consider additional regulations for ponds with a great deal of fishing pressure.

If fish are transported from a pond during a closed fishing season, the pond owner must provide a written statement including the date, place, and by whom the fish were taken; the number and species of fish; the name and address of the person transporting the fish; and the date they were transported.

Special permits

Regulations require pond owners to obtain appropriate permits before using traps, seines, or chemicals for weed or fish control. Propagation permits are required for fish culture in ponds as a whole or in cages. A permit is also necessary to operate a fee-fishing pond. Applications for permits may be obtained from regional offices of the Pennsylvania Fish and Boat Commission or at its home page (**www.fish.state.pa.us**).

Remember:

State regulations relevant to fish ponds are always subject to change. Consult your local Pennsylvania Fish and Boat Commission office or visit the commission's web page for up-to-date regulations.

Aquaculture

Aquaculture is the husbandry of aquatic organisms. Fish culture, a specific form of aquaculture, varies from raising baitfish for sportfishing to producing fish for human consumption. Certain kinds of fish culture can be conducted without interfering with other planned pond uses, while others require the pond to be dedicated to aquaculture.

Commercial fish culture, like any other commercial venture, has rewards and risks. Both should be investigated thoroughly by a prospective entrepreneur. Persons contemplating commercial fish culture will need a basic understanding of biology and water chemistry, as well as business skills. Fish culture has too many ramifications for detailed treatment in this publication.

For more information on aquaculture, contact:

Pennsylvania Department of Agriculture
2301 North Cameron Street
Harrisburg, PA 17110
Phone: 717-787-4737
agriculture.state.pa.us

For applications to start a fish culture operation, contact your local Pennsylvania Fish and Boat Commission office or download the application from its home page, **www.fish.state.pa.us**.

Aquatic Plants and Algae

Aquatic plants and algae occur to some degree in most Pennsylvania ponds. Under normal circumstances, they are beneficial to the pond ecosystem in many ways. They take up carbon dioxide and release oxygen during photosynthesis, and they provide food and cover for a variety of microscopic organisms, fish, amphibians, and wildlife. In many cases, however, pond plants and algae can become overabundant, creating unwanted or undesirable pond conditions.

The desirable level of aquatic plant and algae growth depends on the point of view of the pond user. For example, a pond that is overrun with plants and algae may be desirable to waterfowl enthusiasts for attracting ducks and geese, while the same pond would be displeasing for swimmers who want clean, clear water. Pond owners need to evaluate their objectives when deciding how to manage their pond's aquatic plants and algae.

Pond plants can be either planted or reduced to the level desired by the pond owner. In recent years, the aquascaping business has grown in response to pond owners interested in creating aquatic "gardens." Several commercial nurseries have opened to provide many types of aquatic plants, and many can be accessed on the Internet. More often, pond owners are interested in controlling or eliminating unwanted or overabundant plants and algae, especially during the summer months. This is a complex subject that is given proper detail in other publications. The remainder of this section gives a brief overview of identification and control of aquatic plants, along with references to these more detailed resources.

Identification of Plants and Algae

Algae

Algae are the most common and widely distributed of all aquatic plants. They occur in some form in all ponds. Algae can be separated into three categories, including plankton algae, filamentous algae, and attached-branched algae. Plankton algae are the most important plants in all natural bodies of water because they serve as the beginning of food chains that support higher forms of aquatic life. Plankton algae may "bloom" under the right conditions, turning the pond water brown, yellow, pea-soup green, or even red.

Filamentous algae are especially familiar to many pond owners in Pennsylvania. They usually occur in large floating masses, filaments, mats, or scums that can quickly cover the pond surface.

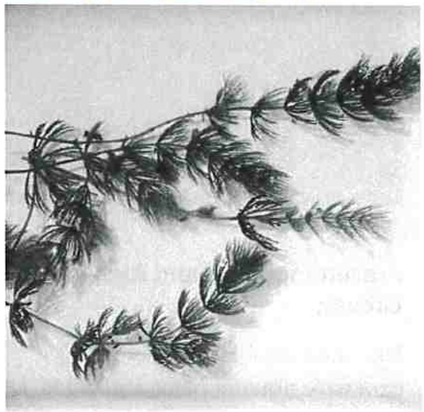
Attached-branched algae are often mistaken for an aquatic plant. They have an erect central main stem with whorls of branches at various intervals. Chara and Nitella are types of attached-branched algae that have a strong, musky odor and are sometimes encrusted with rough, gritty, calcium deposits.

Algae

Aquatic plants

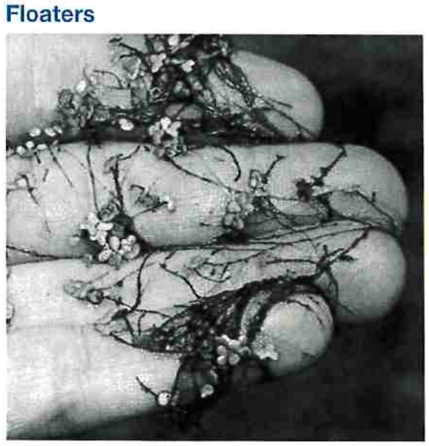
Flowering aquatic plants usually are divided into submergents, emergents, and floaters, based on their growth characteristics. Submergent plants generally grow underwater (except at flowering time) and are attached to the muddy bottom. Flowers protrude a short distance above the surface, where wind and insects aid in pollination. Pondweeds, common elodea, coontail, and watermilfoils are among the common submergents. Emergent plants grow along the shoreline in shallow water and are sometimes called marsh plants. The most common emergents include cattails, arrowheads, rushes, reeds, and sedges. Floating plants have much of their structure floating on the surface of the pond, but most are rooted to the bottom. Common attached floaters are waterlilies, watershield, and spatterdock. Other floaters such as duckweed have small dangling roots that obtain their nutrients directly from the water.

Submerged aquatic vegetation



Emergent plants

Floaters



Identification of the plants and algae in your pond will be necessary before they can be properly managed. Dozens of aquatic plants and algae occur in Pennsylvania ponds. Specific identification can be very difficult and is beyond the scope of this publication. For help in identifying specific plants and algae, consult the following resources:

Aquatic Plant and Algae Identification

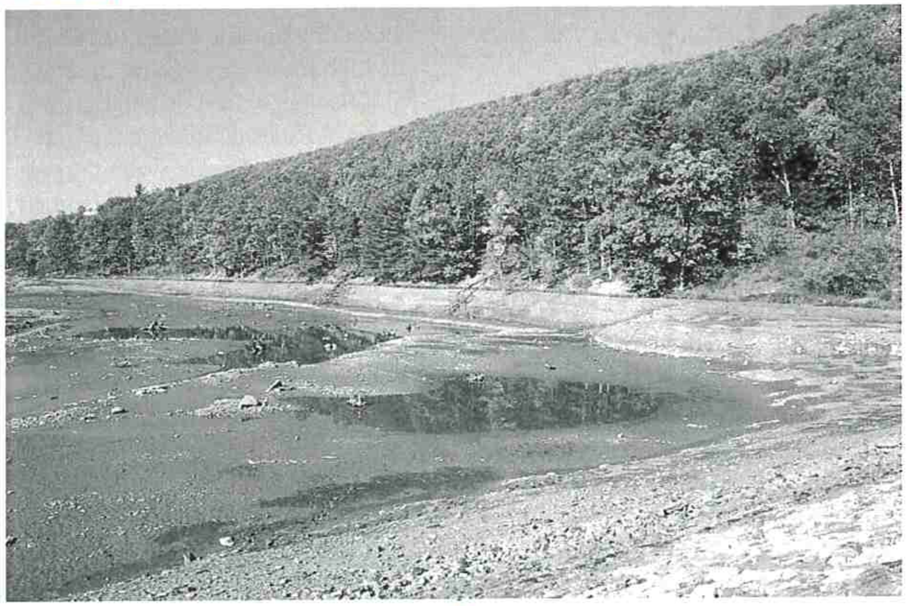
- Experts at your local extension office may be able to help identify aquatic plants.
- Penn State Extension publication AGRS-110, *A Field Guide to Aquatic Plants in Pennsylvania* ($11.00), provides pictures and descriptions of some of the most common aquatic plants in Pennsylvania.

Causes of Plant and Algae Growth

Excessive plant and algae growth is usually caused by nutrients entering the pond from the surrounding pond watershed. The primary materials that stimulate growth are nitrates and phosphates from agricultural fertilizers, lawn and golf course fertilizers, animal wastes, and septic system discharges.

In addition to available nutrients, ponds with dense aquatic plant and algae growth usually have several of the following characteristics: shallow depth, gently sloping shoreline, stable bottoms, warm water, clear water, and high fertility. In contrast, factors that inhibit aquatic plant growth are deep water, moving water, steep shoreline slopes, unstable bottoms, cold water, colored or muddy water, and low fertility. Ponds with soft water (low mineral content) tend to have low fertility and sparse vegetation while hard water ponds (high mineral content) often support a dense growth of many species. The composition of the mud on the lake or pond bottom influences the number and species of plants that will grow. Most aquatic plants grow best in a mixture of sand and organic soils. Soft, mucky soils may be unfavorable to aquatic plants.

Drawdown



Preventing Plant and Algae Growth

Like most problems, preventing excessive aquatic plant and algae growth is more desirable than attempting to control it after it has become a problem. Prevention can be accomplished in several ways. Deepening shallow ponds or lakes offers the most permanent method of preventing aquatic weeds. In ponds where most of the water is over 10 feet deep, submerged vegetation seldom becomes a serious problem. Sunlight penetration at this depth usually is not sufficient to stimulate vigorous growth of aquatic plants. Pond embankments and steep sides that slope rapidly into deep water usually limit aquatic plant growth to the very edges of the pond, where emergent plants may be cut or removed easily by other mechanical means. Steep sides, however, may create a safety hazard to small children, equipment operators, and swimmers.

Drawdown

Drawdown or partial draining can be used to prevent the growth of some species. This is achieved by partially draining the pond beginning in late fall or early winter. Plants usually are killed or rootstocks frost-heaved if the bottom mud freezes to a 4-inch depth for a period of 3 weeks or longer. Use caution in prolonged drawdowns, because oxygen depletion is more likely to occur when fish and organic debris are concentrated in a smaller volume of water.

Nutrient management

Nutrient management practices are desirable for controlling aquatic plant and algae growth because these activities attempt to reduce or limit nutrient entry into the pond. Reducing nutrients will not immediately reduce plant growth, but it will have a long-term benefit. Nutrient reductions can be accomplished by reducing fertilizer and manure applications near the pond, diverting nutrient-rich runoff away from the pond, or creating vegetative buffer strips to trap nutrients. If surface waters entering the pond are passed through a vegetated drainage channel or buffer strip, nutrients, turbidity, and many chemical concentrations may be reduced.

Although in some cases an initial application of a balanced fertilizer will help new ponds become productive faster, it will also make a pond more susceptible to later problems with surplus nutrients.

Barley straw for algae

In recent years, the use of barley straw has been suggested to prevent growth of algae in ponds. Although this practice is still not completely understood, enough evidence appears to exist to suggest that it is beneficial.

Remarkably little straw is needed—approximately two to three bales per surface acre of water. Too much straw can deoxygenate the pond and possibly cause fish kills. The straw should be applied loosely or in cages at several locations in the fall or spring. It is important to note that barley straw does not kill existing algae, so it must be applied before the algae appears.

One of the greatest difficulties with this technique can be locating barley straw. Your local Penn State Extension office or another farm-related organization may be helpful in finding a local barley straw supplier.

Control of Plant and Algae Growth

Although prevention techniques are preferable, it is often necessary to control existing aquatic plant and algae growth. No easy cure-all exists for controlling undesirable aquatic vegetation. Each of the methods described below can be effective, but many factors—including cost, effectiveness, side effects, and difficulty—must be considered when deciding which technique to undertake.

Mechanical removal

Mechanical removal methods consist of cutting, mowing, raking, digging, or pulling plants and algae. As you might expect, these methods are physically demanding but inexpensive if you do them yourself. They are most efficient for small quantities of plants near shorelines. Mechanical treatments often must be repeated several times during a year to eliminate new growth as it appears. Cutting or pulling may be undesirable for some submerged plants, because stem fragments left in the water may establish new plants. If you are physically able, consider mechanical removal methods because they may be safer, less expensive, and longer lasting than chemical controls.

Chemical controls

Herbicides offer a solution to many otherwise difficult aquatic weed problems. But chemical control of aquatic weeds must be undertaken with adequate planning and considerable care. The correct chemical must be selected for the identified problem plant, and precise measurements of water volume and chemicals must be made. Small errors in application rates can cause inadvertent damage to fish and other aquatic life in your pond. As a result, *permits are required before you apply algaecides or herbicides to your pond.* These permits are issued with joint approval of the Pennsylvania Fish and Boat Commission and the Pennsylvania DEP.

You can obtain a permit to apply aquatic herbicides from the following:

- Your local Fish and Boat Commission office
- Your local DEP Office
- Some local Penn State Extension offices
- Downloadable form available online at **www.fish.state .pa.us**

Once you've obtained a permit, *carefully follow the label instructions on the herbicide*, including any water use restrictions. The following tips and cautions may be helpful.

Many herbicides are toxic to fish and other animals, including human beings, but the amounts needed to kill aquatic weeds are usually tolerable to fish and animals. Newly hatched fish appear to have less tolerance to herbicides than do older fish. In some areas, minor fish kills may occur when safe dosages are inadvertently exceeded because of an uneven distribution of the chemical.

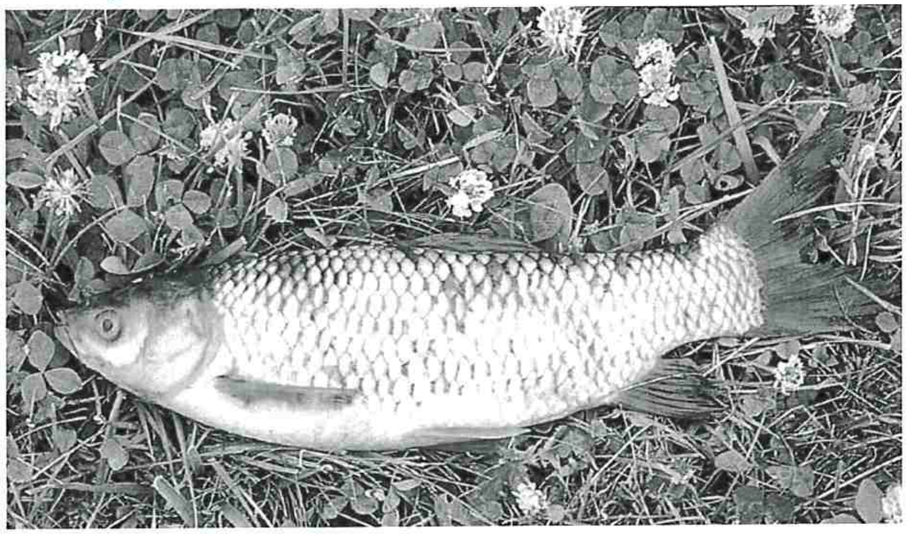
A fish kill also may occur as an indirect result of chemical weed control, because oxygen is consumed by the rapid decay of plants. To minimize this danger, treat only one-third of the pond at any one time, even when plants are present in the entire pond. Make applications at least 1 week apart, or as specified on the label, so that rapid plant decay will not reduce oxygen content of the water to a dangerously low level.

Waters should be treated for aquatic weeds in late spring or early summer when plants are young and actively growing. Treatment at this time of year usually gives best control with the least amount of chemical. Applications in late summer or early fall require more chemical and usually give slower, erratic control. If a problem becomes apparent during the late summer, treat it the following spring, rather than immediately. This probably will reduce your cost and increase the effectiveness of the application.

Aquatic plant control with chemicals can be successful and satisfactory. Once a weed problem is under control, diligent treatment of regrowth is necessary to maintain control. It is much easier and less expensive to conduct periodic maintenance or to make spot treatments than it is to wait until treatment of the entire area is necessary. Using chemicals for control of certain plant species, even though successful, is not likely to end all plant problems.

For more detailed information on chemical control of aquatic plants and algae, see Penn State Extension publication AGRS-102, *Management of Aquatic Plants,* available for $4.00 from your local Penn State Extension office.

Grass carp



Biological control (grass carp)

In recent years, grass carp have become a popular choice for controlling some types of aquatic plants. Grass carp can be very effective in controlling many species of submergent plants. They generally are not effective at reducing filamentous algae or emergent plant growth.

Because grass carp are not native to Pennsylvania, their sale and use are regulated by the Fish and Boat Commission. All grass carp sold and stocked must be triploid, meaning they cannot reproduce, and pond owners must obtain a permit before stocking them. A permit and list of commercial hatcheries that sell triploid grass carp are available from your local Fish and Boat Commission office. Take care not to overstock the pond with grass carp; too many can strip a pond of all vegetation and muddy the water as they search the bottom for more plants. The permit process will be helpful in determining the correct number for your pond. Pond owners should purchase grass carp at least 8 inches and preferably 12 inches long. These large fish usually can avoid predation by other pond fish and will be large enough to begin consuming unwanted plants immediately. Stocking rates for grass carp range from 1 to 15 fish per acre depending on the amount and type of unwanted plants. Other types of fish such as koi or other species of carp are not recommended for aquatic plant and algae control, since they are relatively ineffective in controlling aquatic plants and tend to produce muddy water problems.

Miscellaneous Troubles and Treatments

Fish Kills

Fish kills resulting from a lack of sufficient oxygen occur occasionally in Pennsylvania ponds. Ponds that are poorly constructed, shallow, overpopulated, or have excessive aquatic vegetation are most likely to suffer from oxygen depletion. Most die-offs are observed during an extended period of hot, calm, and cloudy days in summer. Die-offs may also result from the decay of plants and algae after an application of an aquatic herbicide. Occasionally, fish kills from oxygen depletion occur during extremely cold winters when a pond is covered with ice and deep snow for prolonged periods.

The best insurance against a fish kill from oxygen depletion is a well-constructed pond. Spring-fed ponds or ponds with running water where long cold winters are not the rule should have depths of 6 to 8 feet over at least one-fourth of their total area. Ponds without running water or those located in areas with long cold winters should have depths of at least 10 to 12 feet over at least one-fourth of the total area.

Occasionally, fish kills occur from other water quality problems. Most notable among these would be runoff and drift from terrestrial applications of pesticides. Although most of the chemicals degrade quickly, they can be highly toxic to all forms of life, especially fish.

By following a few basic guidelines, you can reduce the likelihood of a fish kill occurring in your pond. Stock only fish that are capable of surviving the water temperatures in your pond. Obtain a permit before using an aquatic herbicide in your pond, and carefully read and follow the label directions. Do not treat more than one-half of the pond with an aquatic herbicide. In ponds where fish kills occur frequently because of low dissolved oxygen levels, installing aeration devices may be helpful. Finally, be especially cautious using pesticides on land adjacent to the pond.

Turtles

Snapping turtles occasionally inhabit larger ponds. They seldom cause problems, but are considered undesirable by many pond owners. Other kinds of turtles are usually desirable. If snapping turtles become a problem, they may be removed by fishing. Use large turtle hooks (1 inch between shank and point) attached to a wire leader and heavy cord. Bait the hook with dead fish or other meat. Place baited hooks in shallower parts of the pond.

Ducks and Geese

Many pond owners wish to attract waterfowl to their pond for viewing pleasure. For example, wood ducks can be encouraged by building nesting structures. However, while small numbers of waterfowl may be desired, large flocks can create numerous problems. In recent years, the large resident population of Canada geese has been especially problematic in Pennsylvania. The waste associated with a large concentration of waterfowl can degrade water quality by increasing both nutrients and bacteria concentrations. To prevent problems, no more than a few waterfowl should be permitted per acre of pond. Short-term visits by larger flocks during spring and fall migration are generally not a problem.

Waterfowl can be discouraged for a short period of time using decoys of natural predators such as hawks and owls. Vegetative barriers of tall grasses or cattails around the pond may provide a longer-term solution. Since geese like to eat most lawn grasses, planting the pond perimeter with less desirable grasses such as tall fescue may discourage geese from inhabiting your pond. A mowing schedule that allows somewhat taller grasses and weeds to grow in the vicinity of the pond will also reduce the use of that area by Canada geese. Tall weeds can create other problems, though, such as attracting water snakes (see next paragraph). Maintaining a relatively small closely mowed area immediately adjacent to the pond will reduce the area attractive to geese, thereby reducing their numbers around the pond.

Snakes

The most practical way to eliminate snakes from a pond is to make it unattractive to them. Keep the pond free of weeds and debris in which they can hide. Keep the banks closely mowed and clean. A few water snakes may occasionally inhabit the pond, but these do little or no harm.

Leeches

Leeches are flat, dark-colored parasites that attach themselves to animals in the water and suck blood through punctures made in the skin. They will attach to swimming humans, but their bite is normally painless. Leeches are rarely abundant enough in Pennsylvania ponds to warrant any concern, but they can be eliminated, if desired, by treating the pond with a very high concentration of copper sulfate (5 parts per million). It is important to note that such a treatment will likely kill all of the fish in the pond and will require a permit from the Pennsylvania Fish and Boat Commission. Spot treatment of only the swimming areas in the pond may be possible to avoid a large fish kill, but the leeches will slowly return from the untreated portions of the pond. Any chemical treatment to eliminate leeches is a drastic step that will greatly affect the pond fish and other aquatic life. Given the side effects of treatment, elimination of leeches can be justified only where fish are already absent from the pond.

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For more information on all aspects of pond and lake management, visit the Penn State Extension pond website at **extension.psu.edu/water/ponds**.

extension.psu.edu

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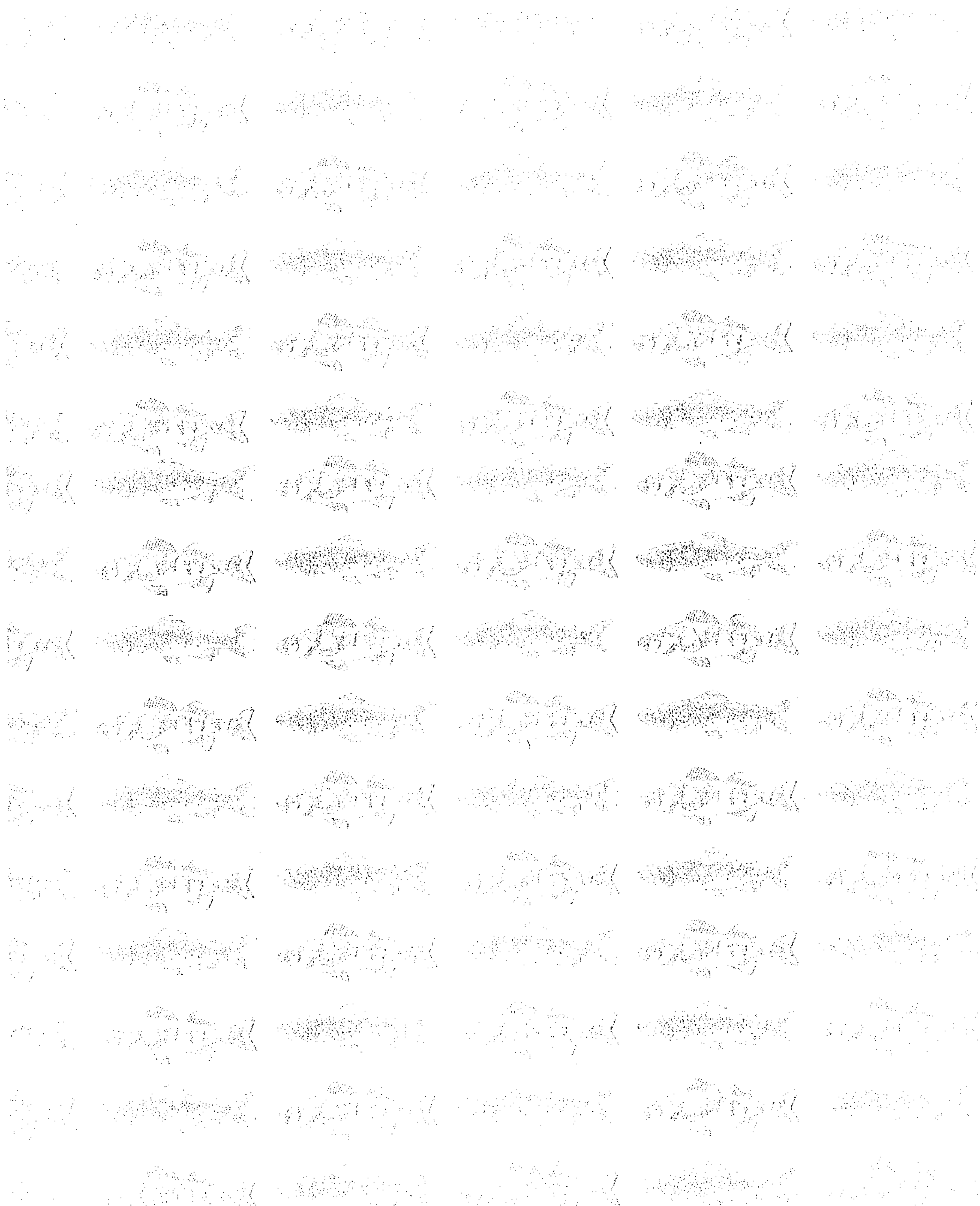

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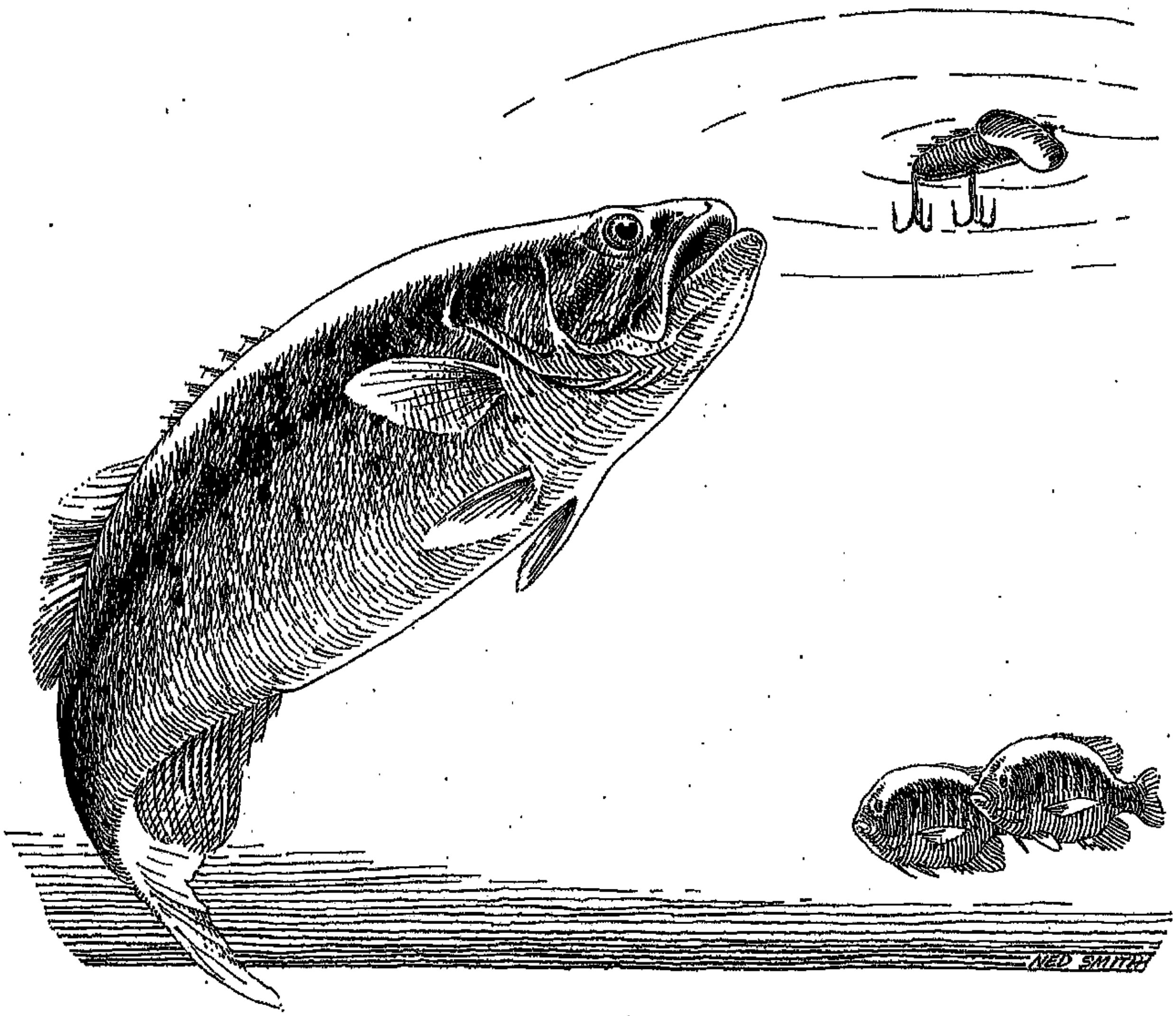
FISH PONDS

Construction and Management in Pennsylvania

Special Circular 263, Natural Resources Series



The Pennsylvania State University, Cooperative Extension Service, University Park, Pennsylvania
In cooperation with the United States Soil Conservation Service

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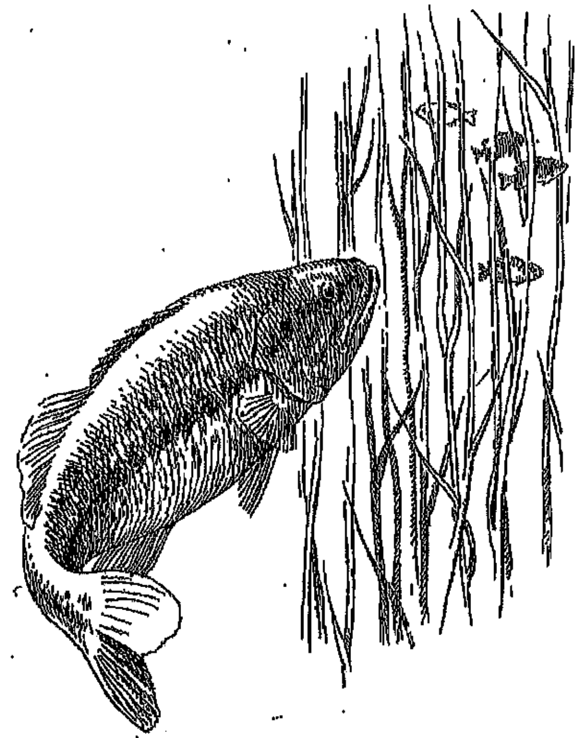


INTRODUCTION

Small lakes and ponds are likely to increase greatly in number and importance in Pennsylvania in the years ahead. Fish production and fishing may not be the most important uses for impounded water, but many small lakes and ponds are being built primarily for this purpose. Recreational uses can add to the benefits of water developments. Most ponds are stocked to provide sport fishing and recreation for the owners, their families, friends, and guests. Fishing and other recreational uses do not deteriorate the quality or quantity of water for other purposes.

Placing a few fish into a pond does not mean that good fishing will result. To a child, a fish is a fish. Regardless of the kind or size, a child usually is satisfied if fish bite. But many fishermen want food-size fish — the kinds that make fishing an exciting sport. To have satisfactory fishing, it is essential to stock the proper kinds and numbers of fish, manage them so that they grow properly, and harvest them in adequate numbers.

POND BIOLOGY

What kind of fishing?
Development and management of ponds and the associated aquatic environments require time, effort, knowledge, and an understanding of relationships among land, water, plants, and animals. In the creation of artificial ponds, different owners have different objectives and, as a result, realize different degrees of satisfaction from certain natural processes which occur in the pond. Pond owners have several choices when it comes to the type of fishing which might be developed. Once a pond is stocked, however, the owner is committed to management procedures for the species stocked, unless he eradicates that fish population and starts over by restocking.

Biology
Regardless of species, all fish are subject to the limitations of the laws of nature, their own characteristics and habits, and the surrounding plant life, animal life, and other environmental factors. These interrelation-

ships are complex.

Food is of primary importance. Natural water supports important food items in the form of tiny organisms called plankton. The presence of plankton causes some ponds to have greenish, bluish, or brownish-green colors. Plankton consists of both plant and animal life. Newly hatched fish may depend on this food source. Plankton is equally important to snails, worms, tadpoles, crayfish, and other pond organisms which thrive in its presence. This fish food supply will strongly affect the fish population.

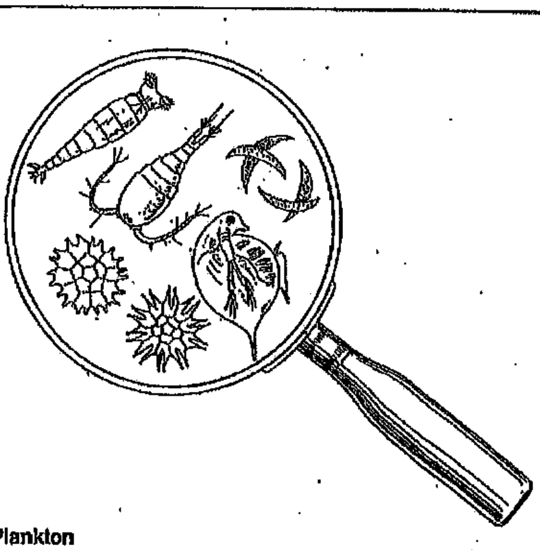
Every pond differs in its capacity to produce plankton, a reflection of the fertility level of the water. Soils, land use in the watershed, water sources, and water chemistry all influence the production of plankton and in turn affect fish food supplies and other pond relationships.

The idea that ponds can support unlimited numbers and pounds of fish is a common misconception. Limits on food and space place a ceiling on satisfactory fish production in any body of water — pond, stream, lake, or sea.

Management of mixed fish populations is usually aimed at stabilizing populations and harvests. A stable fish population is the result of a balance of two opposing forces — production and reduction.

Production

Production of fish results from the combination of everything that favors their reproduction, growth, and survival. Most fish species spawn at an early age and lay large numbers of eggs. With adequate food, growth is rapid; with ample space, production may be high. There are ways by which pond owners can provide adequate food and space for fish, thus assuring satisfactory fish populations.



Plankton

Reduction

Reduction results from the combination of all things that limit reproduction, growth, and survival of fish. Diseases and parasites; predation by mammals, birds, and other fish; overcrowding; and the fishing harvest are some of the forces which reduce fish numbers. Most warm-water fish species have reproductive capacities that will outrun the ability of ponds to produce food to sustain them. However, there are ways by which fish populations can be reduced so that stunting and overcrowding can be controlled and good fishing can be maintained.

KINDS OF FISH WHICH MAY BE STOCKED

Water quality

Farm ponds may be stocked with warm-water fish such as large mouth bass and bluegills, or with cold-water fish such as trout. The decision depends to some degree on the pond owner's desires, but primarily on the quality of the water in the pond. Water conditions that are most important are temperature, acidity or alkalinity, oxygen content, and carbon dioxide content.

Trout requirements

Trout require cool water. They may be able to withstand temperatures of 80 degrees F for a few hours, but long periods with temperatures exceeding 75 degrees F will cause death. They grow best when water temperatures are from 55 to 60 degrees F. Ponds in which water temperatures do not exceed 75 degrees F may be stocked with brook, brown, or rainbow trout.

Trout are not recommended, however, if temperatures approach the lethal limits for extended periods during the summer. High sublethal temperatures can place a stress upon the trout's physiological mechanisms. Although brown trout can withstand slightly higher temperatures than either brook or rainbow trout, they are not recommended for ponds, because they are more difficult to catch than the other two species. Consequently, they may not provide good quality sport fishing.

Trout require water that is high in oxygen content — 5 parts per million is considered the safe minimum. Water acidity suitable for trout ranges from pH 5 to pH 9. Trout that were raised in alkaline hatcheries, however, may find water of pH 5 too acidic initally, and mortality may occur. Low pH in deep water may indicate low oxygen and high carbon dioxide content.

Warm-water species requirements

Ponds with temperatures exceeding 80 degrees F should be stocked with warm-water species. The most common are largemouth bass in combination with bluegill sunfish and golden shiner. Although warm water species may be stocked separately, they usually do best in various combinations.

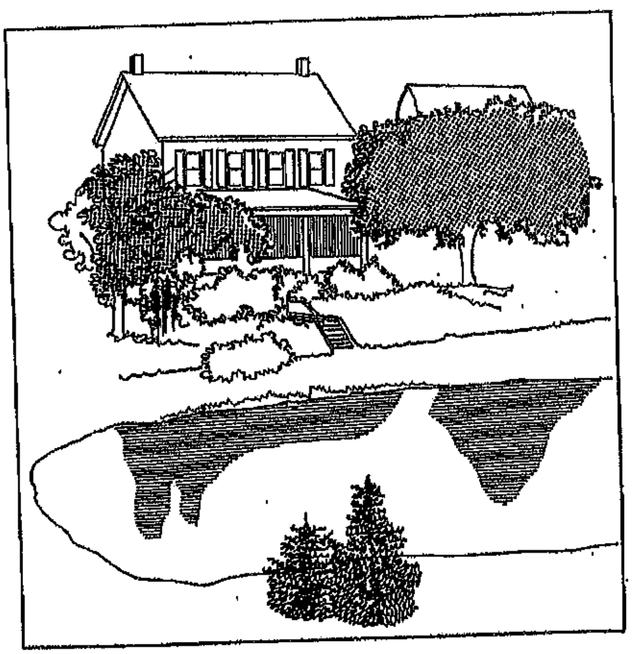
Bass and golden shiners reproduce and grow well if the water temperature remains at about 72 degrees F for several weeks in the early summer. Bluegill spawning is triggered when the water temperature reaches 67 degrees F. These species will grow well at water temperatures that remain above 80 degrees F for several weeks. In general, the warmer the water the more rapidly a fish will grow, within the limits imposed by its physiological makeup. A pH range from 6 to 9 is satisfactory for all species listed. The oxygen concentration should be at least 3 parts per million.

SELECTING POND SITES

Three things very important in selecting sites for fish ponds are topography, soil texture, and water supply. Where these factors are equally satisfactory for several locations, appearance and convenience for the owner may become the overriding considerations.

A pond located near a house, where it can be observed frequently and conveniently, will be safer and more desirable for family recreation. It can be used as a source of water for fire protection or for irrigating a small garden. If there are plans to use it for fire protection, an all-weather road should be constructed to the dam or to a point near the deepest water. Rural fire companies usually carry several hundred feet of hose and can push water a great distance, but they must be able to get their pumps within 15 feet of the water.

Small ponds are not easy to manage for fish. Normally, ponds of less than one-fourth acre in surface area are too small for effective management of warmwater fish. However, ponds as small as one-tenth acre in surface area may be suitable for trout if they have suitable water quality, including cool temperatures (60-70 degrees) during the summer.



Topography

Ideal topography for a fish pond is a natural depression or a broad drainage area with a narrow neck at its lower end where only a short dam will be needed. The most economical site is one that will require the smallest dam and the least amount of work for the size of pond created. Small ponds collecting runoff from large drainage areas require expensive overflow and spillway systems to handle excess water safely.

Soil texture

Soil texture must be taken into consideration when selecting the pond site. The bottom of the pond, the banks, and the earth fill placed in the dam must contain enough clay to impede seepage and make the reservoir hold water. Normally, areas that include exposed bedrock, shale ledges, and beds of sand or gravel are not satisfactory. Anyone who is considering the construction of a pond should have the soils and geological conditions in the area checked by a professional consultant knowledgeable and competent in making site investigations.

Water supply

Springs, seeps, and small streams normally provide cool and relatively clean water suitable for the propagation of fish. Where springs and seeps are not available, surface runoff can be the primary source of water to maintain water level of the pond. The drainage area should be large enough to assure that the combined surface runoff and subsurface seepage is adequate for fish culture during even the driest years. Normally, a drainage area of 10 to 20 acres yields enough water for a one-acre pond.

Fish ponds relying on surface runoff may be difficult to manage if the quantity of water cannot be controlled. Too much water flowing through a pond has a detrimental effect on the fish population. If the drainage area is larger than necessary to maintain the proper water level, some of the runoff can be diverted around the pond. Surface runoff water should be free of silt, pesticides, and other forms of pollution that may be toxic to fish. It may be necessary to establish a sod filter-strip between the runoff area and the pond to trap sediment and keep it out of the water. Barnyard drainage, with its high concentration of natural fertilizer, should be diverted away from the pond. Too much nitrogen and other nutrients will cause excessive growth of weeds and algae, making the pond difficult to manage.

DESIGN AND CONSTRUCTION

Fish ponds designed and constructed according to recommended standards are relatively safe, easy to manage, and relatively economical to build. Ponds constructed haphazardly are unsatisfactory and difficult to maintain. It pays to obtain information and expert advice before you start construction. Educational information can be obtained from county offices of the Penn State Cooperative Extension Service. The assistance of professional Soil Conservation Service personnel is available through local conservation district offices.

Construction permits

Permits for the construction of ponds or dams may be required, depending on the size of the drainage area, the height of the dam, and the capacity of the impoundment. A permit is required for the construction of any dam that impounds the runoff from a drainage area that exceeds 100 acres or provides a maximum storage capacity of 50 acre-feet of water (about 16.3 million gallons). A permit also is required for any pond with a dam more than 15 feet high, even if the pond's only source of water is a spring, a well, or a small pipeline from a stream. Permits will not be required for fish ponds that do not exceed these specifications.

The law authorizing fish-pond construction permits is the Pennsylvania Dam Safety Act. This law, Act No. 325 of the 1978 legislative session, became effective July 1, 1979. Permits are issued by the Bureau of Dam Safety, Obstructions, and Storm Water Management; Department of Environmental Resources (DER).

Top width of dam

The top width of a dam depends on the height of the structure. In most cases, the dam should be wide enough to permit limited use as a roadway for farm vehicles. Table 1 lists a minimum width of 8 feet.

Table 1. Minimum top width of dam based on height

Height of dam (feet)	Minimum top width (feet)
Under 14	8
15 to 19	10
20 to 24	12
25 to 34	14

Source: Ponds for Water Supply and Recreation, Agricultural Handbook No. 387, SCS-USDA

Side slopes of dam

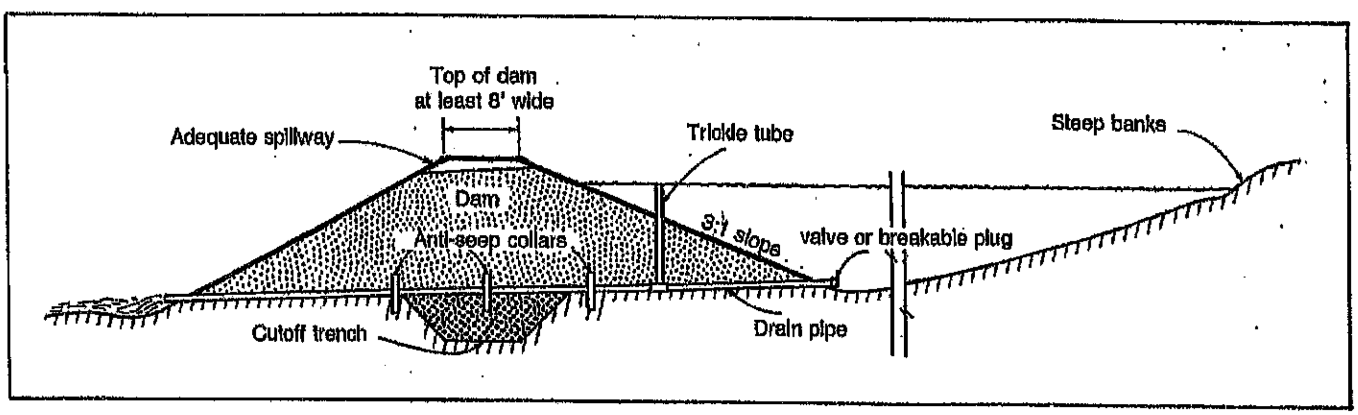
All earth dams should be constructed with side slopes stable enough to prevent erosion and keep the earth fill in place. In most instances, a slope of 3 feet horizontal to 1 foot vertical (3:1) on both the upstream and downstream faces of the dam will be satisfactory. Under no circumstance should either face of the dam or any excavated slope be steeper than 2:1. Proper slope is especially important in the shallow edges of the pond. Water should be at least 3 feet deep at a point 6 feet out from the shoreline, to discourage growth of algae and aquatic weeds. Experience indicates it is best to slope the banks properly at the time of construction.

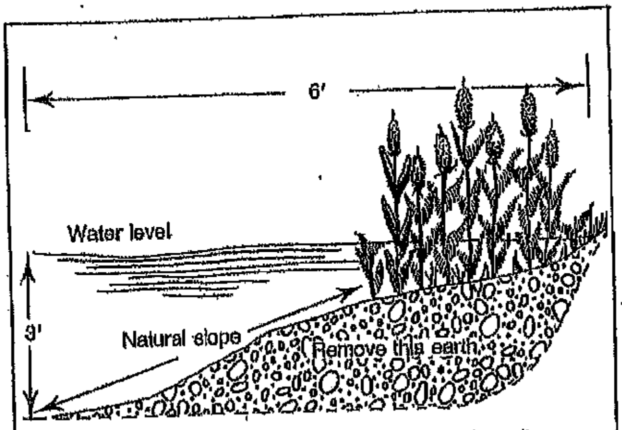
Freeboard above water level

The crest of all earth dams must be higher than normal water level to keep waves and high water from breaking over the top and cutting channels through the structure. After settling, the top of the dam for a one-acre or smaller pond should be at least 3 feet above the normal water level.

Emergency spillway

An emergency spillway is necessary to provide a safe outlet for flood water. Be sure that your pond has one.



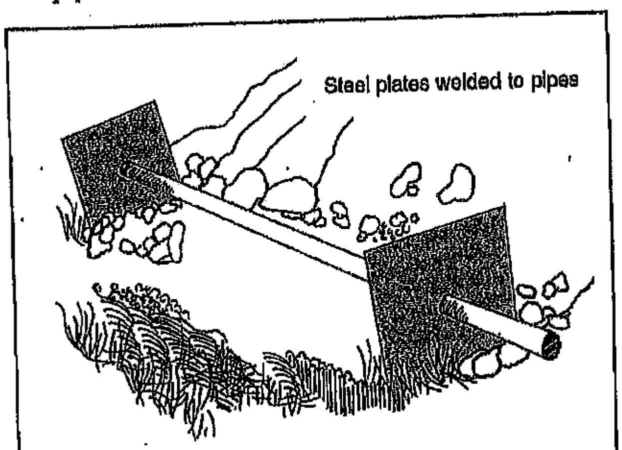


Remove eroded soil in shallow water around the shore line to prevent the growth of weeds and grass.

The spillway should be constructed in the undisturbed bank at one end of the dam. It should have a wide, flat-bottomed channel large enough to handle the overflow caused by a 50- or 100-year rainfall. The spillway, including the side slopes and channel bottom, should be planted with a mixture of grass seed that will produce a thick, tough sod. Good sod prevents rushing flood water from scouring deep ruts in the channel. The pond should not be filled with water until the sod becomes well established and the spillway is ready for use.

Pipes through the dam

Overflow. A pipe spillway or L-shaped trickle tube should be installed through the dam to provide an outlet for the normal flow of water. The trickle tube, which governs the depth of water in the pond, should be about 12 inches below the bottom of the emergency spillway. The tube should be large enough to drain the full pond down to normal water level within 24 hours after the flow through the emergency spillway ends. The pipe thru the dam should be at least 4 inches in diameter, and preferably 6 to 8 inches.



Anti-seep collars

Drain. A combination trickle tube and drainpipe is highly desirable for fish-pond management. It can be used to drain the pond for various fish management practices, pond repairs, or emergency situations.

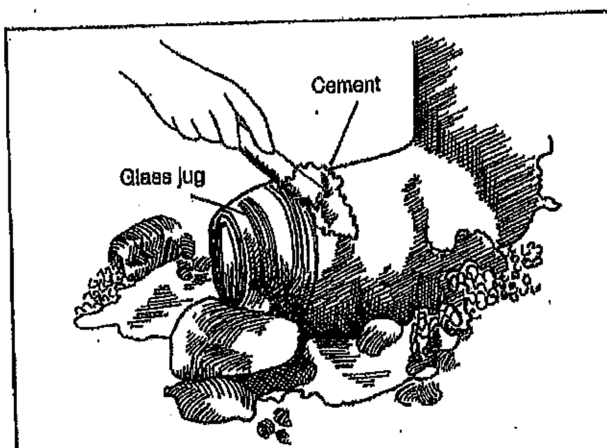
The drainpipe can be closed with a valve or plugged with a bell-end clay tile partially filled with cement. Even a glass jug will work. The plug should be sealed in the inlet end of the pipe with asphalt cement or cement mortar. If a breakable plug is used, the pond can be drained whenever it becomes necessary, but it will be difficult to stop the flow without draining the pond completely.

Cutoff or anti-seep collars should be placed around the drainpipe to prevent water from seeping along the outside of the pipe and cutting a channel through the dam. When steel pipe is used, the collars should be metal plates welded to the pipe. If other types of pipe are used, the collars must be compatible with the pipe. The collars should be three to four times the diameter of the pipe. Two or more collars are necessary, and they usually are placed about 10 to 15 feet apart. Prefabricated drains with anti-seep collars and drain valves may be available where culverts and large corrugated pipes are sold.

Construction procedure

The construction site should be cleared of all large rocks, trees, brush, roots, and other debris. The topsoil should be removed and stockpiled for later use.

Most earth dams should have an anti-seepage core built into the structure. A trench for this core should be dug along the center line of the dam breast and then refilled and packed with the best clay soil available. This trench should extend the full length of the dam breast and be at least 3 feet deep, preferably deeper. The core is to prevent seepage and to establish a good bond with the undisturbed foundation.



Breakable plug

The drainpipe with collars attached should be placed in position through the core and perpendicular to the center line of the dam. The trench for the drainpipe should be filled and tamped to prevent seepage.

The earth fill used in the dam should be free of boulders, stumps, roots, tree limbs, and decaying vegetation. Organic material buried in the dam will eventually decay and leave channels through which water can seep and cause the dam to fail. Earth fill should be spread in 6- to 8-inch layers and compacted with a heavy roller. The top of dam should be built about 10 percent higher than the designed height, to allow for final settling.

The emergency spillway and exposed faces of the dam should be limed, fertilized, and planted with a grass mixture to make the pond attractive and to prevent erosion. Crown vetch is an excellent cover on the dry-slope side of the dam, but it should not be used on the spillway.

It may be possible to avoid some management problems that occur after the pond is completed, by taking precautionary measures at the time of construction. Riprap should be applied to the face of the dam to control wave erosion and discourage muskrats. A fence should be constructed to keep livestock from tramping along the banks and polluting the water. An electric fence or barbed wire, which might injure people using the pond, is not recommended.

Maintenance tips

Inspection and maintenance protects a pond, keeps it attractive, and extends its useful life. It should be inspected frequently. Remove floating debris that can clog the overflow pipe and emergency spillway. Cut the grass and keep weeds, brush, and trees from growing on the dam. Remove cattails and other aquatic vegetation from shallow water. Check the shoreline for signs of muskrats, and repair the damage these animals cause when they burrow into the banks to form dens.

Be sure that the road provided for fire trucks is maintained for the passage of heavy vehicles and is plowed following a heavy snowfall. If a fire truck cannot get to the water, the pond is worthless for fire protection.

STOCKING PONDS

Most landowners who have ponds or lakes stock them with fish. Success of developed fishing areas depends on the water quality, the pond's construction, the owner's interest, time available for management, and preference for certain kinds of fishing. It will take time, work, and knowledge of management to develop satisfactory fishing. This should be considered before stocking a pond.

It is not necessary to stock fish to maintain or improve the quality of farm-pond water. The presence or absence of fish has very little bearing on the suitability of pond water for other uses.

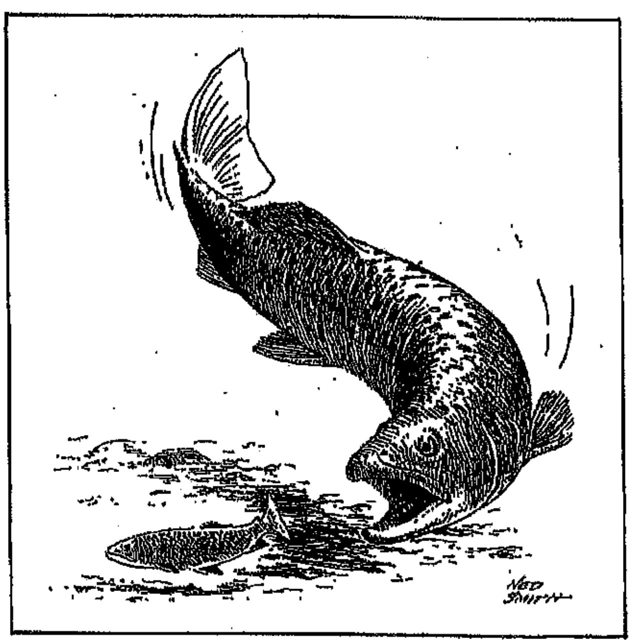
There are high risks of summer and winter fish kills from oxygen deficiencies in shallow ponds. Ponds less than 6 feet deep should not be stocked unless the water comes from a cold, well aerated stream. Although springs provide water of a satisfactory temperature, they often lack aeration and yield water which is low in dissolved oxygen. Such a spring will not be a satisfactory water source for a shallow pond, especially if the spring water enters the pond directly as subsurface water.

Regulations and laws affecting farm fish ponds

The Pennsylvania Fish Commission has the chief regulatory and legal responsibility for fishery resources. In recent years, liberal regulations have been developed for farm ponds.

The resident owner, lessee, his family, and persons residing or regularly employed on a farm do not need licenses to fish in farm ponds on the property. All other persons, including guests of the pond owner, must carry valid fishing licenses while fishing in the ponds. Ponds where this regulation applies must have the water source wholly within the limits of the farm, or take the water from a stream which does not contain game fish. In such ponds there is no closed season, size limit, or other restriction on taking fish.

If trout or bass are transported from the pond during a closed season, the owner must provide a written



statement of date, place, number of fish, and other details of the source of the fish. This protects the fishermen from being charged with a fishing violation.

For more details, consult local Fish Commission representatives and Chapter II, Article VI, Sections 56, 57, 58 of the Pennsylvania Fish Laws.

Regulations also require pond and lake owners to obtain appropriate permits before using traps, seines, or chemicals for weed or fish control. Applications for permits may be obtained from regional offices of the Pennsylvania Fish Commission.

Sources of fish stocks

Fish stocks for private ponds may be obtained from private commercial hatcheries. A list of licensed private fish hatcheries, showing the addresses and the species each has available, can be obtained from the Pennsylvania Fish Commission, P.O. Box 1673, Harrisburg, PA 17120. Hatcheries should be contacted directly for information, and other specific details.

Although it is permissable to stock a pond with adult fish legally taken from public waters or other private ponds, such practice is not recommended for it may complicate management of the pond.

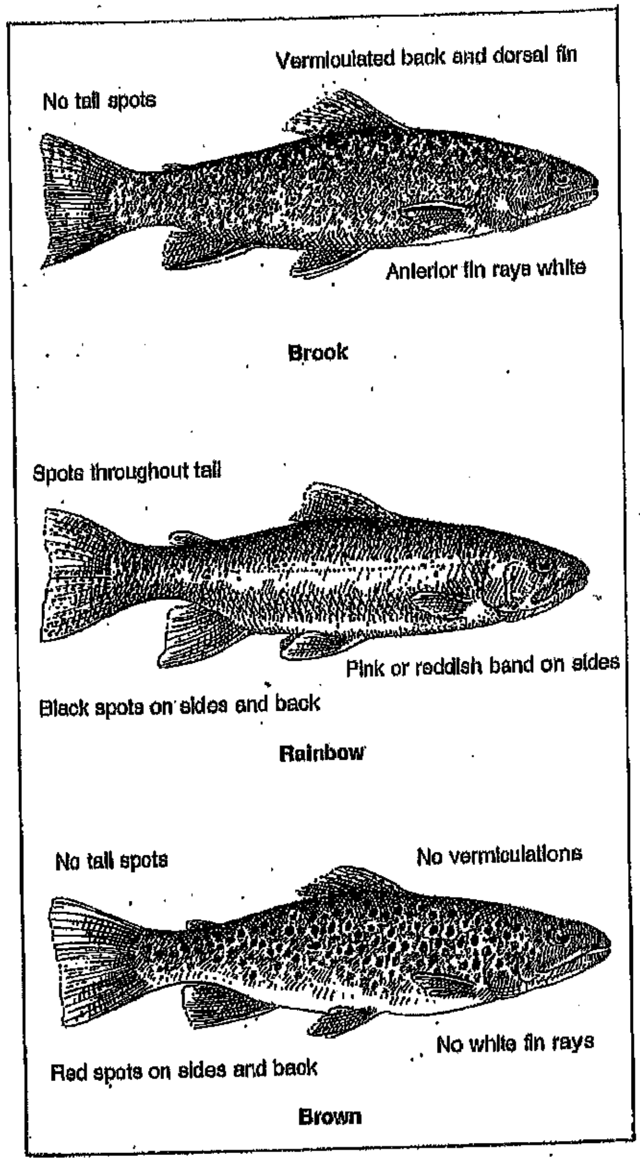
Populations developing from fingerling-size stocks are in balance initially if fingerling stocking recommendations are followed. Adding larger, legal-size fish from public waters may upset population balances through predation of the larger fish on the fingerlings. Introduced extraneous species may interfere with the spawning of desirable species. Introduction of adults of prey species may lead to stunting if they spawn immediately, and get a head start on the predators.

BIOLOGY AND MANAGEMENT OF TROUT PONDS

Kinds of trout

Brook trout and rainbow trout are suitable for small lakes or ponds. Many consider brook trout to be better eating. Although neither species is difficult to catch in the cooler months, it is easier to "fish out" a brook trout population. Rainbows are generally considered to be more spectacular fighters. A mixture of these two kinds of trout can be stocked in a pond to provide variety in fishing. If both species are stocked, they should be about the same size, so that one group will not prey heavily on the other.

Brown trout generally are unsatisfactory in ponds because they are more difficult to catch and consequently provide poorer fishing. Catches are smaller than for either brook or rainbow trout, and old brown trout remaining in a pond prey heavily on fingerlings introduced for restocking. Pond trout thrive in an insect-rich pond, when free from competition with other species.



Trout cannot compete successfully with most other fish in a pond because other fish multiply rapidly and monopolize the food. Adding odd species of fish will ruin the pond for trout production. Minnows should not be stocked.

Stocking

Either spring fingerlings (2 to 3 inches long, 2 to 3 months old) or fall fingerlings (5 to 6 inches long, 7 to 8 months old) may be used in stocking trout ponds. Both types reach catchable size about the same time; that is, in the spring following stocking. However, results with spring fingerlings are much more variable and unpredictable than with fall fingerlings.

When trout are obtained from commercial hatcheries, fall fingerlings usually provide considerably more catchable size trout per dollar than spring fingerlings. It is economically unwise to purchase trout larger than about 6 inches for pond stocking, unless they are to be fished out within a year.

A stocking rate of 600 fall fingerlings (or 2,000 spring fingerlings) per acre of pond surface should produce the best yield and satisfactory growth. Highly productive trout ponds on limestone soils may accommodate 700 fall fingerlings per acre, while ponds located on more acidic soils probably will support fewer fall fingerlings per acre.

To minimize mortality, stock trout only in the cool or cold weather of spring and fall. If the weather is warm, ice should be packed around the tank to keep the water used for transporting below 55 degrees F. Ice made from chlorinated water should not be placed in with the fish, because chlorine is toxic. Oxygen-producing tablets, available in sport or bait shops, may be used when transporting trout. Do not plant the fingerlings near the overflow structure of your pond.

Fishing trout ponds

In unfished ponds, natural losses of trout will reduce the population by 90 percent in two years. For this reason, pond owners should harvest as many trout as possible during this period. The time interval between stocking and initial harvest is a matter of owner preference, but the longer the owner waits before harvesting trout, the lower will be his total harvest.

Pond trout generally are much easier to catch in spring and fall than in the summer. Successful methods of fishing may vary with the season and with the skill of the fisherman. Fly fishing, fishing with live bait, and spin fishing with lures are all effective. Ice fishing with bait or artificial flies may be successful.

Minnows should not be used as bait when fishing trout ponds. If they escape and reproduce, they may eventually ruin the pond for trout production.

Restocking trout

Because trout have a relatively short survival time, a pond should be restocked with trout every 2 years to maintain adequate fishing. Fall fingerlings should always be used for restocking, as "holdover" trout are less likely to prey upon them as they are on spring fingerlings. Fall fingerlings for pond restocking must be purchased from commercial sources.

Feeding

At stocking rates of 600 fall fingerlings or 2,000 spring fingerlings per acre, trout grow rapidly on natural food produced in an established pond. Supplemental feeding may increase the growth rate an inch or two per year, but it is expensive.

Some pond owners may feed trout as a hobby or to maintain much larger trout populations than the 600 per acre recommended for stocking. Feeding is one way to increase the fishing potential, especially in a small pond. Pelleted trout food is available through farm supply stores. Trout usually come to the surface for pellets, and become conditioned to feeding at the same area of the pond.

Use only as much food as the trout will eat immediately. Excess food will settle to the bottom and decompose, removing dissolved oxygen from the water and possibly cause fish kills. Feeding should be done only in ponds that have a year-round supply of good water.

Growth

Brook and rainbow trout in ponds grow at about the same rate. However, growth may vary considerably from one pond to another. Growth generally slows as fish become older, and is usually faster in summer than in winter. Growth may be slower in newly constructed ponds, since aquatic insect life may be limited. Also, trout tend to grow more slowly in soft (acid) water than in hard (limestone) water.

Table 2. Average trout growth in ponds after stocking as fingerlings

	After one year		After two years		After three years	
	Spring	Fall	Spring	Fall	Spring	Fall
Length (in.)	8	10	11	12	13	14
Weight (oz.)	4	8	10	14	17	22

Survival

Pond trout survival rates depend on the size of fingerlings stocked and many environmental factors. Survival rates may vary considerably from pond to pond and from year to year. Larger fish generally have better chances for survival. During the summer immediately following stocking, the survival rate of spring fingerlings in ponds averages 30 percent. In each subsequent year, the rate averages about 50 percent. At the end of the second year, only 5 to 10 percent of the original number remain. Few trout remain in a stocked pond after three years. Fish mortality from natural causes is a gradual and continuous process, even though dead fish seldom are seen.

Reproduction

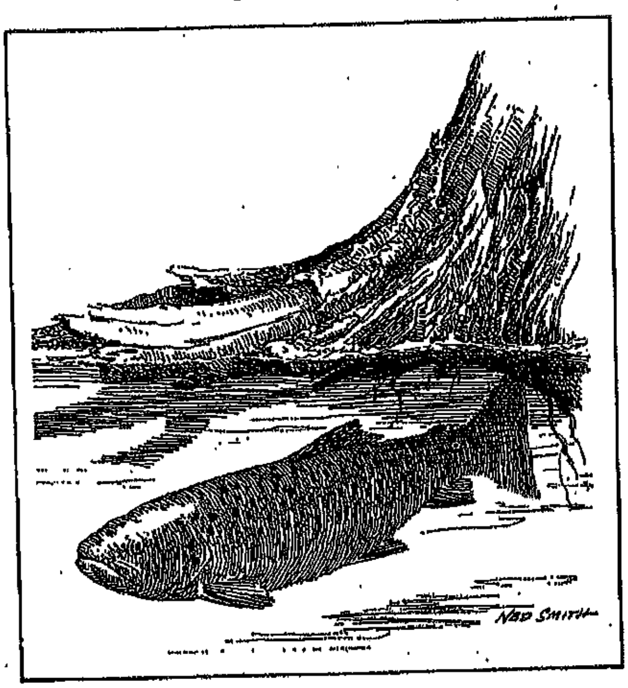
Most ponds lack suitable spawning sites, so trout rarely reproduce in Pennsylvania ponds. They may go through the act of spawning, however. A suitable spawning site for trout is a gravel area through which well-oxygenated water circulates during the incubation period. In ponds with exceptionally large heavy-flowing springs, limited trout reproduction may occur naturally or may be achieved by development of gravel beds in suitable locations. So far, no economical method has been developed to achieve adequate natural reproduction in the average spring-fed pond.

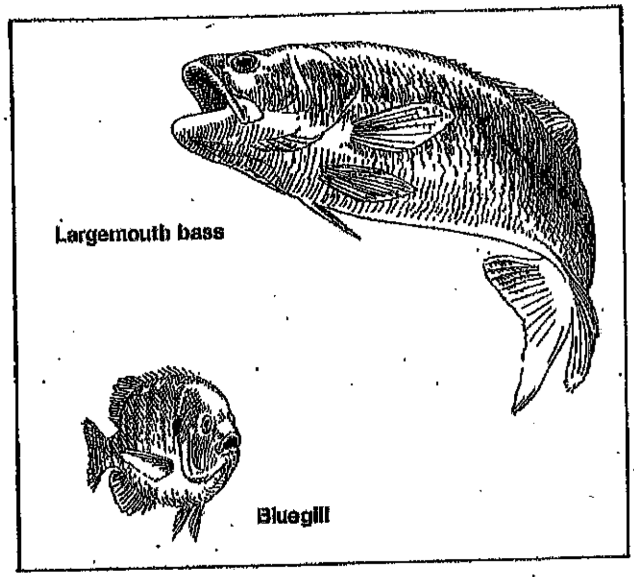
Trout production
Total poundage of trout in a pond at any time following stocking is the result of two opposing processes: growth which increases the poundage, and death or fish losses which reduce the poundage. Total poundage rises rapidly the first year after stocking, then decreases. In an unfished 1-acre pond stocked with 600 fall fingerlings or 2,000 spring fingerlings, an average of 230 trout will remain after one year. They will weigh a total of about 110 pounds. Two years later, only 45 trout will remain. They will weigh about 41 pounds.

Fertilizing trout ponds
In general, it is best not to fertilize trout ponds. A single application of 10-10-10 fertilizer at 300 pounds per acre may hasten the establishment of a natural food supply in newly constructed ponds. Heavy fertilization should be avoided, since it may harm the trout and cause summer or winter fish kills.

BIOLOGY AND MANAGEMENT OF BASS-BLUEGILL PONDS

The bass-bluegill combination is one of the alternative stocking choices for warm-water ponds. Ponds to be stocked with these species should be larger than one-fourth acre and must be deep enough throughout to avoid serious weed problems. Pond owners must have an interest in adequate harvest of bluegills, since this is an essential part of the management system for bass-bluegill ponds.



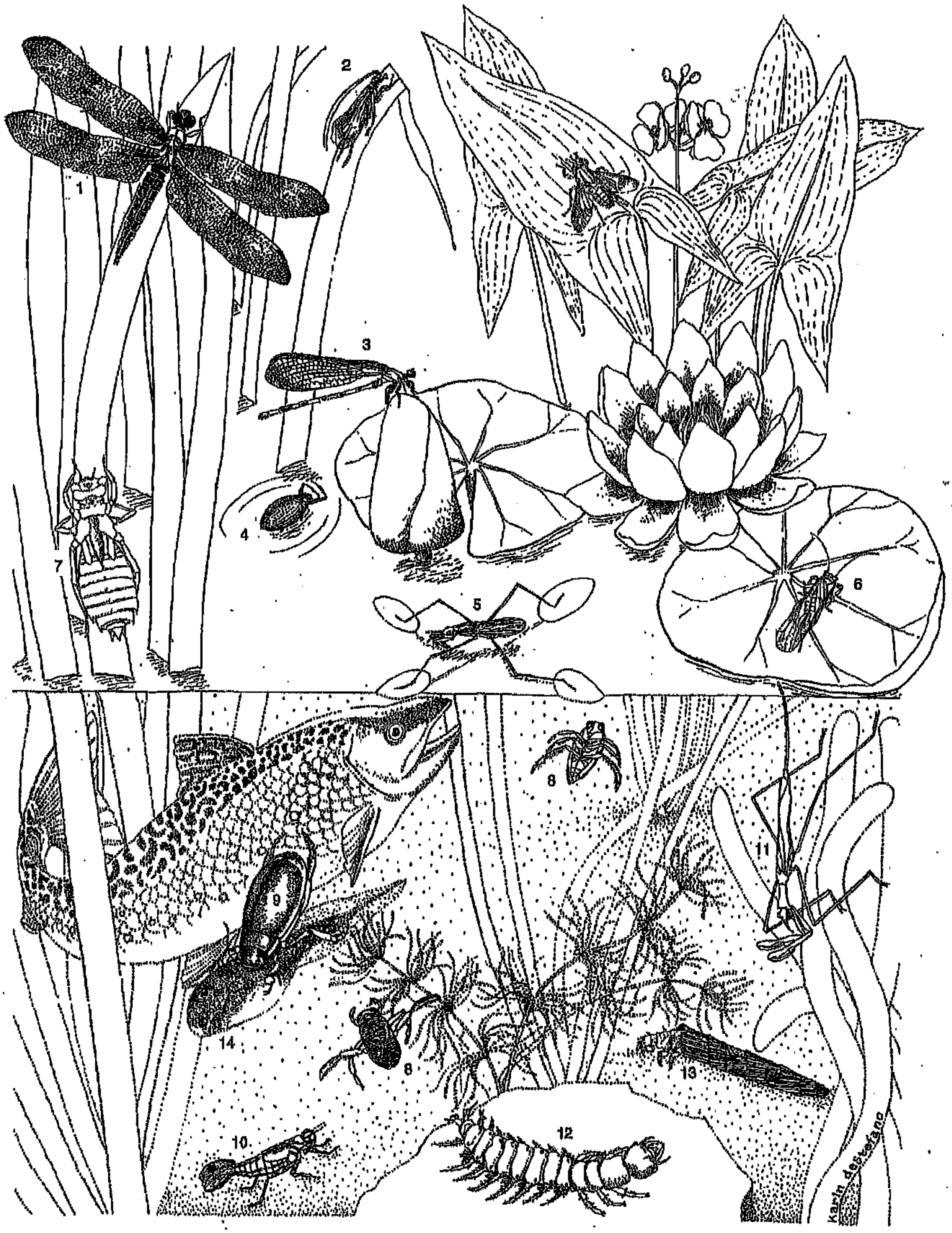


Kinds of bass and sunfish
Largemouth bass are suggested for use in ponds. While smallmouth bass can be supported in most ponds, their suitability for ponds is questionable. Bluegills usually are more suitable for stocking ponds than are other species of sunfish, which either grow too slowly or have smaller maximum size. Use of redear sunfish should be considered experimental even though the redear has some desirable characteristics for pond stocking. All sunfish tend to overpopulate ponds unless intensively managed.

Bass-bluegill stocking
Stock 100 bass fingerlings (1 to 3 inches) and 1,000 bluegill fingerlings (1 inch or less) per acre. The following spring, add 10 to 20 mature bass to insure early bass spawning. These mature bass will feed upon bluegills stocked the preceding year and aid in controlling the very prolific bluegills.

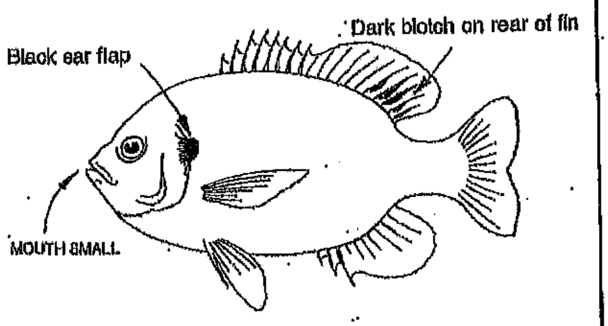
Adult bass probably can be purchased from the same commercial hatchery that provided fingerlings for the initial stocking. No stocking ratio can insure a balance between bass and bluegills; intensive harvesting of bluegills is essential after this initial stocking.

Redear sunfish, or "shellcrackers," are a popular panfish in the South and Midwest. They usually grow faster, but are less prolific, than bluegills. This characteristic may make them preferable to bluegills for stocking in some farm ponds. Their one drawback is

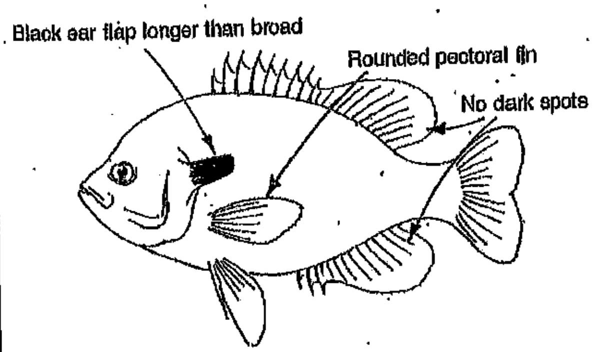


Pond organisms

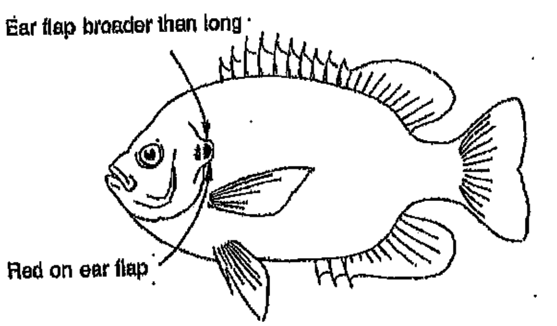
1. Dragonfly
2. Caddisfly
3. Damselfly
4. Whirligig beétle
5. Water strider
6. Stonefly
7. Dragonfly case
8. Back swimmer
9. Predacious diving beetle
10. Damselfly nymph
11. Water scorpion
12. Dobsonfly larva
13. Caddisfly larva and case
14. Tadpole



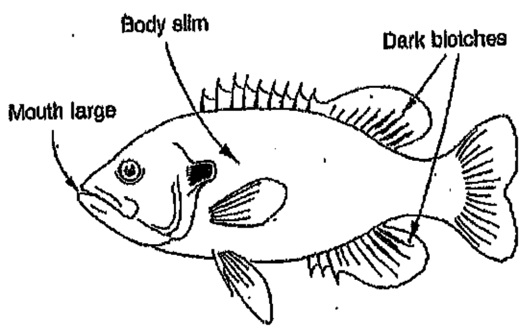
Bluegill



Redbreast sunfish



Pumpkinseed sunfish



Green sunfish

that they are somewhat more difficult to catch than bluegills. Redear sunfish may be used, on an experimental basis, as a substitute for bluegills or in combination with them in warm-water ponds in Pennsylvania.

Growth

Table 3 shows average weights by age of bass and bluegills in ponds. Most rapid growth takes place during the first few years after stocking. Much variation in rates of growth can be expected, however.

Table 3. Average bass and bluegill growth in ponds

	Year after stocking				
	1st	2nd	3rd	4th	5th
Bass					
Length (in.)	8	10	12	14	16
Weight (oz.)	5	10	15	20	24
Bluegill					
Length (in.)	5	6	7	8	8
Weight (oz.)	2	4	6	7	8

Survival

As with trout, natural mortality of stocked bass and bluegills is high. Survival is variable, but natural reproduction quickly compensates for heavy mortality in these species.

In bass-bluegill ponds, bass generally reproduce as 2-year olds or when weighing at least 10 ounces. While it is unusual, bass may spawn the first year after stocking. Bass spawn in late spring at water temperatures about 65 degrees F. Bluegill spawning is likely to occur throughout summer. Spawning activity depends upon water temperature, and bluegill reproduction is often so successful that bass cannot keep them under control. This leads to overpopulation, stunting of bluegills, and destruction of bass spawn or fry by bluegill predation.

Bluegill redds (nests) appear as light circular areas on the pond bottom in shallow water. Usually a number of redds are built close together. Adult bluegills often can be seen attending these redds. A long-handled rake may be used to destroy redds, reducing bluegill spawning success. Such management may prevent or at least postpone the development of a stunted bluegill population.

Production

Maximum rates of growth and production of fish in a bass-bluegill pond occur from 2 to 3 years after stocking. Moderately heavy harvests of both bass and bluegills may help maintain high levels of fish production, if care is taken to leave enough fish of spawning size for reproduction. There is some research evidence that

50 percent or more of the fish population should be removed annually to provide the most desirable conditions for growth, survival, and reproduction.

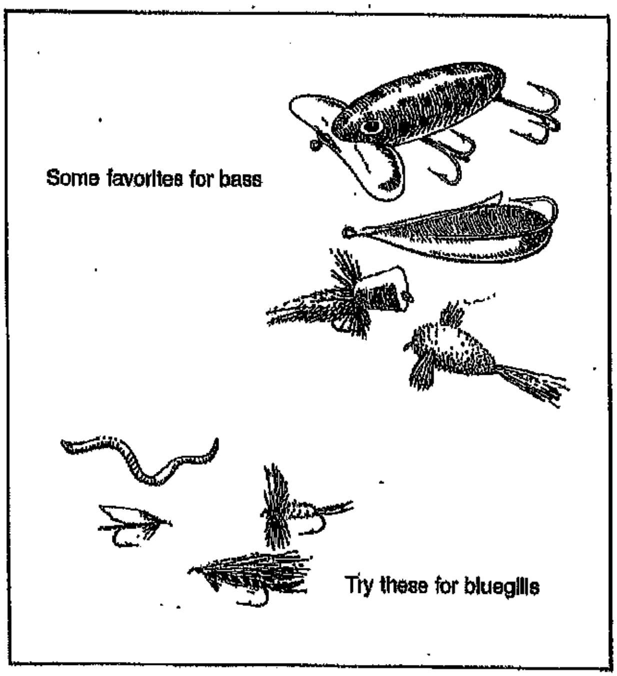
Fishing bass-bluegill ponds
Generally, there is greater interest in fishing for bass than for bluegills. Many ponds thus have heavy bass fishing and little or no bluegill fishing, a situation which is undesirable for management of bass-bluegill ponds.

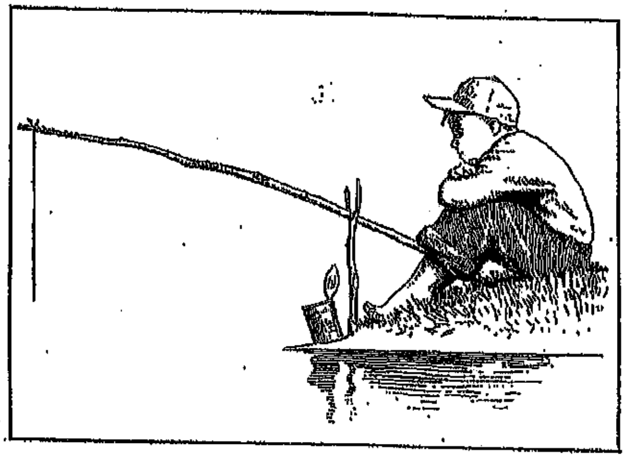
Bass should not be fished until they have reproduced successfully, which often is 2 or more years after stocking. Thereafter heavy fishing is possible, but limited bass removal should be the rule. Bass-bluegill ponds will not support unlimited catches.

Bluegills spawn as yearlings. In the average pond, harvest can start as soon as they have spawned. Heavy harvesting of bluegills must be planned and accomplished as part of the management program for bass-bluegill ponds. On a weight basis, about 6 pounds of bluegills should be taken for each pound of bass.

Bluegill trapping
If bluegills overpopulate a pond, as they often do, large numbers of them should be removed. Since fishing may not remove enough of the small bluegills, trapping may offer a solution. A permit from the Pennsylvania Fish Commission is required to trap fish.

Bluegill traps can be made of 1-inch-mesh poultry wire. The traps are cylindrical, 2 feet in diameter and 5 feet long. One end is closed, while a funnel is fashioned in the other end. The funnel, which has a





2 1/4-inch opening, extends 2 1/2 feet into the trap. A small door permits removal of the trapped bluegills.

The trap should be set in water about 4 feet deep, with the long dimension of the trap parallel to the shoreline. Fasten the trap to a stake with a cord. It is not essential to bait the traps, although cottage cheese or bread suspended in a cloth sack inside the trap may attract bluegills. The 1-inch mesh will selectively trap bluegills of the bothersome intermediate size. Few bass will be trapped.

Traps should be used during late summer and early fall and checked daily. Two weeks of trapping usually will be adequate. Stop trapping when the daily catch drops to one-half the initial catch.

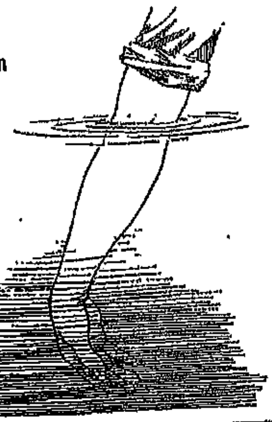
Fertilizing bass-bluegill ponds
Pond fertilization is a standard procedure in the southeastern United States, but the desired results do not always develop in northern areas. Fertilizer is applied to stimulate growth of plankton suspended in the water. Heavy growth of plankton is called a plankton bloom. Increasing plankton often increases production of food organisms and fish production as well. It also may reduce growth of rooted plants by shading the pond bottom.

Fertilizing does not always result in plankton blooms. In fact, it often stimulates other aquatic plant growth and complicates the problem it was intended to suppress. Large amounts of organic material, either plankton or aquatic weeds, may lead to fish kills because of oxygen depletion when organic matter decomposes.

Pond owners wanting a plankton bloom should apply an inorganic fertilizer such as 10-10-10 from very early spring into the summer. Cut the bag and immerse it in 18 inches of water in the windward corner of the pond. If a plankton bloom does not develop within a week or two add another bag of fertilizer at another location, then perhaps others, until the pond becomes colored or cloudy with plankton. Through experience, pond owners can determine the amount of fertilizer to use. No fixed amount will satisfy every pond condition. Fertilize enough to keep the pond cloudy. A bloom can be considered dense enough if the hand cannot be seen when the arm is immersed to the elbow. A halfway job of fertilization is usually worse than none.

If rooted aquatic plants are present, do not fertilize until they are removed. Stop fertilizing if aquatic weeds develop during the season. Do not attempt to fertilize a pond which has excessive water flow. This simply dilutes the fertilizer and washes it out of the pond.

Checking for plankton bloom



BIOLOGY AND MANAGEMENT OF BASS-SHINER PONDS

Species
Largemouth bass and golden shiners are recommended for stocking ponds where the owner desires sport fishing for bass. Smallmouth bass may prove successful in some Pennsylvania ponds, but this is the exception, not the rule.

Stocking
Ponds should be stocked with 100 bass fingerlings and 300 to 400 adult golden shiners, 2 inches or longer, per acre. Stock both species at the same time, between July and September.

Growth and survival
Bass growth and survival rates usually are better in ponds stocked with bass and shiners than in ponds stocked with bass and bluegills, although the total pounds of edible fish is less. Most of the bass in bass-shiner ponds will attain harvestable size within a year, while those in bass-bluegill ponds may require up to 3 years.

Production
Bass reproduce more successfully and more regularly in the bass-shiner ponds, thus providing a larger crop of harvestable bass. Bass usually begin to reproduce at 2 years of age in most Pennsylvania ponds. Occasionally, they may not reproduce until they are 3 or 4 years old. Once they have reproduced, they usually spawn successfully every year thereafter, regardless of the presence or absence of shiners.

Reproduction and development of golden shiners require some aquatic vegetation. Pond owners should consider this aspect of management in ponds stocked with the bass-golden shiner combination.

Shiners will reproduce the first year and continue to reproduce every year thereafter so long as adults are present. Shiners usually reach their peak of abundance during the second year, then gradually decline, probably because of predation by bass. The bass may thrive even after the shiners have disappeared.

Fishing bass-shiner ponds
Fishing should not be allowed before the bass have reproduced. Only a limited number of bass should be removed at one time. The removal of too many large bass from a small pond can result in very poor fishing for a year or two.

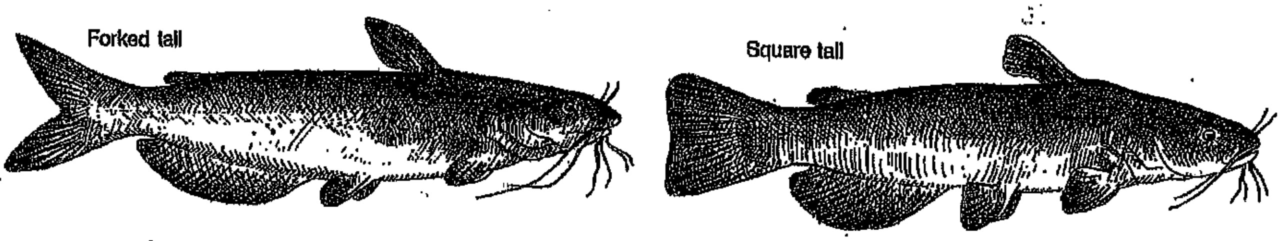
Fertilizing bass-shiner ponds
Bass-golden shiner ponds normally do not require intensive fertilization. However, to hasten the development of a natural food supply and increase fish growth in new ponds, 400 pounds of 10-10-10 fertilizer per acre should be applied during each of the first 2 years. This should be accomplished by applying at the rate of 100 lb. per acre immediately after the pond is finished, and then making equal applications periodically throughout the summer. The same uncertainties exist as were described under fertilization of bass-bluegill ponds, and the same precautions should be taken.

OTHER STOCKING ARRANGEMENTS FOR WARM-WATER PONDS

Little is known about management of other warm-water fish. Studies of the following combinations are few or nonexistent, and results are questionable.

Bass and channel catfish
Largemouth bass and channel catfish are suggested for stocking in ponds where the owner wants greater fish production than is possible with bass alone and where bluegills and other panfish are not desired.

Ponds should be stocked with 500 channel catfish fingerlings and 1,000 fathead minnows per acre in



Channel cat

Brown bullhead

February or March. One hundred bass fingerlings should be stocked from May to July.

Bass growth and survival rates are good in ponds stocked in this manner. Catfish survival immediately following stocking is unpredictable. Where a good survival rate is attained, channel catfish grow well and can be expected to reach one-half pound in weight by the end of their second growing season in fertile ponds. Some have grown to 12 pounds in 8 to 9 years. The bass will reproduce and should maintain a good population level.

Channel catfish reproduction in small ponds is unpredictable. Nail kegs, milk cans, or other similar devices placed on their sides may be used for spawning boxes if they are anchored about 18 inches beneath the water surface. Channel catfish may not spawn, however, even when these devices are provided.

Fishing for channel catfish may begin during the fall following stocking. Fishing for bass should not begin until after they have begun reproducing. Ponds stocked in the manner described should provide satisfactory fishing for 3 to 4 years or longer. When fishing becomes poor, the pond should be drained and restocked.

Bass alone

Largemouth bass may be stocked alone in ponds where the owner's only desire is to produce sport fishing for bass.

The pond should be stocked with 150 to 200 fingerling bass per acre in the fall. The following spring, add eight to ten adult bass before spawning time or before the water temperature reaches 60 degrees F. One thousand fathead minnows stocked with the initial fingerling bass may increase the rate of growth of the bass.

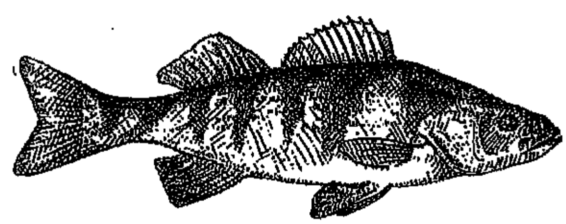
Bass-brown bullhead

Many pond owners are especally interested in bullheads. They often stock them in ponds regardless of other species present. This often produces unsatisfactory results. Bullheads reproduce easily in most small ponds and may quickly overpopulate a pond. Overpopulation by bullheads will cause stunted growth in all forage fish in the pond, because of the intense competition for food.

Cases have been reported where bullheads in combination with largemouth bass gave satisfactory results. Bass eat bullheads. When a bass population is large enough to keep bullhead numbers under control, bullheads may attain a size of 12 inches or larger. Bullheads that size provide a lot of fine sport and good eating.

Do not stock bullheads alone. Without some measure of population control in addition to angling, they quickly overpopulate a pond. Bullheads feed on insect larvae that live on or in the soil of the pond bottom. Too many bullheads usually cause a pond to become roiled, as they continually stir up mud while searching for food. Muddiness restricts the reproduction and growth of other fish in the pond. It can also make the pond unattractive for swimming and other uses.

Bullheads should not be stocked where other species are already present in combination with bass. If the bass-bullhead combination is desired for a pond already containing other species, it is suggested that the existing species be eliminated and the pond owner start over with appropriate numbers of bass and bullheads.



Yellow perch

Yellow perch

Yellow perch are excellent panfish but usually undesirable in small ponds. They are active feeders during winter, and are thus a favorite with ice fishermen.

Yellow perch will live and reproduce in almost any body of water. They are prolific breeders and may quickly overpopulate a pond. They also spawn before bass, and prey on bass fry. These characteristics make them undesirable for stocking in most farm ponds.

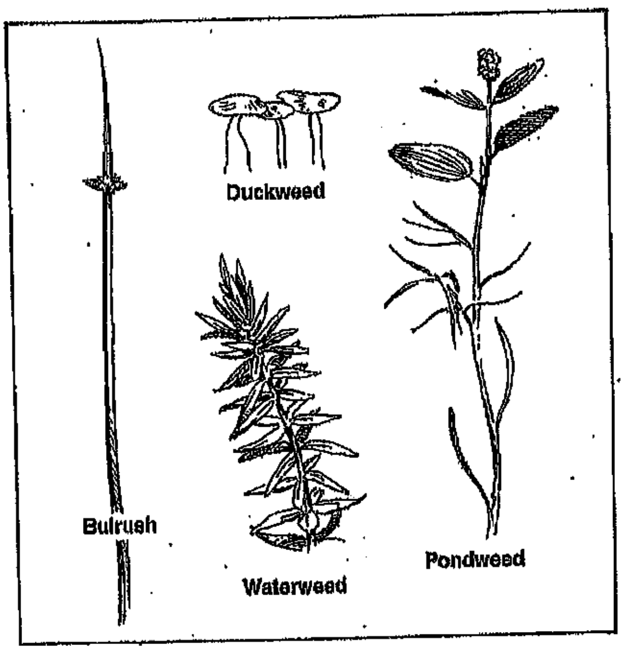
TROUBLES AND TREATMENTS

Some common problems which pond owners may encounter include aquatic plants, fish kills, undesirable animals, and construction faults. Pond location, construction, degree of management, and natural processes influence each of these conditions.

Aquatic plants

When ponds and other aquatic environments are developed, it is natural for aquatic plants and animals to invade them. The management objectives of some owners include maintaining as many natural aquatic features as possible, including native aquatic plants. In these special cases, modification of construction features and management practices may satisfy the owner's interest in having a more natural environment.

However, aquatic plants present problems for most pond owners. Preventive measures and mechanical or chemical controls will not permanently eliminate aquatic plants. Like weeds in a garden, undesirable aquatic plants must be dealt with in a continuous program.



Mechanical means and fertilization

Aquatic plant problems often can be alleviated somewhat by deepening the edges of a pond to three feet with 3:1 side slopes. Shallow water favors the development and growth of many aquatic plants. Vegetation such as cattail, sedges, arrowhead, and bulrush along the pond edges can be pulled by hand when it first appears. Vegetation on the pond shores should be mowed where practical.

Chemical control of aquatic plants

Chemical control should be considered only if it is impossible or uneconomical to control aquatic plants through pond design or mechanical means.

Most aquatic plants can be controlled with chemicals. Manufacturers of chemical herbicides are required by law to provide detailed instructions on the label regarding their use. These instructions must be followed carefully to insure satisfactory and safe performance. Fish kills in the pond and pollution of the water discharged from the pond should not occur if label instructions are followed. Chemicals should be used only for purposes and areas specifically stated on the label.

In order to use aquatic herbicides safely and effectively, the plants to be controlled must be clearly identified, water volumes must be determined, the proper registered herbicide selected, and proper application of the herbicide must be made. County Extension offices have educational materials to aid pond owners who are considering the use of aquatic herbicides. Ask for Special Circular 222 *Aquatic Plants — Management and Control* and the supplemental sheet of registered aquatic herbicides.

Restricted-use pesticides must be applied by, or under the direct supervision of, applicators certified by the Pennsylvania Department of Agriculture. To use any chemical in waters of the Commonwealth, pond owners must apply for and obtain a permit issued jointly by the Department of Environmental Resources and the Pennsylvania Fish Commission.

Applications for permits to use aquatic pesticides are available from the Pennsylvania Fish Commission, Fisheries Management Section, Robinson Lane, Bellefonte, PA 16823, from regional offices of the Department of Environmental Resources, or from county offices of the Cooperative Extension Service.

Muskrat damage

Muskrats may damage a pond by building dens in the banks. They begin burrowing 6 to 18 inches below the waterline and angle up into the bank where they construct living quarters in dry soil above the waterline. Burrows may cause leaks, and dens may collapse under a person's weight.

The best insurance against muskrat damage is a properly designed pond. A wide top and sufficient freeboard will make a dam relatively safe from damage. There is little danger of leaks in dams with adequate top widths, because muskrats usually will not burrow completely through. If sufficient freeboard is provided, there usually will be enough ground cover over the den to prevent a cave-in.

Muskrats are likely to take up housekeeping even in the best designed ponds. They can become a nuisance to the owner, even though their activities may not endanger the pond. If this is the case, the owner may provide protection by riprapping the shoreline with large gravel or small stones. These materials should be placed in a layer 3 to 4 inches thick, and should extend from at least one foot above the normal water level to at least 3 feet below it. Riprapping also protects the shore from erosion of wave action.

Questions often are asked about the legality of muskrat control. The Pennsylvania Game Law provides that any person may kill or capture alive, at any time, any fur-bearing animal (except beaver) in the act of destroying personal property. Refer to Section 603 of the Pennsylvania Game Laws, and contact the local district game protector for further details. Poisons may not be used legally in muskrat control.

Muddy water

Muddy ponds often are a problem. Muddy water prevents maximum production of food organisms and therefore reduces fish growth. It also can interfere with fish reproduction.

Muddy water may be caused by erosion from a cultivated or unprotected watershed, by livestock wading in the pond, by wave action eroding the banks, and by the feeding action of bullheads or carp. The owner should correct these causes of muddy water before resorting to other forms of treatment.

When muddy water results from the action of waves stirring up the bottom sediments, the situation may be corrected by spreading a layer of hay or straw over the bottom of the pond, from the edge to a few feet from shore. This will have the greatest beneficial effect in shallow areas or where wave action is especially heavy. This mat prevents the waves from picking up fine sediments and provides food and cover for aquatic organisms. Introducing too much hay or straw could cause an oxygen depletion as the hay or straw decomposes. This in turn could result in a fish kill.

Sometimes the problem of clearing muddy water is not easy to solve. This is especially true when colloidal particles became suspended in the water and must be precipitated by chemical action.

The following alternative methods may be effective in clearing muddy ponds:

1) Broadcast 1,000 lb. of ground agricultural limestone (calcium carbonate) or 740 lb. of hydrated lime per surface acre of water. This should clear a pond and keep it clear for two years or more. Do not use burned or quicklime (calcium oxide), because it may kill the fish.
2) Broadcast 1,000 lb. of agricultural gypsum per surface acre of water. It may be necessary to repeat this treatment several times a year to keep the pond clean. Gypsum tends to acidify the water, and may result in reduced fish production.
3) Broadcast 250 lb. of aluminum sulfate (commercial alum) per surface acre. Apply treatments weekly until the water clears. Alum will lower the pH of water and reduce yields of fish.

Leaks

The best insurance for avoiding a leaking pond is to select a good pond site and make sure the dam is properly constructed. If an ideal site is not available, a less desirable site must be accepted if the landowner wants and needs the pond.

Seepage may become a problem unless precautions are taken at time of construction. If leaks develop after the pond has been filled, it will be necessary to drain the pond, let the bottom dry, then apply a sealant. Several products are used for sealing pond leaks. One is bentonite, a soft, porous, moisture-absorbing mineral clay that is worked into the soil. When bentonite gets wet, it swells to many times its original size and stops seepage by filling the space between the soil particles. For the average pond, up to 10 feet in depth, one pound of bentonite per square foot will reduce seepage by 80 to 100 percent. It should be thoroughly disked into the soil to a depth of 3 to 4 inches. The area should then be rolled several times to pack the surface.

Sodium polyphosphate is the name given to a group of chemicals used to seal pond leaks. The chemicals are similar to some household detergents and usually are obtained in a white, granular form. Lumpy soils, when treated, break down into fine particles that pack together and hold water better. Small channels and voids, present in the untreated soil, fill with these dispersed particles. The result is a relatively stable, impermeable blanket over the treated area.

Ten pounds of granulated sodium polyphosphate will adequately treat 200 square feet of pond bottom. Thoroughly mix the soil to a depth of 8 inches. Apply the polyphosphate by broadcasting or drilling. Compact the treated area with a rubber-tired roller or a steel roller before filling the pond. Do not use a sheep's-foot roller.

Sodium polyphosphate works best in a limestone soil having a high silt and clay content. It does not work as well with coarse-textured soils. Bentonite works well on coarse-textured soils, but is not effective on highly acidic soils.

Leaks in an established pond may sometimes be eliminated by applying a blanket of clay to the pond bottom. If clay is not available at the pond site, it may be transported from a nearby area. The clay should be applied in a layer, or blanket, about 6 inches deep over the pond bottom and compacted. The water should be returned to the pond as quickly as possible to prevent the clay from cracking because of excessive drying.

Fish kills

Fish kills resulting from a lack of sufficient oxygen are quite common in Pennsylvania ponds. Most die-offs are observed during the summer. Distressed fish are seen easily as they rise to the surface and gasp for oxygen. Dead fish may be seen floating about the pond. Fish kills also occur during extremely cold winters when a pond is covered with ice and deep snow for prolonged periods. Ponds that are poorly constructed, shallow, overpopulated, or have excessive aquatic vegetation are most likely to have kills from oxygen depletion.

The best insurance against a fish kill from oxygen depletion is a well constructed pond. Spring-fed ponds, or ponds with running water where long, cold winters are not the rule, should have depths of 6 to 8 feet over at least one-fourth of their total area. Ponds without running water, or those located in areas with long, cold winters, should have depths of at least 10 to 12 feet over at least one-fourth of the total area.

Summer die-offs usually occur when inadequate amounts of oxygen exist in the water during extended periods of hot, calm and cloudy days. However, not all fish kills are associated with oxygen depletion.

Many agricultural chemicals are highly toxic to all forms of life, especially fish. Pond owners should be especially cautious about using pesticide spray near ponds or streams. Runoff containing pesticides from fields and orchards can kill fish. A fish kill from pesticides may be difficult to detect, because minute amounts of a pesticide can cause losses over a long period.

Turtles

Snapping turtles occasionally inhabit larger ponds. Snapping turtles seldom cause problems, but are considered undesirable by many pond owners. Other kinds of turtles are more common. If snapping turtles become a problem, they may be removed by fishing. Use large turtle hooks (one inch between shank and point) attached to a wire leader, and use a heavy cord for line. Bait the hook with dead fish or other meat. Place baited hooks in shallower parts of the pond.

Parasites

Parasites are common in most farm ponds. Most of these, however, are associated with fish and are not harmful to man.

Threadworms, spiny-headed worms, tapeworms, and flukes are some of the parasites usually found in fish. They are unappealing, but usually do not affect the edibility of the fish. They are not harmful to humans.

Swimmer's itch is caused by a small, free-swimming parasite. It burrows under skin where it dies. This causes an itching that lasts for about a week. A brisk rubdown with a towel immediately after emerging from the water will minimize the irritation caused by this parasite. The most practical way to control these parasites is to control the snails which serve as their intermediate hosts. This can be done by draining the pond and letting it dry for several months. No chemicals are registered for controlling snails.

Snakes

The most practical way to eliminate snakes from a pond is to make it unattractive to them. Keep the pond free of weeds and debris in which they can hide. Keep the banks closely mowed and clean. A few water snakes may occasionally inhabit the pond, but these do little or no harm.

BAIT FISH PRODUCTION AND MANAGEMENT

General

In the past, fishermen could catch minnows for bait from lakes and streams. Because of increased use and pressure on all our water resources, some of these natural waters no longer supply the angler's bait needs. This has created opportunities for management of ponds for the production of minnows.

There are more than 200 licensed bait-fish producers in Pennsylvania, representing a substantial investment in ponds and facilities. Labor and technical knowledge are essential to assure success and protect the investment.

Location of bait enterprises is influenced by the proximity of accessible fishing waters, and by the availability of wild minnows. By choice of species and management procedures, bait producers usually can satisfy the needs of fishermen at various seasons of the year.

Regulations for bait propagation

Raising bait fish requires the appropriate propagation licenses issued by the Pennsylvania Fish Commission.

An application for a bait license must indicate the size, character, and purpose of the propagation facilities. The license authorizes the operator to catch and kill the fish from his facilities with any device except explosives or poisons, and further authorizes the operator to sell or dispose of the fish in any manner and at any time of the year. A licensed bait producer must maintain complete records of the operation. Bait-fish licenses do not permit catching, stocking, or maintaining bait ponds with fish taken from public waters. Specific regulations and applications for bait-fish licenses can be obtained from local Fish Commission representatives. Check Chapter VI, Sections 170 to 181, of the Pennsylvania Fish Laws.

The design, construction, and management of bait-fish ponds is highly specialized and differs from typical ponds discussed in this publication. Individuals desiring information on bait production should refer to technical publications in the reference list.

SAFETY AND LIABILITY

Safety

Ponds, like any body of water, attract people. When the two come together, there is always a chance for accidents.

Consider safety features during pond layout and construction. Remove trees, stumps, and brush which may be a hazard to swimmers. Keep the pond and banks free of rubbish, wire, cans, bottles, and other debris.

After the pond is built and filled with water, mark the swimming area, and post safety rules for all permitted water uses. Place warning signs at all known danger spots.

If boating and swimming are permitted, consider building a dock or pier. Place lifesaving devices such as ring buoys, ropes, or long poles near swimming areas. Never swim, boat, or skate alone. Keep all people out of the water during storms. Boats must contain one U.S. Coast Guard-approved lifesaving device for each passenger. Encourage all who use the pond or lake to learn to swim. Many organizations and groups offer training in swimming, lifesaving, and artificial respiration.

Liability

Many pond owners willingly permit use of their land and developed water areas for many recreational purposes. However, there has been justifiable concern for the landowner's liability for accidents. The 1965 General Assembly enacted a landowner liability law (Act 586) which has as its purpose "encouraging landowners to make land and water areas available to the public for recreational purposes by limiting liability in connection therewith, and repealing certain acts."

Under the act, recreational use includes, but is not limited to, hunting, fishing, swimming, boating, camping, picnicking, hiking, pleasure driving, nature study, water skiing, water sports, and viewing or enjoying historical, archaeological, scenic, or scientific sites.

An owner of land who either directly or indirectly invites or permits without charge any person to use such property for recreational purposes does not (1) extend any assurance that the premises are safe for any purpose (2) confer upon such person the legal status of an invitee or licensee to whom a duty of care is owed or (3) assume responsibility for or incur liability for any injury to persons or property caused by an act of omission of such persons.

This act does not limit liability of landowners for willful or malicious failure to guard or warn against a dangerous condition, use, structure, or activity. Neither is liability of the landowner limited in this act when charges are made for recreational use such as fee-fishing lakes, regulated shooting preserves, rented campsites, or other fee activities, except that in the case of land leased to the state or a subdivision thereof, any consideration received by the owner for such lease shall not be deemed a charge.

This landowner liability law has had the support of farmers, forest landowners, organized sportsmen, and others. They recognize the need for meaningful arrangements to accommodate public use of private lands and waters for recreational purposes on terms satisfactory and acceptable to resource owners and resource users. Protection of private landowners under this act may be a very constructive public action mutually beneficial to landowners and the public.

In addition to the protection offered by this act, most landowners carry comprehensive liability insurance on their property. For more complete information on the question of landowner liability, obtain a copy of the complete landowner liability law passed in 1965. You may also want to consult an attorney and an insurance agent for proper interpretation and protection for the specific circumstances involved.

REGULATED FEE-FISHING LAKES

General

In recent years, more than 200 regulated fee-fishing lakes have been in operation in the Commonwealth. Most of these appear to be located near population centers where few public waters or other fishing opportunities exist.

Operation and management of regulated fee-fishing lakes have not been adequately studied (from the economic and the biological viewpoints) and are not well understood. For this reason, owners should explore all aspects of these enterprises before under-taking development. The most important item to be considered before entering into this type of enterprise is economics. Fee-fishing enterprises require a high capital investment and high annual operating expense — especially if periodic annual stocking is done. This stocking feature appears to be essential to successful fee-lake operations. All costs must be considered in relation to economic returns.

Regulations for fee-fishing lakes

Special licenses and regulations apply to privately developed, fee-fishing lakes. A license application for a regulated lake must indicate the area of fishing water, since license fees are on a size scale:

Less than 5 acres	$25
5 acres but less than 10 acres	$30
10 acres but less than 20 acres	$40
20 acres but less than 40 acres	$50
40 acres but less than 80 acres	$60
80 acres or more	$75

There are no closed seasons on regulated fishing lakes other than those applied by the lake operators. Fishermen are not required to have a fishing license in some regulated fishing lakes, providing certain location and water source criteria are met.

Operators must maintain appropriate records of permits or bills of sale issued to patrons, and of fish purchased for stocking. Additional information may be obtained from Regional offices of the Pennsylvania Fish Commission, and by reference to Chapter II, Article VII, Sections 59 to 65 of the Pennsylvania Fish Laws.

FINAL REMARKS

This publication has been developed to help consolidate and coordinate scientific knowledge, professional competency, action programs, and interests of a variety of public agencies. Each has responsibilities and contributions to be made in the development, management, regulation, and use of water and fishery resources — particularly ponds and associated developments on private lands.

The United States Soil Conservation Service has the responsibility of locating, designing, and engineering impoundments as part of soil and water conservation planning. Responsibilities of the Pennsylvania Fish Commission involve state laws and regulations affecting water and fishery resources.

The interests of The Pennsylvania State University are in the field of research and education; although this is not exclusive since professional workers of other agencies conduct research and have broad public contacts. Researchers and educators have a responsibility to those who make policy affecting the water and fishery resources, as well as to pond owners, fishermen, and other members of the public who are affected by the policies and programs.

In recognition of the various interests and contributions of the agencies and their professional staffs, the Pennsylvania Cooperative Extension Service of The Pennsylvania State University, and the United States Soil Conservation Service, have compiled this publication.

It is intended to serve as a guide for professional workers in Pennsylvania as they counsel pond and small-lake owners. Also this publication is for use and study by those owners who are dedicated in their efforts to apply intensive land and water management, essential for their satisfaction with relatively small aquatic environments.

File No. IVI3o 10M380 U.Ed. 80-75

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

POND

CODE 378

(no)

DEFINITION

A water impoundment made by constructing an embankment, excavating a dugout, or a combination of both.

In this standard, NRCS defines ponds constructed by the first method as embankment ponds and those constructed by the second method as excavated ponds. Ponds constructed using a combination of the excavation and embankment methods are classified as embankment ponds if the depth of water impounded against the embankment at the auxiliary spillway elevation is 3 feet or more above the lowest original ground along the centerline of the embankment.

PURPOSE

This practice is used to accomplish one or more of the following purposes:

- Store water for:
  - Livestock
  - Fish and wildlife
  - Recreational use
  - Fire control
  - Erosion control
  - Flow detention
- Improve water quality

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to all excavated ponds. It also applies to embankment ponds that meet all criteria for low-hazard potential dams as listed below:

- The failure of the dam will not result in loss of life, damage to homes, commercial or industrial buildings, main highways, or railroads, or in interruption of the use or service of public utilities.
- The product of the storage times the effective height of the dam is less than 3,000 acre-feet^2. Storage is the capacity of the reservoir in acre-feet below the elevation of the crest of the lowest auxiliary spillway or the elevation of the top of the dam if there is no open channel auxiliary spillway. The effective height of the dam is the difference in elevation, in feet, between the lowest open channel auxiliary spillway crest and the lowest point in the original cross section taken on the centerline of the dam. If there is no open channel auxiliary spillway, use the lowest point on the top of the dam instead of the lowest open channel auxiliary spillway crest.
- The effective height of the dam is 35 feet or less.

CRITERIA

General Criteria Applicable to All Ponds

Plan, design, and construct the pond to comply with all Federal, State, and local laws and regulations. Notify landowners and/or contractor of their responsibility to locate all buried utilities in the project area, including drainage tile and other structural measures. The landowner is also required to obtain all necessary permits for project installation prior to construction.

Design a minimum sediment storage capacity equal to the design life of the structure, or provide for periodic cleanout. Protect the drainage area above the pond to prevent sedimentation from adversely affecting the design life.

Design measures necessary to prevent serious injury or loss of life according to the requirements of NRCS National Engineering Manual (NEM) (Title 210), Part 503, "Safety."

Seed or sod the exposed surfaces of earthen embankments, earth spillways, borrow areas, and other areas disturbed during construction in accordance with the criteria in NRCS Conservation Practice Standard (CPS) Critical Area Planting (Code 342). When necessary to provide surface protection where climatic conditions preclude the use of seed or sod, use the criteria in NRCS CPS Mulching (Code 484) to install inorganic cover material such as gravel.

Cultural resources

Evaluate the existence of cultural resources in the project area and any project impacts on such resources. Provide conservation and stabilization of archeological, historic, structural, and traditional cultural properties when appropriate.

Site conditions

Select or modify the site to allow runoff from the design storm to safely pass through a natural or constructed auxiliary spillway, a combination of a principal spillway and an auxiliary spillway, or a principal spillway.

Select a site that has an adequate supply of water for the intended purpose through surface runoff, ground water, or a supplemental water source. Water quality must be suitable for its intended use.

Reservoir

Provide adequate storage volume to meet user demands for all intended purposes. Account for sedimentation, season of use, evaporation loss, and seepage loss when computing the storage volume.

Additional Criteria for Embankment Ponds

Geological investigations

Use pits, trenches, borings, and reviews of existing data or other suitable means of investigation to characterize materials within the embankment foundation, auxiliary spillway, and borrow areas. Classify soil materials using ASTM D2487-17e1, "Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)." Determine from the investigations if problem soils exist at the embankment pond site for defensive design measures. Problem soils, include but are not limited to dispersive clays, collapsible soils, soft clays, expansive clays, low internal erosion resistance soils, loose coarse-grained soils, high soluble content soils, and caliche soils.

Foundation cutoff

Design a cutoff of relatively impervious material under the dam and up the abutments as required for preventing seepage. Locate the cutoff at, or upstream from, the centerline of the dam. Extend the cutoff deep enough to intercept flow and connect with a relatively impervious layer. Combine seepage control with the cutoff as needed. Use a cutoff bottom width adequate to accommodate the equipment used for excavation, backfill, and compaction operations. Design cutoff side slopes no steeper than one horizontal to one vertical.

Seepage control
Include seepage control if—

- Foundation cutoff does not intercept pervious layers.
- Seepage could create undesired wet areas.
- Embankment stability requires seepage control.
- Special problems require drainage for a stable dam.

Filter zones may be required in some embankment designs to address the problem of cracking and internal erosion of the embankment for sites with problematic conditions such as dispersive clays, steep abutments, and other issues.

Control seepage with—

- Foundation, abutment, or embankment filters and drains.
- Filter diaphragms.
- Reservoir bottom blanketing.
- A combination of these measures.

Top width
Table 1 provides the minimum top widths for dams of various total heights. Total height is the vertical distance between the settled top of the dam and the lowest elevation at the downstream toe.

Design a minimum width of 16 feet for one-way traffic and 26 feet for two-way traffic for the top of a dam used as a public road. Design guardrails or other safety measures where necessary and follow the requirements of the responsible road authority. For dams less than 20 feet in total height, maintenance considerations or construction equipment limitations may require increased top widths from the minimum shown in table 1.

Table 1. Minimum Top Width for a Dam.

Total Height of Dam (feet)	Top Width (feet)
Less than 10	6
10–14.9	8
15–19.9	10
20–24.9	12
25–35	15

Side slopes
Design each side slope with a ratio of two horizontal to one vertical or flatter. Design the sum of the upstream and downstream side slopes with a ratio of five horizontal to one vertical or flatter. As required, design benches or flatten side slopes to assure stability of all slopes for all loading conditions. Flatter slopes may be required for stability for some problematic embankment or foundation soils such as highly plastic embankment soils or very soft clays. Downstream or upstream berms can be used to help achieve stable embankment slopes.

Slope protection
Design special measures such as berms, riprap, sand-gravel, soil cement, or use special vegetation as needed to protect the slopes of the dam from erosion. Use NRCS Engineering Technical Release (TR) 210-56, "A Guide for Design and Layout of Vegetative Wave Protection for Earth Dam Embankments," and TR-210-69, "Riprap for Slope Protection against Wave Action," as applicable.

Freeboard
Design a minimum of 1 foot of freeboard between design high-water flow elevation in the auxiliary spillway and the top of the settled embankment. Design a minimum 2 feet of elevation difference between the crest of the auxiliary spillway and the top of the settled embankment when the dam has more than 20 acre drainage area or more than 20 feet in effective height. Design a minimum of 1 foot of freeboard above the peak elevation of the design hydrograph to the top of the settled embankment when the pond has no auxiliary spillway.

Settlement
Increase the height of the dam by the amount needed to ensure that the settled top elevation of the dam equals or exceeds the design top elevation. Design a minimum settlement allowance of 5 percent of the total height of the dam associated with each dam cross section, except where detailed laboratory soil testing and settlement analyses or experience in the area shows that a lesser amount is adequate.

Principal spillway
A pipe with needed appurtenances shall be placed under or through the dam, except where rock, concrete, or other types of lined spillways are used, or where a vegetated or earth spillway can safely handle the rate and duration of the design flow.

Design a minimum of 6-inches difference between the crest elevation of the auxiliary spillway and the crest elevation of the principal spillway when the dam has a drainage area of 20 acres or less. Design a minimum of 1 foot difference when the dam has a drainage area of over 20 acres.

Provide an anti-vortex device to handle pressure flow in the principal spillway pipe. Design the inlet and outlet to function for the full range of flow and hydraulic head anticipated.

Design adequate pipe capacity to discharge long-duration, continuous, or frequent flows without causing flow through the auxiliary spillway. Design a principal spillway pipe with a minimum inside diameter of 4 inches. Design pipe with a minimum inside diameter of 1-1/4 inches for water supply pipes or for pipes used for any other purpose.

Design pipe using ductile iron, welded steel, corrugated steel, corrugated aluminum, reinforced concrete (precast or site-cast), or plastic. Do not use cast iron or unreinforced concrete pipe if the dam is 20 feet or greater in total height.

Design and install pipe to withstand all external and internal loads without yielding, buckling, or cracking. Design rigid pipe for a positive projecting condition. Design flexible pipe according to the requirements of NRCS National Engineering Handbook (NEH) (Title 210), Part 636, Chapter 52, "Structural Design of Flexible Conduits."

Design connections of flexible pipe to rigid pipe or other structures to accommodate differential movements and stress concentrations. Design and install all pipes to be watertight using couplings, gaskets, caulking, water stops, or welding. Design joints to remain watertight under all internal and external loading, including pipe elongation due to foundation settlement.

Design a concrete cradle or bedding for pipe if needed to reduce or limit structural loading on the pipe and improve support of the pipe.

Design outlet structures, such as cantilever pipe outlet sections and impact basins, to dissipate energy as needed.

Corrosion protection
Provide protective coatings for all steel pipe and couplings in areas that have traditionally experienced pipe corrosion or in embankments with saturated soil resistivity less than 4,000 ohm-cm or soil pH less than 5. Protective coatings may include asphalt, polymer over galvanizing, aluminized coating, or coal tar enamel.

Ultraviolet protection
Use ultraviolet-resistant materials for all plastic pipe or provide coating or shielding to protect plastic pipe exposed to direct sunlight.

Cathodic protection
Provide cathodic protection for coated welded steel and galvanized corrugated metal pipe where soil and resistivity studies indicate that the pipe needs a protective coating and where the need and importance of the structure warrant additional protection and longevity. If the original design and installation did not include cathodic protection, consider establishing electrical continuity in the form of joint-bridging straps on pipes that have protective coatings. Add cathodic protection later if monitoring indicates the need.

Internal erosion
Install filter diaphragms for internal erosion control or anti-seep collars to reduce hydraulic gradient along the pipe extending through the embankment with inverts below the peak elevation of the routed hydrograph when the effective height of the dam is 15 feet or greater.

Filter diaphragms
Design the filter diaphragm according to the requirements of 210-NEH, Part 628, Chapter 45, "Filter Diaphragms." Locate the filter diaphragm immediately downstream of the cutoff trench, but downstream of the centerline of the dam if the foundation cutoff is upstream of the centerline or if there is no cutoff trench.

To improve filter diaphragm performance, provide a drain outlet for the filter diaphragm at the downstream toe of the embankment. Protect the outlet from surface erosion and animal intrusion.

Ensure that the filter diaphragm functions both as a filter for adjacent base soils and as a drain to intercept seepage. Materials for the filter diaphragm must meet the requirements of 210-NEH-Part 633, Chapter 26, "Gradation Design of Sand and Gravel Filters".

Anti-seep collars can be used where the following soil and site conditions apply:

- Embankment soils are documented to be non-dispersive by crumb testing or evidence that the site is located in geologic formations that are known to be non-dispersive.
- Soils tests show that embankment soils have a plasticity index (PI) equal to or greater than 15.
- The water content of the soils at the time of construction is such that a 1/8-inch diameter thread 1/2-inch long may be rolled out on a flat surface without breaking or falling apart.
- Natural or excavated ground slopes transverse to the embankment centerline in the vicinity of the conduit are no steeper than 2 horizontal to 1 vertical.
- Laboratory or field tests show that the foundation soils left in-place under the embankment and principal spillway are medium to very stiff in saturated consistency or medium dense to very dense depending on if these soils are cohesive or cohesionless, respectively.

When using anti-seep collars in lieu of a filter diaphragm, ensure a watertight connection to the pipe. Limit the maximum spacing of the anti-seep collars to 14 times the minimum projection of the collar measured perpendicular to the pipe, or 25 feet, whichever is less. Locate anti-seep collars no closer than 10 feet apart. Use a collar material that is compatible with the pipe material.

Design the collars to increase the seepage path along the pipe within the fill by at least 15 percent.

Trash guard
Install a trash guard at the riser inlet to prevent clogging of the pipe, unless the watershed does not contain trash or debris that could clog the pipe.

Pool drain
Provide a pipe with a suitable valve to drain the pool area if needed for proper pond management or if required by State law. The designer may use the principal spillway pipe as a pond drain if it is located where it can perform this function.

Auxiliary spillways
A dam must have an open channel auxiliary spillway, unless the principal spillway is large enough to pass the peak discharge from the design hydrograph and the trash that comes to it without overtopping the dam. The minimum criteria for acceptable use of a closed pipe principal spillway without an auxiliary spillway consists of a pipe with a cross-sectional area of 3 square feet or more, an inlet that will not clog, and an elbow designed to facilitate the passage of trash.

Design the minimum capacity of a natural or constructed auxiliary spillway to pass the peak flow expected from a total design storm of the frequency and duration shown in table 2, less any reduction creditable to the principal spillway discharge and detention storage.

Design the auxiliary spillway to safely pass the peak flow through the auxiliary spillway, or route the storm runoff through the reservoir. Start the routing either with the water surface at the elevation of the crest of the principal spillway or at the water surface after a 10-day drawdown, whichever is higher. Compute the 10-day drawdown from the crest of the auxiliary spillway or from the elevation attained from impounding the entire design storm, whichever is lower. Design the auxiliary spillway to pass the design flow at a safe velocity to a point downstream where the flow will not endanger the dam.

A constructed auxiliary spillway consists of an inlet channel, a control section, and an exit channel. Design the auxiliary spillway with a trapezoidal cross-section. Locate the auxiliary spillway in undisturbed earth or in-situ rock. Design stable side slopes for the material in which the spillway is to be constructed. Design a minimum bottom width of 10 feet for dams having an effective height of 20 feet or more.

Design a level inlet channel upstream from the control section for the distance needed to protect and maintain the crest elevation of the spillway. If necessary, curve the inlet channel upstream of the level section to fit existing topography. Design the exit channel grade according to 210-NEH-628, Chapter 50, "Earth Spillway Design," or with equivalent procedures.

Structural auxiliary spillways
Design chute spillways or drop spillways according to the principles set forth in 210-NEH, Part 650, "Engineering Field Handbook"; and 210-NEH, Section 5, "Hydraulics"; Section 11, "Drop Spillways"; and Section 14, "Chute Spillways." Design a structural spillway with the minimum capacity required to pass the peak flow expected from a total design storm of the frequency and duration shown in table 2, less any reduction creditable to the pipe discharge and detention storage.

Additional Criteria for Excavated Ponds

Runoff
Design a minimum of 1 foot of freeboard above the peak elevation of the design hydrograph. Design a pipe and auxiliary spillway that meets the capacity requirements of table 2. Consider runoff flow patterns when locating the excavated pond and placing the spoil.

Side Slopes
In the excavated area, design side slopes that are no steeper than one horizontal to one vertical.

Inlet Protection
Protect the side slopes from erosion where surface water enters the pond in a natural or constructed channel.

Excavated material
Place the material excavated from the pond so that its weight does not endanger the stability of the pond side slopes and so that the soil will not wash back into the pond by rainfall. Dispose of excavated material in one of the following ways:

- Uniformly spread to a height that does not exceed 3 feet, with the top graded to a continuous slope away from the pond.
- Uniformly place and with side slopes assuming a natural angle of repose. Place excavated material

at a distance equal to the depth of the pond, but not less than 12 feet from the edge of the pond.

- Shape to a designed form that blends visually with the landscape.
- Provide for low embankment construction and leveling of surrounding landscape.
- Haul material offsite.

Table 2. Minimum auxiliary spillway capacity

Drainage area *(acre)*	Effective height of dam[1] *(feet)*	Detention storage *(acre-feet)*	Minimum design storm[2]	
			Frequency *(years)*	Minimum duration *(hours)*
20 or less	20 or less	< 50	10	24
20 or less	> 20	< 50	25	24
> 20	all	< 50	25	24
All others	all	all	50	24

[1]. Defined above in "Conditions where Practice Applies."

[2]. Select rain distribution based on climatological region.

CONSIDERATIONS

Visual Resource Design

Carefully consider the visual design of ponds in areas of high public visibility and those associated with recreation. The shape and form of ponds, excavated material, and plantings are to relate visually to their surroundings and function.

Shape the embankment to blend with the natural topography. Shape the edge of the pond so it is generally curvilinear rather than rectangular. Shape excavated material so the final form is smooth, flowing, and fitted to the adjacent landscape rather than angular geometric mounds. If feasible, add islands to provide visual interest and attract wildlife.

Fish and Wildlife

Locate and construct ponds to minimize the impacts to existing fish and wildlife habitat.

When feasible, retain trees in the upper reaches of the pond and stumps in the pool area. Shape upper reaches of the pond to provide shallow areas and wetland habitat.

If operations includes stocking fish, use NRCS CPS Fishpond Management (Code 399).

Watering ramp

When wildlife or livestock need access to stored water, use the criteria in NRCS CPS Watering Facility (Code 614) to design a watering ramp.

Vegeation

Stockpile topsoil for placement on disturbed areas to facilitate revegetation.

Consider selecting and placing vegetation to improve fish habitat, wildlife habitat, and species diversity.

Water Quantity

Consider effects on components of the water budget, especially—

- Effects on volumes and rates of runoff, infiltration, evaporation, transpiration, deep percolation, and ground water recharge.
- Variability of effects caused by seasonal or climatic changes.
- Effects on downstream flows and impacts to the environment such as wetlands, aquifers, and social and economic impacts to downstream uses or users.

Water Quality

Consider the effects of—

- Erosion and the movement of sediment, pathogens, and soluble and sediment-attached substances that runoff carries.
- Short-term and construction-related effects of this practice on the quality of downstream watercourses.
- Water level control on the temperature of downstream water to prevent undesired effects on aquatic and wildlife communities.
- Wetlands and water-related wildlife habitats.
- Water levels on soil nutrient processes such as plant nitrogen use or denitrification.
- Soil water level control on the salinity of soils, soil water, or downstream water.
- Earth moving potentially uncovering or redistributing toxic materials.
- Livestock grazing adjacent to the pond. Consider fencing to prevent livestock activities having direct contact with the pond and dam.

PLANS AND SPECIFICATIONS

Prepare plans and specifications that describe the requirements for applying the practice according to this standard. As a minimum, include—

- A plan view of the layout of the pond and appurtenant features.
- Typical profiles and cross sections of the principal spillway, auxiliary spillway, dam, and appurtenant features, as needed.
- Structural drawings adequate to describe the construction requirements.
- Requirements for establishing vegetation or other ground surface protection, as needed.
- Safety features.
- Site-specific construction and material specifications.
- Utility location and notification requirements.

OPERATION AND MAINTENANCE

Prepare an operation and maintenance plan for the operator.

As a minimum, include—

- Periodically inspect all structures, earthen embankments, spillways, and other significant appurtenances.
- Promptly repair or replace damaged components.
- Promptly remove trash from pipe inlet and trash rack.
- Promptly remove sediment when it reaches predetermined storage elevations.
- Periodically remove trees, brush, and undesirable species.
- Periodically inspect safety components and immediately repair if necessary.
- Maintain vegetative protection and immediately seeding bare areas, as needed.
- Pevent the establishment of woody vegetation on constructed embankment fill and around spillway

appurtenances.

REFERENCES

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Algae in Ponds and Lakes

Written by **Robert B. Hesser**, *Fishery Resource Biologist*

Algae are the most common and widely distributed of all aquatic plants. Green, blue-green, and yellow or brown-green are the most common. There are some 15 to 20 thousand species of green algae alone, which indicates how abundant and diverse these minute organisms really are.

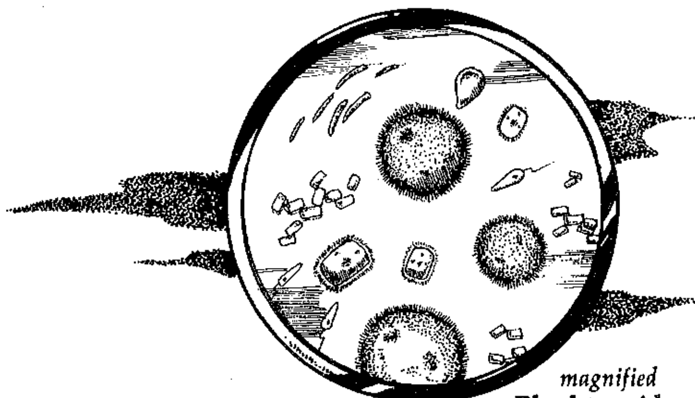
Many species are motile, this means they swim about like animals with the help of appendages called flagella.

Algae are plants, they need sunlight to live and grow. Through the process known as photosynthesis, carbon dioxide and water are utilized by algae to manufacture carbohydrates and other energy compounds. Some of these compounds are used quickly by the algae and others are stored in their tissues for later use. This ability to manufacture and store energy compounds makes them the lowest link in food chains which support most higher forms of aquatic life. Nearly all waters, even those affected by acid wastes from coal mining, contain algae. All but a few species are too small to see without magnification. They become visible only when the individual cells or filaments are so abundant that they appear as surface blooms, scums or floating mats.

Algae can be categorized into three major types: plankton, filamentous, and muskgrass.

PLANKTON ALGAE

All suspended forms of algae (phytoplankton), combined with great numbers of minute suspended animals (zooplankton), make up a diverse community known as plankton. When plankton algae become overabundant, they may color a water brown, yellow, peasoup green or occasionally red during the warm dry seasons of the year. When this occurs, the lake or pond is said to have a bloom. A certain amount of this algae is necessary to maintain food chains or food webs in an aquatic ecosystem. An overabundance of algae may make water unattractive or undesirable for swimming or use as a domestic water supply. A few species have the potential for producing toxic substances (endotoxins). These can cause severe sickness or, in isolated cases, death to pets, livestock, wildlife, and even man.



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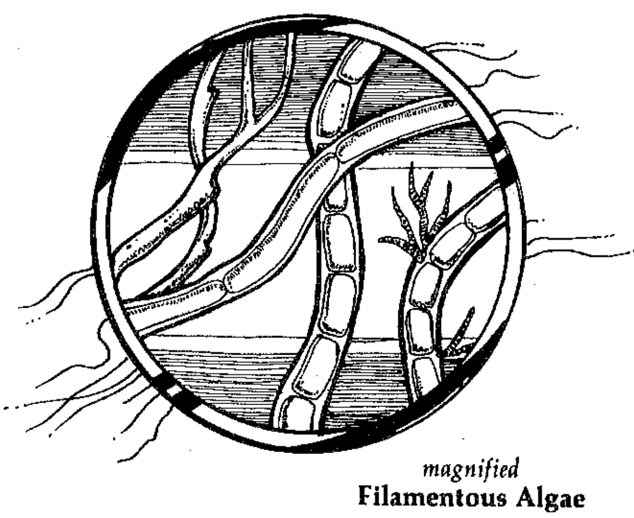
Plankton Algae

Filamentous Algae

Filamentous algae is often erroneously described as moss or slime because of its appearance when it forms a mat or fur-like coating on stones or other objects in aquatic environments. It actually consists of stringy, hair-like filaments or strands, some of which form branches and networks similar to a fish net.

Overabundance of filamentous algae can cause more interference with beneficial water uses than planktonic algae by impeding activities such as fishing or boating. A dense concentration of filamentous algae can also destroy the beauty of a pond or lake.

As it is the case with plankton algae, several species of filamentous algae have the potential for producing substances toxic to mammals, including man.



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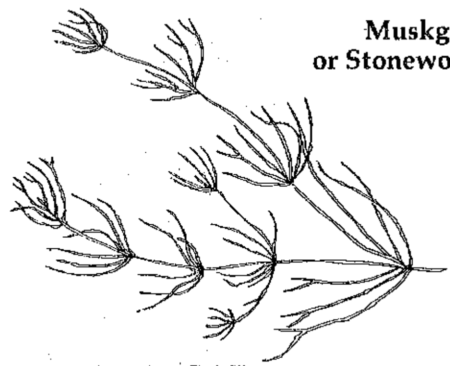
Filamentous Algae

PENNSYLVANIA FISH COMMISSION

Muskgrass Algae

Muskgrass or stonewort, represents the more evolutionary advanced forms of algae. Although they have no true roots, they grow attached to a lake or slow-flowing stream bottom by a primitive appendage. The term muskgrass is appropriate for some species because of their strong, musky, skunk-like odor. The term stonewort describes the rough, gritty calcium deposits which sometimes encrusts certain species which inhabit ponds or lakes having a highly alkaline and hard limestone water source. A few species, however, can thrive in soft or mildly acidic waters. These species seldom exhibit the musky odor or gritty deposits which characterize their relatives from more alkaline waters.



Muskgrass or Stonewort Algae

FUNCTION OF ALGAE

Algae, as the primary or lowest plant forms in aquatic food chains, are essential in water, particularly when fishes are to be a major part of the water's management program. Even if fishes are present only for ornamental or aesthetic purposes, they must have a source of food. In most ponds and lakes, the organisms upon which fishes feed are sustained by microscopic aquatic plantlife. So if a good fish population is the top priority, all algae should not be eliminated in trying to make a water area more desirable for another use, such as swimming.

When the goal for a given water is a variety of uses such as domestic or livestock water supply, swimming, a water hazard on a golf course or irrigation, algae becomes a detriment more than a benefit. In these cases, the less algae the better. Combinations of some of these uses and fishing frequently are not compatible. At this point, the water owner must decide what are the most important management priorities.

CONTROL OF ALGAE

If management priorities call for algae to be controlled in a pond or lake, drastic measures such as chemical treatment usually must be employed. The use of biological control measures such as the introduction of exotic fishes, hailed in some areas as a cure-all might not only be illegal, but also ineffective. Some physical measures like water drawndown over winter or hand raking can be helpful.

The best way to control algae is to prevent excess nutrients from entering the water. Since algae are plants, their growth like farm crops, is stimulated by natural and artificial fertilizers. These nutrients enter water by runoff, percolation, or leaching from the soil. They may result from improper disposal of human and animal wastes, agricultural wastes, or a host of other activities caused by man. When too many nutrients accumulate in a water, algae and other plantlife become overabundant, causing an ecological imbalance in the food chain. All water which is not hopelessly polluted has the capability for producing a measurable amount of what the biologist calls biomass. This consists of algae, higher plants and animals such as fish which live in balance in that water. The basic natural nutrients in the water provide the original building materials for the first link in the chain —the algae. If these nutrients are increased, algae growth will likely also increase. This upsets the original balance among the organisms. When algae dominates the biomass, the more desirable organisms will be displaced and later eliminated. And, in the process, the increased amount of algae will become a nuisance to beneficial water uses.

If chemical control is determined to be the only way to eliminate or control algae in a water, certain steps on a priority basis must be taken by the water owner. They are:

1. Identify the algae — determine to which of the three major types it belongs.
2. Prioritize pond uses. This will determine the amounts of algae that can be tolerated.
3. Determine from literature and product labels the best compound to use.
4. Make certain your herbicide is approved for algae control and can legally be used. If it is a *restricted use product*, proper certification of the purchaser must be obtained through the Pennsylvania Department of Agriculture prior to its purchase and use.
5. Find where the material can be purchased. This is usually at a local farm or garden supply store.
6. Consider downstream uses and possible harmful effects the chemical might have on downstream properties and other water users such as domestic water consumers, livestock, pets, waterfowl and other animals.
7. Consider potential harmful effects to waterside plantings, including trees.
8. Accurately compute the pond or lakes' depth and surface acreage. These measurements must be precise to avoid improper dosage.
9. Analyze some of the chemical characteristics of the water, especially pH and total hardness.
10. Determine the desired treatment period as well as the number and frequency of treatments to be made during the year.
11. Obtain a joint annual permit through the Pennsylvania Fish Commission and the Department of Environmental Resources prior to the actual application of either restricted use or general use chemicals. *It is unlawful to introduce such materials into any Commonwealth waters, either private or public, without proper authorization.*
12. Read application instructions carefully. Don't add or subtract from label directions, and be certain to read the product label thoroughly.

SOME ADDITIONAL SUGGESTIONS

Control is most effective and least costly when undertaken before the algae become dense enough to constitute a serious problem. Through experience with a given water, including familiarity with past problems, growing season, weather conditions and other factors, one may be able to anticipate when chemicals should be applied. Additional treatments during the year may become necessary and must be anticipated when a permit application is filed.

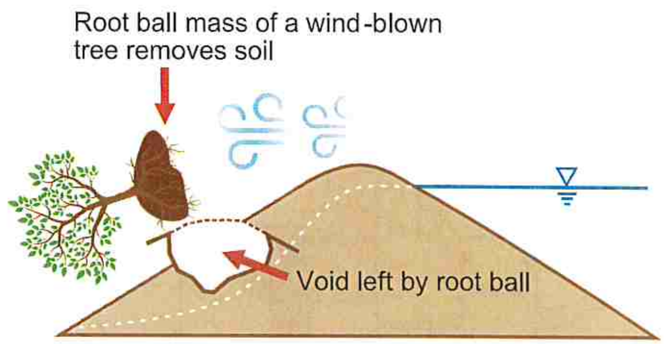
If additional help in pond management becomes necessary, contact the local Pennsylvania Fish Commission's Waterways Conservation Officer or Area Fisheries Manager; or contact the Fishery Resources Biologist, 450 Robinson Lane, Bellefonte, PA 16823. Other sources of help include the agricultural extension agent or soil conservation office usually found in each county.

VEGETATION AND EROSION CONTROL ON DAMS

Problems Created by Trees, Brush and Woody Vegetation

Trees and brush on a dam's earthen embankment and along the downstream toe can hide developing structural problems and create the potential for new problems in the future. The sudden uprooting of a tree by a strong wind can leave an exposed hole in the embankment where the tree's root ball was pulled out. Such a hole in a dam embankment can lower the crest elevation, reduce the effective width of a dam, and promote or enhance seepage. Additionally, a falling tree can damage concrete, steel, stone, or timber elements of the dam.

The root system of a healthy, standing tree can be a potential hazard by creating seepage pathways though a dam embankment. When trees die, the decaying roots form a network of voids that can increase seepage within the dam's embankment or foundation and decrease the stability of the embankment. This seepage can develop into a serious condition called "piping" that removes soil particles from the embankment or foundation in a process called internal erosion. This internal erosion can lead to a slow or even sudden failure of the dam.



Brush, woody vegetation, and even tall grass can hinder the visual inspection of the embankment by obscuring sinkholes, animal burrows, seeps, and other irregularities. Also, trees and brush provide excessive shade that hinders the growth of sturdy, thick grass cover on the dam embankment.

Grass and Erosion Control

Establishment of a dense grass cover is a very effective and inexpensive method to prevent erosion of embankment surfaces. The stems and root systems of grasses tend to trap fine particles of soil, thusly inhibiting their migration. An even grass cover provides an excellent means of protection against erosion due to runoff caused by rains and can protect the embankment during limited overtopping. Sparse grass cover is more prone to surface erosion than dense turf.

Maintenance

Grass cover must be mowed periodically to permit detailed visual inspection of the dam's embankment. **Trees and brush should never be allowed to grow on or very near a dam.** Trees and woody vegetation should be removed from the embankment and from the downstream area within 10 feet of the toe of the dam. The Division of Dam Safety should be contacted to discuss the proper removal of trees over six inches in diameter and their root balls.

For more information visit www.dep.pa.gov or contact:

Department of Environmental Protection
Bureau of Waterways Engineering and Wetlands
Division of Dam Safety
P.O. Box 8460
Harrisburg, PA 17105-8460
717-787-8568

DEP's Waterways Engineering and Wetlands Program
Regional Offices

Northwest Region
230 Chestnut St.
Meadville, PA 16335-3481
814-332-6984

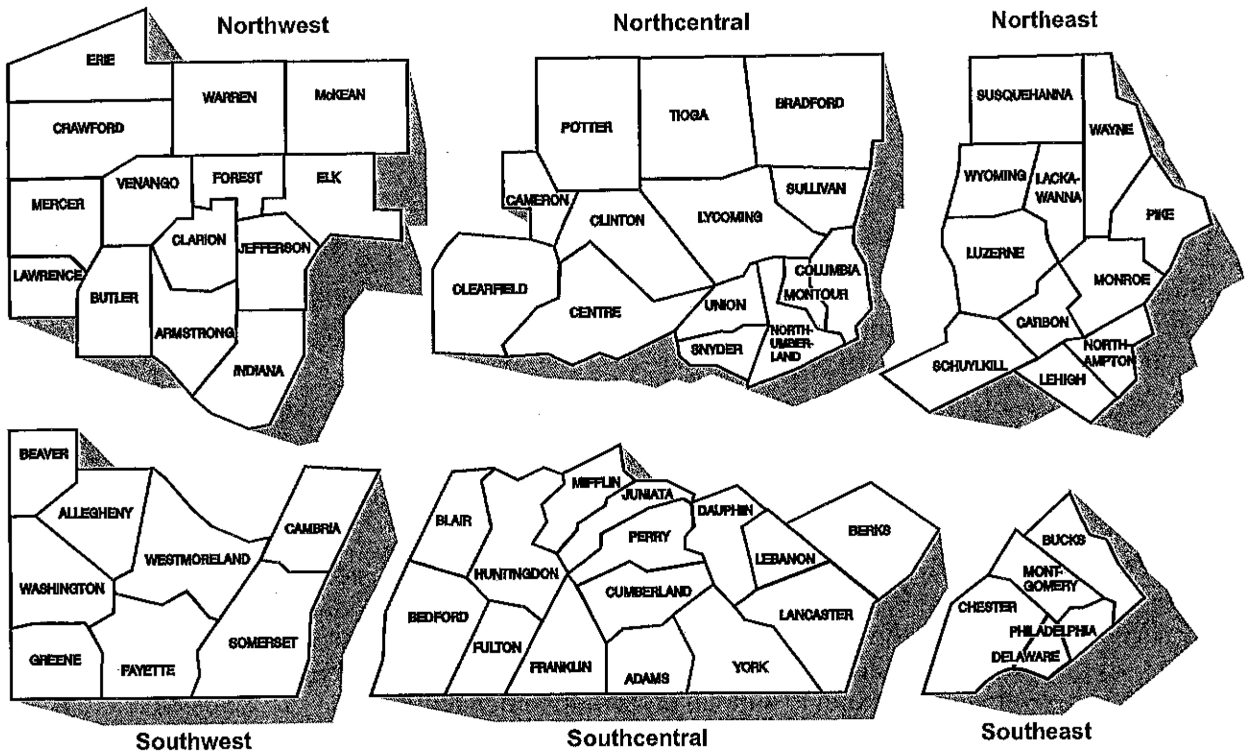
Counties: *Armstrong, Butler, Clarion, Crawford, Elk, Erie, Forest, Indiana, Jefferson, Lawrence, McKean, Mercer, Venango, and Warren*

Northcentral Region
208 W. Third St., Suite 101
Williamsport, PA 17701-6448
570-327-3574

Counties: *Bradford, Cameron, Clearfield, Centre, Clinton, Columbia, Lycoming, Montour, Northumberland, Potter, Snyder, Sullivan, Tioga, and Union*

Northeast Region
2 Public Square
Wilkes-Barre, PA 18701-1915
570-826-2511

Counties: *Carbon, Lackawanna, Lehigh, Luzerne, Monroe, Northampton, Pike, Schuylkill, Susquehanna, Wayne, and Wyoming*



Southwest Region
400 Waterfront Dr.
Pittsburgh, PA 15222-4745
412-442-4314

Counties: *Allegheny, Beaver, Cambria, Fayette, Greene, Somerset, Washington, and Westmoreland*

Southcentral Region
909 Elmerton Ave.
Harrisburg, PA 17110-8200
717-705-4802

Counties: *Adams, Bedford, Berks, Blair, Cumberland, Dauphin, Franklin, Fulton, Huntingdon, Juniata, Lancaster, Lebanon, Mifflin, Perry, and York*

Southeast Region
2 East Main St.
Norristown, PA 19401-4915
484-250-5160

Counties: *Bucks, Chester, Delaware, Montgomery, and Philadelphia*

COMMONWEALTH OF PENNSYLVANIA
FISH AND BOAT COMMISSION - DEPARTMENT OF ENVIRONMENTAL PROTECTION

APPLICATION TO DRAW OFF WATER FROM IMPOUNDMENTS

Submit one copy of the completed application to the Pennsylvania Fish and Boat Commission, Division of Environmental Services, 595 E. Rolling Ridge Drive, Bellefonte, PA 16823 Telephone (814) 359-5237.

This application will be reviewed jointly by the Pennsylvania Fish and Boat Commission (PFBC) and the Department of Environmental Protection (DEP) Bureau of Waterways Engineering and if acceptable, a permit will be issued under the PFBC Fishing and Boating Regulations, 58 Pa. Code, §51.81.

General Information	
1. Name of Applicant (owner or lessee): Is the applicant: ☐ owner ☐ lessee If not owner, provide owner name: **(Note: If owner is not dam permittee, Transfer of Dam Permit is required; Please call 717-787-8568 to obtain Transfer of Dam Permit Forms.)**	Telephone Number: - - Fax Number: - - E-Mail address of owner:
2. Contractor/consultant name if conducting drawdown for permittee:	Contractor telephone : - - Contractor E-Mail: ________________
3. Address of Applicant:	
4. Name of Impoundment:	DEP ID. No. **D**_____-_____
5. County Location:____________ **ATTACH A MAP (USGS topo map, PennDOT County Highway or equivalent map of a suitable scale to locate your impoundment)**	Municipality:____________ Check one: ☐*City* ☐*Borough* ☐*Township*
6. Type of Impoundment (Check one) ☐ *Natural* *or* ☐ *Man-made*	
7. Name of receiving stream: (If unnamed, indicate "unnamed tributary to _____ Creek"	
8. Is the impoundment open to public fishing? (Check) ☐*Yes or* ☐*No*	Stocked by PFBC? (Check) ☐*Yes or* ☐*No*
9. Does the impoundment contain fish or other aquatic organisms? (Check) ☐*Yes or* ☐*No*	

Specific draw down information		
10. Proposed dates of draw down	From:	To:
11. Impoundment area (acres):	Maximum depth (feet):	Depth of draw down: (feet below normal pool)
12. Draw down method – ***(Check One)*** ☐Valve ☐Gate ☐Stoplog ☐Siphon ☐Pump ☐Other (specify)_____		
13. If fish are to be transferred, state: A. Destination water:		B. Method of transfer:

Purpose of draw down			
A. Construction, maintenance or elimination (check)		B. Construction or maintenance	(check)
*1. Dam or spillway repairs	☐	8. Ice damage prevention or control	☐
*2. Dam, Spillway, or outfall structure repair/modification	☐	9. Install fish habitat structure or cover	☐
*3. Dredging – Indicate number of acres:_____	☐	10. Other (explain)	☐
*4. Pond elimination and backfill	☐		
*5. Construction or maint. of shoreline structures	☐	C. Fish or other aquatic life management	(check)
*6. Beach renovation	☐	11. Eliminate unwanted fish species	☐
*7. Dock Construction or Maintenance	☐	12. Permit predation on overabundant forage species	☐
***IMPORTANT: Complete DEP Supplement on reverse side if project purpose includes any of items 1 through 6.**		13. Aquatic vegetation control	☐
		14. Other (explain)	☐

Applicant Certification and Signature

The applicant :(a) is responsible for any damages incurred as a result of this draw down. (b) certifies the truth of the above statements.

Applicant Signature: ______________________________ **Date:** ____________

Print Name: ______________________________

COMMONWEALTH OF PENNSYLVANIA
FISH AND BOAT COMMISSION - DEPARTMENT OF ENVIRONMENTAL PROTECTION

APPLICATION TO DRAW OFF WATER FROM IMPOUNDMENTS

DEP SUPPLEMENT

Many activities related to reservoir draw downs require separate DEP and/or U.S. Army Corps of Engineers approval(s) prior to beginning the activity(s). The information provided on or attached to this supplement will be used by the appropriate DEP office to process the necessary state and/or federal authorizations or to determine additional permitting requirements. Providing the information described on this form will allow DEP to this review and approval or screening procedure while the draw down application is being processed.

Often, the applicant has already submitted documentation for the proposed activity to a DEP office. The applicant should still complete this supplement to the draw down application, indicating what information was sent to which office.

The primary purpose of this supplement form is to simplify the submission, review and approval of minor projects requiring written state or federal authorization. This form and the information attached are not intended to replace state and federal requirements for obtaining individual permits for major projects. The appropriate DEP office having jurisdiction over the proposed activity will generally provide the applicant with the necessary authorization to proceed with the work, a request for additional information, or a determination that an individual permit(s) is required.

Specific Project Information

The following information to be provided for each type of activity does not need to follow any particular format but should provide sufficient detail to allow DEP to establish appropriate jurisdiction, waiver or general permit eligibility, small project eligibility, appropriateness of permit by letter, or the need for full state or federal permits.

	Attached	Previously Submitted
Dam or Spillway Repairs		
• Engineering plans & specs	☐	☐
• Color photos	☐	☐
Dam or Spillway Modification		
• Conceptual plan & scope of work	☐	☐
• Color Photos	☐	☐
Dredging/Disposal of Accumulated Sediment		
• Color photos	☐	☐
• Dredging plan	☐	☐
• Disposal plan	☐	☐
Pond Elimination and Backfill		
• Site plan & dimensions of dam & pond	☐	☐
• Drainage area	☐	☐

	Attached	Previously Submitted
Construction or Maintenance of Bulkhead, Retaining Wall, or Other Shoreline Structures		
• Plan view	☐	☐
• Cross-section	☐	☐
• Details	☐	☐
Beach Renovation		
• Plan view	☐	☐
• Cross-section	☐	☐
Dock Construction or Maintenance		
• Dock plan & design	☐	☐
• Cross-section	☐	☐