

Woodland Ponds

A FIELD GUIDE



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EM 9104

April 2015

Oregon State | Extension
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Woodland Ponds: A Field Guide

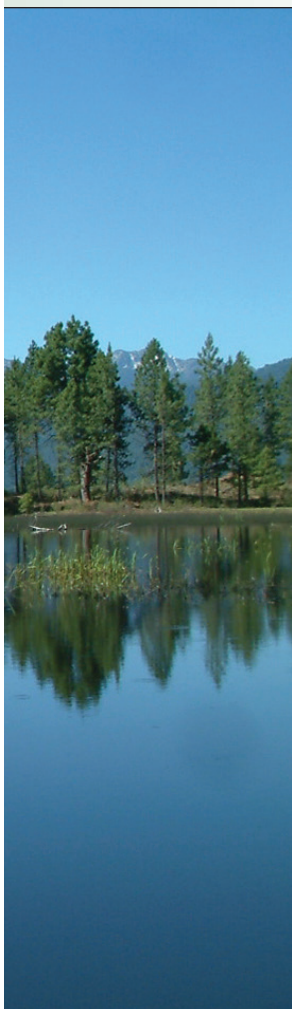
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OREGON STATE UNIVERSITY EXTENSION SERVICE



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Introduction



Ponds with docks offer a variety of recreational values to a woodland property.

Few amenities better enhance the value of a woodland property than a pond. Ponds provide water for livestock and game animals, fishing, boating, swimming, fire protection, wildlife habitat, aesthetics, and higher land value. Woodland ponds deliver more benefits when they are sited correctly, and designed and built properly. Before digging, woodland owners should identify what value they hope to derive from their pond and incorporate those features into a carefully planned project sited in the best possible location. A well-planned and carefully supervised project will reduce long-term maintenance and repairs, and lead to a better final result.

Woodland owners have been building ponds for years, often without much guidance. The purpose of this handbook is to provide basic planning guidance as well as crucial information on permits and construction standards that will help ensure the long-term benefits of a woodland pond.

Feasibility of a pond

There is more to building and maintaining a pond than just digging a hole in the ground and waiting for it to fill with water.

The first step is to find out if your property can sustain a pond. To determine that, you need to know:

- Site elevation, topography, and annual precipitation of your property
- Water source(s) and watershed area
- Primary soil types
- Necessary permits

In addition to those four fixed parameters, there are other factors to consider when assessing the feasibility of a pond on your woodland property. These factors can be manipulated to accommodate the limitations of the fixed parameters, and include:

- Pond design (area, depth, and volume in acre-feet)
- Construction methods
- Erosion control techniques
- Available revenue
- Amenities (fish and wildlife, vegetation, recreation)
- Maintenance regimes

Some properties may be so restricted in terms of water availability that it is impossible to sustain a pond, regardless of the amount of time, effort, and money. If you suspect this may be the case on your property, consult with a professional to determine if your suspicions are valid.

Getting started

Many woodland activities, including building and maintaining a pond, require a Notification of Operations with the Oregon Department of Forestry (ODF). Other agencies may have additional requirements. For example, the Oregon Water Resources Department (OWRD) requires a permit to build a pond. The process of getting the necessary permits may seem complicated, but the goal of this field guide is to help you better understand why these permits are required, how long it takes to secure them, and what agencies are involved.



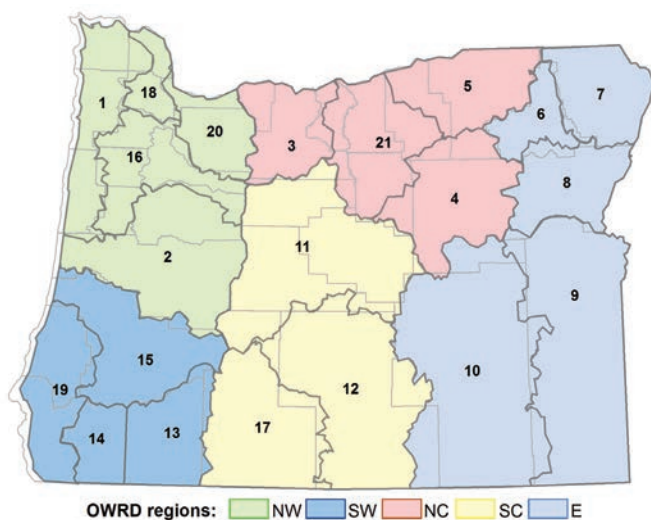
Porous soils and a lack of proper soil compaction caused this pond to fail before the summer was over.

Woodland owners play an important role in maintaining not only their own land but also the surrounding watersheds, wetlands, estuaries, and other sensitive ecological sites. Many woodland owners protect and enhance the ecological values of their land voluntarily, but there are also laws and rules they must follow that are designed to protect public and private natural resources. Local, state, and federal agencies require permits to ensure these laws and rules are followed.

New or modified ponds that will impact existing wetlands, waterways, or fish passage require additional levels of restrictions, regulations, and permits. These procedures are not covered in this guide. For information on waterway or wetland activities that often require additional professional assistance and permits, consult the Oregon Watershed Enhancement Board (OWEB) publication, *A Guide to Oregon Permits Issued by State & Federal Agencies—with a focus on permits for Watershed Restoration Activities*.

If you want to build a pond on your woodland property, an important initial step is to contact your local watermaster, who can help you determine if your property will have any impact on fish passage or sensitive ecological areas. Watermasters are located throughout the state, so contact the one who has jurisdiction over your property.

Oregon Water Resources Department regions and offices



Northwest Region

725 Summer St. NE, Suite A
Salem, Oregon 97301
Phone: 503-986-0893
Fax: 503-986-0903

District 1

c/o Port of Tillamook Bay
4000 Blimp Blvd. Suite 400
Tillamook, Oregon 97141
Ph: 503-815-1967
Fax: 503-815-1968

District 2

125 East 8th Avenue
Eugene, Oregon 97401-2926
Ph: 541-682-3620

District 18

1400 SW Walnut St.
Suite 240
Hillsboro, Oregon 97123
Ph: 503-846-7780
Fax: 503-846-7785

District 20

1678 S Beaver Creek Road,
Suite L
Oregon City, Oregon 97045
Ph: 503-722-1410
Fax: 503-722-5926

District 16

725 Summer St. NE, Suite A
Salem, Oregon 97301
Ph: 503-986-0889
Fax: 503-986-0903

Southwest Region

10 S. Oakdale, Room 309A
Medford, Oregon 97501
Ph: 541-774-6880
Fax: 541-774-6187

District 13

10 S. Oakdale, Room 309A
Medford, Oregon 97501
Ph: 541-774-6880
Fax: 541-774-6187

District 14

700 NW Dimmick St.
Grants Pass, Oregon 97526
Ph: 541-479-2401
Fax: 541-479-2404

District 15

Douglas County Courthouse,
Room 306
Roseburg, Oregon 97470
Ph: 541-440-4255
Fax: 541-440-6264

District 19

225 N Adams
Coquille, Oregon 97423
Ph: 541-396-1905
Fax: 541-396-1906

South Central Region

231 SW Scalehouse Loop
Suite 103
Bend, Oregon 97702
Ph: (541) 306-6885
Fax: (541) 388-5101

District 11

231 SW Scalehouse Loop
Suite 103
Bend, Oregon 97702
Ph: 541-306-6885
Fax: 541-388-5101

District 12

513 Center St.
Lakeview, Oregon 97630
Ph: 541-947-6038
Fax: 541-947-6063

District 17

5170 Summers Lane
Klamath Falls, Oregon 97603
Ph: 541-883-4182
Fax: 541-885-3324

North Central Region

116 SE Dorion Ave.
Pendleton, Oregon 97801
Ph: (541) 278-5456
Fax: (541) 278-0287

District 3

2705 E 2nd St.
The Dalles, Oregon 97058
Ph: 541-506-2652
Fax: 541-506-2651

District 4

Grant County Courthouse
201 S Humboldt
Suite 180
Canyon City, Oregon 97820
Ph: 541-575-0119
Fax: 541-575-0641

District 5

116 SE Dorion Ave.
Pendleton, Oregon 97801
Ph: 541-278-5456
Fax: 541-278-0287

District 21

221 S Oregon St.
P.O. Box 427
Condon, Oregon 97823
Ph: 541-384-4207
Fax: 541-384-2167

Eastern Region

Baker County Courthouse
1995 3rd St., Suite 180
Baker City, Oregon 97814
Ph: (541) 523-8224
ext. 224
Fax: (866) 214-3493

District 6

10507 N McAlister Road #6
La Grande, Oregon 97850
Ph: 541-963-1031
Fax: 866-214-3493

District 7

401 NE 1st Street
Enterprise, OR 97828
Ph: N/A
Fax: N/A

District 8

Baker County Courthouse
1995 3rd Street, Suite 180
Baker City, Oregon 97814
Ph: 541-523-8224 ext 231
Fax: 866-214-3493

District 9

Malheur County Courthouse
#4
251 B St. W
Vale, Oregon 97918
Ph: 541-473-5130
Fax: 541-473-5522

District 10

Harney County Courthouse
450 N Buena Vista #3
Burns, Oregon 97720
Ph: 541-573-2591
Fax: 541-573-8387



Ponds built without a permit do not have a water right.

Permits

According to Oregon law, all water is publicly owned. With very few exceptions, individuals and organizations must first obtain a permit from the Oregon Water Resources Department (OWRD) to use or store water in a reservoir. This water can originate from springs, seeps, streams, or surface runoff. *Woodland owners with water flowing through their property do not automatically have the right to use that water without a permit from OWRD.* Permits and water rights are important because during times of a shortage, water use may be curtailed based on the priority date of the right. The date of application for a permit to use water usually becomes the priority date of the right: the older the right, the more senior the entitlement for the use of water.

Anyone planning on building a pond will need a water right. A water right is a type of property right and is attached to the land. This is a part of the permitting process that is often overlooked by the applicant, but it is required by OWRD.

Many existing ponds were built without an OWRD permit, and these property owners need to go through the permitting process. If the pond complies with current OWRD requirements, a permit and water right may be granted post-construction.

The application for a permit to store water in a reservoir (build a pond) comes in two forms. The **Application for a Permit to Store Water in a Reservoir (Standard Review)** is required for any reservoir that holds more than 9.2 acre-feet of water and has a dam higher than 10 feet. This type of permit requires engineered plans and specifications that must be approved by the Dam Safety Section of OWRD prior to construction. If you are contemplating a pond like this, employ an engineer with previous experience in pond designs and specifications.

The second form is the **Application for a Permit to Store Water in a Reservoir (Alternate Review)**. This permit allows a dam height of 10 feet or a reservoir holding more than 9.2 acre-feet of water. This gives landowners greater leeway to build a larger pond provided they do not exceed both limits. Most ponds built on a woodland property will use the Alternate Review process.

In addition, most out-of-reservoir uses of water require a “secondary” permit. To initiate the process of applying for a “secondary” permit, contact the local OWRD watermaster.

There are liability issues associated with building and maintaining a pond; any damage to downstream property resulting from reservoir operations may expose the pond owner to civil action.



A pond causing downstream problems may result in civil action against the pond owner.

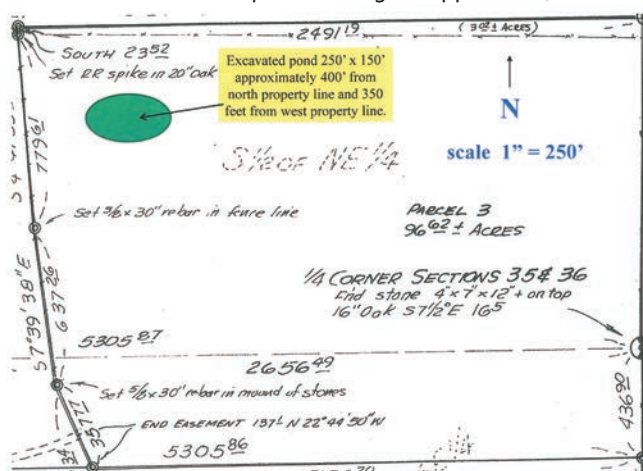
The following timeline shows the basic process and time requirements for planning and completing a pond project. A permit is required before any excavation can start. OWRD allows 180 days for the permit process; this schedule assumes a successful process within these time limits.

- 12 months prior to start date in June: Obtain necessary maps and reconnoiter potential sites. Schedule meeting with local watermaster.
- 11 months prior to start date: Complete *Application for a Permit to Store Water in a Reservoir (Alternate Review)* and obtain necessary Oregon Department of Fish and Wildlife (ODFW) and watermaster reviews.
- 10 months prior to start date: Submit application to OWRD
- 8 months prior to start date: Conduct search for contractor(s)
- 4 months prior to start date: Visit local government office to submit **Land Use Information Form**
- 3 months prior to start date: Finalize contract with contractor and complete **Notifications of Operations** to Oregon Department of Forestry (ODF)
- Begin project
- Allow at least a month for completion of any project
- 2 months after start date (August): complete any access roads and accessories for pond

The permit application (http://www.oregon.gov/owrd/pubs/docs/forms/alt_res_5_8_2012.pdf) includes a step-by-step description of the application process. Once again it should be noted that now is the time to contact your local watermaster because an incomplete permit application will be returned to the applicant. Follow these steps to complete the application:

Step 1: Print out the *Application for a Permit to Store Water in a Reservoir (Alternate Review)*. Included with the form will be three supplemental forms:

1. Watermaster Alternate Reservoir Application Sheet (This is completed by the local watermaster upon receiving the application.)



A detailed map of the pond location is important.

2. Oregon Department of Fish and Wildlife (ODFW) Alternate Reservoir Application Review Sheet (This is completed by a representative of the ODFW.)
3. Land Use Information Form (This is completed by the respective local planning department.)

Step 2: Complete the form and prepare a map. This step includes the applicant's contact information, details about the project, and a map. The map should be submitted on 8½- by 11-inch paper in a standard scale not less than 4 inches = 1 mile (quad maps, title company maps or aerial photos are not acceptable). Applicants need to include the location of the dam and reservoir. If construction involves an excavated pond (no dam), then use the center of the reservoir as the reference point. Locations should be referenced in feet from public land corners and include the township, range, section, and quarter-quarter section. Tax lot lines and lot numbers should also be indicated on the map, along with a North directional symbol. Project details include information on the source of water to fill the pond, uses of the water, potential environmental impacts, and dimensions of the pond's dam height and storage capacity. To determine storage capacity, consult the Design section.

Step 3: Obtain a completed review from the local watermaster. At this point, the watermaster will complete the Watermaster Alternate Reservoir Application Review Sheet and determine if the project will cause injury to an existing water right and whether water is available for the proposed use. If it is determined that the project will injure an existing water right and no alternatives exist to mitigate the situation, the application may be rejected by OWRD.



When determining where to put a pond, avoid streams and other sensitive areas.

Step 4: Obtain a completed review of the ODFW Alternate Reservoir Application Review Sheet from the local ODFW fish biologist. ODFW will review the application and determine whether the project poses a significant detrimental impact to existing fishery resources. If an impact is identified with no alternatives to mitigate the situation, ODFW cannot accept the application and the applicant may have to abandon the project. Note: If the Alternate Review is declined by ODFW, the landowner will have a difficult time obtaining the necessary permits to complete the process. At this point, consider abandoning the effort or relocating it to a less-sensitive location.

Note: In many ways, the requirements of Step 4 can be more difficult than those encountered in Step 3; thus, the applicant may want to reverse Step 3 and Step 4.

Step 5: Obtain a completed Land-Use Information Form or receipt stub from the local county planning department. The planner will determine if the proposed use of water is consistent with local land-use rules. The planning official may elect to complete the form while the applicant waits, or return the receipt stub. If the planning department does not contact OWRD within 30 days, it is presumed the proposed water right is compatible with any comprehensive land-use plans.

Step 6: If the watermaster and ODFW find the project acceptable, submit the application, supplemental forms, map, and fees to OWRD. The Land Use Information Form or the receipt stub must be the original. The permit recording fee can be paid when you submit the application to OWRD or when the permit is issued, but processing is faster if it is paid at the time of submission. If the project is rejected, the recording fee will be refunded.

Step 7: If the application has been accepted, it is now time to get to work!

Step 8: Obtain your water right. This step is sometimes overlooked. You do not automatically receive a water right when the project is completed. When the project is complete, fill out a CLAIM OF BENEFICIAL USE form from OWRD at <http://www.oregon.gov/owrd/pages/pubs/forms.aspx#other>.

The **Claim Of Beneficial Use** form can only be used in conjunction with the Alternate Review permit (less than 9.2 acre-feet of water and a dam less than 10 feet high). All of the necessary information required in the form is contained in the Alternate Review permit. Complete the form and mail it to the OWRD. Upon obtaining the form, OWRD will send you a water right. There is no need to file your water right with any state or county agency. You are registered with the OWRD as the holder of a water right for the use of your pond.

If you applied for the Standard Review, additional steps will be required to obtain a water right. The first step is to contact your local watermaster for instructions. This is yet another reason to design your woodland pond within the parameters of the Alternate Review permit.



When soliciting bids, look for contractors who have experience building woodland ponds.

Contracts

In today's highly litigious society, the importance of a written contract cannot be over-emphasized when planning and implementing any type of woodland operation. It is imperative that woodland owners develop a contract stipulating the performance requirements. The publication *Contracts for Woodland Owners* (EC 1192), available at <https://catalog.extension.oregonstate.edu/ec1192>, provides valuable information for developing a contract for various woodland activities.

What is a contract? In its most simple form, a contract:

- Is a promise between two parties
- Serves as a binding legal document
- Specifies who is responsible for doing what, when, how, and for whom
- Is a concise document that can allow for modifications or amendments

A contract can define goals and objectives of the activity, and also serves as a means to achieve those goals and objectives while protecting the interests of the involved parties. Contracts can limit legal liability with insurance, limitations, and exclusions, and can serve as a basis to recover damages if performance obligations are not met. When retaining an attorney, request references and recommendations from the attorney's previous clients and find out how much experience the attorney has with woodland management issues.

All contracts should contain:

- Parties' names, addresses, and signatures
- Landowner's name
- Operator, contractor, or both
- Subcontractor (if applicable)
- Third-party interests, administration, or representative
- Exhibits, maps with legal descriptions
- Start and end dates
- Work schedule
- Payment schedule and method

Other requirements may include:

- In-stream work
- Provisions for wet-weather operations
- Provisions for extensions, adjustments, termination, etc.
- Access: fees, maintenance, easements
- Equipment requirements
- Fire protection or compliance
- Permits, written plans, prior approvals
- Provisions for substandard or incomplete work
- Assignment of contract (subcontracting)
- Collateral damage (both personal and property damage)
- Insurance requirements, including:
 1. General liability
 2. Logger's "broad form" (covers property damage)
 3. Workers' compensation

If a landowner decides to contract the pond construction, maintenance, or both, the contract should also include:

- Type of pond to be constructed or maintained, i.e., an excavated or embankment pond
- Initial clearing of the construction site, and methods and disposition of logs and vegetative debris
- Location and stabilization of excavated material
- Type and method of dam's drainage, i.e., in-dam pipe or overflow
- In-stream and road drainage structures for fish passage (if applicable)
- Pond location (either direct or survey and office design), including standards for minimum and maximum dam widths, slopes, and curve lengths
- Upland erosion-control methods
- Type of equipment and measures for compaction

Unless you have all of the equipment and experience using it, a contractor will be needed. Obtain bids from a number of contractors to be sure the job will get done at the lowest possible cost.



Multiple contractors may be needed, depending on the complexity of the project. In this case, a contractor was hired to place habitat logs.

If one of the contractors comes in substantially lower than the others, it may be that the contractor overlooked some of the logistics required to perform the job. It's also possible they intentionally "low-balled" their bid in order to "get their foot in the door" with the intent to renegotiate the contract once the job has started.

Ensuring selection of the right contractor requires that you supply them with adequate information with which they can accurately determine their bid. Larger and more complex projects often need a professional engineer, who can assist in the design and provide other contractors with details about the project. For simpler projects, landowners will still need a written plan detailing pond dimensions, dam size, and amenities such as roads, docks, or landscaping. Be sure to include an estimate of the total volume of excavation (in cubic yards) because this is the single, greatest variable in calculating a bid).

Include drawings of the project that highlight the dam, dimensions and extent of the trench, location of the spillway, and, if applicable, the design of the pipe inlet in the dam. The construction and building material specifications include site-specific requirements and measures for quality control. Be clear and precise. Bidders who are unclear may submit higher bids that provide them "wiggle room" for unexpected work.

Make sure each contractor is basing their bid on the same information. Verbal explanations will vary, but written specifications will not.

Location



There are many factors to consider when determining where to build a pond. It pays to carefully examine and study a site before deciding whether a pond there is practical or economically viable.

Although many landowners might assume that low areas offer the best location for a pond, upland sites are often superior because the groundwater table generally follows the land's contours and may be fairly close to the surface at higher elevations. Low areas may be muck-filled and more difficult to excavate, and in some instances may require additional permits. Marshes, lowland woodlands, brushy wetlands, bogs, and other wetland areas provide important wildlife habitat, and converting them to ponds may not be the optimal use, or even allowed.

Scout pond locations during the dry months. Avoid sensitive wetland areas, but look for small areas that indicate the presence of a high water table. First, look for vegetation that grows on wet sites. Rush (wiregrass) or any area showing green vegetation instead of brown grasses may have potential. Also, look for tree species that prefer wet sites. Oregon ash, found in proximity to oak or madrone trees, often indicates the presence of a high water table. West of the Cascades, ponderosa pine has adapted to dry and wet sites. These are often excellent sites if located in an area containing other plants indicating the presence of moisture.

Favorable wet sites may have unstable soils, however, especially on steeper slopes.

Looking for telltale signs of water



Cattails and tall grass (1) indicate a spring or significant seepage that might make a good location for a pond. Wiregrass and an oak tree dead through root rot (2) is a sign of high water where a pond might be located. Evidence of leaning, or sweep, in trees (3) indicates soil movement—not a desirable condition for a pond. Green grass during the dry months of summer (4) also indicate a good location for water.

Look for trees bending themselves to an upright position (sweep). This is a sign of soil movement, which is not desirable around a pond. This does not mean a pond cannot be located on these sites, but you may need an engineer to evaluate the area.

To get the most pond for the money, locate it where the largest storage area can be obtained with the least amount of excavation, which is the most expensive aspect of the project. A favorable location might be a narrow section of a valley or swale, where less material is needed to construct the dam. The slope of the ground uphill from the dam should allow water to flood the area.

The majority of woodland ponds become a center of fish, wildlife, and recreation. Consequently, you may also decide to build an all-season road to the pond. The cost of building and maintaining an all-season road is likely to be the second largest expense in the project.



When initial excavation reveals heavy clay soils and water seepage, you may have found the ideal location for a pond.

Do not locate the pond near a dwelling, feedlot, corral, drain field, or any location that may generate contaminated runoff that could reach the pond. If such a location must be utilized, take special care to redirect surface runoff from these sources away from the pond. If these areas impact a substantial portion of the drainage area, there may not be enough surface runoff to fill the pond.

Do not locate a pond where failure of the dam could injure people or livestock, or damage buildings, roads, or ecologically sensitive areas. If the only suitable location for a pond may threaten these features, consult with a qualified engineer to reduce the possibility of failure from improper design or construction. Remember: The owner is responsible for a pond and its proper operation and maintenance.



Soil movement caused by ponds can damage poorly placed roads, leading to costly repairs and environmental damage.

Water source

The water source for your pond can be the natural water table, seeps or springs, surface runoff, or a combination of any of these.

Water table: Ponds often depend on the prevailing level of the water table in the area. Ideally, the level should be within 2 feet of the top of the ground, but other sources can ameliorate this requirement.

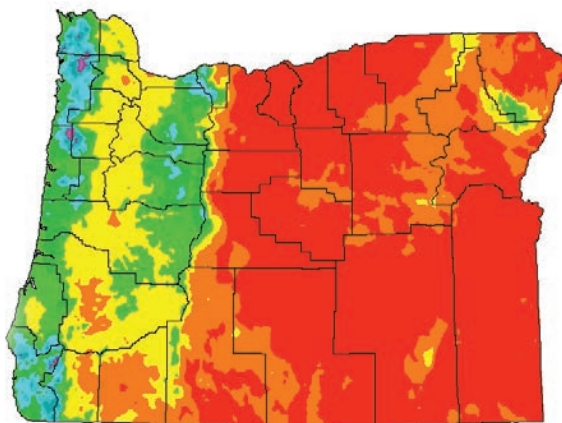
Surface water: Ponds can be located in broad drainage swales, taking advantage of the natural topography to appear as a more “natural” pond. The drainage area should not produce runoff with substantial amounts of sediment, fertilizers, manure, or pesticides. If relying primarily on surface water as the water source, the western part of the state requires a drainage area of about 1 to 2 acres for each acre-foot of water. Eastern regions require a minimum of 30 to 60 acres for each acre-foot of water. Drier portions of southwest Oregon likely fall between these two estimates. Once you have identified a potential pond location, use a topographic map to estimate the total area that generally drains towards that spot.

The actual annual runoff from a given area depends on topography, soil infiltration, subsurface drainage rates, and vegetation cover. The amount, intensity, and duration of precipitation also affect water yield.

The map below lists the average annual precipitation in Oregon. This map, in addition to the previously mentioned factors, gives a reasonable estimate as to the ability of a site to sustain a pond.

Average annual precipitation in Oregon

Rainfall in inches





Engineers inspect the soil profile to determine if this site would make a good location for a pond.

The website <http://average-rainfall.findthebest.com/d/d/Oregon> lists the average precipitation by month for selected Oregon towns and cities. This information gives a more precise geographical location for estimating potential surface runoff, but it is an information source for towns and cities and may not precisely estimate the precipitation levels at the pond site.

Springs or seeps: These sites may increase construction costs, but can help retain pond water levels during the dry months. Additionally, groundwater is ideal for aquatic life because it is cool and clean. The ideal location for a pond is one that takes advantage of all these water sources.

Wells: Pumping water to supplement a pond can be expensive and affect the flow of any adjacent wells.



Supplementing a pond with well water ensures a stable water level during the dry season.

Soils

Soils are classified into four hydrologic groups based on infiltration and water transmission rates.

A: Deep, well-drained sand or gravel soils have a high infiltration rate and a low runoff potential.

B: Medium-fine to medium-textured soils have a moderate infiltration rate when wet.

C: Moderately fine to fine-textured soils have a layer that impedes downward water movement and have a slow infiltration rate when wet.

D: Primarily clay soils have a slow infiltration rate. They have a high swelling potential with a permanent high water table, a clay pan at or near the surface, and shallow depth over a nearly impervious material. The runoff potential is high.

Landowners can learn more about soil types through the USDA Natural Resource Conservation Service (NRCS). People in many regions of the state can determine the soil types of their property at <http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>.

Suitability of the pond location depends on the ability of the soils and shallow bedrock near the bottom of the pond to hold water.

The bottom should contain a layer that is impervious and thick enough to prevent excessive seepage. Clay and silty clays are excellent soil types for this purpose, while coarse-textured soils, such as sand, gravel, or sand-and-gravel mixes, are highly permeable and often unsuitable. Permeable soil types may be acceptable if they have a spring or seep. The absence of clay soils, springs, and seeps in sandy-gravel soils does not preclude the site. Various treatments can help seal the pond, but these are expensive and not always effective.

Silt and clay soils can be relatively impervious, but they are often unstable and are not good foundation materials for large-sized dams. However, clay and silt soils are usually satisfactory for ponds that are less than 9.2 acre-feet in volume with dams that are 10 feet high or less. More gentle slopes on the dams may be necessary to reduce the unit load on the foundation due to the lower degree of stability.

Plastic soils are not good soils for the construction of a dam. Plastic soils are soils that can be transformed from a solid to a putty-like state by adding water. Increasing the moisture content of a plastic soil reduces the soil's shear resistance to sliding. The only way to prevent that sliding in plastic soils is to use soil amendments—a costly procedure.

To fully assess the soil type, landowners can excavate a small area prior to beginning a full-scale operation. Three or four diggings per acre are adequate to assess the soil profile over the site, although more may be required if there are substantial variations in soil conditions. If other landowners in the area have constructed woodland ponds, check with them to see what soil issues they may have encountered during their project.

If bedrock is present, it should be more than 5 feet below the surface for an adequate site. Excavating bedrock is difficult and time consuming, and broken layers can fracture and become difficult to seal. Bedrock often contains faults and fissures that can create a leaky bottom. To ensure an adequate seal, at least 2 feet of clay will be required—a costly amendment.

Any potential pond site with bedrock should be investigated carefully. A geologist may be able to determine whether the pond area can retain water, whether the dam can support an earth-fill embankment, and whether the overflow system can be properly excavated and equipped with a suitable foundation.



Clay deposits and water seepage immediately after excavation are good signs; clay helps hold water in the pond, and the seepage will help keep it full during dry periods.

Design

Once you have selected the location of the pond, you need to develop a design plan for the project. This should include the pond itself as well as the location of the dam and spillway, any amenities such as a cabin or dock, and road access.

The design of a pond includes a profile of the center line of the dam, the location of the spillway or overflow, and adequate measurements to determine the water capacity of the pond. This consists of an approximate geometric shape and the planned depth of the pond. Listed below are some shapes that might be incorporated into a pond design and their estimated water capacity. If the intended use of the pond includes water supply or irrigation, a more precise estimate may require the help of a licensed surveyor or engineer and a complete topographic survey of the entire site.

The basic formula for estimating the water carrying capacity of a pond of any shape is as follows:

$$V = ((A + 4B + C) / 6) \times (D / 27)$$

V = volume of excavation

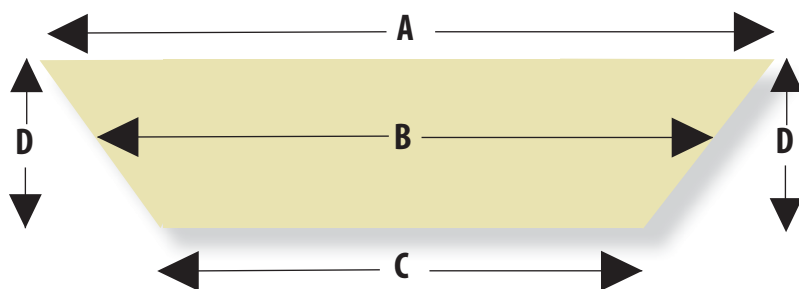
A = area of excavation at ground level in square feet (sq ft)

B = area of excavation at the middle depth of the pond (sq ft)

C = area of excavation at the bottom of the pond (sq ft)

D = average depth of the pond (feet)

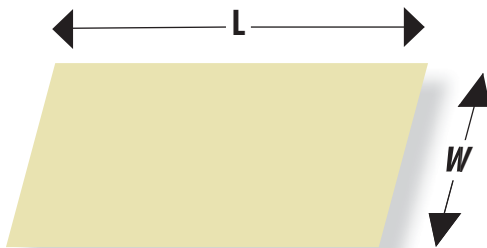
27 = conversion factor (cubic feet to yards)



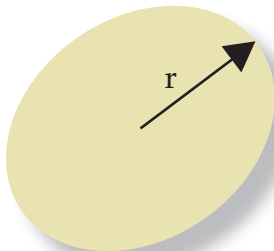
NOTE! When determining ground level A, you are measuring the entire area of the excavated pond. To accurately measure the area of the pond that is actually holding water, the water level will be determined by the depth of the spillway or overflow. For an accurate water volume measurement, determine the high water mark and use this measurement for "A" when determining volume.

Ponds come in all shapes and sizes. The above formula can be adapted to fit virtually any geometric shape. A few different shapes, and their respective formulas for determining A, that may be included on a pond design include:

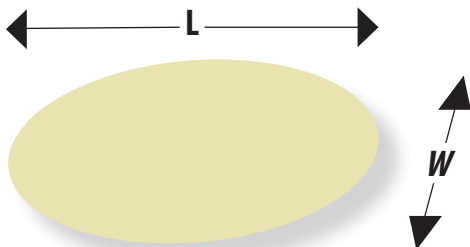
Rectangle $A = L \times W$



Circle $A = \pi r^2$



Ellipse $A = (3.14/4) \times (L \times W)$ Note: $(3.14 / 4) = 0.7854$



Example: Measuring an elliptical pond

An ellipse is a common and popular pond shape. Here's how to determine the water volume of an elliptical pond with a major axis (L) of 150 feet, a minor axis (W) of 70 feet, a 2:1 ratio for the slope of the pond, and a depth of 10 feet.

Step 1: Using the basic formula $V = (A + 4B + C) / 6 \times (D / 27)$, calculate the surface area.

$$A = 0.7854 \times (150 \times 70) \text{ or } 8,247 \text{ sq ft}$$

Step 2: Determine the dimensions for the bottom of the pond (C). Since the pond slopes at a 2:1 ratio and the depth is 10 feet, the bottom of the pond will be 20 feet narrower on each side than the surface. The bottom dimensions will measure 110 feet (150 feet – 40 feet) by 30 feet (70 feet – 40 feet).

Step 3: Determine the area (the formula for "A") of the bottom of the pond (C).

$$C = 0.7854 \times (110 \times 30) \text{ or } 2,592 \text{ sq ft}$$

Step 4: Determine the middle depth of the pond (B). Since the middle depth is exactly halfway between the surface (A) and the bottom (C), simply add the two measurements together and divide by 2.

$$(150 + 110) / 2 = 130 \text{ feet (major axis) and } (70 + 30) / 2 = 50 \text{ feet (minor axis)}$$

Step 5: Determine the area at the middle depth (B) of the pond.

$$B = 0.7854 \times (130 \times 50) \text{ or } 5,106 \text{ sq ft}$$

Step 6: Determine the total volume (V) of the pond in cubic yards.

$$V = (8,247 + (4 \times 5,106) + 2,592) / 6 \times (10 / 27)$$

$$V = (31,263 / 6) \times (10 / 27)$$

$$V = 1,930 \text{ cubic yards or } 52,110 \text{ cubic feet } (27 \text{ ft}^3 = 1.0 \text{ cu yd})$$

The size of your pond can be measured in acre-feet of water by converting cubic yards into cubic feet. In the above example, a 150-foot by 70-foot pond with a depth of 10 feet and a 2:1 slope ratio has approximately 1.2 acre-feet of water (52,110/43,560). In terms of construction time and costs, a more important number is how much soil needs to be displaced in order to make the pond.



An excavator is the best machine for moving soil, creating the reservoir, and displacing soil. If the soil needs to be moved any distance, trucks will be needed.

Earth moving and trucking tends to be measured in cubic yards. For example, assume the entire volume of soil for a pond excavation needs to be transported to another site. The average dump truck can haul approximately 10 yards of material.

A 1.2-acre-foot pond would require moving nearly 200 loads of soil to make the pond! This is an excellent example why an embankment, or combination excavated-embankment pond, often makes more sense for woodland owners. There are substantial savings in the construction when soil doesn't have to be trucked away.

A rectangular shape is another popular, though not quite as aesthetically pleasing, pond design. Using the same dimensions as those of the ellipse example, we can determine the water volume of a rectangular pond with a major axis (L) of 150 feet, a minor axis (W) of 70 feet, a 2:1 ratio for the slope of the pond and a depth of 10 feet.

Step 1: Using the basic formula $V = (A + 4B + C) / 6 \times (D / 27)$ calculate the surface area.

For the area (A) of a rectangle ($A = L \times W$)

$A = (150 \times 70)$ or 10,500 sq ft

Step 2: Determine the dimensions for the bottom of the pond (C). Since the pond slopes at a 2:1 ratio and the depth is 10 feet, the bottom of the pond will be 20 feet narrower on each side than the surface. The bottom dimensions will measure 110 feet (150 feet – 40 feet) by 30 feet (70 feet – 40 feet).

Step 3: Determine the area (the formula for "A") of the bottom of the pond (C).

$$C = (110 \times 30) \text{ or } 3,300 \text{ sq ft}$$

Step 4: Determine the middle depth of the pond (B). Since the middle depth is exactly halfway between the surface (A) and the bottom (C), simply add the two measurements together and divide by 2.

$$(150 + 110) / 2 = 130 \text{ feet (major axis) and } (70 + 30) / 2 = 50 \text{ feet (minor axis)}$$

Step 5: Determine the area at the middle depth (B) of the pond.

$$B = (130 \times 50) \text{ or } 6,500 \text{ sq ft}$$

Step 6: Determine the total volume (V) of the pond in cubic yards (cu yd).

$$V = (10,500 + (4 \times 6,500) + 3,300) / 6 \times (10 / 27)$$

$$V = (39,800 / 6) \times (10 / 27)$$

$$V = 2,456 \text{ cu.yd. or } 66,330 \text{ cubic feet } (27 \text{ cu ft} = 1.0 \text{ cu yd})$$

A rectangular pond with the same length and width as an ellipse pond will differ in volume by the factor of 0.7854 used in the ellipse example. It will have slightly over 1.5 acre-feet of water (66,330/43,560). Consider the limiting factor for pond volume and dam height (9.2 acre-feet of water with a 10-foot dam) while imagining a pond the size of a football field (300 feet by 160 feet) with the same depth and slope as our examples. A football-field-sized pond 10 feet deep would have slightly over 9 acre-feet of water, within the limits of the Alternate Review Permit.

By just about anyone's standards, a pond the size of a football field is a big pond. This is merely serving as an example that regardless of the individual's goals and objectives, with careful planning and implementation, they will likely be able to design and build a pond without any additional permitting or engineered plans.

This pond uses the natural contours of the surrounding land. Additional contours were created during the excavation process to make it even more aesthetically pleasing.



Photo by Greg Fox



It's always wise to let the natural topography dictate the size and location of a woodland pond.

If the shape of the pond is designed to conform to the contours of the natural topography, calculating the volume of a rectangle or elliptical shape may not generate accurate volumes. More precise calculations can be made using a planimeter, a measuring instrument used to determine the area of an arbitrary two-dimensional shape. To get these more precise volume estimates, you should get the help of an engineer. Most woodland owners who build ponds are satisfied with a reasonable volume estimate of their pond, and utilizing one of the listed geometric shapes will generate satisfactory results.

After determining the volume of soil to be displaced by constructing the pond, consider any other significant excavation, such as:

- the spillway
- additional work needed to direct the water safely away from any structures
- excavation on the backslope and abutments of the dam that improve transformation to the surroundings



This dam has a long, gradual slope to add strength and stability. The gradual slope makes maintenance easier, too.

These considerations will provide a more accurate cost of the project, and help you secure more accurate bids from contractors.

A well-designed pond adds variety to a landscape, creates a pleasing shoreline, and should be compatible with the natural landscape. Identify major viewpoints from which the pond will be seen. If possible, locate the pond to ensure that the major sight line crosses the longest portion of the pond. The pond should be located so a person will see the water before noticing the dam, pipe inlet, or spillway. Minor changes in the alignment of the dam can shift these elements out of view and make the pond surface the center of attention.

Create a natural shape: The ideal pond should fit the contours of the natural landscape. Locate the pond to retain existing trees and shrubs along or near the shoreline. Vegetation adds aesthetic value by casting reflections on the water, providing shade in the summer, and blending the man-made structure into the natural landscape. Rectangular shapes are often the easiest and cheapest to build, but a pond with rounded corners, indefinite shapes, and even islands, has more eye appeal and increased wildlife habitat.

A transit is the most accurate way to determine area. A less-accurate but acceptable method would be a measuring tape. You can also use pacing to get a rough area measurement, but it's better to employ a measuring tool.

If the pond will be used to water livestock or for fish, it's important to ensure the pond has adequate water volume. Table 1 (page 33) contains some unit conversions to help determine whether the pond will be big enough to meet your objectives.

Size: How big do you want your pond?

People typically correlate size with surface water area, not water capacity. But a pond that is the size of a football field and a foot deep holds the same amount of water as a pond that is a quarter the size of a football field but 10 feet deep. Having a larger surface area but a shallow depth is not a good idea for woodland landowners who want to use the water for swimming or fishing, but it might work if you want to have a giant mud puddle or you're interested in raising frogs!

This pond location provides an excellent view of the nearby valley and relies entirely on surface runoff, instead of seeps and springs, to stay full during dry months. Topography was the primary factor in determining the surface water area.





This pond utilizes the natural topography to create a substantial project. The pond is supplemented by a well in the summer.

Topography plays an important role in determining the size of your pond. Digging a pond on steep slopes may create erosion problems, and digging a pond on flat ground can increase excavation costs. These factors can be reduced somewhat by different types of construction, but to minimize dam height, avoid additional permitting and engineering costs, and retain a somewhat natural setting, pond builders need to work with what nature has provided them. If access is a critical issue, locating a pond on steeper slopes will mean high environmental and economic costs for road construction and maintenance.

Additional factors involving water retention in the pond include season of usage, sedimentation from erosion, evaporation, and seepage losses. If surface runoff is the primary source of water, soils become even more important in preventing excessive seepage losses due to the inability to adequately compact the soil in the dam. If springs or seeps provide an additional water source, it may be possible to locate a pond containing less than optimal soil types.

Drainage area: If you're relying primarily on surface runoff to supply water to your pond, the landscape above a pond must be protected against erosion, which will shorten the effective life of the pond by filling it with silt. The best erosion protection is to retain as much of a natural, undisturbed upland drainage area as possible. When necessary, terraces, conservation tillage, strip-cropping, or conservation cropping can help. If these applications are necessary, delay construction until the upland erosion measures are in place.

The drainage area should be large enough to deliver sufficient surface runoff and groundwater flow to the pond. In western Oregon, the ratio of pond surface to drainage area should be at least 1:10. In eastern Oregon, the ratio should be 1:300.

Another perspective: west-side ponds need a minimum of 1 to 2 acres per acre-foot of water in the pond while east-side ponds require 30 to 60 acres per acre-foot of water.

If the ratio is too low, the drainage area may not yield sufficient water to fill the pond. If the ratio is too high, the overflow system may require excessive construction and maintenance costs. It's better to have too much water than not enough, but either scenario is not as bad as having poor soil types and inadequate compaction of the dam.

Pond size will be determined by the woodland owner's time, money, and equipment, and the selected site's soil, topography, and water sources. After your pond project is completed, you may wish you'd made it a little bigger. That happens with almost any woodland project, be it building a road or erecting a barn, so allow yourself some "wiggle room," and ensure that the entire area is of more than adequate size.

Remember that any man-made activity that changes the natural topography will result in Mother Nature trying to change the landscape back to its original form. A lighter "footprint" when designing and constructing a pond will have a longer life and less construction and maintenance issues than a pond incorporating major changes to the landscape.

This pond is small but deep. With the exception of a small access area, it has a primarily steep shoreline that allows it to contain a large volume of water intended as a water source for livestock and wildlife.



Depth: Accounting for seepage and evaporation

For most ponds, depth is more relevant than surface area. To ensure a permanent water supply, a pond must be deep enough to meet its intended use and allow for seepage and evaporation. If warm-water fish production is the major objective of a pond, the pond needs to be at least 10 to 12 feet deep. If creating native wildlife habitat is the goal, a pond needs to be 4 to 6 feet deep. If multiple objectives are sought, deeper water levels take precedence. It is generally accepted that a minimum desired pond depth should be at least 10 feet.

The depth of a pond varies between winter and summer, but a deep pond with a smaller surface area will lose less water to seepage and evaporation than a shallow pond with a larger surface area. Proper design and location will ensure that the pond fills during the winter months, but smaller, deeper ponds will experience less dramatic shoreline exposure during dry summer months than larger, shallow ponds.

Even though flows from underground seeps and springs are difficult to measure, it is safe to conclude that ponds fed by both surface and underground water sources will lose less water during the dry months than ponds relying solely on surface water flow.

The dimensions of your pond will be dictated in large part by topography, intended use, and the size of the watershed draining into the pond. Pond length and width are more related to aesthetics, but depth will dictate what kind of uses the pond can have and how much water levels will fluctuate between summer and winter months. Pond shape and dimension will also dictate what equipment you need to build the pond. Equipment selection is discussed fully in the **Construction** section of the guide, starting on page 45.

Table 1. Useful conversion factors

1 acre	43,560 square feet 4,840 square yards 235 feet (diameter of a circle) 208 feet/side (square)
1 acre-foot	43,560 cubic feet 1,613 cubic yards 325,850 gallons 2,718,144 pounds
1 cubic foot	7.48 gallons 62.43 pounds
1 gallon	8.34 pounds



Ponds with an even depth and distinct shape are easy to measure for water volume.



An excavated pond is a good choice for flat terrain.

Types of ponds

An excavated pond is dug into ground that is reasonably flat. This type of pond is 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 where evaporation losses are high and the water source is primarily runoff during the wet season. The simple design, compactness, low risk of damage from flood flow, and low maintenance requirements make them popular in many areas of the state.

While flat terrain is the safest location, woodland property ponds are typically located in uneven, broad, and natural drainage areas sufficient to fill the pond during the wet season. It is best to intercept the surface flow and minimize water diversions to the pond. A good location for the pond is in a natural depression where different topographies converge. Allowing the natural topography to fill the pond minimizes erosion-causing activity in the uplands, preventing damaging sedimentation in the pond and retaining the natural surroundings. This pond makes for a more aesthetically appealing site.

Excavated ponds can also be built on gentle to moderate slopes, but it is important to have an engineer determine slope stability. Unstable slopes can affect the structural integrity of the pond. Typically, these are smaller ponds because they require the costly removal of a large volume of soil.



Ponds like this one use excavated material incorporated into a dam while using the excavated area as part of the reservoir. These combination ponds can usually be built faster and cheaper than excavated ponds.

An embankment pond is a pool of water that collects behind a dam. The surrounding areas may have slight to steep slopes. Embankment ponds are more complex than excavated ponds, and may require an engineer to design. It's important to make sure water does not back onto an adjacent owner's property or into an area of specific concern, and that there are no homes, buildings, or roads that would be affected by a dam failure.

Embankment ponds are not as popular as excavated ponds because most require high dams in order to accumulate the desired water capacity. High dams typically require additional permits, the help of an engineer, greater damage risks, and increased maintenance requirements. High dams also can detract from the aesthetic values of the natural surroundings.

In a **combination pond**, excavated material is used to build the dam, saving time and money. An engineer may need to design the project and oversee construction.

All these pond types utilize the surrounding topography. By incorporating excavation along with building a dam, the owner gets a "bigger bang for the buck." Attention needs to be given to excavating the upland area where the water will be stored to avoid excessive erosion, pond sedimentation, and damage to the natural surroundings. Owners will want to minimize dam height and thus avoid additional engineering and permitting costs.

Water levels

There are various methods available for regulating the water level behind the dam. A pipe inlet in the dam can control the water level, providing drainage for pond repairs and allowing water to escape without erosion. Incorporating a pipe inlet in an earth dam should be done with professional consultation because an improper installation increases the chance of unwanted water loss and damage to the project's structural integrity.

While it is not a legal requirement for ponds less than 9.2 acre-feet and dams less than 10 feet in height, some woodland owners may prefer to have an outlet conduit under or through their dam. The pipe does not need to be sized to handle an extreme weather event because the overflow or spillway is designed to accommodate that.

There are three basic designs for outlet conduits.

A drop inlet consists of a pipe located under the dam and a riser placed at a pre-determined height in the pond. The point at which water drains into the pipe should be at the high water mark or slightly higher, but at least 1 foot below the top of the dam. This structure assists in water discharge during severe weather events, lessening the discharge and potential damage caused by water passing through the overflow or spillway. The inlet should have a trash rack to prevent debris flowing into it and obstructing water flow. The diameter should be at least 6 inches, but larger—up to 12 inches wide—is better. The major disadvantage of this kind of spillway is its inability to be used as a drain.

A drainage pipe through or under the dam, with the inlet located at the bottom of the pond, should be located at least 2 feet above the bottom of the pond. This takes into account the sediment and debris that will naturally form on the pond bottom. A trash rack should also be installed. Locate the valve controlling the water flow in a conspicuous and accessible area.

These structures allow you to drain a pond for maintenance or repairs or to supplement the water discharge during an extreme weather event. It doesn't allow you to decrease the water flow through the overflow or spillway during an extreme weather event, but these structures should effectively and efficiently handle excessive water flow.

A combination of both a drop inlet at the high water mark and a drainage point slightly above the bottom of the pond, using the same pipe, allows both features to

operate individually or in unison. This structure costs more and requires a visible trash rack, which is increasingly exposed during the dry months as the water level drops.

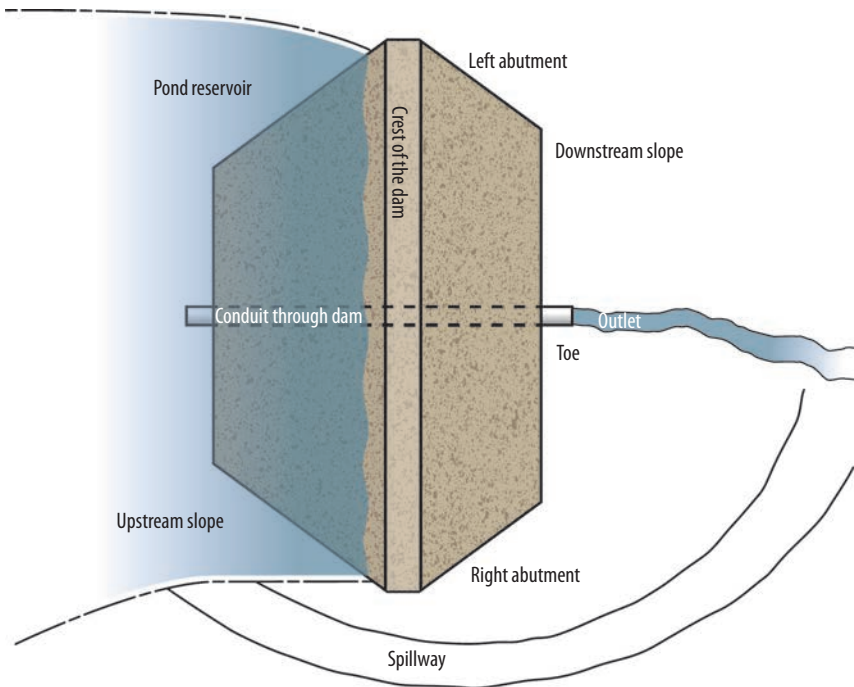
All the joints used in these structures need to be watertight, utilizing some type of rubber gasket to allow flexibility. Careful compaction is needed to restrict seepage around the discharge pipe. A seepage collar should be installed somewhere near the center line of the fill (in the “key” area). The pipe should extend at least 5 feet beyond the downside of the dam.

The control valve should be kept free of vegetation and in a location where it will not be damaged by machinery.



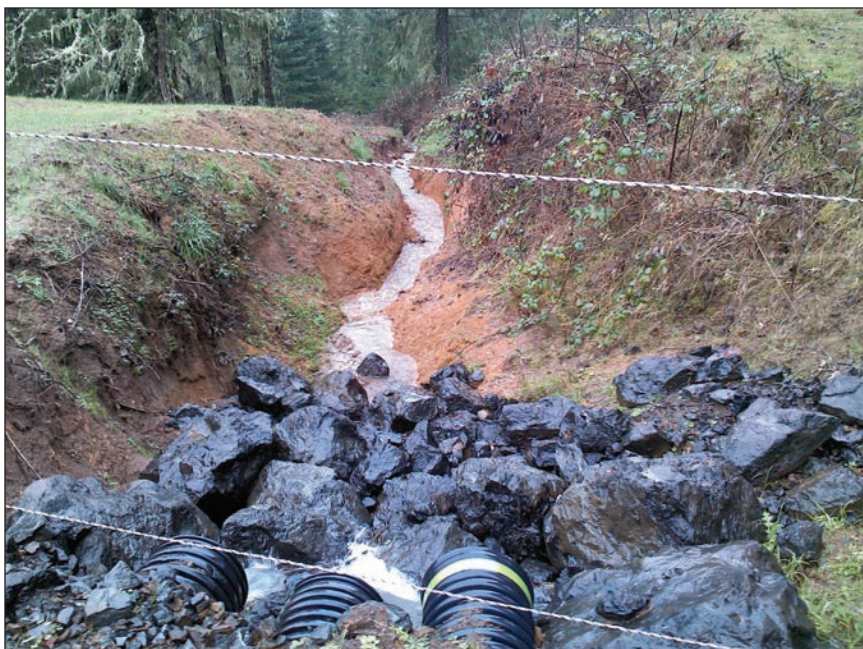
A half-pipe or riprap should extend several more feet beyond the end of the pipe to prevent erosion and sediment entering any nearby streams.

Peak discharges for small watersheds are usually caused by intense, brief rainfalls that may occur during a longer storm. It's impractical to design the pipe inlet to accommodate peak runoff; an emergency overflow or spillway is required, regardless of pond size.



The spillway routes water around or through the dam to prevent an overflow or breach. Without a secondary water-drainage structure, pond water could rise high enough to overtop the dam, damaging the downstream slope of the dam and threatening a catastrophic failure of the structure. Regardless of how well a dam has been built and the size and quality of the water control structure in the dam, an extreme weather event will overwhelm the pipe inlet.

The secondary structure overflow (an open spillway or culverts) should be located away from the center of the dam at the point where the natural topography intersects the excavation work. Discharge should not flow against any part of the dam. This protects the dam from erosion and places the overflow somewhat out of view when observing the pond.



Riprap is essential when directing a pond's overflow into a somewhat narrow channel. In this case, erosion is evident below the rock. Without riprap at the point of discharge, severe erosion could pose serious future problems.

The level width of an open spillway at the bottom of the structure should be at least 5 feet. This diminishes the velocity of the water flowing through the structure, reducing the chances for erosion and structural damage. The slope of the overflow should not be greater than the natural topography bordering the pond.

Any changes in the water flow direction should be wide and smooth until it reaches an undisturbed location and resumes a natural runoff downhill from the pond area.

Overflow channels normally should be lined with rock (6-inch minimum) or riprap to prevent erosion, but there are circumstances in which the area needs to be seeded. Seed areas around the pond to prevent erosion and weeds. Grass cover can reduce maintenance costs, prevent the erosion of disturbed areas, and cut down on sediment degrading the water quality of any nearby streams. When seeding, use a mixture of perennial grasses; no single species can survive and thrive in all conditions. Species capable of establishing themselves rapidly can stabilize a site quickly, while more aggressive, perennial, well-rooted grasses prevent erosion, provide forage, and impede undesirable plants.

Annual ryegrass is often used with later-maturing, lower-profile fescues and/or bentgrass. Ryegrass has far fewer seeds per pound than most perennials, so do not evaluate the seed mixture based on volume. Table 2 on page 39 shows pertinent characteristics of some common grasses and legumes.

Table 2. Characteristics of common grasses and legumes

Common name	Longevity	Growth rate	Growth profile	Seeds/pound	Comments
Annual ryegrass	short	very rapid	erect	200,000	Inexpensive, very fast growing
Perennial ryegrass	short	rapid	bunch	250,000	Both forage and turf varieties available
Orchardgrass	long	medium	bunch	500,000	Not for wet sites, drought tolerant
Timothy	long	medium	bunch	1,000,000	Excellent horse hay
"forage" tall fescues	long	low	bunch	200,000	Deep-rooted grasses
"fine" turf fescues	long	low	sod	500,000	Shade tolerant
Alfalfa	medium	medium	erect	200,000	A legume excellent for wildlife forage
White clover	medium-long	medium	erect	800,000	Good on wet soils; all clovers are legumes
Red clover	short	low-medium	erect	700,000	Good on wet soils
Sub clover	medium	medium	erect	700,000	Must plant in fall; expansive root system
Highland bentgrass	long	low-medium	sod	5,000,000	Low-profile grass, long lasting

Grate: A grate or “bridge” is excavated similar to the open spillway, with the primary difference being that you can cross the area without navigating through water. Utilize some sort of structure such as a cattle guard or heavy grate that allows access by foot traffic or vehicles. Inspect the grate occasionally to ensure it isn’t covered with debris.



Using a grate in the spillway eliminates water passing over the entire surface, allowing for a walkway or road passage. The water passes through the grate, collects in a culvert, and discharges on the down side of the pond. If using a grate, perform regular maintenance to ensure that it doesn’t become plugged. Incorporate culverts that are large enough to handle the volume of water generated by an extreme weather event.

Table 3. Culvert sizing by cubic-foot flow capacity

Diameter (inches)	Capacity (cubic feet per second)
18	<5
24	5-11
30	12-20
36	21-31
42	32-46
48	46-64
54	65-87
60	88-113
72	145-178

If utilizing culverts in the spillway, be sure they are large enough to handle an extreme weather event. The size of the culvert is determined by the Oregon Department of Forestry’s (ODF) stream guidelines.

Step 1: Determine the drainage area in square miles above the point of interest using an accurate map or air photo and dot grid or planimeter.

Step 2: Use the ODF Peak Flows for Forest Streams map and interpolate to obtain the 50-year flow for a square-mile area at the site.

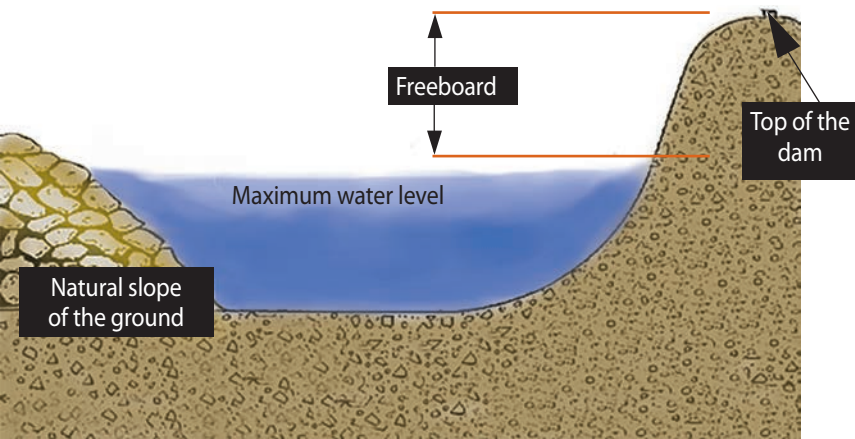
Step 3: Multiply the square miles (Step 1) to get the peak flow in cubic feet per second for that location.

Many woodland owners use plastic rather than steel pipe for their projects. Plastic is easier to use and lasts longer than steel. The following chart compares plastic and steel culverts.

Table 4. Comparing plastic and steel culverts

Attribute	Plastic	Steel
Price	Cost is less if < or = 12"	Cost is less for 18" and larger
Ease of use	Easier than steel	Harder to use than plastic
Size	Usually 36" or less	Available in virtually every size and shape
Availability	Readily available	Readily available
Strength	Comparable to steel	Comparable to plastic
Durability	> 30 years	Approximately 30 years
Repairable (damaged ends)	Generally not repairable	Generally repairable
Fireproof	No	Yes

Regardless of how you choose to drain water from your pond, water cannot be allowed to run over the top of the dam. The amount of “freeboard”—the difference in height between the overflow or spillway (the pond’s maximum water level) and the height of the dam—varies. Some pond builders recommend keeping at least 3 feet of freeboard, while others prefer much less. The less freeboard in a dam, the higher the risk your pond will be unable to handle extreme weather events.



Construction



This pond project incorporates a fabric-and-rock roadway across the dam and a spillway consisting of armored culverts located so as to not compromise the structural integrity of the dam. The wide dam is designed with gradual slopes that will lessen the force of the water on the dam itself.

Careless construction can result in the failure of the most well-designed and planned-out pond project. Large projects require the greatest attention to detail, but even small and simple pond projects must adhere to prescribed construction techniques.

Mark the proposed site: Once the site has been determined, define the outline of the pond with markers, typically stakes. If a consultant or engineer assisted in the pond design, they should do the staking.

Building a level dam or roadway, and properly sloping overflows and pipes, requires the use of a level or transit. A contractor will own this type of equipment, but most woodland owners who decide to build their own pond with a bulldozer or even an excavator quite likely do not. Working on uneven topography is difficult and deceiving, but transits or level units—which include the transit itself, a tripod on which to mount the mechanism, and a rod to record the measurements—make the job easier. Ensure that the tripod is level before recording any measurements.

Before starting any excavation, establish a benchmark by picking out a permanent point or structure, such as a mark on a tree or a designated stake that will not be affected by moving equipment or displaced materials. The benchmark is the basis for all measurements during the operation.

Handheld clinometers can be used to estimate slope during the initial excavation. Handheld clinometers are relatively inexpensive and accurate, but final measurements should be determined with a more accurate transit.



A laser level should be located where it can remain out of the way throughout the construction project.



A tripod and level are needed to determine slope when installing culverts or road grades.



A level stick is used in conjunction with the level to determine slope.



Once the site has been marked, all vegetation must be removed from the location of the pond and dam. Try to avoid damaging the surrounding landscape.

Clear the site: Clear any vegetation down to bare ground several feet from the planned dam site, pond area, spillway, and area from which additional topsoil may be used during construction. Brush, grasses, and sod decompose but do not compact well, so leaving them within the construction site could endanger the pond's structural integrity. The planned site will most likely take more area than anticipated, so include additional space to accommodate any future alterations.



After clearing the site, the desired pond depth is achieved by a series of “lifts.” Each lift displaces 2 to 4 feet of soil, and the process is repeated until the desired depth is reached. Care must be taken to protect the natural vegetation surrounding the pond during excavation.

Plan what to do with construction slash. It can be removed from the site, but if it’s left nearby, pick a spot where the material won’t create a stability, aesthetic, or erosion problem. The material may be shaped into a natural landform, covered with excess topsoil, and planted with native vegetation.

If any trees need to be removed, uproot them while they are standing. Pushing or pulling on the tree stem gives added leverage to uprooting a tree. Excavation is much more difficult if trees are felled before removing, although the procedure is somewhat easier using an excavator instead of a bulldozer. Be sure to remove all trees before proceeding with installing the “key,” digging the pond area, and constructing the dam. A tree’s roots can extend into pervious material, creating holes or less-compacted areas that may cause excess seepage.

While it is important to remove all vegetation before beginning the pond, minimize impacts to surrounding areas. This conserves the ambiance and reduces the need to re-establish vegetation. This is especially important on the upside of the pond, where retaining natural vegetation minimizes erosion and maintains aesthetics.

Avoid impacting any trees you want to save. Trees can be damaged if you place more than a foot of fill over its base, which can deprive its roots of oxygen. You can also damage a tree if you excavate the soil around it and destroy the feeder roots.

Set aside topsoil: If applicable, stockpile topsoil during excavation and place it on the finished slopes and around the pond. This provides fertile soil in which to plant grass and native vegetation, adding to the pond’s aesthetic qualities and decreasing erosion during wet periods.



The second lift makes the pond deeper. The transit remains in place, in a position where it will not be affected by the digging.

Install a “key” or cutoff trench on embankment ponds: Excavate a trench “key” in the solid-clay soil of the dam to stop leaks and ensure a bonding of excavated material with the natural ground. The trench should be located at or slightly above the center line of the dam. It should be at least 2 feet deeper than the bottom of the pond and extend into a relatively impervious layer of soil. The trench should be at least 8 feet wide—about the width of a bulldozer blade — and filled with the most impervious material available on the site.

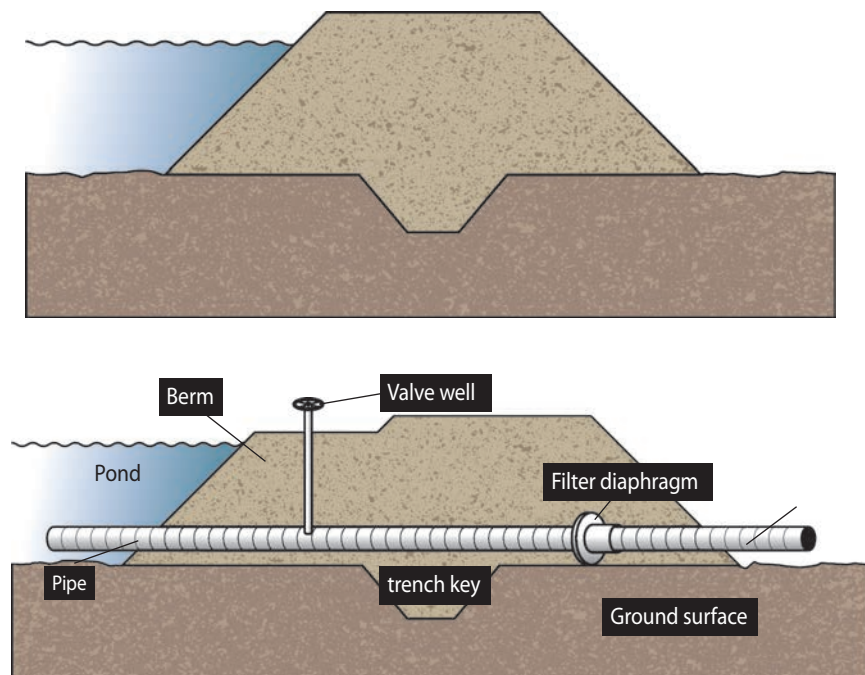
Material removed when making the key can be used to build the dam. Place this material on the downside of the dam. Backfill the cutoff trench to the natural ground surface with suitable fill material, placing it in thin layers and compacting it with the same methods used to build the dam. While the dam is the vital component of the pond, consideration also needs to be given to the upslope of the project; give it special attention if you are concerned with its stability.

Once the key has been filled to the surface, install the in-dam pipe, riser, filter, anti-seep collar, trash rack, and any other mechanical components. Ensure that the devices are placed on a firm foundation and the backfill is tamped around the structures before beginning the dam. Use the same procedure when incorporating overflow pipes or conduits. These areas have the greatest chance for damage or failure, so use extra care during installation.

If the site has an adequate layer of impervious material at the surface with adequate material to construct the dam, you may be able to eliminate the cutoff trench. The only time this portion of the construction may be excluded is when there is an abundance of quality, impervious material, the dam is less than 10 feet in height from the natural surface, and the site is located on relatively flat ground.

Key components of a woodland pond dam

Simple dam projects (top illustration, below) include just a well-compacted earthen dam. More elaborate dams (bottom illustration, below) include a drainage pipe, valve, and filter.



The cutoff trench, or “key,” should be at least 2 feet deeper than the bottom of the pond. It should be about 8 feet wide and be located at or slightly above the center line of the dam.

Many successful ponds have been built without a cutoff trench, but a key provides additional insurance that the dam will retain its structural integrity with a minimum of seepage.

Constructing the dam: A dam is not part of the design of excavated ponds, but most woodland ponds have them. Material for the dam becomes available as the lifts are being performed. Once the key and in-dam pipe are completed, start building the dam. Do not use frozen or saturated soil; neither will compact properly, and they can take years to properly solidify, compromising the structural integrity and greatly increasing the chances for excessive seepage. This is why ponds should be built during the dry months.

If the fill material varies in texture and gradation, use the more impervious material in the cutoff trench, center, and upstream areas of the dam. Fill material should not have sod, roots, stones larger than 12 inches in diameter, or any material that won't compact well.



As the project proceeds with lift No. 3, minimize damage to the natural vegetation surrounding your deepening pond excavation. This will make your pond more attractive and limit erosion and sedimentation when the pond fills during the upcoming wet season.

The structural integrity and maintenance of the dam depends on the volume of earth fill used to build the structure. It must extend above the high water level of the pond and provide adequate access and freeboard. Although not essential, the top of the dam should be wide enough to serve as a roadway. A minimum width of 10 feet is necessary for vehicle traffic. This provides permanent access and a platform for maintenance or repairs. If mowing is part of a maintenance regime, the sides of the dam should be no steeper than 3 feet horizontally for each vertical foot. A gentler slope usually increases stability and aesthetic values, blending better into the surrounding landscape and decreasing the potential for washouts from animal burrows.

When possible, construct a curved dam versus a straight alignment. A curvature reduces the visual impact, primarily by reducing the apparent size of the dam. In general, your pond will look better when excavation uses gentle slopes and curves rather than sharp angles.

Compaction: Earth-fill dams should be constructed by placing impervious material in layers less than 1 foot thick and compacting each layer before placement of the next layer. This ensures that the dam will be impervious and adequately hold back the pond's water.



It is important to contour and compact displaced soil as the excavator continues digging the pond. There is no such thing as too much compaction, especially at the top of the dam if it is to be used as a rocky road.

Use caution and patience. A bulldozer works well in conjunction with an excavator; the dozer can focus on shaping and compacting, not digging. Larger dam projects may call for special equipment, such as sheepfoot rollers or larger bulldozers or excavators. Follow the adage: "Move the dirt for show, but compact to avoid water flow."



A culvert in the center of the dam must run beyond the base of the dam and onto natural, undisturbed soil. Regardless of the position or size of the culvert, always employ an open spillway as a secondary measure for water drainage.

If not properly compacted, porous soil—containing more air and organic material—has a greater tendency to settle, decreasing the available freeboard. Inadequate compaction in ponds with dams less than 10 feet in height face more problems with seepage than with settlement.

When the pond fills, compaction limits the amount of water that can saturate the dam, allowing it to maintain its structural integrity. Inadequate compaction and soil with insufficient clay are two of the greatest errors in pond construction, and there are no easy remedies once everything is in place.



A completed pond sits with the first lift of rock on top of the dam.

Equipment selection

There are several factors to consider when selecting the equipment to construct your pond. These include:

- Size
- Speed
- Cost
- Availability
- Desirability

Size is the leading factor in selecting the equipment to build your pond. Small backyard ponds can be dug with anything from a hand shovel to a steel track excavator. But larger ponds call for larger equipment in order to do the work quickly and efficiently.

Speed is the second most important factor. Since the work is best done during the dry months, you'll need equipment that lets you work within that limited time frame. Failing to finish the work before the fall rain arrives causes a variety of problems: the unfinished pond will have to be drained the following summer, topsoil set aside for landscaping could wash away; re-established vegetation will have to be cleared a second time; and a contractor will have to be secured for a second year of work. The moral of the story: get the right equipment on the site and get the job done!

Cost is driven by the type of equipment used and how fast you get the job done. Too often, individuals will employ a small machine at a lower cost per hour than a larger, faster-working machine at a higher hourly rate. But two small or medium-sized bulldozers cannot come close to displacing soil as fast as a single large excavator. While dollars per hour are important, do not allow it to be the primary factor in equipment selection.



A dump truck can be used to remove soil from a pond site and then used to deliver and spread rock along the road.

Table 5. Choosing the right equipment

Equipment type	Cost (\$/hour)	Size	Availability	Usage	Comments	Recommendations
Rubber tire tractor or backhoe	Low to medium	Small farm tractors to large contractors	Readily available from building and excavating contractors	Use for small ponds less than 0.25 acre-feet	Limited capacity to move large volumes of material	Use only for small backyard ponds
Bulldozer	Medium to high	Small to huge	Readily available from logging and excavating contractors	Depending on size, can build any size pond	Versatile; can be used anywhere and can move large volumes efficiently	Good alone, and excellent with excavators; good for shaping, contouring
Steel track excavator	High to very high	Some quite small, but mostly larger machines	Available from construction and logging contractors	Depending on equipment size, can build any size pond	Extremely efficient earth-moving machine	Valuable for ponds greater than 3 acre-feet. Use dozer for compaction
Belly dump	High to very high	Large machines	Primarily through large excavating contractors	Used only for very large ponds	Rare for woodland pond construction	Not recommended for woodland ponds
Dump truck	Medium	Single axle hauls 5 yards, double axle hauls 10 yards	Readily available from many types of contractors	Use in conjunction with loader equipment	Sometimes necessary; but adds significantly to total costs	Limit hauling distance; multiple units prevent excavator bottleneck
Sheepsfoot roller	Low to medium	Can be used with any other size equipment	Not as readily available as other equipment	Used for compaction only	Available as tow equipment or power driven	A bulldozer can compensate in compaction
Front end loader	Medium to high	Small farm tractors to large size tractors	Available from many building and excavating contractors	Use for ponds less than 0.25 acre-feet.	Limited capacity, normally used in conjunction with loaders	Not recommended for woodland ponds. Poor ability to shape and contour landscape
Dragline	High to very high	These are large machines	Very few are available for any type of service	Excellent for dredging seeps, springs, bogs	Attachments can shape excavation	Great for cleaning ponds, but quite rare

Availability: To ensure you get the right machine and the right operator, reserve them ahead of time. Equipment is more readily available than good operators. The good ones stay busy.

Table 5 on page 53 lists machinery often used in a woodland pond project. Some are easy to find, and others are rare. Draglines, for example, were once common, but rules and restrictions placed on dredging rivers and streams have made them and their operators scarce. On the other hand, rubber-tired backhoes and bulldozers are plentiful, so you will find a wide variety of machines and operators. Choose carefully.

Desirability relates to the old axiom: the right tool for the right job. If you plan on building a 5-acre-foot pond with a 10-foot dam, even the best small bulldozer in the world run by a superior operator can't do the job. Myriad shapes, sizes, and amendments available in a woodland pond project means you might employ a single piece of equipment, or several of them to effectively and efficiently perform the job.



A backhoe works on a woodland road.

Here's a little more information on the equipment:

Rubber-tired tractor backhoe: These are best for small ponds. They are equipped with a front-end loader to excavate soil and carry it to a truck or another location, but they are limited on volume and ability to compact soil. They are available any time of year; select a good one at the right price with an experienced operator.



Bulldozers can compact and shape the soil but aren't efficient when used to excavate a large pond.

Bulldozer: Bulldozers only push excavated material—though some are equipped with front-end loaders—so if excavating a large pond, these machines will be time-consuming and expensive. They are good at compacting, shaping landscapes, and building roads. Despite their limitations, if you were forced to choose just one piece of equipment, the bulldozer would be it. Bulldozers are especially effective when the pond site contains seeps or springs. Seeps and springs mean you will lose less water during the summer and enjoy cooler and cleaner water (better for you and the wildlife) throughout the year. Unfortunately, they also mean you will have water in your pond at the start of each workday. If the slopes are not too steep, you can continue to dig the pond. Although you cannot operate under optimal conditions, a low level of standing water will not impede a bulldozer. However, wet soil should not be incorporated into the dam because it doesn't compact well.

At the beginning of the day, as material is being displaced, push the wetter soil to the downside of the dam and not into the interior or upper portion of the dam. After a period of time (depending on the volume of water; usually less than an hour), the pond site will continue to seep water, but you will be moving enough soil so as to prevent working in standing water. As you begin displacing “drier” soil, it can be placed in the interior of the dam. This situation is somewhat cumbersome, but when done successfully, the finished product will be worth the effort and expense, as you will have a pond that retains water during the driest of weather conditions.



An excavator is the champ when it comes to moving a lot of dirt in a hurry. It is a slow compactor, however, and is best when used with a bulldozer.

Steel-track excavator: If moving dirt is the objective, an excavator can move more dirt, more efficiently and faster, than any other machine. But compaction is also important, and while excavators have reasonable capacities for compaction, they are slow compactors and better suited for excavation. What's more, an excavator can move the heavy, wet soil easier and faster than the bulldozer. Typically, excavators perform a series of "lifts" until reaching the desired depth. Their limited reach explains why bulldozers and dump trucks are often used in conjunction with these machines. However, since excavators can displace material faster than a bulldozer can form and compact it, it may be wise to start and end daily operations with the bulldozer and dump trucks, operating the excavator fewer hours. This reduces equipment costs and downtime while providing adequate time for compaction and shaping the dam and landscape. Used correctly, the steel-track excavator and bulldozer combination can efficiently build any size and shape of woodland pond.

Belly dump: Belly dumps are used on flat terrain and when material needs to be moved substantial distances. They are more efficient and less expensive than a front-end-loader-and-dump-truck combination. They can only be used on flat ground and with clean soil free of large rocks or other debris. Because of these limitations, belly dumps are typically utilized in agriculture operations. They are not as available as other machines, but they can be found with a little bit of research.

Dump truck: You'll need a dump truck if you are building a rock road for year-round access to your pond. For additional information on woodland roads, see *Managing Woodland Roads: A Field Guide* (<https://catalog.extension.oregonstate.edu/pnw641>). If using trucks to transport material away from the pond site, the only prerequisite is a truck with a hoist. A local farmer or dairy owner may have one available, often at substantial savings.



Most excavated woodland ponds will be completed with an excavator and a bulldozer working in tandem; the excavator removes the soil and the bulldozer shapes and compacts it.



An excavator is used to place boulders on a liner used in conjunction with a French drain.



A sheepfoot, whether pulled by a rubber-tired tractor or on a power-driven compactor, is useful in compacting a pond site. Adequate compaction will help strengthen the dam and limit excessive seepage.

Sheepsfoot roller: A sheepsfoot is not required to adequately compact the pond site, but it will provide favorable results. Power-driven compactors are more expensive than a tow-type unit, so woodland owners with a rubber-tired tractor or other equipment capable of pulling a sheepsfoot can save some money. A sheepsfoot is particularly valuable if the excavated soils are not ideal for compaction. If you are building your pond using a rubber-tired backhoe or front-end loader, a sheepsfoot roller is needed to adequately compact the dam to limit excessive seepage.

Front-end loader: A front-end loader is not often used to build a pond. An excavator or rubber-tired backhoe is better for loading material and can perform other duties at the pond site. Front-end loaders can be used to help build the pond, but should not be used in place of other machines better suited to digging and loading.

Dragline: On sites where substantial water accumulates at the bottom of a pond and the surface area cannot be reached by an excavator, a dragline is the only kind of equipment that operates satisfactorily. They are expensive but worth the cost. This equipment is also used to dredge existing ponds to remove sedimentation or excessive vegetation. If using during construction of a new pond, excavated material should be placed as close as possible to its final location.



A front-end loader can be used in a pond project to load displaced material into trucks to be hauled away, but they are not designed to be used for excavation or compaction.

Because excessively moist soil should not be used to build a dam, you may need to dig a deeper pond and rely less on a dam. If using a dragline, a bulldozer, power-driven or tractor-pulled graders, or other type of equipment will be needed to displace and form the soil.

Explosives: Explosives can be a viable and useful tool in constructing a pond. It is difficult for private landowners to obtain and use explosives, but some companies specialize in demolition. Explosives help remove large stumps, and they displace large amounts of soil in areas where water is accumulating. People and structures need to be protected, of course, and builders should be cautious around seeps and springs, which can be sealed up by an explosion.

Renting equipment

Woodland owners considering renting heavy equipment to build a pond themselves should have extensive skill and experience operating and maintaining the equipment. Doing it yourself may not be cheaper than hiring a contractor, and unless you are highly skilled, the quality of the job may not be as high for do-it-yourselfers. The finished pond may not look as nice or be structurally sound.

Maintenance



Pond builders who choose the wrong location or use a poor design may find themselves draining their pond to make repairs.

After the pond is completed, woodland owners should plan and budget for periodic mowing, waterline debris removal, restocking fish, herbicide applications, repairing docks, and maintaining the access road. Regularly check for signs of leaks or seepage. Do not expect pond levels to remain constant; evaporation happens, even with substantial water flow from seeps and springs.

In western Oregon, consider the pond's location, design, and construction a success if the water level falls less than 3 feet during summer. East of the Cascades, consider a project successful if levels vary nearly twice those on the west side. Here are some things that can reduce the volume of water loss:

Steeper slope: Smaller ponds with deeper water evaporate more slowly than larger ponds with shallow water.

Vegetation: The more grasses, shrubs, and trees around your pond means more water being taken by plants during the dry months.

Out-of-reservoir uses: Water taken from your pond for other uses will not be recovered until the following wet season.

Water loss

The key to repairing seepage is to identify the problem and select an appropriate solution.

The importance of compaction has been stressed numerous times. This procedure can be applied as a post-construction measure to reduce leakage, but at greater time and effort than during the initial construction. If the extreme measure of draining the pond is deemed necessary, make repeated passes with a sheep'sfoot roller on the upslope and downslope of the dam. Continue using the roller until it is penetrating less than half the height of the individual "feet." This may take up to a dozen passes. If repeated trips over the area show no significant signs of compacting, it will be necessary to adopt additional methods to reduce the permeability of the soil.



Extensive measures, such as placing large boulders on the slopes above a pond to prevent slumping, may be necessary in some locations.

Even if proper time, technique, and equipment have been employed, a pond may still experience excessive seepage. The most common causes of seepage are:

- Improper construction
- Permeable soils
- Thin layers of soil with fractured bedrock or sinkholes



Reed grass and green vegetation in late summer are a sign of excessive seepage at the bottom of this dam. The visible undulations on the ground are evidence of slumping in the dam, which is likely to need repair in the near future.

In some cases, the problem is apparent (fractures or slumping of the dam), while in others the cause may be unknown. The first thing to do is inspect the dam and areas directly below the pond. Seeps, wet spots, or wetland vegetation on or below the dam indicate water is seeping through or under the structure. There are a number of possibilities, including:

- Improper compaction of the dam
- Inadequate removal of vegetation before constructing the dam
- Animal burrows
- Seeping around drain or overflow pipes

Before concluding the pond is leaking, consider these possibilities:

- There are springs or seeps in and around the pond.
- At the outset of the wet season, cracks and fissures in the dam need time to reseal with the swelling of the wet soil.
- A new pond needs time to “seed” while microbial activity and fine sediments help seal the pond.

In most instances, excessive seepage occurs due to poor site selection; soils are too permeable to hold water. In these instances, plans need to be incorporated into the design that will reduce the expected volume of seepage. There are measures to control seepage due to improper soils or inadequate compaction, but these measures typically involve extensive time and money and end with questionable results.

There may be other instances where no amount of time or money can solve the problem. There is no substitute for an optimal site that has been carefully inspected and developed with the help of a professional engineer experienced in pond construction.



In an effort to control excessive ground movement, this French drain was located a few hundred feet above a pond. The goal is to intercept runoff and divert it into drains that empty into the pond. This design reduces the volume of water across the upslope, thus reducing the force and soil movement and providing a more stable upslope.



In an effort to compensate for a poor pond location, builders used upslope boulders to cover a French drain running parallel to this pond. The French drain directs water to a culvert, which discharges water into a rock-lined shoreline.

When soil conditions and added compaction don't adequately seal a pond, clay soils, bentonite, or liners may help. Expenditures for these methods can be determined on a material cost per square foot.



Soil movement and stability can be a problem on the downslope side of a woodland pond. In this picture, the rocky area indicates the location of a French drain, which is designed to divert water away from the base of the dam to a flatter, more stable area.

Example: Determine the square footage of a rectangular pond

Referring back to the example in the Design section, determine the square footage of a rectangular pond, 150 feet x 70 feet with a 2:1 slope ratio and a depth of 10 feet.

We can amend the pond volume equation to find the surface area of the pond. For this problem, we need to find the surface area of the bottom of the pond and the sides of the pond (the surface area of the container holding the water).

The volume equation $V = ((A + 4B + C) / 6) \times (D / 27)$ is amended to find only "B" and "C." Determining the dimensions at the middle depth of the pond "B" gives us the surface area of one side of the pond. Multiplying this by 4 generates the surface area of the sides. Then, merely add the surface area of the bottom of the pond to determine the pond's square surface area. The square footage of the surface area of the pond equals:

$$S = 4B + C$$

S = surface area of the pond that is holding water

B = area of excavation at the middle depth of the pond (square feet)

C = area of excavation at the bottom of the pond (sq ft)

With a 10-foot depth and 2:1 slope, we determined “B” to equal 130 feet x 50 feet and “C” equals 110 feet x 30 feet.

$$S = 4 \times (130 \times 50) + (110 \times 30)$$

$$S = (4 \times 6,500) + 3,300$$

$$S = 29,300 \text{ sq ft}$$

(If this were an elliptical pond, we would multiply “S” by 0.7854)

Note: S gives us the surface area that is holding water. Lining a pond with amendments requires they be applied to the level of the top of the dam, thus a “fudge factor” needs to be incorporated to get a more accurate determination of necessary supplies. A 10 percent factor is often employed, so for our example we should use slightly more than 32,000 sq ft in cost estimates. Inserting current costs of these amendments shows that these techniques are extremely expensive (and often bring questionable results). This emphasizes, once again, the importance of pond location.

Table 6 . Treatment options for leaky ponds

Problem	Possible reason	Treatment options	Requirements	Degree of success
Seepage through clay	Poor compaction	Compaction	Drain pond	High, but expensive
Seepage through mostly clay soil	Pockets of sandy soil types	Mix or amend soil	Drain pond	Mixed results, expensive
Exposed porous soil, sand, or gravel mixes	Inadequate compaction	Compaction	Clay additive	Questionable, time consuming, and expensive
	Too little clay	Additional clay	Clay soil	Questionable and expensive
		Bentonite	Supporting foundation soil	Highly questionable
		Liner	Smooth pond surface	Excellent but very expensive
Thin layer of soil over bedrock and fractures	Poor compaction	Additional compaction	Clay soil over 12" deep	Very expensive, time consuming
	Too little clay soil	Compaction of additional clay	Nearby source of clay	Questionable, time consuming, expensive
		Liner	Smooth pond surface	Very expensive
Clay soil that leaks	Seepage because of aggregated soil structure	Compaction	Proper soil moisture content and equipment	Satisfactory; usually accept limited seepage
		Soil dispersant with compaction	Soil dispersants	Additional costs for questionable results



If you use bentonite or liners, it is important to restrict livestock from the pond because they will puncture the liners or fracture the bentonite application, exposing untreated soil and causing leaks.

Clay lining

Another expensive and time-consuming technique involves soil amendments or clay blankets. When using this technique, it is necessary to cover the entire area where water will be held at a height equal to the high water mark. The blanket should consist of soil with at least 20 percent clay. These soil types are often available somewhere near the construction site, thus hauling can be done at a reasonable cost. If none are available nearby, and it becomes necessary to transport the material over longer distances, a cost analysis should be done to compare this approach to other available techniques.

A minimum of 12 inches is required over the pond area; up to 2 feet of material, applied in layers, is optimal. Spread the material 6 to 8 inches thick and compact it using the same amended techniques as previously described. To protect the clay against cracking from drying and rupture caused by potential freezing, spread approximately a foot of gravel over the area. Obviously, this becomes a time-consuming and expensive alternative to an optimal site, but clay amendments to the site have proven to be reasonably effective.

Bentonite

Adding bentonite is another option to reducing excessive seepage. Bentonite is a fine-textured colloidal clay. It can absorb several times its weight in water and swells up to 20 times its original volume.



Bentonite, below, is a powdery substance that, when it becomes wet, fills the pores of porous soils, making them more impervious to water. Using bentonite on ponds is expensive and doesn't always work. In the top photo, bentonite has been sprinkled on the top 4 to 5 feet of the pond and on the sides. If the water level drops, the bentonite can be exposed and become cracked, compromising its effectiveness.





Pond liners are expensive, but they are the most effective way to prevent seepage.

The concept of applying bentonite is for the substance to fill the pores of more coarse-grained soils to the point where the mixture is nearly impervious to water.

Unfortunately, when bentonite dries, it returns to its original volume and leaves cracks in the soil. Woodland ponds that have substantial fluctuations in water levels are not good candidates for bentonite. Also, wildlife and livestock can leave deep indentations on the surface and compromise the bentonite layer, thus allowing seepage.

Bentonite is expensive. It needs to be added at the rate of 1 to 3 pounds per square foot and mixed approximately 6 to 9 inches deep in the soil with a rototiller, disk, or harrow. After mixing, compact the area with a sheepsfoot roller using the same procedure as if no additives have been applied to the surface.

If considerable time elapses before the pond fills with water (as in the case of most ponds constructed during the summer and waiting for the fall rains), it may be necessary to protect the area from cracking. Mulch the area with straw prior to the last passage of the sheepsfoot roller. Use wheat or barley straw; hay will contain weed seed.

If a pond has a water source, such as a well, that is sufficient to sustain a steady water level during the summer months, bentonite may be an effective treatment to decrease seepage.

Chemical additives

Chemicals such as sodium chloride (common salt) and soda ash are dispersing agents that can be applied in small amounts to fine-grained clay soils to achieve a better seal and prevent seepage. The chemicals change the soil structure and arrangement of the clay particles, but are not effective in coarse-grained soils. A laboratory analysis of the soil in the pond area is essential to determine which chemical agent will be most effective and how much of the chemical to apply. The chemical is mixed with the soil, compacted, and protected using the same technique as applying bentonite. The chemicals should be mixed to a depth of 12 inches and can be applied with a seeder, drill, fertilizer spreader, or by hand. It's best to consult with a professional experienced in the use and application of chemical additives.

Waterproof linings

Linings are the most effective way to prevent seepage, but they are also the most expensive, especially for larger ponds. Linings are effective on all soil types, and are made with polyethylene, vinyl, butyl-rubber membranes, and asphalt-sealed fabric.

Different materials have different properties. Black polyethylene is less expensive. Vinyl is more resistant to puncture and can be easily seamed and patched. Most materials require a covering of at least 6 inches of soil or gravel to prevent punctures. Butyl-rubber membranes do not require covering except in areas exposed to livestock or wildlife. If considering the use of a waterproof lining, consult with the manufacturers of these products and carefully follow instructions for installation. While effective, linings are very expensive and may be compromised by wildlife and livestock.



This pond is rich in floating vegetation and cattails, making it an excellent habitat for fish and wildlife.

Vegetation control

Aquatic plants are an important link in pond ecosystems. Algae are the foundation of the food chain for fish. Free-floating and rooted aquatic plants provide escape cover and shelter for fish and wildlife. However, too many plants can kill fish and degrade habitat. How much is too much? Healthy ponds have a faint, green color, and you should be able to see at least 2 feet below the surface. But water with a greenish-yellow color indicates an algae bloom that is harmful to fish and will hamper recreational activities.

Aquatic vegetation often reaches nuisance levels in many ponds, causing owners to consider aquatic herbicides or algaecides. It's important to know when to apply these treatments to prevent fish kills or to ensure that aquatic plants are prevented in time for recreational pursuits, such as swimming during the warm months.



This pond's primary purpose is fishing and water recreation, and its steep slopes help minimize weeds.

Invasive plants spread easily, often outcompeting native plants and reducing plant diversity. A number of techniques, often used in combination, can help control this problem, including:

- **Mechanical:** Hand pulling, cutting, mowing, tilling, mulching, solarization, flooding, and prescribed burning.
- **Biological:** Wheat or barley straw in ponds can help control excessive algae.
- **Chemical:** Pesticides and other chemical measures can help control invasive plants, but they can also contaminate surface and groundwater. Herbicides must be licensed for use in or around water, wetlands, and other aquatic systems. When selecting an herbicide, consider growth habits of the target species, any possible long-term effects on water and soil quality, effects on wildlife, application methods, and the safety of anyone who frequents the area.



Cattails can be aesthetically pleasing and attract wildlife to your pond. But, if left unchecked, cattails can take over a pond.

There are various types of pond vegetation.

Emergent vegetation such as cattails, bulrushes, and smartweeds should be controlled when the plant is finishing its flowering stage and beginning to set its seed head.

Submerged vegetation such as pondweeds, elodea (waterweed), and coontail should occur in May or June before they have attained maximum growth. Treatment of submerged plants should minimize the amount of decaying vegetation. For ponds containing fish, it is generally not recommended that liquid herbicides be used after late June if there is an abundance of submerged plant material. The chances of a summer fish kill due to oxygen depletion are greatly increased after whole pond herbicide treatments in July, August, and September because warmer water contains less oxygen and the decomposition of dead plant material requires large amounts of oxygen. The more plant material killed, the more oxygen required for decomposition, which results in less oxygen available to fish and other aquatic animals.



Floating vegetation may attract wildlife, but once it is established, it can quickly cover a pond's surface and render the pond less appealing for other activities, like swimming.

Floating vegetation such as water lilies and pennywort can be controlled with glyphosate herbicides applied immediately after the peak flowering period. Duckweed and watermeal can cover a pond in a matter of weeks. It is recommended to use a fluridone product over several weeks or the treatment of small areas (one-fourth of the pond at a time) every couple of weeks.

Algae. Most alga species reach maximum growth in early to mid-summer, depending on pond nutrient levels. Treatments should begin in May or early June. Copper compounds should never be used until water temperatures reach 60 degrees and remain there for a week. Shallow areas can get very warm on calm, sunny spring days while the main area of the pond is still too cold for a general application. Apply the granule earlier in the shallow areas, then on the whole pond after an increase in water temperatures.

When applied at the correct time, aquatic herbicides and algaecides can be cost-effective and successful with little risk of a fish kill.

Product labels provide important information related to when and how to apply herbicides and algaecides. The status of herbicide label clearances is subject to change, and you should contact appropriate individuals as to the current status of their usage. These labels should be read and followed carefully to help determine if and when these options are applicable to your situation.



A pond owner placed barley bales where most of the runoff enters the pond. This ensured good circulation of the chemical action needed to control algae.

Table 7. Treatment response of aquatic plants to registered herbicides

Aquatic group and vegetation	Copper & copper complexes	2,4-D	Reward (diquat)	Aquathol Hydrothol (endothall)	Rodeo (glyphosate)	Sonar (fluridone)
Algae						
planktonic	E	P	P	G1	P	P
filamentous	E	P	G	G1, P2	P	P
<i>Chara/Nitella</i>	E	P	P	G1, P2	P	P
Floating plants						
duckweeds	P	F3	G	P	P	E
salvinia	P	G	G		G	E
water hyacinth	P	E	E		G	P
watermeal	P	F	F			G
Submerged plants						
coontail	P	G	E	E	P	E
elodea	P		E	E	P	E
fanwort	P	F	G	E	P	E
naiads	P	F	E	E	P	E
parrotfeather	P	E	E	E	F	E
pondweeds	P	P	G	E	P	E
Emergents						
alders	P	E	F	P	E	P
arrowhead	P	E	G	G	E	E
buttonbush	P	F	F	P	G	P
cattails	P	F	G	P	E	F
common reed	P	F	F		E	F
water lilies	P	E4	P		G	E
frogs bit	P	E	G			
pickerelweed	P	G	F		F	P
sedges & rushes	P	F	G		G	P
spike rush	P		F		P	G
smartweed	P	E	F		E	F
southern watergrass	P	P			E	G
water pennywort	P	G	G		G	P
water primrose	P	E	F	P	E	F
willows	P	E	F	P	E	P

E = excellent control, G = good control; F = fair control; p = poor control; blank = unknown

1 Hydrothol formulations; **2** Aquathol formulations; **3** Liquid 2,4-D formulations;

4 Granular 2,4-D formulations

http://wildlife.tamu.edu/files/2010/04/3_Aquatic_Weed_MGMT_Herbicides.pdf

Straw can be an effective, inexpensive, and environmentally friendly treatment for algae. Although straw can be applied to a shoreline to prevent erosion, straw scattered over the surface of a pond can discourage algae growth. The effect on vegetation, fish, and wildlife is minimal, and some studies suggest fish habitat is improved by the application of straw.

Barley straw is more effective than wheat or oat straw. If straw other than barley is used, there needs to be an increase in the quantities and frequency of application, although the chemical reactions controlling algae are the same, regardless of the type of straw.

Straw works best in well-aerated water. If used in bales or limited areas of the pond, water movement will be insufficient to be effective. Muddy or dirty ponds will require additional volumes of straw because the mud deactivates the effects on the algae. When applying the straw, place it where there is the best opportunity for water movement, such as the upper area of the pond where runoff occurs or the windy side (if applicable) of the pond.

The rate of straw application depends on the amount and type of algae, water movement in the pond, pond cleanliness, and the location of the straw. A good starting point is to apply 4 to 6 bales of straw per acre-foot of water. There are few environmental consequences from applying too much. Applying the straw before the appearance of algae will have the best results and require smaller amounts. The likely interval between applications is approximately 6 months, but more frequent treatments may be necessary.

Copper Sulfate (various trade names): Used to control algae. It is a contact herbicide and can be harmful to fish if not used properly.

Chelated Copper (*Cutrine, Komeen, K-Tea*, others): Copper held in an organic complex and used to control various types of algae. These products are less toxic to fish, and under proper conditions remain active longer than copper sulfate. They are not effective in water with high alkaline concentrations.

Diquat (*Reward, Weedtrine-D*): A contact herbicide used to control submerged and emergent vegetation. It is not effective in muddy water or on mud-coated weeds.

Endothall (*Aquathol, Hydrothol*): Used for spot or partial pond treatments involving certain types of algae and submerged weeds.

Fluridone (Sonar): This chemical controls most submerged and emergent weeds. It slowly kills plants, which prevents depletion of dissolved oxygen. It is not an effective spot treatment, and the entire pond must be treated to control the target weed.

Glyphosate (Rodeo): Foliar-applied, translocated (spreads through plant) herbicide used to control most shoreline vegetation and some emergent weeds. An approved surfactant should be used. Rainfall within 6 hours of use can reduce its effectiveness.

2,4-D (various names): This is a translocated herbicide that controls some floating and submerged weeds and is toxic to fish. Only use formulations labeled for aquaculture.



Mechanically removing cattails can eliminate the root system, making it difficult for cattails to become re-established. Mechanical removal eliminates decomposing vegetation, which depletes oxygen in the water and can be unsightly.

Hand pulling: Hand pulling aquatic plants is similar to pulling weeds out of a garden. This technique can be advantageous because it impacts only the affected areas and can be cost-effective if applied to small areas. It involves removing entire plants (leaves, stems, and roots) from the area of concern and disposing of them away from the shoreline. In water less than 3 feet deep, no specialized equipment is required, although a spade, trowel, or long knife may be needed if the sediment is packed or heavy. In deeper water, hand pulling is best accomplished by divers with SCUBA equipment and mesh bags for the collection of plant fragments. For larger areas, hand pulling is difficult and time consuming.

Mechanical removal is environmentally friendly, much faster, and often more effective. A drawback is a larger amount of soil is displaced when using a machine. This material needs to be placed away from the pond and formed to retain the aesthetics of the shoreline of the pond. When using a machine, attempt to remove only the plant and avoid removing excessive amounts of soil.

Cutting and mowing: Effective for some species, but some weed varieties sprout aggressively when cut. Cutting differs from hand pulling in that the roots are not removed. Cutting is performed by standing on a dock or on shore and throwing a cutting tool into the water. A non-mechanical aquatic weed cutter is commercially available. Two single-sided stainless steel blades (razor sharp) forming a "V" shape are connected to a handle, which is tied to a long rope. The cutter can be thrown about 20 to 30 feet into the water. As the cutter is pulled through the water, plants can be removed when they rise to the surface.



These pond owners dug up weeds and mulched with sawdust to control invasive vegetation. It's hard work, but the results are rewarding.

When considering cutting or mowing, it is important to know how the target species will react to these techniques. This technique works well on and around the dam (areas out of the water), but has limited success with aquatic plants.

Tilling and mulching: In the area surrounding the pond, tilling is most effective against annuals and shallow-rooted perennials. Deep-rooted plant species will often re-sprout after tilling. Mulching helps control invasives, but it can have negative impacts on the growth of desirable species.

Solarization, flooding, and burning: Solarization involves covering affected areas with plastic to trap solar radiation, which increases soil temperatures that can kill unwanted seeds, plants, or insects. Negative impacts involve altered soil temperatures that can change the properties of the soil, impacting the growth of desirable plant species. Flooding shallow pond areas or increasing or decreasing water levels, or a combination of these processes, can be effective in controlling aquatic invasives. If retaining pond levels during the dry months is important, flooding may not be possible if relying only on runoff and no additional water sources, such as springs or seeps, to amend water supply. Prescribed burning can be an effective control for invasive plants, such as cattails or common reed. Prescribed burning is a complex, technical practice that should not be attempted before consulting experts. This category is little used due primarily to the required changes in water levels in addition to the difficulty of obtaining permission for prescribed burns during the time of year when it is most effective.



A pond builder spreads out straw along the downslope of the excavation site where the pond will be. Straw makes an excellent weed deterrent and is an environmentally sound way to control both weeds and erosion. The straw will also attract a variety of wildlife.

Raking: A sturdy rake makes a useful tool for removing aquatic plants. Attaching a rope to the rake allows removal of a greater area of weeds. Raking literally tears plants from the sediment, breaking some plants off and removing some roots as well. Specially designed aquatic plant rakes are available. Rakes can be equipped with floats to allow easier plant and fragment collection. Raking is an effective treatment option, but requires repeated entries to effectively control aquatic plants.

There are trade-offs that need to be considered when evaluating manual, chemical, or mechanical maintenance regimes. A few points to consider:

Advantages

- Manual methods are easy to use around docks and swimming areas.
- The equipment is inexpensive.
- Hand pulling allows the flexibility to remove undesirable aquatic plants while leaving desirable plants.
- These methods are environmentally safe.

Disadvantages

- As plants regrow or recolonize the cleared area from fragments, the treatment may need to be repeated several times each summer.
- Because these methods are labor intensive, they may not be practical for large areas or for thick weed beds.
- Even with the best containment efforts, it is difficult to collect all plant fragments. Most aquatic plants can regrow from fragments.
- Some plants, like water lilies, which have massive rhizomes, are difficult to remove by hand.
- Pulling weeds and raking stirs up the sediment and makes it difficult to see remaining plants.
- Hand pulling and raking disturbs bottom-dwelling animals.

Fish, Wildlife and Recreation



An elk takes advantage of a woodland pond.

Photo by Scott Fitkin

Ponds are a great way to provide food, cover, and nesting habitat for a variety of wildlife species, including amphibians, reptiles, fish, birds, and mammals. A well-designed and functioning pond increases watershed health, reduces erosion and sedimentation, conserves habitat, and provides opportunities to introduce or maintain an extensive array of plant and animal species.

In terms of fish and wildlife, managing for a particular species may be detrimental to another. Because of this issue, owners need to determine specific goals for their pond before building and putting a management plan into effect. Table 8 on page 88 provides information on various wildlife groups and how to manage them accordingly.

A diversity of vegetation within the pond and uplands near the pond can offer a variety of food and cover to wildlife. Planting and maintaining aquatic plants suited for the pond help maintain water quality and temperature, maintain oxygen levels, and reduce bank erosion. Reducing bank erosion is very important. Soil eroding into your pond can result in unnaturally high levels of nutrients in the water, which, in turn, can cause excessive algae growth. In this process, called eutrophication, when algae die and decompose, oxygen in the water is depleted and fish and other organisms may die. In nature, eutrophication is a natural, slowly progressing process, but heavy erosion speeds up that process considerably.

Buffer zones of trees, shrubs, grasses, and forbs assist in maintaining a pond's depth and quality. These zones increase water infiltration of the soil, preventing sediments from entering the pond. Any change in the natural topography (roads, ponds, etc.) results in nature trying to negate those man-made enterprises. A diversion or grassed buffer above the pond can divert or absorb sediments and nutrients before they reach the pond. Additional barriers, such as rock berms, can reduce unwanted materials from entering the pond.



A sediment barrier at this pond employs a log with large, clean rock on the upslope. The barrier captures sediment but also serves as habitat enhancement.



A log has been placed in this pond as habitat enhancement and to improve its visual appeal.



A large oak that has fallen into this pond will provide excellent fish habitat as well as an access point for small mammals who need water.

Native plants

Native plants are plants that occur historically and naturally around your property. Once established, native plants do not generally require fertilizers, pesticides, or irrigation. In most cases, utilizing native plants of the region makes good sense because they are adapted to the local climate, have a better survival rate, and often require less maintenance.

Native aquatic plants are difficult to find at retail stores. The popularity of water gardens has resulted in several nurseries specializing in aquatic and wetland species, but few of these nurseries carry native plants suitable to woodland ponds. Before purchasing aquatic plants from a retail outlet, determine whether these plant species are indeed native to the region.

Some individuals may prefer to collect their plants in the wild. There are a few things to consider:

- Do not disturb rare plants (if you cannot identify it, assume it is rare).
- Collect seeds, seedlings, or cuttings near your location and leave plenty on the site for future propagation.
- Do not introduce non-native, cultivated plants into your pond area.

Pond Habitats

- Aquatic plants maintain water quality and oxygen levels, reduce bank erosion, and provide food, spawning grounds, and cover.

- Logs provide basking and sunning opportunities for amphibians and turtles, egg-laying sites and perches for birds, and shelter for fish.
- Deeper water provides fish habitat.
- Vegetated buffer areas provide nesting and cover for wildlife, increase aesthetic quality and soil water filtration, and provide habitat for beneficial aquatic insects.
- Islands provide resting and escape cover, protected nesting habitat for birds, and feeding areas for waterfowl.

Recommendations for managing amphibians and reptiles

- Avoid clearing or replacing natural vegetation.
- Provide buffers of unmanaged habitat around ponds.
- Do not introduce non-native plants or animals.
- Leave logs, snags, and woody debris on site and logs floating in the pond.
- Develop vegetated corridors between habitat fragments.
- Minimize mowing shorelines and drainage ditches.
- Keep livestock out of pond and buffer areas.
- Avoid activities that reduce plant diversity.
- Carefully remove non-native or weedy species.

Stocking fish

Private fish ponds have been around for decades. They provide recreational opportunities for children and pond owners to create and manage their own personal habitat for raising fish. However, these activities can seriously harm native populations of fish, birds, wildlife, and plants in adjacent streams, lakes, and rivers by introducing non-native species and diseases.

ODFW allows pond owners to stock only species that are currently found in adjacent waters. In ponds connected to public waterways, landowners must provide screened-in barriers across the inlet and outlet of their ponds to ensure fish cannot escape into public waters. Specifications for screening are determined by the ODFW. Landowners should avoid locating ponds in streams where these measures must be utilized; projects like that usually require additional permits and are often rejected by the ODFW.

Fish species that are allowed to be stocked are categorized in four ways:

Low risk—ODFW will generally allow stocking of non-reproducing species from approved producers.

Moderate risk—ODFW would allow releases such as diploid rainbow trout, crappie, and largemouth bass after permit review in watersheds that already contain introduced species but also contain populations of native species.

High risk—ODFW would be unlikely to allow stocking of non-native species (e.g., largemouth and smallmouth bass, bluegill, bullhead, channel catfish) without strong safeguards. These stocking sites must be isolated from waters where native fish or threatened or endangered species are present.

Prohibited—ODFW will not allow stocking of carp, pike, brown trout, brook trout, walleye, bowfin, alligator gar, or any fish listed in its Prohibited or Controlled Species Fish List. A complete listing of these species can be found at: <http://www.dfw.state.or.us/OARs/56.pdf>.

In addition, Oregon's Removal-fill Law requires a permit for most removal and fill activities in areas designated as "essential indigenous anadromous salmonid habitat." This law requires any person who plans to "remove or fill" material within "waters of the state" to obtain a permit. Contact the ODFW and the Oregon Department of State Lands (DSL) if conducting any activities associated with salmon habitat.

Species selection

If you want to stock your pond, a permit is required to transport fish. The permit is obtained through the ODFW. The survival of fish species is dependent on pond size, depth, and inflow.



For a pond to support fish, it needs to have a balance of cover and clear water.



This completed pond has incorporated multiple water levels and rocks to serve as habitat for fish.

Trout will not survive in ponds that have no summer inflow or substantial springs to deliver fresh, cold water. Warm-water fish such as bass and bluegill generally do well and are capable of reproducing. Catfish is a popular warm-water fish, but non-native species require special care not to be introduced into natural waters.

A good start to finding fish suitable for stocking is contacting the local ODFW office, the U.S. Natural Resources Conservation Service, or county Extension offices. When ponds are stocked with fish, it is important to consider the effect of fish on amphibians and other aquatic life. Young fish and amphibians need shallow-water areas that restrict access by larger predatory animals. If possible, consider an additional, smaller, shallow pond adjacent to the primary, deeper pond for other aquatic wildlife besides fish.

To successfully raise fish, you must ensure a balanced population, provide appropriate water temperature, and limit growth of emergent (cattails and bulrushes) and sub-emergent (pondweed and milfoil) plant species. The minimum depth for sustaining warm-water species like bass and panfish is 10 feet. For trout and other cold-water species, minimum depths are 12 feet or more unless a cold spring or stream feeds the pond. Warm water temperatures and inadequate depths make it difficult to raise trout.

The entire pond need not be 10 to 12 feet deep, but unless 25 to 50 percent of its surface area lies at such depths, the pond will not provide the right amount of dissolved oxygen in winter and range of temperatures in summer that fish need to survive. Even though some fish may live in shallower ponds, they will not grow as fast nor as large as they would in better habitat. In addition, they are vulnerable to winter and summer kills in shallow water. Ideally, fish ponds should have a half acre or more in water surface area.

Most emergent species of weedy vegetation grow in water less than 4 feet deep. Minimizing the amount of shallow edge around your deep-water pond will reduce the establishment of emergent vegetation. For this reason, create steep slopes to a depth of 4 feet or more. Slopes should range from a minimum ratio of 2:1 (2 feet of horizontal per 1 foot drop) to a maximum of 3:1 (3 feet of horizontal per 1 foot drop). Minimize the amount of edge by constructing a circular or rectangular pond.

Fish provide recreation for people and food for assorted wildlife species. Ponds



A heron takes advantage of a fallen tree to survey a pond.

that are not stocked properly in the beginning can develop unbalanced populations of slow-growing, unhealthy fish. The key to successfully stocking a pond is selecting the proper combination of fish. Stocking numbers are difficult to determine because most species, without competition from other fish species, tend to overpopulate over time.

A number of fish species are possible for stocking, but the following species represent the vast majority of fish found in woodland ponds. Different fish species are allowed in certain areas in Oregon. A listing of ODFW fish districts and the fish allowed in each district can be found at: http://www.dfw.state.or.us/fish/private_ponds/map.asp

Bluegill: These fish are well-suited to warm-water ponds and are often stocked in combination with bass. Bluegill is one of the bass's favorite meals. Bluegill are prolific

spawners and can quickly become stunted if sufficient numbers of bass are not present, or the pond becomes choked with vegetation, or both of these situations occur. Young bluegills eat microscopic animals, while adults prey on insects, fish eggs, small crayfish, and, occasionally, small fish.

Channel catfish: These fish, a favorite of many fishermen, do well in warm-water ponds and can be stocked in combination with bluegill and bass. They do not cause problems unless overstocked. They will not reproduce in ponds. General recommended stocking numbers are 100, 2- to 4-inch fingerlings per surface acre of water. Existing ponds should be stocked with 100, 4- to 6-inch fish to avoid having them eaten by the resident bass population.

Crappie: While a popular fish with anglers, crappie have several drawbacks. They prey on small fish and compete with bass for food. They spawn earlier than bass or bluegill, giving them a head start on these species. Crappies are prolific reproducers and will often become overstocked, resulting in small, slow-growing fish.



Beavers can damage a man-made pond and a dam by burrowing and destroying trees.

Largemouth bass: These predators are probably the most common fish in warm-water ponds. Bass will eat virtually anything, from small fish and frogs to ducklings. They grow rapidly when food is plentiful, can weigh several pounds, and are fun to catch. They tend to overpopulate when stocked as the only fish species in a pond.

Grass carp: Grass carp are used to control unwanted aquatic plants. In Oregon, grass carp are a controlled species and require a stocking permit. There are specific rules that apply to these fish. Most grass carp stockings are in man-made ponds, where native fish are not expected or known to occur. Containment is critical as these fish indiscriminately eat both exotic and native vegetation, thus potentially eliminating or reducing cover, food, and shelter for native species.

Many licensed operators will deliver fish to your pond, ensuring the fish arrive healthy with minimal stress from the transport. This improves their chances of surviving and thriving in your pond. If owners transport their own fish, speed is important; when enclosed in limited volumes of water, fish rapidly consume the available oxygen, and they may arrive so stressed that they are unable to recover and die soon after being released into the pond.

Table 8. Pond characteristics for fish and wildlife

Group	Subgroup	Physical characteristics	Biological characteristics
Amphibians	Frogs and salamanders	Temporary or permanent water	Abundant aquatic floating, emergent, and submerged vegetation
		Shallow and deep water	Absence of fish
		Clear water	Supply of aquatic invertebrates
		High oxygen content	Quality upland vegetation
Fish	Fish that eat plant material and invertebrates	Permanent water	Aquatic floating, emergent, and submerged vegetation
		Clear water	Quality upland vegetation
		High oxygen content	Substantial upland vegetation area
		Constant range in temperature	Trees for shade; seeps and springs
		Spawning substrate	Bottom gravel; variable pond depth
	Fish that eat other fish	Permanent water	Supply of small fish
		Clear water	Supply of tadpoles
		High oxygen content	Upland vegetation
		Constant range in temperature	Shade and in-pond seeps and springs
		Spawning substrate	Sand gravel bottom
Birds	Shorebirds	Permanent or temporary water	Floating, emergent, and submerged vegetation
	Waterfowl	Clear water	Floating, emergent, and submerged vegetation
	Wading birds and songbirds	Mudflats	Quality upland vegetation; good supply of fish and aquatic insects
Reptiles	Snakes	Suitable habitat for burrows	Good supply of small mammals, amphibians, and lizards
		Compost or wood chips for nesting	
		Suitable cover such as rock piles	
		Ponds located away from roads	

Chart continues on next page

Table 8. Pond characteristics for fish and wildlife

Group	Subgroup	Physical characteristics	Biological characteristics
	Turtles	Muddy bottom	Submergent aquatic vegetation
		Rock piles, stumps, and floating or suspended logs	Good supply of fish and insects
		Sunny clearings or embankments for nesting	
Animals	Deer and elk	Permanent water	Quality upland vegetation
	Raccoons	Permanent water	Good supply of fish; quality upland vegetation
	Rabbits, mice, and voles	Permanent water	Quality upland vegetation
		Suitable cover	Quality upland vegetation



Islands and water-surrounded logs will attract many bird species that use these areas for loafing and reproduction.

Other types of wildlife: There are other types of amphibians, birds, and mammals that use pond habitat. Some invasives, such as bullfrogs and nutria, can become pests as well as degrade your pond both in terms of structural integrity and habitat for other native species. If you want to attract native species, such as the western pond turtle, native frogs, or wood ducks, contact your local ODFW office and ask them for tips.

Wildlife species attracted to constructed shallow-water ponds (depending on size) include waterfowl, songbirds, shorebirds, wading birds, amphibians, and reptiles, as well as some upland birds and mammals. Although a portion of the pond can be 6 feet or deeper—to reduce emergent plant growth and to maintain an opening useful to waterfowl and other wetland birds—depths ranging from 6 inches to 4 feet are most productive for a variety of wildlife. Ponds deep enough to house fish can have a negative impact on the production of wildlife such as frogs, toads, salamanders, and even ducklings.



This 50-year-old pond was originally built as a water source for livestock. Over the years, it has become overgrown with weeds, and sediment has reduced its water capacity. Now it's a refuge for wildlife and aquatic species.

Wildlife ponds often host some of the same plants as wetland marshes, including cattails and bulrushes in the shallow areas, and pondweed and other submerged plants in the deeper spots.

For shallow ponds, increasing the amount of edge can make the pond more productive for wildlife. Irregular-shaped ponds or long, rectangular ones with scalloped edges will increase the value for wildlife. Slope design should be flat, ranging from 3:1 to 10:1 (horizontal:drop), and projects that are at least 60 feet wide reduce the impact of predators on ducklings and other young birds.



Birdhouses are a great way to attract birds to your pond. Birdhouses come in all shapes and sizes—to accommodate birds of all shapes and sizes.

Amphibians: Amphibians such as toads, frogs, and salamanders are unique because they use lungs, gills, and skin to breathe during various phases of their life cycle. This requires aquatic habitats some time during their lives. They deposit eggs in water or moist upland areas, and upon hatching, their survival is dependent upon suitable aquatic habitat.

Reptiles: Many species of reptiles need aquatic habitats for reproduction. For example, turtles and snakes do not need water to breed, but depend on the habitat associated with water for food and cover. A constructed pond can provide suitable habitat if attention is given to habitat considerations (See Table 8, page 88).

Birds: Shorebirds, such as plovers and sandpipers, can utilize ponds where shallow water is provided. They use the muddy shorelines as resting and feeding areas during migration. Waterfowl also use woodland ponds for breeding, feeding, brood-rearing, and resting during migration periods.

Waterfowl require emergent vegetation and upland vegetation for nesting cover, and a pond with shallow areas can provide suitable habitat for wading birds. Islands within the pond are aesthetically pleasing and provide excellent habitat for nearly all birds, especially mallards and Canadian geese, giving protection from terrestrial predators, such as raccoons. Floating islands are a possibility when earthen islands are not logistically feasible.



Raccoons are attracted to water. They can be a nuisance to bird populations, however, so measures may need to be taken to protect year-round bird species with housing and in-pond structures.

Mammals: Mammals will use woodland ponds and the accompanying vegetation, although they are not as dependent on them as previously discussed wildlife. Deer, elk, raccoons, squirrels, mice, and voles are especially attracted to a pond's habitat. Beavers, otters, muskrats, and nutria are attracted to woodland ponds. These are burrowing animals and special care needs to be taken to prevent them from compromising the structural integrity of the pond. A pond constructed in an area that does not contain nearby water during the summer months will serve as a magnet for virtually all wildlife species.



Deer are naturally inquisitive, and human activity will attract them. When they find suitable habitat, like a woodland pond, they will make it an often-visited part of their territory.



If you don't live near your pond and can't monitor it closely, you'll need a gate to restrict access. This is important for privacy but also for liability reasons.



Docks and other in-pond structures can be built any time, but they are easier to put in before the pond fills. Once completed, docks for fishing and recreation are a great amenity.

Woodland ponds provide an assortment of habitat for birds, fish, wildlife, and humans. Retaining the natural landscape around a pond provides for the best habitat, both in terms of survival and aesthetics. There are times when fabricated structures complement and enhance the values of a woodland pond. Remember, the pond itself is a man-made structure. Careful evaluation and implementation of these amendments can enhance the experience of owning and using a pond.

Woodland owners may want to realize income from providing water for recreational use. An increasing urban population means more pressure on public parks, and urban dwellers may desire a private getaway. Keep in mind that access to your pond by private individuals carries a risk of legal issues, so be sure liability insurance is part of your plan.

If recreational opportunities are one of your objectives, complete auxiliary projects, such as docks or sanded or rocked access areas, before the pond fills. Common sense dictates these projects be constructed as the pond is being built, but keep in mind the growing ideas and opportunities a pond presents for various woodland management projects; plans sometimes must be altered accordingly.

A pond used for recreation needs enough water supply to compensate for evaporation and seepage in order to maintain a desirable water level. Designing a portion of the bank with a gentle slope will increase access and improve the safety of the pond for recreation. A sand or pea gravel bottom at the point of access will reduce the problem of muddy water.

Again, there is no substitute for careful site evaluation and selection. If recreation is one of the primary objectives of a woodland pond, the importance of proper site selection is paramount to a successful outcome.

Landowner Assistance and Resources

Landowner programs

Various public and private organizations are available for technical and financial assistance to woodland owners interested in constructing a pond. Table 9 provides some potential assistance to owners in implementing a variety of wildlife and natural resource conservation activities.

Table 9. Contacts

Program	Eligibility	Type of assistance	Contact
Agricultural Management Assistance (AMA)	Applicants must own or control land and agree to conservation practices	5- to 10-year contract for federal cost share of 75% or eligible practices	Natural Resources Conservation Service (NRCS) or Farm Services Agency (FSA) state or local office
Conservation Security Program (CSP)	Tribal and private working lands	Financial and technical to promote conservation and improvement of soil, water, plant, and animal life	NRCS state or local office
Conservation Technical Assistance (CTA)	Landowners and land-users interested in assistance with resource management	Technical assistance in the planning and implementing of conservation systems	NRCS state or local office
Environmental Quality Incentive Programs (EQIP)	Cropland, range, grazing lands, and other agricultural lands in need of treatment	Up to 75% cost-share for conservation practices with 1- to 10-year contracts	NRCS state or local office
Watershed Protection Watershed Surveys and Flood Prevention	Private lands	Technical and financial assistance to survey and develop plans for natural resource and erosion management	NRCS state or local office
Waterways for Wildlife	Private lands	Technical and program development assistance in wildlife habitat that meets watershed goals	Wildlife Habitat Council
Wildlife Habitat Incentive Program (WHIP)	High-priority fish and wildlife habitats	Up to 75% cost-share for conservation practices under 5- to 10-year contract	NRCS state or local office



A successful pond project is something to share with friends and neighbors.

Information and assistance

The following listings may assist you with various questions about permits, planning, design, construction, and maintenance of your woodland pond. They may provide information about local individuals and agencies that can work more closely with you. Also, you may want to contact your local watershed council or Soil and Water Conservation District office for additional information and assistance.

Oregon Department of Agriculture
635 Capitol Street, NE, Salem, OR 97310
503-986-4700
<http://www.oregon.gov/oda/Pages/index.aspx>

Oregon Department of Environmental Quality
811 SW 6th Ave., Portland, OR 97204
503-229-5696 or 1-800-452-4011
Water Quality Division: 503-229-5279
<http://www.oregon.gov/DEQ/Pages/index.aspx>

Oregon Department of Fish and Wildlife
2501 SW First Ave., PO Box 59, Portland, OR 97207
Habitat Division: 503-872-5255
Fish Division: 503 872-5252
<http://www.dfw.state.or.us/>

Oregon Department of Forestry
2600 State St., Salem, OR 97310
503-945-7475
ODF personnel also available at local ODF offices
<http://www.odf.state.or.us>

Table 10. Oregon Department of Forestry offices

Office	Counties covered	Address	Phone
Astoria	Clatsop	92219 Highway 202, 97103	503-325-5451
Baker City	Baker	2995 Hughes Lane	541-523-5831
Central Point	Jackson	5286 Table Rock Road, 97502	541-664-3328
Columbia City	Columbia, Clatsop	405 E Street, 97018	503-397-2636
Coos Bay	Coos, Curry, Douglas	63612 5th Road, Bay Park, 97420	541-267-4136
Dallas	Benton, Polk, Yamhill	825 Oak Villa Road, 97338	503-623-8146
Forest Grove	Tillamook, Washington, W. Multnomah, Yamhill	801 Gales Creek Road, 97116-1199	503-357-2191
Fossil	Wheeler, Morrow, Gilliam	45945 Hwy19, 97830	541-763-2575
Grants Pass	Josephine	5375 Monument Drive, 97526	541-474-3152
John Day	Grant	PO Box 546, 97845	541-575-1139
Klamath Falls	Klamath, Lake	3200 Delap Road, 97601	541-883-5681
LaGrande	Baker, Malheur, Union	611 20th Street, 97850	541-963-3168
Lakeview	Lake, Klamath	2290 N 4th Street, 97630	541-947-3311
Mehama	Linn, Marion	22965 N Fork Road SE, Lyons 97358	503-859-2151
Molalla	Clackamas, E. Multnomah	14995 S Hwy 211, 97038	503-829-2216
Monument	Grant, Wheeler	PO Box 386, 97864 (May Street)	541-934-2300
Pendleton	Umatilla, Grant, Morrow	1055 Airport Road, 97801	541-276-3491
Philomath	Benton	24533 Alsea Hwy, 97370	541-929-3266
Prineville	Crook, Deschutes, Jefferson	3501 E 3rd, 97754	541-447-5658
Roseburg	Douglas	1758 NE Airport Road, 97470-1499	541-440-3412
Springfield	Lane	3150 E Main Street, 97478	541-726-3588
Sweet Home	Linn	4690 Hwy 20, 97386	541-367-6108
The Dalles	Hood River, Sherman, Wasco	3701 W 13th Street, 97058	541-296-4626
Tillamook	Tillamook	505 3rd Street, 97141-2999	503-842-2545
Toledo	Lincoln	763 NW Forestry Road, 97391	541-336-2273
Veneta	Lane, Douglas	PO Box 157, 97487 (87950 Territorial Hwy)	541-935-2283
Wallowa	Wallowa	802 W Hwy 82	541-886-2881

Oregon Department of Land Conservation and Development
635 Capitol St. NE, Suite 150, Salem, OR 97301
503-373-0050
<http://www.oregon.gov/lcd/Pages/index.aspx>

Oregon Department of State Lands
775 Summer St., Suite 100, Salem, OR 97301
503-378-3805
<http://www.oregon.gov/DSL/pages/index.aspx>

Oregon State University Extension Forestry and Natural Resources
109E Richardson Hall, Corvallis, OR 97331
541-737-3700
<http://extension.oregonstate.edu/>



It's much easier to use heavy equipment to put habitat-enhancing logs into the pond.



The best time to install docks and other features is before the pond fills with water.

Table 11. Oregon State University Extension forestry experts

County/Department	Area	Address	City, State, Zip Code	Phone #
Forest Engineering	Watershed Specialist	263 Peavy Hall	Corvallis, OR 97331	541-737-2946
Clackamas/Hood River/Marion County Extension	Extension Forester	200 Warner-Milne Road	Oregon City, OR 97045	503-655-8631
Southern Oregon Research & Extension Center	Extension Forester	569 Hanley Road	Central Point, OR 97502-1251	541-776-7371
Douglas County Extension	Extension Forester	1134 SE Douglas	Roseburg, OR 97470	541-672-4461
Deschutes County Extension	Extension Forester	3893 SW Airport Way	Redmond, OR 97756-9654	541-548-6088 ext. 16
Columbia/Washington/Yamhill County Extension	Extension Forester	505 N Columbia River Hwy	St. Helens, OR 97051	503-397-3462
Wood Science & Engineering	Marketing Specialist	108 Richardson Hall	Corvallis, OR 97331	541-737-6083
Coos/Curry County Extension	Extension Forester	631 Alder Street	Myrtle Point, OR 97458	541-572-5263 ext. 294
North Willamette Research & Extension Center (NWREC)	Extension Forestry – Christmas Trees	15210 NE Mile Road	Aurora, OR 97002-9543	503-678-1267 ext. 142
Wood Science & Engineering	OWIC Director	119 Richardson Hall	Corvallis, OR 97331	541-737-4212
Union/Wallowa/Umatilla County Extension	Extension Forester	10507 North McAlister Road	LaGrande, OR 97850	503-963-1010
Baker/Grant County Extension	Extension Forester	2610 Grove Street	Baker City, OR 97814	541-523-6418
Lincoln/Tillamook/Clatsop County Extension	Extension Forester	29 SE 2nd Street	Newport, OR 97365-4496	541-574-6534 ext. 19
Forest Science	Forest Health Specialist	321 Richardson Hall	Corvallis, OR 97331	541-737-2845
Forest Resources	Leadership Educator	321 Richardson Hall	Corvallis, OR 97331	541-737-3197
Linn/Benton/Polk County Extension	Extension Forester	4th & Lyons Street	Albany, OR 97321	541-967-3871
Klamath County Extension	Extension Forester	6923 Washburn Way	Klamath Falls, OR 97603	541-883-7131

Oregon Water Resources Department
158 12th Street NE, Salem, OR 97301
503-378-8455
<http://www.oregon.gov/OWRD/pages/index.aspx>

Oregon Watershed Enhancement Board
775 Summer St. NE, Suite 360, Salem, OR 97301
503-986-0181
<http://www.oregon.gov/OWRD/Pages/index.aspx>

U.S. Army Corp of Engineers (ACOE)
P.O. Box 2946, Portland, OR 97204
503-808-4373
<http://www.usace.army.mil/>

U.S. Bureau of Land Management (BLM)
P.O. Box 2965, Portland, OR 97201
503-952-6418
<http://www.blm.gov/wo/st/en.html>

U.S. Forest Service (USFS)
Pacific Northwest Region, P.O. Box 3623,
Portland, OR 97208
541-750-7181
<http://www.fs.fed.us>

U.S. Fish and Wildlife Service (USFW)
2600 SE 98th Ave., Suite 100
Portland, OR 97266
503-231-6179
<http://www.fws.gov/>

U.S. National Marine Fisheries Service
525 NE Oregon St., Suite 500
Portland, OR 97232
Phone: 503-231-2224
<http://www.usa.gov/directory/federal/national-marine-fisheries-service.shtml>

Natural Resources Conservation Service
101 SW Main, Suite 1300
Portland, OR 97204
503 414-3231
<http://www.nrcs.usda.gov/wps/portal/nrcs/site/national/home/>



Many man-made ponds take advantage of their native surroundings to look completely natural.

Glossary

Abutment: A portion of a valley cross section higher in elevation than the valley floor. The slope above the valley floor.

Acre-foot: The primary method to measure the volume of water in a reservoir, measured as water 1 foot deep covering 1 acre and equating 325,850 gallons.

Aggregate: Mechanically crushed, angular rock used for various woodland operations where erosion and stability are issues.

Antiseep collar (or diaphragm): A constructed barrier installed perpendicular to a pipe or conduit, usually made of the same material as the pipe or conduit. The purpose is to intercept the flow of seepage along the pipe and to make the seepage path longer.

Appurtenance: Interrelated elements or components of a designed system or structure.

Backslope: The downstream slope of an embankment.

Berm: A strip of earth, usually level, in a dam cross section. It may be located on either the upstream side slope, downstream side slope, or both.

Benchmark: Point of known elevation for a survey used as a fixed reference point throughout a project.

Borrow area: An area from which earth fill materials are taken to construct the dam.

Bottom width: A flat, level cross section element normally in an open channel, spillway, or trench.

Center line: The established center point of the dam.

Clearing limits: The limits of clearing the pond site as designated on the ground.

Conduit: Any channel intended for the conveyance of water, whether open or closed.

Compaction: Mechanically compressed soil or rock, resulting in increased density in pounds per cubic foot.

Construction slash: All vegetative material not suitable for pond building, such as tops and limbs of trees, grass, brush, and removed stumps.

Core trench: The trench in the foundation material under an earth embankment or dam in which special materials are placed to reduce seepage and increase structural integrity of the design.

Cross section: A section formed by a plane cutting an area, usually at right angles to the axis.

Culvert: A drainpipe that channels water across and off a road or dam.

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 controls flood water.

Drain: An appurtenance installed in the dam, the foundation, or both to safely collect

and discharge seepage water.

Drawings: A graphical representation of the planned details of the project.

Drop inlet: A vertical entrance joined to the section of a principal spillway.

Earth fill: Soil, sand, gravel, or rock construction materials used to build a dam and its components.

Effective fill height: The difference in elevation between the lowest auxiliary spillway crest and the lowest point in the original cross section on the center line of the dam. If there is no auxiliary spillway, the top of the dam becomes the upper limit.

Embankment pond: Soil, aggregate, or rock material placed on a prepared ground surface and constructed to grade. The embankment is the fill material on the downhill side of the pond.

End haul: Moving excavated material a distance (usually by dump truck) to the fill site, as opposed to side-casting the cut directly onto the fill.

Environmental impact: An activity that has an effect on the surrounding environment, such as eroded soil from a pond spillway silting a nearby stream.

Erosion: The process of dislodging and transporting soil particles by wind, flowing water, or rain.

Excavated pond: A reservoir constructed mainly by excavation in flat terrain. A relatively short embankment section on the downstream side may be necessary for desired storage volumes.

Excavation: Removing earth from an area.

Exit channel (of an open channel spillway): The portion downstream from the control section that conducts the flow of water to a point where it may be released without jeopardizing the dam.

Fifty-year flood: A flood event that has a 2 percent probability of occurring annually. The size of this projected flood will determine the dimensions of several components of the road built around streams, such as bridges and culverts.

Fill height: The difference in elevation between the existing ground line and the top of the dam elevation, including allowances for settlement.

Filter (or buffer) strip: A strip of land adjacent to a water body; its vegetative cover is used to filter the sediments out of surface runoff water from roads.

Filter and drainage diaphragm: A control device installed on the downstream side of a pipe or conduit, consisting of aggregate or riprap. Its purpose is to intercept water flow and prevent erosion.

Fill: Earth material used to build a structure above natural ground level, as with fill sections when constructing a dam.

Fill slope: Areas on the side of a dam that must have excavated material placed on them to build a section up to grade.

Flow depth: The depth of water in the auxiliary spillway or any other channel.

Foundation: The surface upon which the dam is constructed.

Freeboard: The difference in elevation between the minimum settled elevation of the top of the dam and the highest elevation of expected depth of water through the auxiliary spillway.

Grubbing: The digging and removal of stumps, roots, and duff within the clearing limits of the pond site.

Hooded (canopy) inlet: A fabricated assembly attached to the principal spillway pipe to improve the hydraulic efficiency of the overall pipe system.

Lift: A layer of soil or surface rock.

Peak discharge (flow): 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 spillway designed to convey water from the reservoir (pool area).

Profile view: The side view of an object.

Riprap: Rock from a quarry that has not been crushed and ranging from the smallest size aggregate to large boulders, commonly placed on exposed soil to reduce erosion from moving water.

Riser: The vertical portion of a drop inlet.

Secondary (auxiliary) spillway: The spillway, slightly higher than the principal spillway, designed to convey excess water through, over, or around a dam.

Site investigation: Site visit to evaluate physical features of a proposed project or watershed, including soils data and any characteristics of the watershed pertinent to the project.

Slope ratio: The steepness of a slope expressed as a ratio of the slope's horizontal to vertical distance ratio. For example, a 1:1 slope changes 1 foot horizontal to every 1 foot vertical (45 degrees).

Slope stability: A natural or artificial slope's resistance to movement or to failure.

Specifications: Detailed statements prescribing standards, materials, dimensions, and workmanship for works of improvement.

Spillway: An open or closed channel, conduit, or drop structure used to convey water from a reservoir. It may contain gates, manually or automatically controlled, to regulate the discharge of water.

Slump: A failure of natural or constructed slope.

Storage volume: The total volume of water available from the bottom of the reservoir to the top of the dam, not to be confused with effective fill height.

Water right: A right to use water that is obtained from OWRD in three steps: (1) obtain a permit to use the water; (2) construct a water system and use the water; and (3) “proving” the water use. Once a water right is developed, it is referred to as certified and is a type of property right attached to the land where it was established.

Selected references and websites

Constructing a Pond. Fact Sheet 17. USDA Natural Resources Conservation Service, Oregon. 1999. Available at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_043951.pdf

Ponds—Planning, design, construction. USDA Agriculture Handbook Number 590. Natural Resources Conservation Service. Slightly revised Sept. 2000. Available at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_030362.pdf

Calculating Area and Volume of Ponds and Tanks. Southern Regional Aquaculture Center Pub. No. 103. 1991. Available at: <https://srac.tamu.edu/index.cfm/event/viewAllSheets/>

Renovating Leaky Ponds. Southern Regional Aquaculture Center Pub. No. 105. 1999. 6 p. Available at: <https://srac.tamu.edu/index.cfm/event/viewAllSheets/>

Farm pond ecosystems. Fish and Wildlife Habitat Management Leaflet Number 29. Wildlife Habitat Management Institute, Natural Resources Conservation Service. May 2005. Available at: http://www.umesc.usgs.gov/documents/reports/2005/knutson_farm_pond_2005.pdf

Woodland Fish & Wildlife Publications (includes titles on trout, beavers, muskrats, nutria, wood ducks, etc.). Some may be available at local OSU Extension Service offices and all can be downloaded at: <http://ext.wsu.edu/forestry/publications/woodland.html>

State Water Related Permits—User Guide. Oregon Dept. State Lands. 2012. Available at: http://www.oregon.gov/dsl/PERMITS/docs/water_related_permits_user_guide_2012.pdf

Application for a Permit to Store Water in a Reservoir (Standard Review). Oregon Water Resources Dept. Updated August 2011. (permit used for ponds over 9.2 acre-feet and dams over 10 feet) Available at: http://www.oregon.gov/owrd/pubs/docs/forms/storage_standard_updated_3_12_14.pdf

Alternate Reservoir Process and Application for a Permit to Store Water in a Reservoir (Alternate Process). Oregon Water Resources Dept. Updated February 2012. (permit and guidance used for ponds less than 9.2 acre-feet or dams less than 10 feet) Available at: http://www.oregon.gov/owrd/pubs/docs/forms/alt_res_5_8_2012.pdf

Water Use Authorizations. Infosheet 6. Oregon Water Resources Dept. 2003. 2 p. Available at: <http://www.oregon.gov/OWRD/PUBS/docs/infosheet6.pdf>

A Guide to Oregon Permits Issued by State & Federal Agencies—with a focus on permits for Watershed Restoration Activities. The Oregon Plan for Salmon & Watersheds and the

Oregon Watershed Enhancement Board. 82 pp. Available at: <http://www.oregon.gov/oweb/pages/publications.aspx>

Annual & monthly precipitation totals, based on 1971–2000 or 1981–2010 records. The *PRISM Data Explorer* uses latitude and longitude entries or interactive map base to generate local estimates for precipitation, as well as maximum and minimum temperatures: <http://prismmap.nacse.org/nn/index.phtml>

Soil survey maps (NRCS). County and area soil surveys are available at many local libraries and NRCS offices. The NRCS *Web Soil Survey* uses latitude and longitude or public land survey entries to create interactive soil maps: <http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx>

Surface Water Right Application Guidebook. http://www.oregon.gov/owrd/pubs/docs/forms/surfacewaterbook_updated_02_1_2012.pdf

Application for a permit to use surface water http://www.oregon.gov/owrd/PUBS/docs/forms/final_draft_surface_water_app_2_1_2012.pdf

Water Rights in Oregon: An Introduction to Oregon's Water Laws. <http://www.oregon.gov/owrd/pubs/docs/aquabook2013.pdf>

Water Resources Department Oregon Dam Safety Program. http://www.oregon.gov/owrd/pages/sw/dams_in_oregon.aspx

Acknowledgements

Thanks to Jim Reeb, OSU Extension forester Lincoln County; Fran Cafferata, Cafferata Consulting; Paul Adams, professor emeritis, Oregon State University Extension watershed specialist; Glenn Ahrens, OSU Extension forester, Clackamas County; and Dan Lovell, OSU Extension forester, Klamath County, for manuscript review. Also, special thanks to Arne Skaugset, forest hydrologist, and Ben Leshchinsky, geotechnical engineer, both of Forest Engineering Resource Management, for technical materials and support. The Oregon Forest Resources Institute, with the administrative support of Mike Cloughesy, provided partial funding for this project. Dave Williams, Oregon Water Resources Department watermaster, Roseburg, Oregon, provided technical materials and support. Woodland owners, contractors, consultants, educators, and the general public who actively support such educational efforts play a vital role in the sustainability of Oregon's forest resources and the communities those resources support.

Use pesticides safely!

- Wear protective clothing and safety devices as recommended on the label. Bathe or shower after each use.
- Read the pesticide label—even if you’ve used the pesticide before. Follow closely the instructions on the label (and any other directions you have).
- Be cautious when you apply pesticides. Know your legal responsibility as a pesticide applicator. You may be liable for injury or damage resulting from pesticide use.



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Published April 2015.

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