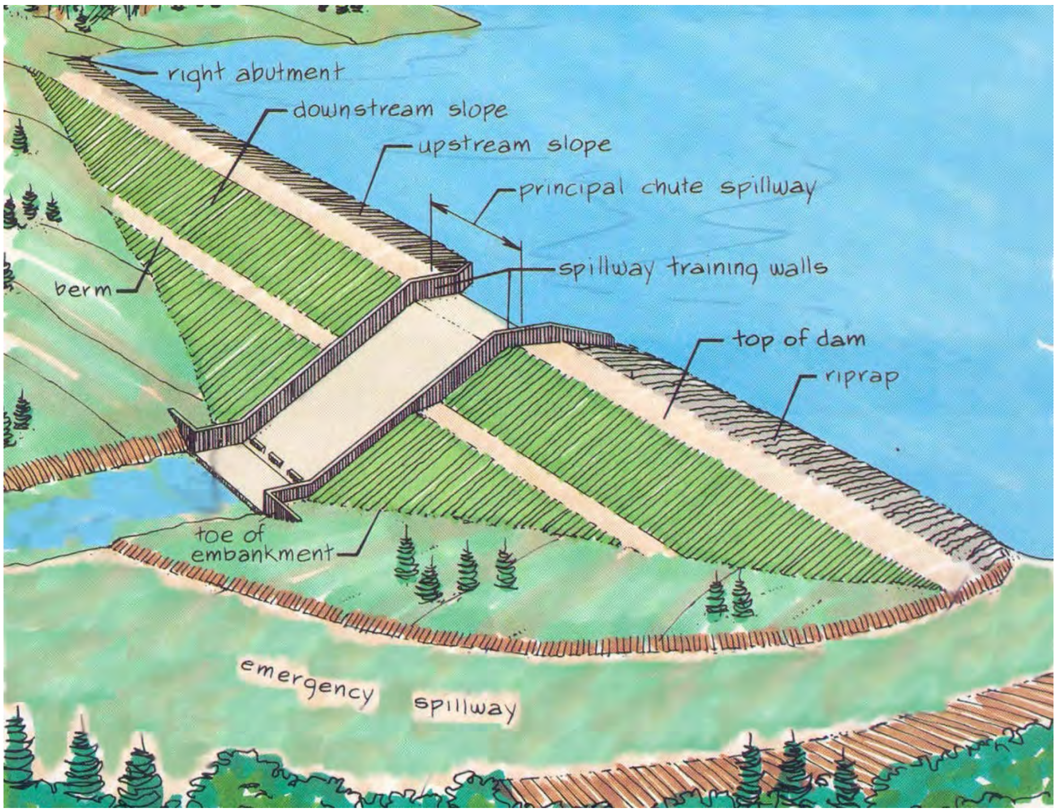
Best Management Practices Guidebook for Dams

Best Management Practices to Improve Surface Water Quality and Instream and Riparian Habitat at Dams



OHIO DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER RESOURCES

FINANCIAL ASSISTANCE WAS PROVIDED UNDER AWARD NA11NOS4190075 FROM THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, U.S. DEPARTMENT OF COMMERCE THROUGH THE OHIO COASTAL MANAGEMENT PROGRAM, ADMINISTERED BY THE DEPARTMENT OF NATURAL RESOURCES, OFFICE OF COASTAL MANAGEMENT.

This Guidebook was prepared by the Ohio Department of Natural Resource Division of Water Resources under award NA11NOS4190075 from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce through the Ohio Department of Natural Resources, Office of Coastal Management. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the National Oceanic and Atmospheric Administration, Department of Commerce or the Ohio Department of Natural Resources Office of Coastal Management.

Portions of the text have been taken partially or directly from:

USEPA Guidance Document:
Chapter 7: Practices for Implementing Management Measures
National Management Measures to Control Nonpoint Source Pollution from Hydromodification
EPA 841-B-07-002
July 2007

Assessment and Watershed Protection Division Office of Water
U.S. Environmental Protection Agency

The full text of the USEPA Guidance Document can be found at:

https://www.epa.gov/sites/production/files/2015-09/documents/chapter_7_practices_web.pdf

All attempts have been made to provide appropriate references and attribution to the contributors of Chapter 7 of the National Management Measures to Control Nonpoint Source Pollution from Hydromodification.

Specific resources and references for

USEPA Guidance Document
National Management Measures to Control Nonpoint Source Pollution from Hydromodification

can be found at:

https://www.epa.gov/sites/production/files/2015-09/documents/hydromod_all_web.pdf

Table of Contents

Introduction

A Brief Overview of the History of Dams in Ohio

Wyandot Indian Mill and Lowhead Dam
Wyandot County, Ohio
http://oldmills.scificincinnati.com/ohio_mills_wyandot_indian_page.html
Photo: Great Lakes Society for the Preservation of Old Mills

This Guidebook is intended as a resource to dam owners who would like to improve the water quality of their ponds, lakes, or reservoirs. It is for guidance purposes only and does not include any requirements unless specifically stated in the Guidebook. If dam removal or dam modifications are proposed, please contact the Division of Water Resources, Dam Safety Program for coordination and approval.

History

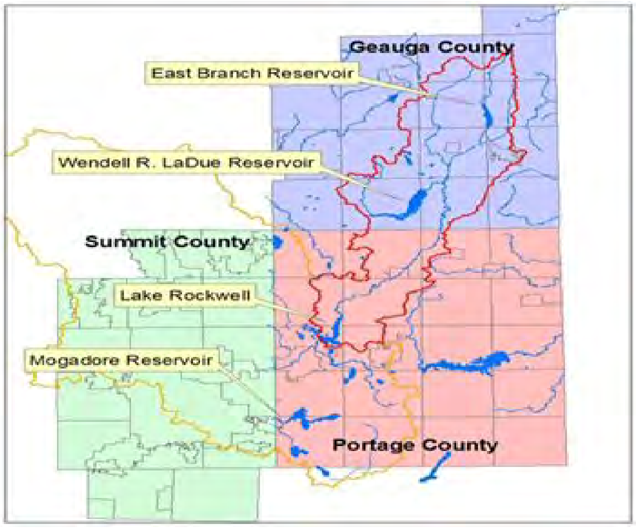
Dams have been constructed in Ohio for a variety of purposes since the first days of statehood. Many early dams were constructed to create mill ponds. The necessity to process corn and other grains into flour created the need for mills powered by water. Dams were constructed to create pools in streams and rivers to supply water to millraces. The water held back by the dams was used to generate power for grist mills to support agriculture.

McCoppin's Mill, Highland County
Photo: Great Lakes Society for the Preservation of Old Mills

Lucas County Mill and Canal Lock
Photo: ODNR

In the early years following statehood the easiest way to travel into the interior of Ohio was through the streams, rivers and lakes of the state. As Ohio grew as a state, dams were constructed for purposes associated with water transportation. Reservoirs were created by dams to provide reliable water supplies to canals, and lock and dam systems were created to enhance navigation on rivers and streams. Canals were built and navigable waterways were enhanced to support transportation in the state, making it easier for goods and services to move to markets.

With the expansion of Ohio's population, towns and villages were developed upon the banks of many rivers and streams. The towns and villages needed predictable water supplies for consumption by the local population. Dams were used to collect water in reservoirs or pools to support public water supply systems. Large and small dams were placed across rivers, and reservoirs were constructed near the towns and villages to provide predictable water supplies.



City of Akron Water Supply Reservoirs
http://www.akronohio.gov/cms/Water/Watershed/index.html

The same towns and villages that relied upon rivers and streams for commerce, transportation and water supplies were often located in areas that were susceptible to flooding. Homes and businesses became vulnerable to flooding as towns and villages grew and expanded into floodplains. Many dams, dikes and levees were constructed to collect and release floodwaters in an effort to save property and lives.

Ohio Flood of 1913
Photo: Dayton Daily News

When electric power came to prominence in the 1900's, newly proposed dams (and some of the dams constructed earlier in the 1800's) were used to generate hydroelectricity. Smaller dams were equipped with hydroelectric generators to supply power to municipalities. Locks and dams located on major rivers such as the Ohio were converted to add capacity for hydroelectric power. In recent decades dams (such as the O'Shaughnessy Dam in Powell, Ohio) were upgraded to add hydroelectric facilities.

The O'Shaughnessy Dam on the Scioto River near Columbus
Photo: ODNR

The advent of various state and federal pollution control laws in the 1960's and 1970's led to the construction of impoundments with dams for retention of waste products collected as part of pollution control requirements. Lagoons associated with wastewater treatment facilities were constructed using dams. Other laws enacted over the last 40 years related to water pollution have led to the construction of dams for purposes of sediment control, stormwater retention and even wetland mitigation.

Wetland Mitigation - Dorset Wildlife Area Dam, Ashtabula, Ohio
Photo: ODNR

Impacts of dams

Today there are thousands of dams in Ohio serving a variety of needs and purposes. Along with the benefits associated with dams are tradeoffs associated with water quality and habitat loss. Water quality issues created by the presence of dams can include but are not limited to:

- Decreased oxygen levels
- Increased water temperatures
- Accretion of sediment in the reservoir/pool, loss of sediment to the downstream areas
- Loss of stream habitat and shoreline habitat within receiving streams and rivers
- Concentration of nutrients in sediments that accumulate in the reservoir/pool, providing food for algae and other aquatic microorganisms and contributing to their growth

Many of these water quality issues are increased by factors associated with point and nonpoint source pollution. Polluted runoff from urban and rural sources, contributions from improperly operating sewage treatment facilities and home septic systems, and loss of habitat and stream functionality upstream of the impoundment can all add to problems in the reservoirs and areas downstream of the dams.

The presence of a dam across a river or stream can also affect river morphology. The terms *river morphology* and its synonym *fluvial geomorphology* are used to describe the shapes of river channels and how they change over time. The morphology of a river channel is a function of a number of processes and environmental conditions. These include:

- The composition and erodability of the bed and banks (e.g., sand, clay, bedrock)
- Vegetation and the rate of plant growth
- The availability of sediment
- The size and composition of the sediment moving through the channel
- The rate of sediment transport through the channel
- The rate of deposition on the floodplain, banks, bars, and bed (source *Fluvial Processes in Geomorphology*, Leopold, Wolman, Miller, 1992).

Dams can affect sediment resources and how they are distributed upstream and downstream of a dam. Changes to the rates and quantities of water flow near the dam can cause changes to where sediment is deposited in the channel.

In recent decades studies of dams in tributaries leading to larger water bodies (such as Lake Erie) or major river ecosystems (such as the Ohio River) have highlighted the role of the dams as impairments to the migration of both native and invasive aquatic species.

Harpersfield Dam on the Grand River
The dam has served as a barrier to the upstream migration of Sea Lampreys.
Photo: ODNR

These dams have served as barriers to fish populations that might benefit from access to spawning areas upriver of the dams. These dams have also served to prevent upriver migration of sea lamprey populations that have impacted native fish populations within Lake Erie and the streams and rivers leading to the Lake. They also may play a role in deterring the migration of Asian Carp from the Ohio River basin into the Great Lakes basin. Options to address habitat and water quality impacts may be limited at some dams because of the downstream presence of invasive aquatic species.

Acton Lake Dam, Butler County
Photo: Middletown Journal staff photographer Nick Daggy

The costs of maintenance and repairs, the age of many dams and the usefulness of the dams in serving their original purposes are factors in determining whether a dam might be modified or eventually removed. Navigational safety, liability issues associated with dam ownership, and opportunities to restore fisheries, stream health and water quality are also factors that play a role in determining whether to maintain, upgrade, repair, modify or remove dams in Ohio's streams and rivers.

Summary

There are many types, sizes, shapes and uses of dams across Ohio. Ohio has dams that have been in service for well over a century. Many dams are in good condition, while others need substantial maintenance and repair. Most of the dams across Ohio continue to serve as valuable resources for the people of the state, and their continued maintenance and upkeep is essential to the communities, businesses and residents of the state. These dams still provide flood control, stormwater management, water supplies, and in a few cases electric power generation. Dams continue to provide recreational boating and fishing opportunities to Ohio's citizens, and in some circumstances have helped create and restore wetland habitats.

The variability in dams and their uses will result in different types of water quality and habitat issues and different approaches to solving those issues. Solutions to address water quality and habitat issues associated with existing dams must take into consideration the unique uses supported by the presence of each dam, the effects of activities upstream of the dams, and the unique water quality and habitat issues with each dam and the associated stream or river.

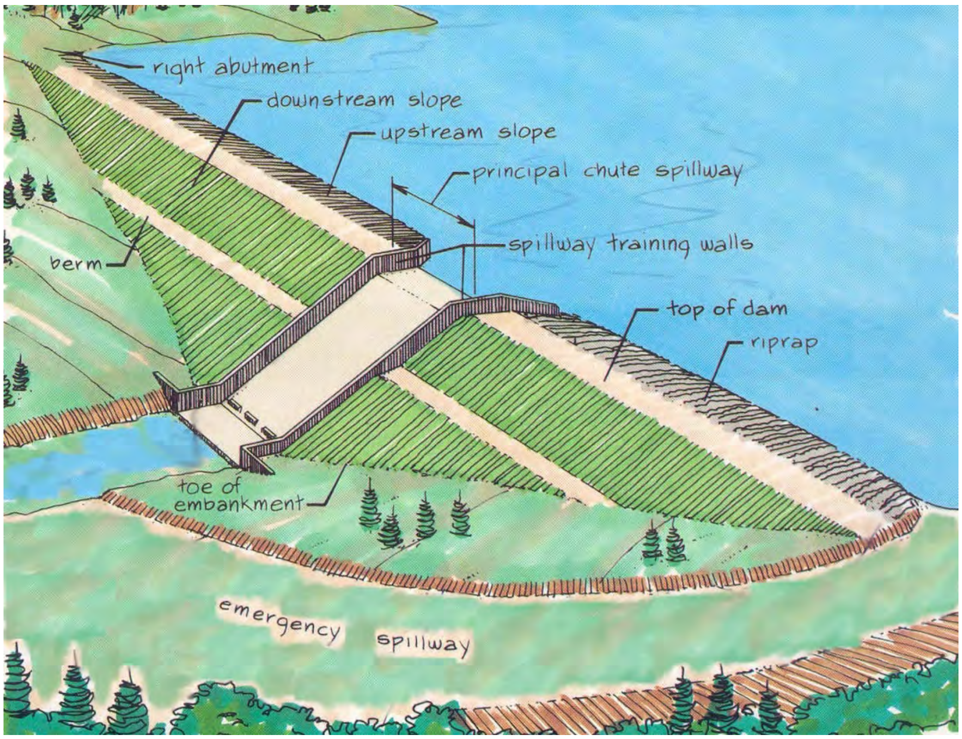
Chapter 1

Types of Dams and Surface Impoundments

Lake View Cemetery Dam
Photo: Ohio DNR

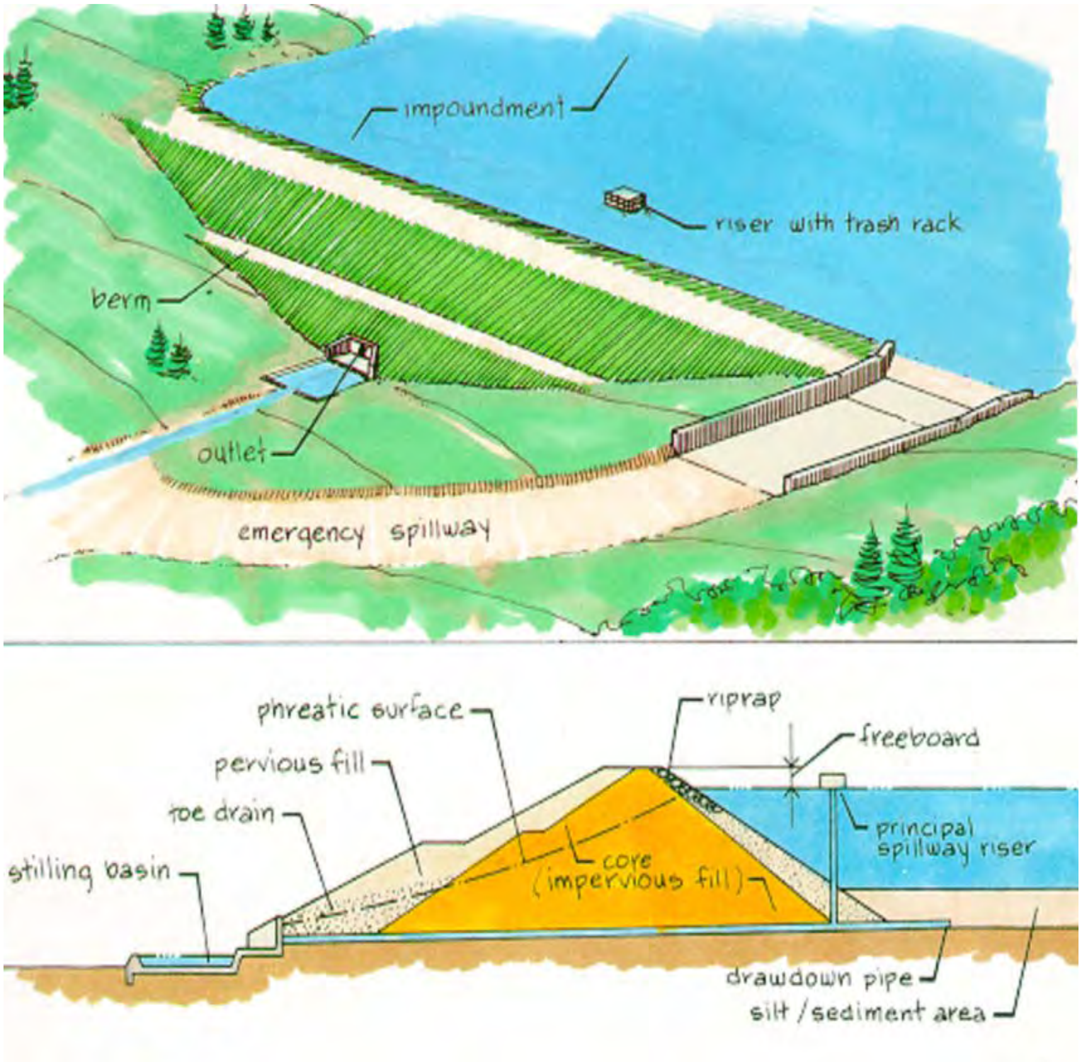
What is a Dam?

A dam is an artificial barrier usually constructed across a stream or river for the purpose of impounding or controlling water. There are significant differences in the types of dams and the materials used to construct them. There are also a wide range of uses for each dam. The following sections describe typical dams that might be encountered in Ohio. These sections and the associated examples do not cover the entire universe of dams, but they do illustrate the general types of dams and how they work. The knowledge of how an individual dam operates, the concepts behind the design of the dam, and an understanding of the uses served by the dam are important in determining which Best Management Practices might be utilized at each dam to address water quality or aquatic habitat issues arising from the presence of a dam.



Earthen Dam with Spillway
Photo: Ohio DNR

Timber, rock, concrete, earth, steel or a combination of these materials are generally used to build a dam. Most dams in Ohio are constructed of earth and utilize concrete and steel for inlets, outlets and pipes. Dams must have spillway systems to safely convey normal stream and flood flows over, around, or through the dam. The main (principal) spillways are commonly constructed of non-erosive materials such as concrete or steel. Secondary (emergency) spillways may be constructed of concrete or steel, and may or may not be constructed on natural ground.



Typical Dam diagram showing common terms
Photo: Ohio DNR

Dams are generally built with an impervious core that minimizes seepage of water from the reservoir through the dam. They are also built with erosion protection (usually rock of sufficient size) near the top of the dam on the side of the lake to protect from wave action that might erode the dam. Freeboard (the amount of height between the water surface and the top of the dam) is incorporated into the design of the dam to make sure the dam does not become overtopped from a rise in the water level, boat wakes or by waves created by wind passing over the water. Dams usually have a drain or some other mechanism for controlling the level of the water. These drains are used to lower water levels to conduct normal maintenance and respond to emergencies.

What are Levees and Dikes?

A levee is any artificial barrier together with appurtenant works (floodgates, floodwalls, pumps, etc.) that will divert or restrain the flow of a stream or river. A levee is used for the purpose of protecting an area from inundation by flood waters. A dike is used to divert or restrain flood waters from large bodies of water. In Ohio several areas along the western shoreline of Lake Erie are protected by dikes.

Flood Control Levee
Photo: US Army Corps of Engineers

A levee is not a dam, although during periods of flooding a levee will act to control floodwaters in a manner similar to a dam. A levee prevents the movement of water laterally into areas adjacent to the river, but does not impede the flow of water moving downstream in the floodway.

Information Marker – Ohio River Levee
Photo: US Army Corps of Engineers

A levee diverts or restrains flood waters from streams and rivers such as the Ohio or Muskingum Rivers. A number of communities in central and southern Ohio such as Chillicothe, Zanesville and Portsmouth rely upon levees to protect areas from flooding by rivers.

Ownership of Dams

Most dams in Ohio are small and are owned by private individuals, landowners, homeowner associations and businesses. These dams and the waters impounded by them are used mainly for water supply, recreation, swimming, fishing, agriculture and other purposes. Larger dams are usually owned by units of government or industries to form reservoirs for water supply or waste storage. The federal government owns and operates dozens of dams in Ohio for flood control, recreation and water supply purposes. Dams placed on navigable waterways for navigational purposes are primarily owned and/or operated by state and federal agencies.

The State of Ohio also owns hundreds of dams. Many of these dams are located in state parks and wildlife areas. Dams are also owned and maintained by watershed conservancy districts. These dams are used mainly for flood control, and the lakes impounded by the dams are widely used for recreation.

Leesville Lake Dam
Photo: Muskingum Watershed Conservancy District

The owner of a dam is responsible for ensuring that the dam is maintained and operated in such a way that it does not constitute a hazard to life, health, or property. Because a dam holds back or has the potential to hold back water, it poses a foreseeable risk to persons and property downstream. The owner of the structure is responsible for taking certain safety measures such as operating the dam safely, maintaining the dam in a safe condition, conducting regular inspections to identify issues, and taking proactive steps to resolve problems before they become larger issues.

Types of Dams

Dams can be described in many ways. They can be characterized by the type of material used to construct the dam (example: earthen dams, concrete dams, steel dams), the shape, structure and architecture of the dam (arch dam, buttress dam, trapezoidal dam, gravity dam, embankment dam), or the use of the dam (flood control dam, water supply dam, recreational dam, channel dam, storage dam, diversion dam). The types of dams found in Ohio can generally be described as:

- Lowhead Dams
- Channel Dams
- Hydropower Dams
- Flood Control Dams
- Upground Reservoir Dams
- Recreational Dams
- Agricultural Dams
- Stormwater/Water Quality Dams

Lowhead Dams

A lowhead dam is a dam of low height, usually less than fifteen feet. They are made of timber, stone, concrete, steel or other structural material and extend from bank to bank across a stream or river channel. A lowhead dam may sometimes also be referred to as a channel dam.

Former Munroe Falls Dam
Photo: Ohio EPA - Lowhead Dam removal fact sheet, October 2010

Lowhead dams usually have a continuous flow across the length of the dam and create an impoundment upstream of the dam. Lowhead dams have been used to form pools for recreational fishing areas, water intakes for public and industrial uses, water sources for canals, and navigable areas in rivers. Lowhead dams can provide aeration of water flowing over the crest, but may create stagnant areas in pools upriver of the dam during times of low flow. Many lowhead dams are barriers to migration of aquatic species and may directly impact the distribution of aquatic organisms upstream and downstream of the dam.

Lowhead dams also create navigational hazards. Canoeists, kayakers, other recreational boaters and swimmers can be pulled by the current over the top of lowhead dams and get caught in the undertow below the dam. Once in the undertow area, the circulation pattern of the water next to the downstream face of the dam pulls boats and people underwater. This results in hazardous situations for emergency response personnel and may end in drowning for those unable to extricate themselves from the undertow.

A significant safety problem with lowhead dams is created by the hydraulic conditions at the downstream base of the dam.
Photo: ODNR- Division of Watercraft

Channel Dams and Locks

Channel dams also stretch from bank to bank across rivers, creeks and streams. Larger channel dams are primarily used in combination with lock systems to support commercial navigation on rivers. Numerous channel dams with locks span the Ohio River between Ohio and West Virginia/Kentucky. Other smaller channel dams with locks exist on the Muskingum and Little Miami rivers in the southern part of the state. A few other smaller dam and lock systems still exist as part of the remnants of the old canals in Ohio.

Belleville Lock and Dam
Photo: US Army Corps of Engineers

Channel dams back up water in the river to create a pool of sufficient depth for waterborne traffic. They also retain water in quantities necessary for vessels to travel through the lock systems. Some of the channel dams on the Ohio River impound water that provides hydroelectric power to local and regional power systems. These channel dams have moveable gates and weirs that can be used to both control water levels upstream and divert water to hydroelectric intakes.

During periods of lower flows the dams can be used to retain sufficient water levels to support navigation on the river. This retention of water for navigation may limit the ability to release water downstream in quantities sufficient to address water quality problems. Some of the channel dams can assist with flooding and can be used to store limited amounts of floodwaters, although great care must be taken to not impact the gates, weirs and locks associated with the dams.

Hydropower Dams

Hydropower dams use the potential energy difference between upstream pools and the downstream areas to generate power. These include old grist mills that turn wheels and gears connected to millstones to process grains. Hydroelectric dams are another subset of the category of hydropower dams. Hydroelectric dams use the difference in water level elevations between the impoundment and the outfall of the dam to power turbines that produce electricity.

Hydroelectric plants can be situated at lowhead dams or at much taller dams made of concrete or earth. Large concrete dams on western rivers such as the Hoover Dam in Nevada and Glen Canyon Dam in Arizona are examples of hydroelectricity generated at dams. Most hydroelectric dams in Ohio are smaller in scale, and many are no longer operational.

Defiance Hydroelectric Power Dam
Photo: Ohio DNR

As with a non-power generating dam, a hydropower dam and its associated impoundment can impact aquatic habitat and water quality. Additional challenges with hydropower include fish impingement on turbines, variations in oxygen levels and temperature, and synchronization of energy needs with water quantity requirements in the downstream areas.

Flood Control Dams

Some dams are partially or solely focused on flood control. These dams are designed for the purpose of collecting, holding and slowly releasing flood waters. Some of the dams provide permanent pools that are used for recreation during warmer seasons. The water levels behind these dams may be lowered annually to provide storage capacity for floodwaters that might be expected during the winter and spring seasons. These dams and their outlet structures are designed for operation with a wide range of water levels.

Dover Flood Control Dam
Photo: Muskingum Watershed Conservancy District

Some flood control dams do not retain a permanent pool; they only store water during certain flood events. During lowers flows these dams may allow the stream or rivers to pass through them with little interruption. This allows the flow of water in a manner that closely corresponds to normal conditions for the stream or river.

New development of homes or businesses within the pool area upstream of these dams is generally discouraged or prohibited because the areas upstream of the dam are used to impound water during significant flood events. Homes or businesses that are built below the potential elevation of the upstream pool might be flooded when water is collected behind the dam.

Upground Reservoir Dams

Upground reservoirs are created to hold water in areas where impounding water in a stream or river channel is not feasible or will not meet the water supply needs of the community or business. Upground reservoirs usually do not cross a stream or river. They are typically built near a water supply such as a stream, river or well field, but are not located directly in the waterway.

These reservoirs can be partially excavated into the ground to gain capacity for water, but most of the storage capacity for the water is gained by building a long continuous dam around the perimeter of the impoundment. The water to fill these reservoirs generally comes from a nearby source such as a stream or river, although groundwater wells are sometimes used as a source of water. The stream or river from which the water is supplied does not flow directly into the upground reservoir, so overtopping of the dam from riverine flooding is generally not a concern.

Upground Reservoir - Village of Wellington
Photo: ODNR

Water quality issues can develop within the impoundment. Aeration and/or circulation at strategic locations may be needed to keep oxygen levels adequate for aquatic life within the reservoir. The main water quality issue associated with these dams can actually derive from the quantity of water withdrawn from the stream or river to fill the reservoir. If too much water is withdrawn from streams and rivers during low flow conditions, insufficient water levels and quantities in streams and rivers may result in impacts to water quality and the habitat.

Recreational Use Dams

Recreational uses of lakes can include but are not limited to swimming, boating, water skiing and fishing. Most of the pools created by dams, channel dams, hydropower dams, flood control dams and even upground reservoirs may support one or more recreational uses. Many dams and associated lakes have been created throughout the state for the primary (or exclusive) purpose of supporting recreational uses.

Dam spillway at Van Buren State Park
Photo: ODNR

The dams supporting recreational uses are usually associated with parks, campgrounds, wildlife areas, nature preserves and stream or river corridors. These dams are generally designed to maintain a constant volume and depth in the upstream lake or pool. Many of these dams are owned by local park districts or communities with parks departments. Private campgrounds and organizations focused on recreational uses also own a large number of these dams.

Agricultural Dams

A considerable number of dams have been constructed across Ohio to support agricultural needs. The dams are usually small in size, but can hold substantial amounts of runoff from agricultural areas. These dams can be used to control runoff and collect sediment, provide water supplies for irrigation and livestock, and serve as holding areas for animal waste. Very few of these dams are large enough to fall under the Ohio dam safety laws, and most collect runoff from relatively small watersheds.

Farm Pond with Dam
Photo: Informed Farmers

The sizing and configuration of these impoundments can vary greatly depending upon the use and purpose of the impoundment. An impoundment designed to pass surface water runoff while collecting sediment and agricultural nutrients may be designed with sediment traps within the impoundment. The volume of the impoundment may be low and might even be designed to drain fully so that trapped sediments can be cleaned out and redistributed on fields.

Livestock Water Tank
Oklahoma Farm Report

Impoundments designed to collect and hold water for irrigation or livestock may hold large volumes of water over long periods of time. Some ponds may be designed to allow direct access for livestock to the water. Others are designed to allow siphoning to water tanks.

Storm Water/Water Quality Basins

Thousands of dams have been constructed across Ohio to collect storm water runoff and treat surface water that contains nonpoint source pollution. These dams form basins which serve to hold water that runs off of urban landscapes. They are usually installed to offset the impacts on stormwater runoff from commercial or residential development activities.

Storm Water Basin
Photo: NRCS

Commercial and residential development can reduce the ability of the land to absorb rainfall. The rainfall runs off of hardened surfaces such as pavement or roofs, picks up pollutants that accumulate on these surfaces, and collects rapidly in streams and rivers. Storm water/water quality basins collect the runoff before it reaches the stream or river, allowing the water to be released slowly. The increased time the water is held in the basin allows pollutants to evaporate or drop to the bottom of the basin, keeping some of the pollutants from entering the stream or river.

Water Quality Basin
Photo: NRCS

Types of Impoundments

Surface impoundments form upstream of dams. These impoundments are generally characterized using four terms:

- Pools
- Ponds
- Lakes
- Reservoirs

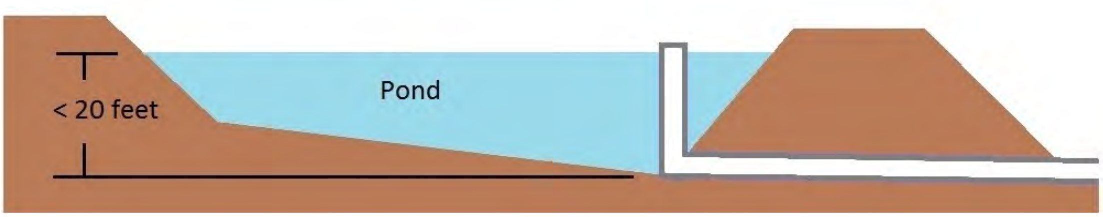
A short description of each term is presented below. The terms pond and lake are sometimes used interchangeably for naturally occurring and man-made bodies of water. Natural ponds and lakes differ from reservoirs in their geologic history and setting, basin morphology, and hydrologic factors (Kennedy et al., 1985; Kennedy, 2001). The descriptions below are intended to highlight the general characteristics of each term in relation to impounded water bodies. A discussion about the thermal characteristics of ponds, lakes and reservoirs follows the description of the four terms.

Pools

Pools are generally found in stretches of rivers or streams upstream of low head or channel dams. They are characterized by low water velocities and above average water depths.

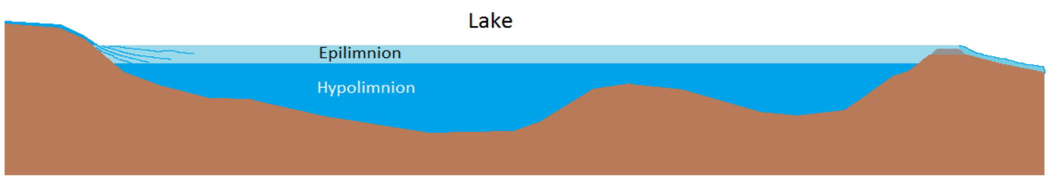
Ponds

Ponds are shallow natural or manmade impoundments generally under 12- 20 acres in surface area. All but the deepest areas in ponds can usually be reached by sunlight. Many of the dams in Ohio were installed to create ponds.



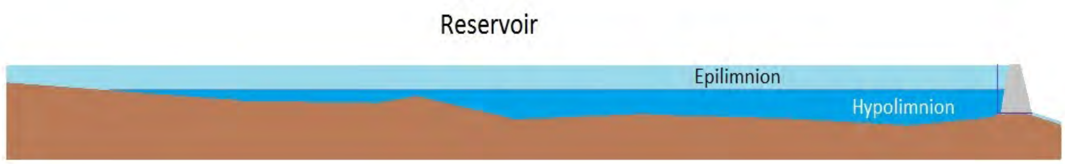
Lakes

Lakes are larger and deeper natural or manmade bodies of water and can be of considerable size. Lakes are usually located within a basin and are fed and drained by rivers and streams. Grand Lake-St Mary's, Chippewa Lake, and Lake Erie are examples of larger lakes found in Ohio.



Reservoirs

Reservoirs are manmade artificial lakes, storage ponds or impoundments. Reservoirs can be constructed for single or multiple purposes such as providing or enhancing public water supplies, irrigation, flood control, stormwater management, hydroelectric power, navigation (headwater storage, lock and dam), and recreational (boating, swimming, fishing) opportunities. LaDue Reservoir in Northeast Ohio and Hoover Reservoir located north of Columbus are two examples of large water supply reservoirs in Ohio.



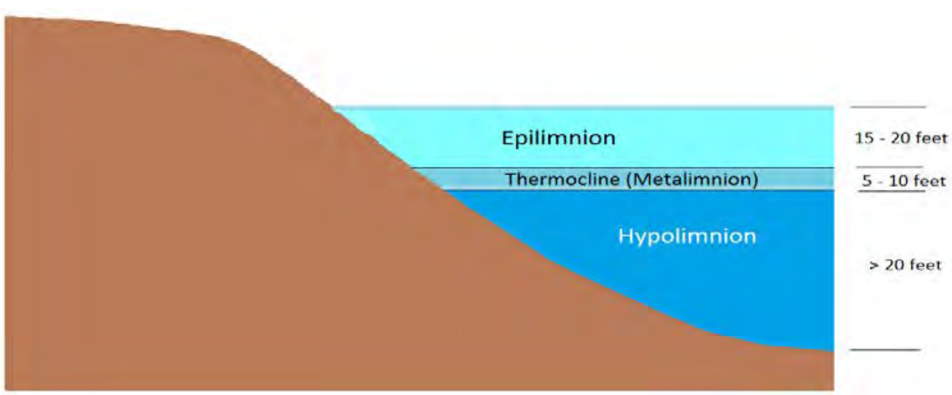
Whether a reservoir, lake, pond or pool, all impoundments may have water quality issues and can impact aquatic habitat and the migration of aquatic species. In deeper impoundments the thermal structure of warmer shallow water and cooler deep water can create challenges when attempting to address water quality problems. Efforts to address water quality issues should factor in these challenges when seeking to determine the appropriate Best Management Practices for a dam.

Stratification

The term "thermal structure" describes the range of water temperatures in a body of water. Surface waters are generally warmer than deep water under most conditions. Stratification is a term used to describe layers of water with different water temperatures. Understanding the thermal structure of the water in a reservoir, lake or pond is an important consideration when establishing a water quality program as part of a water management plan.

Typical language that is used to describe stratification in lakes can be applied to pools, pond, lakes and reservoirs. The term "*epilimnion*" is generally used to describe the surface layer of a reservoir, and can be characterized as a warm layer of constant or equal temperature with abundant oxygen. The term "*metalimnion*" describes a transition layer and can be characterized as a warm to cold thermal discontinuity with variable oxygen levels. A "*thermocline*" is the region in a thermally stratified body of water which separates warmer surface water from cold deep water and in which temperature decreases rapidly with depth.

The "*hypolimnion*" is a lower layer and can be characterized as a cold layer of constant or equal temperature with little or no oxygen. The hypolimnion generally has higher concentrations of organics and nutrients.



Thermal Stratification

The presence of thermal stratification presents both challenges and opportunities in addressing water quality problems in impoundments. Techniques to address water quality problems described later in the document include selected withdrawal, artificial circulation, hypolimnic aeration, aeration/oxygen of reservoir releases (Pastorek et al,115, page 58, Alternatives in Regulated River Management), and localized mixing.

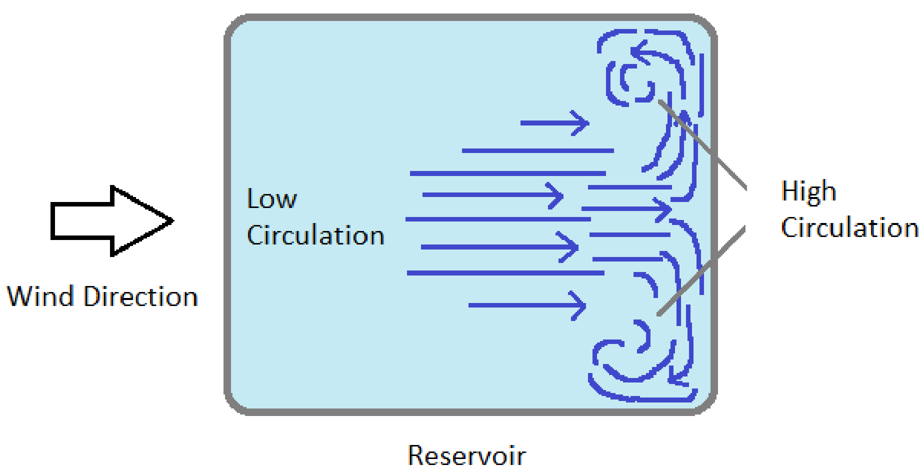
Hypoxia

Hypoxia is a term used to describe a condition where the dissolved oxygen content of water is reduced to very low or nonexistent levels. This condition usually occurs during the summer months in deeper lake basins where the water column stratifies into layers. The warmer oxygenated waters at the surface become separated by a thermocline from the colder, denser water near the bottom of the lake.

High external nutrient inputs carried by stormwater into the lake stimulate the production of excessive organic material (algae and other organisms) in the sunlit surface layers. As this organic material dies and falls to deeper water, the subsequent decomposition of this material in the bottom waters rapidly depletes the supply of oxygen in the hypolimnion. Dissolved oxygen levels may become so low in these deeper areas that aquatic life cannot survive.

Depth, Volume and Shape

The depth, volume, shape and surface area of the impoundment can have impacts on the water quality and habitat within the impoundment. An impoundment with a circular or square shape with relatively uniform depth will have different characteristics than an irregular shaped impoundment with shallow areas, coves and embayments. A tree lined reservoir will have cooler temperatures and aquatic habitat near the shoreline edges, but will have less water circulation from wind driven waves. Prevailing winds during different seasons may influence circulation in larger reservoirs and lakes, with downwind sides of impoundments being stirred by waves while upwind sides see little circulation.

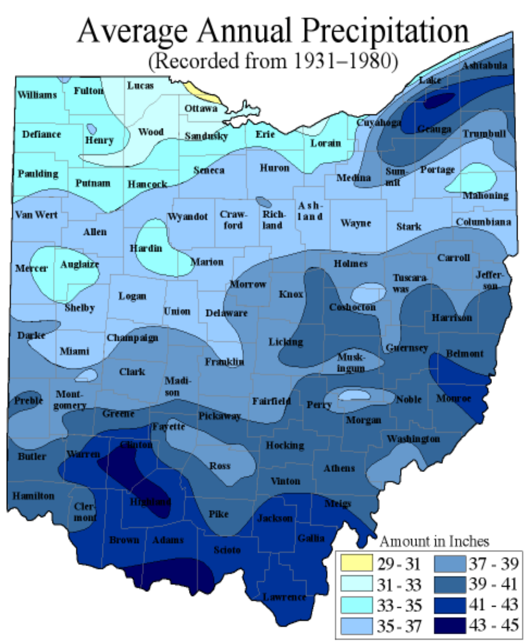


Precipitation

A major influence on the quality of water within an impoundment can be the amount of water that is recharged or replenished every year in the impoundment. Surface water bodies such as pools, ponds, lakes, and reservoirs rely largely upon the recharge provided by precipitation and surface water runoff. Adequate turnover of water in an impoundment can be a key component of maintaining water quality within a reservoir and in the waters released to streams and rivers.

In Ohio, there is generally enough precipitation over a year to provide adequate recharge to most impoundments if there is a sufficiently sized watershed leading to the impoundment. Based on the 50-year period of 1931-80, Ohio averages 37.57 inches of precipitation annually. The general trend is for precipitation to be greatest in the south and east, diminishing in amount toward the northwest. The average annual precipitation ranges from a high of nearly 44 inches in the northeast near Chardon (Geauga County) and in the southwest near Hillsboro (Highland County) to less than 30 inches at Put-in-Bay on South Bass Island (Ottawa County). Snowfall ranges from greater than 100 inches in the northeast counties in Ohio's snowbelt to less than 20 inches in the south along the Ohio River (10 inches of snow roughly averages 1 inch of rain when melted). The snowfall contributes significantly to the average annual precipitation total in the snowbelt areas.

Precipitation in Ohio varies throughout the year. The spring and summer months are typically the wettest while the fall and winter months are the driest. June and July are statistically the wettest months while October and February are the driest months.



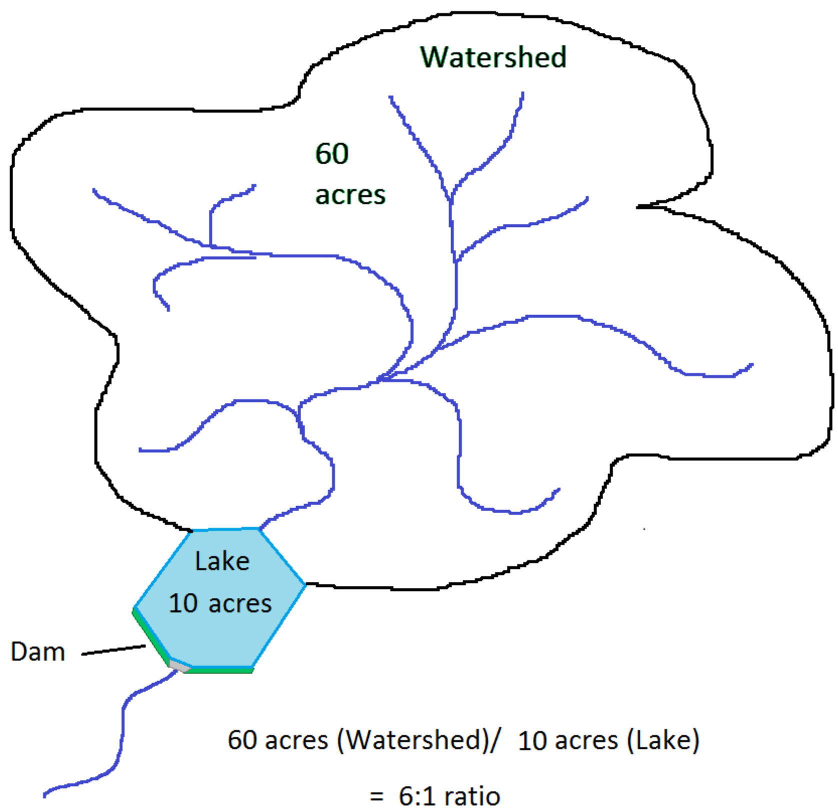
(Source: Ohio DNR)

Floods and Droughts

Floods and droughts are natural periodic occurrences in Ohio. Both flood and drought conditions can have impacts on water quality and habitat within reservoirs and downstream habitats. Droughts can occur during any season, but are usually more noticeable during the spring and summer months. Floods usually last from a few hours to a few days, whereas droughts generally last from a few months to a few years. Localized problems can occur with seasonal droughts, and the volume of the impoundment relative to the amount of runoff from the watershed leading to the impoundment can be a factor in long term water quality problems.

Watershed size

Impoundments with comparatively large watersheds are fully replenished with new water more frequently than impoundments that have watersheds that are smaller in comparison to the volume of the impoundment. A stream or river fed impoundment can sustain good water quality if the water entering the impoundment is relatively clean, has sufficient oxygen levels, relatively low pollutant levels, and sufficient runoff from the watershed leading to the impoundment. A general ratio of 6 to 1 of watershed surface area to the surface area of the impoundment is typically needed to provide sufficient recharge to a shallow impoundment. Higher ratios may be needed for deeper impoundments, and in drier climates the ratio may need to be even higher.



Chapter 2

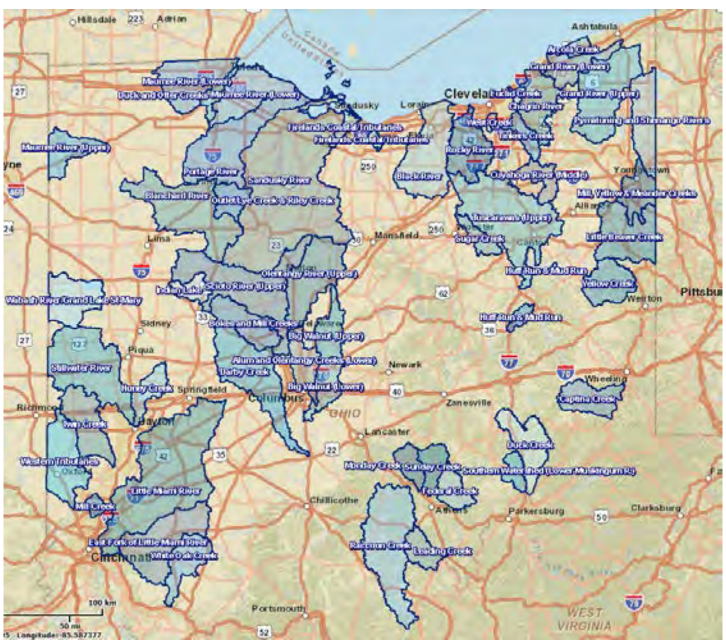
Best Management Practices in the Watershed

Wellington Creek
Photo: Angela Schaeffer

<u>Best Management Practices in Watersheds</u>

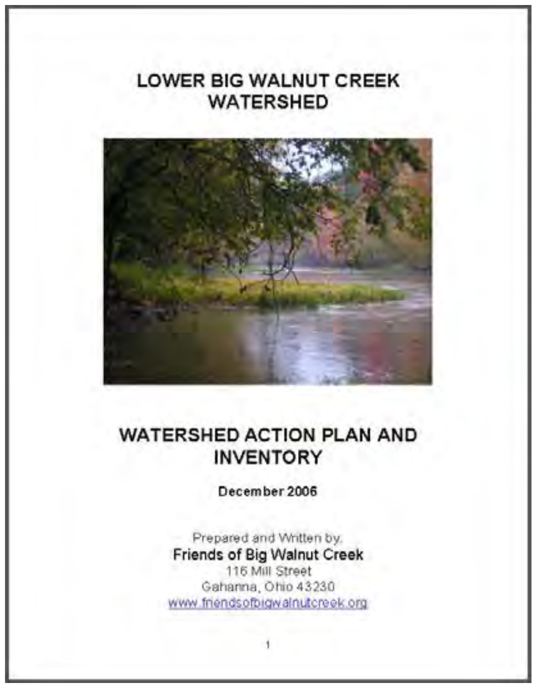
Many nonpoint source pollution problems (e.g., sediment, nutrients, metals, and pathogens) in ponds, lakes and reservoirs or other impoundments result from activities in the watersheds upstream of a dam. Management of pollution sources within a watershed has been found to be a cost-effective solution for improving water quality in reservoirs and waters released from dams (Tennessee Valley Authority [TVA], 1988). Improving watershed protections by installing and maintaining Best Management Practices in the drainage areas upstream of a dam can assist in improving the quality of surface waters flowing into the impoundment.

The local use of watershed protection practices, the identification and application of Best Management Practices for nonpoint pollution sources, and the restoration of stream and river systems in the watershed can result in positive effects to impoundments upstream of a dam and the waters being released from dams to downstream areas. A particular challenge for the owner of a dam or reservoir is that implementation of appropriate watershed Best Management Practices can be outside of their direct control. Dam owners usually do not control many of the activities in the watershed that contribute to water quality problems, and therefore may have a limited ability to directly impact those activities through the use of Best Management Practices.



Ohio Watershed Programs
Image: Ohio DNR

Opportunities exist for dam and reservoir owners to work collaboratively with landowners and watershed interests to address nonpoint pollution issues. A broad-based watershed approach can be beneficial to preventing or controlling runoff of nutrients, sediment and other pollutants from residential, agricultural, and urban environments. The Ohio Department of Natural Resources, Ohio EPA and other state partners have invested in local watershed management programs to support watershed coordinators and local communities' efforts to develop and implement science-based watershed action plans.



LOWER BIG WALNUT CREEK WATERSHED

WATERSHED ACTION PLAN AND INVENTORY

December 2006

Prepared and Written by,
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Multi-jurisdictional watershed action plans have been developed across the state by local government or non-profit organizations employing watershed coordinators. These action plans meet protection and restoration needs for local water resources and incorporate broader goals and policies of statewide nonpoint source management programs. While water quality is a major focus, broader water resource management issues such as flooding, floodplain management and protecting drinking water supplies are also addressed. The watershed programs have an additional emphasis on stream protection, assisting public and private riparian owners with cost-effective means of stream management.

Watershed coordinators are trained professionals who work with a myriad of stakeholders to determine the best opportunities to solve water resource challenges and assemble the technical and financial resources to launch focused projects in their watersheds. They access and align federal, state, and local grants and funding programs to help landowners adopt practices that are helping improve water quality across the state.

Further details on watershed action plans and watershed coordinators can be found at: http://www.agri.ohio.gov/divs/SWC/SWC.aspx#tog

Locally led watershed programs exist in many areas across the state. These programs are a resource for dam owners to learn about water quality and habitat issues in the watersheds upstream and downstream of their dams. Working together with watershed organizations, landowners and communities upstream of the dam can heighten awareness of water quality and habitat issues and lead to solutions that may not be readily apparent at first. Understanding the composition of land uses in the watershed leading to the dam may lead to a better understanding of the water quality problems at each dam and create opportunities for collaborative solutions.

Many watershed action plans highlight Best Management Practices that have been identified for a particular watershed. Watershed based Best Management Practices generally fall into the following categories:

- Watershed Protection Practices
- Identifying and Addressing Nonpoint Source Contributions
- Watershed Restoration Practices

These categories of Best Management Practices are described in further detail throughout the rest of this Chapter.

Watershed Protection Practices

Watershed protection is a technique that can provide long-term water quality benefits. Watershed protection practices are preventative and usually lack high operation and maintenance costs. The cost of constructing, operating, and maintaining water quality structure and controls can often be avoided by preventing problems up front. Watershed protection management practices generally fall under the following categories:

- *Conservation Planning and Local Land Use*
- *Establishing and Protecting Riparian Buffers*
- *Identifying and Preserving Critical Areas*

Many states and local communities have adopted watershed protection practices, and numerous state and local governments have already implemented detailed watershed planning programs to address problems in watersheds.

Conservation Planning and Local Land Use

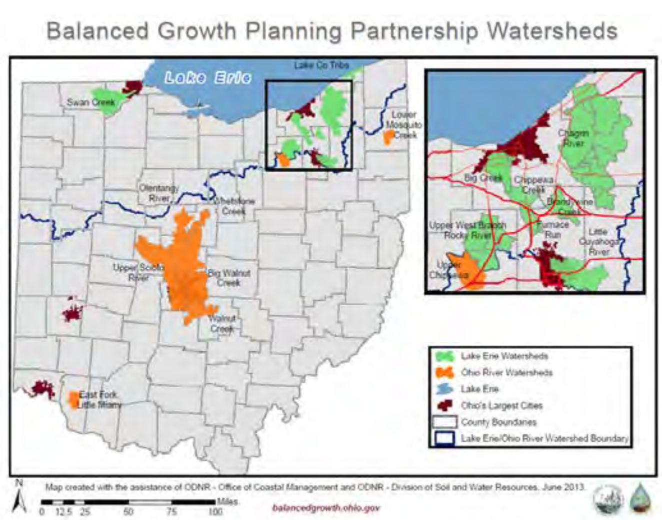
Conservation Planning includes techniques that can be used to adjust development density or redirect density to less environmentally sensitive areas. Conservation Planning can help to identify existing nonpoint pollution sources and prevent future problems that may impact dam construction, operation, and reservoir management. Conservation planning can include the implementation of Best Management Practices that guide future land use activities. Several techniques include:

- Using cluster zoning and planned unit development
- Establishing natural resource protection areas
- Establishing overlay/mixed zones that balances development and conservation
- Establishing bonus or incentive zoning to assist with conservation practices
- Using watershed-based zoning to plan for conservation across political subdivisions

Land use plans that establish guidelines for permissible uses of land within a watershed can serve as a guide for reservoir management programs in addressing nonpoint source pollution. Watershed land use plans may identify suitable uses for land surrounding a reservoir, establish sites for economic development and natural resource management activities, and facilitate improved land management.

Ohio has developed the Ohio Balanced Growth Program to assist communities and interested parties in addressing conservation and development activities in ways to protect the waters of Ohio. The Ohio Balanced Growth Program is a voluntary, incentive based program to encourage local governments to engage in watershed-based regional planning and water quality oriented best local land use practices. The goal of the program is to protect and restore Lake Erie, the Ohio River, and Ohio's watersheds and drinking water source areas to assure long-term economic competitiveness, ecological health, and quality of life in Ohio. The program focuses state funded development and redevelopment into suitable areas, and concentrates state conservation investments into areas of ecological and hydrological significance.

The Ohio Balanced Growth Program supplies information on best local land use practices to minimize development and redevelopment impacts on water quality while enhancing economic benefit. Program resources include guidance documents, example zoning codes, a bibliography supporting the cost effectiveness of the practices, technical assistance with implementing the practices, and training opportunities for local government elected officials and staff.



Balanced Growth Planning Partnership
Photo: ODNR

Information about conservation planning and participation in the Ohio Balanced Growth Program can be found at: http://www.balancedgrowth.ohio.gov/BestLocalLandUsePractices.aspx A series of Best Local Land Use Practices are available as a resource for those involved in conservation planning. The publication "Linking Water Resources and Best Local Land Uses Practices" has been adopted by the Ohio Lake Erie Commission and the Ohio Water Resources Council and serves as an outline for those interested in pursuing conservation planning. Chapters 2, 3 and 4 of "Linking Water Resources and Best Local Land Uses Practices" describe Comprehensive Planning and conservation based development in the context of protecting the waters of Ohio. More details about these techniques and case studies can be found in "Protecting Wetlands: Tools for Local Governments in the Chesapeake Bay Region (Chesapeake Bay Program, 1997)". Additional information about watershed protection, specifically developing and implementing watershed plans, is available from USEPA's draft *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*. The handbook is available at https://www.epa.gov/nps/handbook-developing-watershed-plans-restore-and-protect-our-waters

Establishing and Maintaining Riparian Buffers

Stream/River buffers and wetlands can provide long-term pollutant removal capabilities without the comparatively high costs usually associated with constructing and maintaining structural controls. Conservation or preservation of these areas is important to water quality protection. Land acquisition programs may help to preserve areas that are considered critical to maintaining surface water quality.

Riparian Buffers
Photo: USDA NRCS

Adequate buffers along stream banks provide protection for stream and river ecosystems, help stabilize streams and rivers, and prevent stream and river bank erosion (Holler, 1989). They can also protect and maintain near-stream vegetation that controls the release of sediment into stream channels. Buffers should be protected and preserved as conservation areas because these areas provide many important functions and benefits.

Such benefits and functions include:

- Providing room for lateral movement of a stream or river
- Holding and conveying floodwaters
- Protecting stream banks from erosion
- Treating runoff and reducing drainage problems from adjacent areas
- Providing nesting areas and other wildlife habitat functions
- Mitigating stream warming
- Protecting wetlands
- Providing recreational opportunities and aesthetic benefits

Specific stream buffer Best Management Practices may include:

- Establishing a stream buffer ordinance
- Developing vegetative and land use strategies within buffer zones
- Establishing provisions for stream buffer crossings
- Integration of structural runoff management practices where appropriate
- Developing stream buffer education and awareness programs

More information on establishing and protecting stream buffers is available from US EPA's "National Management Measures to Control Nonpoint Source Pollution from Urban Areas," a document for use by state, local, and tribal managers in the implementation of nonpoint source pollution management programs. It contains a variety of practices and management activities for reducing pollution of surface and ground water from urban areas (USEPA, 2005). The document can be found at: https://www.epa.gov/nps/urban-runoff-national-management-measures .

A Series of Stream Management Guides has also been developed for Ohio. These guides are maintained on the Ohio Department of Natural Resources, Division of Soil and Water Resources.

Stream Management Guides

01	An Introduction to Stream Management
02	Who Owns Ohio's Streams?
03	Natural Stream Processes
04	A Catalog of Contacts for Stream Topics:
05	Ohio Stream Management Guides: Index of Titles

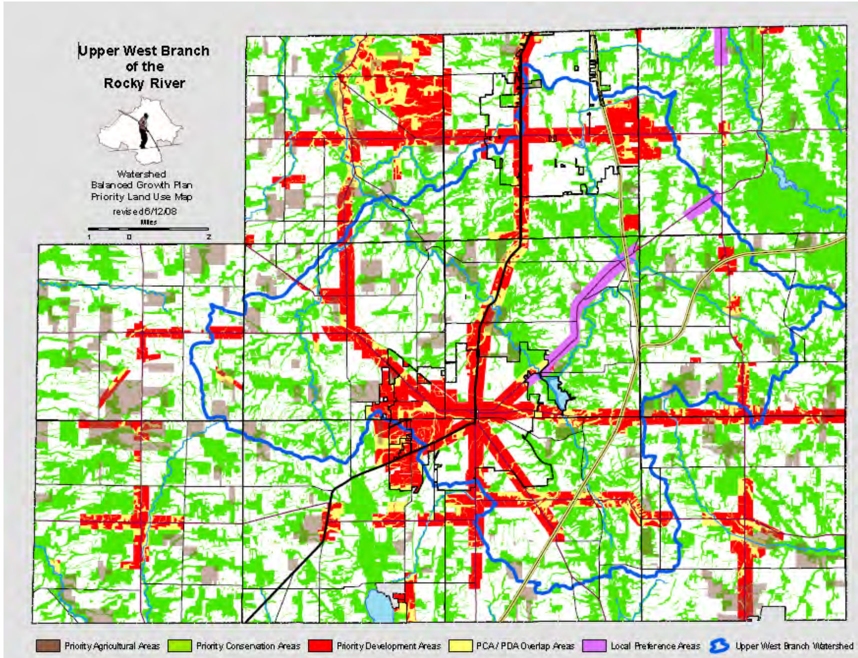
06 Permit Checklist for Stream Modification Projects
07 Restoring Streambanks with Vegetation
08 Trees for Ditches
09 A Stream Management Model
10 Biotechnical Projects in Ohio
11 Tree Kickers
12 Evergreen Revetments
13 Forested Buffer Strips
14 Live Fascines
15 Gabion Revetments
16 Riprap Revetments
17 Live Cribwalls
18 Obstruction Removal
19 Deflectors
20 Eddy Rocks
21 Large Woody Debris in Streams
22 Gravel Riffle

These Guides provide detailed information about methods to protect or restore stream buffers. The Guides can be found under Publications at:

http://www.agri.ohio.gov/divs/SWC/SWC.aspx#tog

Identifying and Preserving Critical Areas

Protection of areas that provide water quality benefits (e.g., natural wetlands and riparian areas) can assist in minimizing the impacts of development on receiving waters and associated habitat. A comprehensive planning approach that includes the use of riparian buffers, open space, bioretention, and structural controls can maintain natural hydrologic characteristics of the watershed as well as minimize detrimental impacts to water quality and habitat.



Rocky River Balanced Growth Plan Map
Photo: Medina County Soil and Water Conservation District

Identifying land areas that could maintain or improve water quality and reduce the impacts of urban and rural runoff if preserved or enhanced is an important first step. Identifying sensitive or critical areas on a watershed map and superimposing this information on a tax map can help identify land for conservation. Owners of potential conservation lands can include a mix of individuals, corporations or other business entities, homeowner associations, government agencies, and land trusts. Various approaches such as those offered through the Ohio Balanced Growth Program (http://balancedgrowth.ohio.gov/) can be used to identify critical conservation areas for consideration.

Preserving areas for conservation can include tools such as land acquisition, easements, and development restrictions of various types. There are several options for landowners who would like to retain ownership of the parcel while relinquishing stewardship and conservation management to another organization. These nonexclusive management options include establishing leases, deed restrictions, covenants, transfer of development rights (TDRs) or conservation easements.

Leases

Leasing a property allows the agency, trust, or organization to actively manage the land for conservation. Even though government agencies, land trusts, and other nonprofit organizations would prefer that conservation lands be acquired by donation, or that conservation easements be placed on the property, some lands hold so much value as conservation areas that leasing is worth the expense and effort.

Deed Restrictions

Restrictions can be included in deeds for the purpose of limiting the use of the land to conservation purposes. Deed restrictions are designed to perform functions similar to those of conservation easements. Unlike conservation easements, deed restrictions do not necessarily designate or convey oversight responsibilities to a particular agency or organization to enforce protection and maintenance provisions. Also, deed restrictions can be relatively easy to modify or vacate through litigation.

Covenants

A covenant is similar to a deed restriction in that it restricts activities on a property, but it is in the form of a contract between the landowner and another party. The term "*mutual covenants"* is used to describe a situation where one or more nearby or adjacent landowners are contracted and covered by the same restrictions.

Transfer of Development Rights (TDRs)

The concept of TDRs as a watershed protection tool is based on the premise that ownership of land includes a "bundle" of property rights. One of these rights is the right to develop the property to its "highest and best use." Although this right can be restricted by zoning, building codes, environmental constraints, and other types of restrictions, the basic right to develop remains.

A TDR system creates an opportunity for property owners to transfer development potential or density at one property, called a sending area, to another property, described as a receiving area. In the context of watershed planning objectives, TDR programs can be an effective way to transfer development potential from sensitive watersheds to other watersheds that can better deal with increased imperviousness. More information on TDRs can be found in Chapter 13 of "Linking Water Resources and Best Local Land Use Practices (2012)" (http://balancedgrowth.ohio.gov/).

Conservation Easements

A conservation easement is a legal agreement that transfers specific rights concerning the use of land by sale or donation to a government agency (municipal, county, or state), a qualified nonprofit organization (e.g., land trust or conservancy), or other legal entity without transferring title of the land (Cwikiel, 1996). Modifying or nullifying an easement is difficult, especially if tax benefits have already been realized. For these reasons, conservation easements are generally preferred over deed restrictions.

Conservation Easement signage
Photo: USDA NRCS

The American Farm Bureau Federation has sponsored the development of "The Landowners Guide to Conservation Easements", a book focused on conservation easements and decision making processed for landowners.

Identifying and Addressing Nonpoint Pollution Contributions

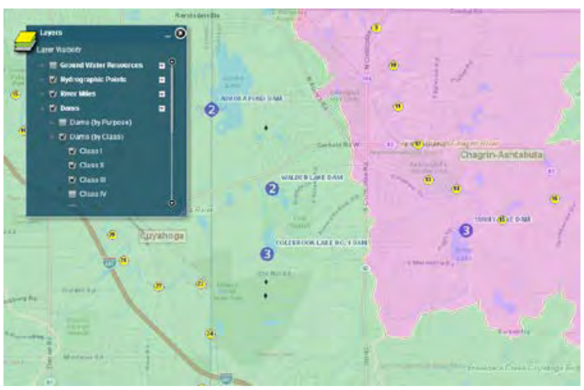
Many different land use activities can contribute nonpoint pollutants. Identifying probable upstream sources of nonpoint source pollution is an important step in providing solutions to minimize the impacts of such pollutants on water quality. Best Management Practices to reduce nonpoint pollution contributions generally focus around the following areas:

- *Soil Erosion Control*
- *Animal Waste Control*

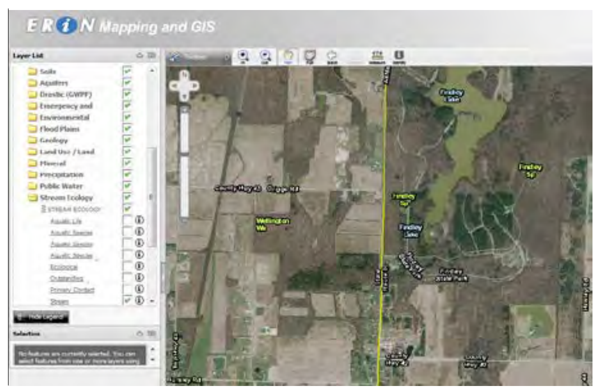
- *Agricultural Nutrient Management*
- *Home Sewage Treatment Systems*

Nonpoint source screening and identification methods are available to evaluate the total nonpoint pollution contributions in a watershed. For example, modern geographic information systems (GIS) can be used to locate and map specific areas of concern where a high probability of nonpoint pollution exists from soil erosion, animal wastes, failing home sewage treatment systems, and other types of nonpoint pollution.

Other remote sensing techniques, such as analysis and interpretation of stereoscopic color infrared aerial photographs or of satellite imagery, can be used to map areas of concern within a watershed (TVA, 1988). Geographic information systems enable watershed planners and modelers to rapidly assess large watersheds in a cost-effective manner.

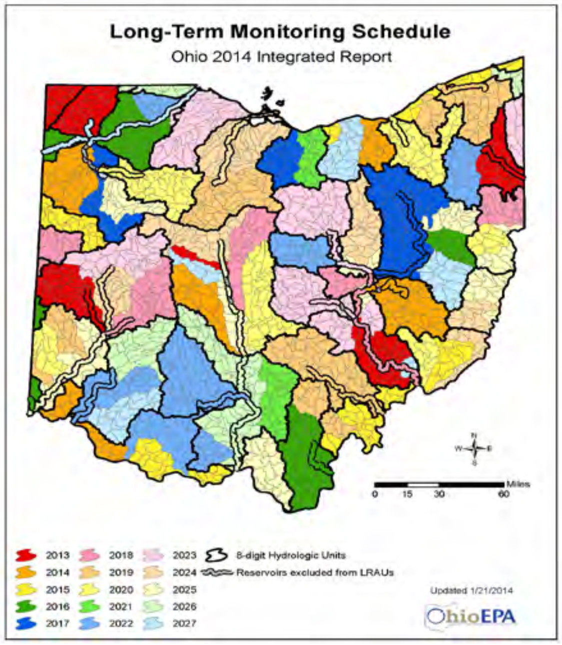


Ohio Coastal Atlas GIS Map Viewer
Photo: ODNR
http://coastal.ohiodnr.gov/



Ohio Earth Resources Information Network
Photo: ODNR
http://geospatial.ohiodnr.gov/gis-home

The development of Total Maximum Daily Loads (TMDL) in a watershed is also helpful in generating a plan to address pollution sources throughout the watershed. A TMDL is a written, quantitative assessment of water quality problems and all contributing sources of pollution in a waterbody. The TMDL specifies the amount each pollutant needs to be reduced to meet water quality standards, allocates pollutant load reductions, and provides the basis for taking actions needed to restore a waterbody (OEPA, 2008). Stakeholders throughout the watershed are often involved in the development of a TMDL, and may be involved with the implementation of activities specified in the TMDL plan.



Ohio EPA TMDL map
Photo: Ohio EPA

Ohio EPA conducts TMDL studies throughout Ohio and updates previously completed TMDL studies on a regular basis. The status of each existing study, information on water quality impairments in watersheds, and information on upcoming TMDL studies can be found in the "Ohio Integrated Water Quality Monitoring and Assessment Report". The report can be found at http://epa.ohio.gov/dsw/tmdl/OhioIntegratedReport.aspx.

Soil Erosion Control

Soil erosion has been determined to be the major source in surface water of suspended solids, nutrients, organic wastes, pesticides and sediment (TVA, 1988). Soil erosion generally occurs as a result of **construction** activities, **post construction** surface water runoff that results in erosion in stream and river beds, and **agricultural** or other activities that disturb soil. Various techniques are commonly utilized to address each of these types of activities, including:

Best Management Practices for Soil Erosion Control at Construction Sites

Sedimentation Basins

A sedimentation basin is a temporary settling pond that releases surface water runoff at a controlled rate. The basin is designed to slowly release runoff, detaining it long enough to allow most of the sediment to settle into the basin. Sediment basins typically consist of a dam or embankment, the pool area for water and sediment storage, principal and emergency spillways, and a controlled dewatering device or skimmer. Secondary benefits include runoff control and preserving the capacity of downstream reservoirs, ditches, canals, diversions, waterways and streams. The entire structure may be removed when construction is complete and the drainage area is stabilized or may be converted to a detention basin for post-construction storm water management.

Silt fence

Silt fence is a sediment-trapping practice that utilizes a geotextile fence, topography and sometimes vegetation to create conditions favorable to sediment deposition. Silt fence reduces the ability of surface water runoff to transport sediment by ponding surface water runoff and dissipating small concentrated flows into uniform sheet flow. Silt fence is used to prevent sediment-laden sheet flow runoff from entering into downstream creeks and sewer systems.

Silt Fence/Vegetative Cover
Photo: Armtec Infrastructure Inc.

Sediment Traps

A sediment trap is a temporary settling pond formed by construction of an embankment and/or excavated basin. The trap has a simple outlet structure that is typically stabilized with geotextile and rip-rap. Sediment traps are constructed to detain sediment-laden runoff from small areas for a sufficient period of time to allow the majority of the sediment to settle out. They are established early in the construction process using natural drainage patterns and favorable topography when possible to minimize grading.

Filter berms

Filter berms are sediment trapping practices that utilize a compost/mulch material. Filter berms reduce sediment from runoff by slowing and filtering runoff, and dissipating flow.

Post Construction Stormwater Management

Water Quality Ponds

Water quality ponds are stormwater ponds designed to treat runoff for pollutants and control increases in stream discharge and bedload transport. Water quality ponds may be predominantly dry between storm events, or have a permanent pool and wetland features. Water quality ponds remove pollutants by settling of pollutants, chemical interaction and biological uptake by plants, algae and bacteria. The efficiency of settling suspended solids and the ability to treat dissolved pollutants is improved with the addition of wetlands and permanent pools. Water quality ponds are often designed to provide flood control by including additional detention storage above the volume specified in this practice.

Water Quality Pond
Photo: Ohio EPA

Infiltration Trenches

An infiltration trench is a rock-filled trench that collects storm waterrunoff, allowing it to infiltrate into the ground. These structures provide temporary underground storage in the form of a trench or other storage chamber filled with uniform graded stone. Infiltration trenches are used in conjunction with sediment removal practice so that most suspended solids are removed before passing runoff into the infiltration trench. This is typically accomplished by passing runoff through a forebay, a grass filter strip or a water quality swale prior to the trench.

Infiltration is the single most efficient post-construction stormwater practice, providing several benefits other control practices do not. Infiltration tends to reverse the hydrologic consequences of urban development by reducing peak discharge and increasing base flow to local streams. Infiltration trenches must be very carefully constructed to ensure they will continue to function over time, and they often have high long-term maintenance requirements. Infiltration practices also are limited by site constraints, particularly soils, which must be within a narrow range of permeability.

Sand & Organic Filters

Sand filters utilize a sedimentation chamber and a filtration chamber to treat stormwater. The first chamber (sedimentation) removes large particles from stormwater by allowing them to settle out of suspension, while the second chamber (filtration) removes finer particles by filtering stormwater through a bed composed of sand or a combination of sand and organic material overlying a drain system. Sand filters provide good treatment for most surface water pollutants except nitrates. Since these facilities attenuate the peak flows of common storm events, they are expected to reduce the potential for downstream channel erosion.

Grass Filters

Grass filter strips, also known as vegetated filter strips, treat the water quality of small sheet flows coming from developed areas. They are uniform strips of dense turf or meadow grasses with minimum slope, best suited to accept diffuse flows from roads and highways, roof downspouts, and very small parking lots, usually prior to runoff being collected by swales, ditches or storm drains. They are also an ideal component of stream buffers or as pretreatment to a structural practice.

Dense turf creates a thick porous mat, which slows runoff velocity from small flows causing deposition and filtration of particulates. Other pollutant removal mechanisms are nutrient uptake, adsorption and infiltration. Grass filter strips are generally not very effective for treating soluble pollutants. Their overall effectiveness is highly variable depending on slope, the quality of turf, and flow rates. It is critically important to maintain sheet flow through the filter strip; otherwise the practice provides little to no treatment.

Bioretention Areas

Bioretention practices are stormwater basins that utilize a soil media, mulch and vegetation to treat runoff and improve water quality for small drainage areas. Bioretention practices provide effective treatment for many runoff quality problems including reduction of total suspended solids, heavy metals, organic compounds, bacteria and nutrients (phosphorous and nitrogen) by promoting settling, adsorption, microbial breakdown, and nutrient assimilation by plants.

A bioretention area consists of a depression that allows shallow ponding of runoff and gradual percolation through a soil media, after which it either infiltrates through undisturbed soils or enters the storm sewer system through an underdrain system. Bioretention practices are sized for common storm events (the water quality volume) whereas runoff volumes from larger events are typically designed to bypass these practices.

Bioretention Area
Photo: Ohio DNR

Information on Post Construction Surface Water control practices and information on construction site sediment control practices can be found in the "Ohio Rainwater and Land Development Manual". The manual can be accessed at: http://epa.ohio.gov/dsw/storm/technical_guidance.aspx

Soil Erosion Control at Agricultural Sites

- Terracing

  A terrace is an earthen embankment, ridge or ridge-and-channel built across a slope (on the contour) to intercept runoff water and reduce soil erosion. Terraces are usually built in a series parallel to one another, with each terrace collecting excess water from the area above. Terraces can be designed to channel excess water into grass waterways or direct it underground to drainage tile and a stable outlet.

  There are three main types of terraces. Broad-based terraces are designed to be entirely farmed; they are generally suitable for long, uniform gentle slopes of up to

6% or so. Grassed back-slope terraces are designed to be farmed on the front slope of the ridge but the back slope is graded to a steep pitch and grassed; they are generally suitable on slopes up to 15%. With narrow-based terraces, the entire ridge is grassed instead of just the back slope, and both sides of the ridge are steeply pitched; the narrow ridges require only a small part of the field to be removed from production.

- Contour Farming

Contour farming consists of growing crops "on the level" across or perpendicular to a slope rather than up and down the slope. The rows running across the slope are designed to be as level as possible to facilitate tillage and planting operations on the contour. Contour farming is often used in conjunction with terracing on fields with higher slopes.

Contour Farming
Photo: Encyclopedia Britannica

- Conservation Tillage

Conservation tillage is any method of soil cultivation that leaves the previous year's crop residue (such as corn stalks or wheat stubble) on fields before (and sometimes after) planting the next crop to reduce soil erosion and runoff. Conservation tillage is especially suitable for erodible cropland. Conservation tillage methods include no-till, strip-till, ridge-till and mulch-till. Each method requires different types of specialized or modified equipment and adaptations in management.

- Grass Filter strips

Grass Filter Strips are planted strategically between fields and surface waters (rivers, streams, lakes and drainage ditches) to protect water quality. They slow runoff from fields, trapping and filtering sediment, nutrients, pesticides and other potential pollutants before they reach surface waters. They can also be planted around drainage tile inlets for the same purpose.

- Grassed Waterways

Grassed waterways are a type of conservation measure used to prevent soil erosion by controlling runoff water from adjacent cropland. As water travels down the waterway, the grass vegetation slows the water and prevents erosion that would otherwise result from concentrated flows. Grassed waterways are designed with a shallow slope that follows the drainage contours of the field. When properly located and designed grass waterways also help prevent gully erosion in areas of concentrated flow.

Grassed waterway
Photo: USDA NRCS

- Cover crops

Cover crops are grasses, legumes or forbs planted to provide seasonal vegetative cover on cropland when the soil would otherwise be bare—i.e., before the crop emerges in spring or after fall harvest. Cover crops are best suited to areas with plenty of water available in the soil for both the cover crop and the main crop. Cover crops have many different uses and names, depending on the main purpose being served.

A **winter** cover crop is planted in late summer or fall to provide soil cover over winter. A **catch** crop is a cover crop planted after harvesting the main crop, primarily to reduce nutrient leaching. A **smother** crop is a cover crop planted primarily to outcompete weeds. **Green manure** is a cover crop incorporated (plowed) into the soil while still green to improve soil fertility. Cover crops also can serve as short-rotation forage crops when used for grazing.

Various programs are available to help reduce soil erosion associated with agricultural lands. The U.S. Department of Agriculture (USDA) and state and county agencies offer landowners financial, technical and information assistance to implement conservation practices on privately owned land. Using this help, farmers and landowners apply practices that reduce soil erosion and improve water quality. The following are brief overviews of natural resource conservation programs that provide cost share assistance and are based on the voluntary participation of the landowner:

Conservation Reserve Program (CRP): The largest and most popular of the USDA's incentive programs, CRP provides land rental payments to farmers and landowners who are willing to sign long-term contracts converting cropland into conservation practices, in order to reduce erosion, improve water quality, and increase wildlife habitat and forestland. Continuous signup in this program is offered for riparian forest buffers, waterways and environmental practices.

Conservation Reserve Enhancement Program (CREP): The Program provides increased financial incentives to install conservation buffer practices in the western part of the Ohio Lake Erie watershed. This program is designed to improve water quality, erosion control and wildlife habitat in specific geographic areas which have been adversely impacted by agricultural activities, with emphasis on addressing non-point source water pollution and habitat restoration in a cost-effective manner. Riparian forest buffers and wetland restorations are some of the conservation practices used in CREP.

Environmental Quality Incentives Program (EQIP): EQIP provides technical, educational and financial help to eligible farmers and landowners for conservation practices that address soil, water and related natural resource concerns on their farmland in an environmentally beneficial and cost-effective manner. Grassed waterways, stream fencing, critical area planting, terraces, manure management systems including storage structures and barnyard runoff protection, are a few of the many conservation practices used in this program. Only agricultural producers on agricultural land are eligible for this program.

Northwest Ohio Windbreak Program: The windbreak program is an inter-agency effort to assist landowners in establishing field windbreaks in Northwest Ohio. It provides both the trees and planting services.

Windbreak along Farm Field
Photo: USDA NRCS - Indiana

Local USDA/Natural Resources Conservation Service office or county Soil and Water Conservation District office should be contacted for information on these programs. Additional information can be found by visiting: http://www.nrcs.usda.gov/wps/portal/nrcs/site/national/home/

Animal Waste Control

Wastes from animal confinement facilities can be a major contributor to reservoir pollution in some watersheds. The Tennessee Valley Authority (1988) estimated that in the Tennessee Valley, farms produced about six times the organic wastes versus the human population of the valley. A cooperative program was established to address the animal waste problem in the

Tennessee Valley. The results of demonstration facilities in the Tennessee Valley reduced NPS pollution from animal wastes by 25,000 tons in the Duck River basin. The program also had the benefit of reducing the additional input of 1,400 tons of nitrogen and 200 tons of phosphorus to farm fields (TVA, 1988).

Animal Waste Storage Facility
Photo: Coshocton Soil and Water Conservation District

Best Management Practices associated with Animal Waste Control include:

- Controlled access of livestock to water bodies
- Controlled runoff from barnyards and feedlots
- Managed barnyards, pastures and feedlots that minimize buildup of manure
- Effective manure storage that minimizes contributions from rainfall
- Maintaining a balance between the number of livestock and acres available for manure application.

Controlled Stream Access
Photo: The Western Pennsylvania Conservancy

Information on Animal Waste Management can be found at: http://go.usa.gov/KoB or by calling a local USDA/Natural Resources Conservation Service office or county Soil and Water Conservation District office.

Agricultural Nutrient Management

Commercial and natural nutrients are used to enhance the productivity of agricultural lands. Phosphorous and nitrogen contained in fertilizers and animal wastes are applied to farmland for the purpose of maintaining and enhancing crop yields. The proper application and management of these nutrients is essential to effective crop production as well as water quality in nearby streams, rivers and impoundments. The principle for using these nutrients in a manner that also reduces the potential for runoff into waterways is the 4R concept. The 4R concept promotes using the:

- Right Fertilizer Source, at the
- Right Rate, at the
- Right Time, with the
- Right Placement.

Fertilizer Spreader
Photo: (USDA NRCS)

Recent studies indicate that the timing of fertilizer application, and how well it is incorporated into the soil layer, significantly reduces dissolved phosphorus runoff. Recommendations for improving production while using Best Management Practices to address water quality issues include:

- Taking frequent soil samplings and following soil fertilization rates based on guidelines from the Ohio State University
- Not spreading fertilizer on frozen or snow covered ground
- Maintaining good fertilization records
- Incorporating fertilizer into soil layers as much as possible

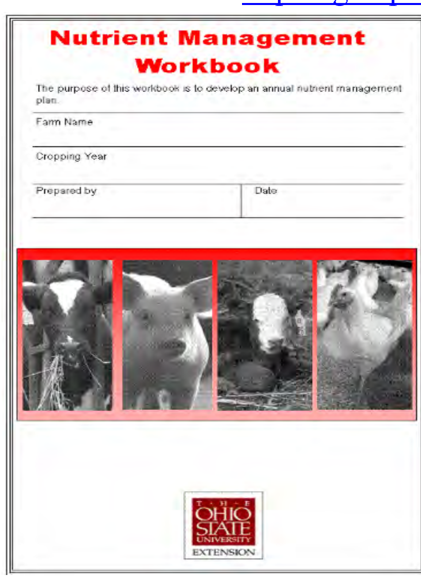
Ohio's Directors of Natural Resources, Agriculture and the Ohio Environmental Protection Agency have developed recommendations for improving Ohio's waterways while maintaining the integrity of the region's agricultural industry. The Directors' Agriculture Nutrients and Water Quality Working Group released a report in March 2012 outlining these recommendations. The report can be viewed at:

http://www.agri.ohio.gov/topnews/waterquality/docs/FINAL_REPORT_03-09-12.pdf.

The guidelines for the 4R principles are endorsed and supported by the International Plant Nutrition Institute, The Fertilizer Institute, The Canadian Fertilizer Institute, and the International Fertilizer Industry Association. Further information on the 4R principles, training on the use of 4Rs, and guidance on implementing the 4Rs can be found at: http://www.agri.ohio.gov/topnews/waterquality/

Manure Spreader
Photo: (USDA NRCS)

Nutrient Management Plans are an ideal tool to utilize for farms involved in livestock production, crop production, or both. Soil testing programs coupled with Nutrient Management Plans that follow uniform agronomic recommendations represent appropriate Best Management Practices in watersheds draining to impoundments. Further information on Nutrient Management Plans and soil sampling protocols can be found at: http://agcrops.osu.edu/NMW.



Nutrient Management Workbook

The purpose of this workbook is to develop an annual nutrient management plan.

Farm Name

Cropping Year

Prepared by

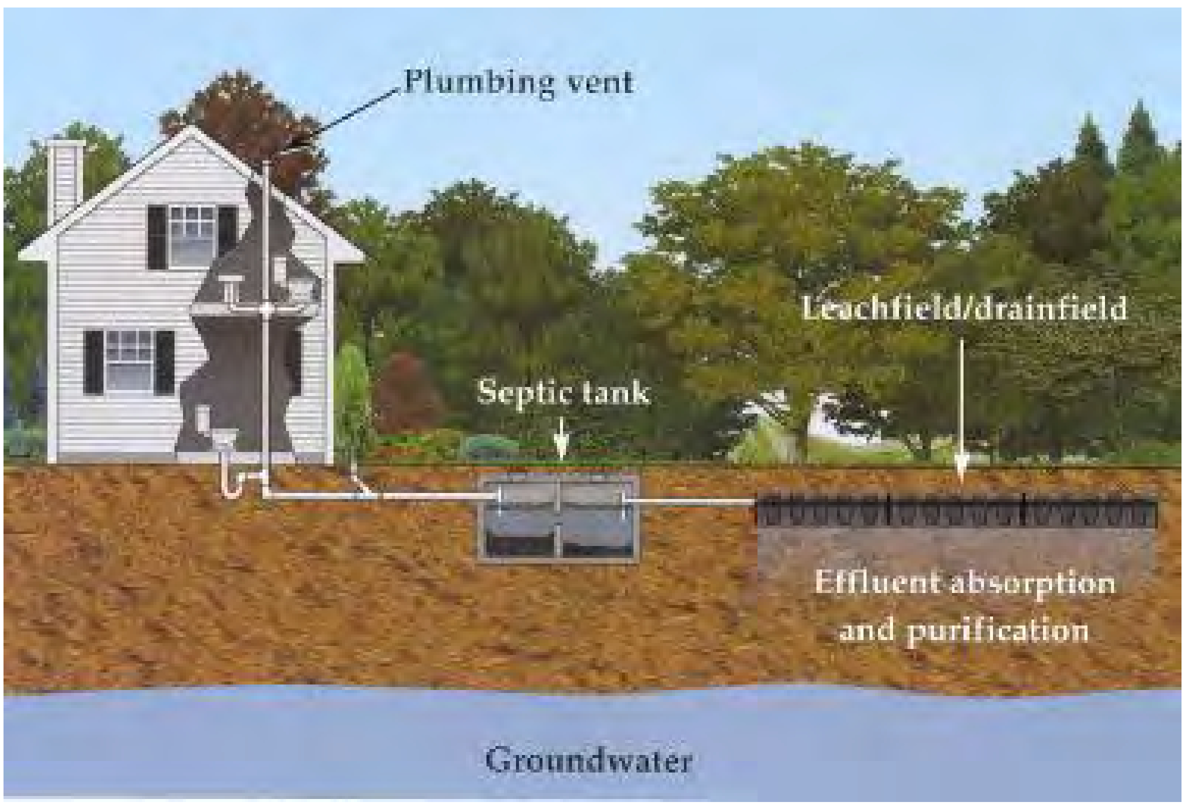
Date

THE OHIO STATE UNIVERSITY EXTENSION

Home Sewage Treatment Systems

Failing septic tank or home sewage treatment systems are another source of NPS pollution in reservoirs. Replacing failing systems and maintaining existing systems are management practices that can help control NPS pollution and improve water quality. Key Best Management Practices include:

- Regular Inspections (recommended annually)
- Maintain systems – lines, leach fields, vaults, aerators
- Clean out vaults when at capacity
- Ensure new systems meet standards,
- Upgrade existing systems where possible



Home Septic System
Photo: The Natural Home

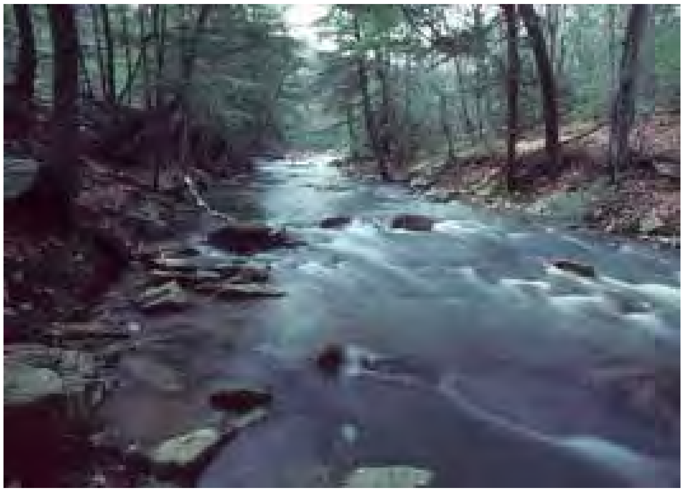
USEPA has developed "The Homeowners Guide to Septic Systems" to assist landowners with the proper maintenance and inspection of Home septic treatment systems. The Guide can be found at: http://www.odh.ohio.gov/-/media/ODH/ASSETS/Files/eh/STS/RES-SepticSmartHOGuide.pdf?la=en.

Watershed Restoration Practices

Restoring Natural Stream characteristics to Channelized Watercourses

Human activities that impact stream ecosystems can and often do cause problems by impairing stream functions and beneficial uses of the resource. Solving stream management problems requires knowledge and understanding of the stream's natural processes. Streams in their natural state perform many beneficial functions. Natural streams and their flood plains convey water and sediment and temporarily store excess flood water. They also filter and entrap sediment and pollutants in overbank areas, recharge and discharge groundwater, naturally purify instream flows, and provide supportive habitat for diverse plant and animal species. The stream corridors where these beneficial functions occur give definition to the land and offer "riverscapes" with aesthetic qualities that are attractive to people

Streams in their natural condition typically exist in a state of dynamic equilibrium. When a stream is in dynamic equilibrium, the amount of sediment delivered to the channel from the watershed is in long-term balance with the capacity of the stream to transport and discharge the sediment. A balance also exists between communities of aquatic organisms inhabiting a stream and the biochemical processes that recycle nutrients from natural pollution sources, such as leaf fall, to purifying the water. The natural stream tends to maintain itself through the flushing flows of annual floods that clear the channel of accumulated sediments, debris, and encroaching vegetation. Extreme floods may severely disrupt the stream on occasion, but the natural balance of the stream ecosystem is restored rapidly when it is in a state of dynamic equilibrium.



Natural Stream System
Photo: Medina County Soil and Water Conservation District

Many of Ohio’s streams and rivers upstream of dams have been altered from their natural state by channelization. Channelization and channel modification are terms used to describe river and stream channel engineering undertaken for the purpose of flood control, navigation, and drainage improvement, and include such activities as straightening, widening, deepening, or relocating existing stream channels. In a natural system, headwater streams provide four basic functions:

1. Drainage of overland flow—headwater stream areas form the principal interface between land and water resources. These areas collect water runoff and deliver it downstream in a more concentrated pattern.

2. Trapping of pollutants and sediments—in natural headwater streams, the near-stream areas and unconcentrated nature of flow allows for pollutants and sediments to be trapped in organic matters of the riparian areas. Nitrogen, phosphorus, and sediments are all trapped by natural headwaters.

3. Water storage and slow release—headwater stream areas have a great capability to store water in their banks, beds, and floodplains and later release this water in a gradual manner . This serves to replenish and maintain base flows in streams and rivers.

4. Basic energy supply—organic materials contributed by headwater stream areas form the basis for healthy aquatic life. Debris from wooded riparian corridors, filter strips and overland flow is delivered to the stream and forms the basic building blocks for the aquatic food web.

Channelization can adversely affect these four basic functions. Physical changes to tributary streams cause significant water quality degradation. Known as "habitat alteration," these actions, including straightening, deepening, widening, damming or otherwise altering a river's natural form and flow cause the failure of many of Ohio's streams to meet water quality standards. Such actions include:

- Relocating streams to the property edge to maximize amount of developable areas in new land development projects,

- Decreasing channel length by cutting off oxbows or natural stream meanders,

- Filling in headwater streams and small wetlands (such as vernal pools or swales) and routing runoff into detention ponds or into ditches,
- Straightening and steepening the gradient in streams to increase the flow velocity,
- Confining floodwaters by raising the height of the channel banks with levees,
- Use of structures and hard engineering (e.g., gabions, riprap, steel piles) to control bank erosion,
- Decreasing the hydraulic resistance and increasing the flow velocity by removing obstructions,
- Clearing stream or river banks of trees and woody vegetation to decrease resistance and increase the flow velocity or merely to provide a view of the river or creek,
- Using impoundments, water withdrawals, and dams constructed for flood control, water supply, or power generation to control flow in a stream or river,
- Construction of river crossings that may require culverts or structures in the river that change the flow pattern or channel slope,
- Construction of stream or ravine crossings with tube or box culverts that alter stream bottom substrate and banks,
- Removing water from natural wetlands by increasing the rate of drainage to the river system; loss of groundwater recharge areas.

Channelized Stream
Photo: US Fish & Wildlife Service

Effects of channelization include increased water temperatures, lower oxygen levels, increased stream energy, downcutting of stream beds and flooding in downstream areas. Nonpoint pollutants such a sediment, phosphorous, nitrogen, road salt, pesticides and heavy metals have little chance of absorption or filtering in channelized waterways, with many of these pollutants ending up in lakes and reservoirs downstream of the watershed.

Restoration of streams can often involve the removal or modification of structures that have been used to channelize the waterway. Decisions about removing or altering these structures should be made with a full understanding of the reasons why the channelization occurred in the first place. Effects on the stream or river might include increased flooding in unexpected areas, and lateral migration of the stream or river as it tries to reform to its natural condition.

Best Management Practices associated with stream and rivers include efforts to preserve and restore the natural functionality of streams and rivers when possible. These can include:

- restoring channels to their original locations,
- reconnecting streams to oxbows, floodplains and natural stream meanders,
- using concentrated development techniques to avoid relocation of streams on a property,
- minimizing culverts in new projects and daylighting culverted portions of streams in restoration projects,
- restoring floodplains and using two stage channels where possible,
- retaining and restoring natural vegetation and shading along waterways,

- utilizing natural systems and solutions for streambank erosion instead of engineered structures,

A suite of spreadsheet tools, the STREAM (Spreadsheet Tools for River Evaluation, Assessment and Monitoring) Modules, has been developed by the Ohio Department of Natural Resources and Ohio State University. This ongoing project began in 1998 and currently provides the following free tools:

1. Reference Reach Spreadsheet for reducing channel survey data and calculating basic bankfull hydraulic characteristics,
2. Regime Equations for determining the dimensions of typical channel form,
3. Meander Pattern that dimensions a simple arc and line best fit of the sine-generated curve,
4. Cross-section and Profile that can be used to illustrate the difference between existing and proposed channel form,
5. Sediment Equations which includes expanded and condensed forms of critical dimensionless shear, boundary roughness and common bed load equations, and finally
6. Contrasting Channels that computes hydraulic and bed load characteristics in a side-by-side comparison of two channels of different user defined forms.

These tools can be accessed at the Ohio DNR Stream Restoration and Management Program web site at http://www.agri.ohio.gov/divs/SWC/SWC.aspx#tog.

Additional resources for stream restoration can be found in a number of publications. The North Carolina Stream Restoration Institute and North Carolina Sea Grant have created "Stream Restoration, A Natural Channel Design Handbook" for those looking to increase their knowledge about stream restoration techniques. The Handbook can be found at: https://www.bae.ncsu.edu/programs/extension/wqg/srp/guidebook.html.

The USDA Natural Resources Conservation Service also has Engineering Handbooks available for Stream Corridor Restoration and Stream Restoration Design. These can be found at: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/water/manage/restoration/?cid=stelprdb1043243.

Chapter 3

Practices for Improving Water Quality within Impoundments

Findley State Park Lake
Photo: Angela Schaeffer

Best Management Practices for Impoundments

Surface impoundments such as pools, ponds, lakes and rivers are slow moving bodies of water that collect and concentrate nutrients. These nutrients can be generated from aquatic organisms and vegetation within the impoundment, and can also be produced by plants and animals along the edge of the impoundment. Other nutrients are transported into the impoundment from upstream areas in the watershed leading to the impoundment. The sources of these nutrients can be natural, such as decaying plants and leaves, or man-made, such as fertilizer on farm fields or effluent from waste water treatment facilities or home septic systems.

Sediment in Lake
Photo: USGS

Some of the nutrients are transported out of the impoundment and downstream in surface waters that are released from the impoundment. Other nutrients are used as food by aquatic life within the impoundment, and are recirculated in the natural food web within the impoundment. Most of the nutrients end up in sediments on the bottom of the pond, lake, or reservoir and remain at the bottom unless the sediments are disturbed.

Aquatic microorganisms such as algae feed on these nutrients. Under certain temperature conditions the population of these microorganisms may grow rapidly in response to the availability of the nutrients in the impoundment. After a short life cycle, these large populations of microorganisms die off. The use of oxygen by the decomposing microorganisms can reduce the available oxygen in the water. This lack of oxygen in the water can lead to large die offs of fish and other aquatic life in the impoundment.

Strategies to address water quality issues within impoundments generally focus on maintaining adequate oxygen levels and reducing the amount of nutrients available to microorganisms. Techniques such as aeration can increase oxygen levels in the water, and pumping can be used to circulate oxygen rich water within the impoundment. Collecting and removing sediment that has nutrients and keeping the bottom sediments from being disturbed by bottom feeding fish can also reduce the availability of the nutrients as a food source for microorganisms.

Aeration/Circulation Practices

Water contains oxygen that is used to sustain aquatic organisms. Aeration of water (the introduction of air into water through natural or man-made means) by various methods and in various locations can increase oxygen levels sufficiently for water based organisms to thrive. Best Management Practices for aerating water generally focus on aeration of water within the impounded water body (pool, pond, lake or reservoir) or in water that is released through or over the dam into a river or stream.

Pond Aeration System
Photo: Living Water Aeration

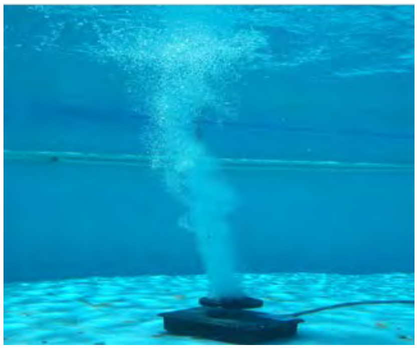
The primary goal for aerating impounded water is to increase oxygen levels throughout the impoundment or in specific areas with low oxygen levels. Systems that have been developed and tested for reservoir aeration rely upon atmospheric air, compressed air, or liquid oxygen to increase dissolved oxygen concentrations in impounded water. Other water quality factors may also see improvement through the uses of aeration in impoundments. These factors include:

- Decreases in levels of dissolved metals and nutrients,
- Destratification of the water column,
- Improved oxygen levels in releases to downstream areas, and
- Decreases in the potential for algal blooms within the reservoir.

Aeration can primarily be accomplished through two methods, **Diffusion** or **Surface Agitation**. The introduction of artificial circulation through aeration of the impoundment may provide the opportunity for an expanded fishery, reduce internal phosphorus loadings, and eliminate problems with iron and manganese in drinking water (Cooke and Kennedy, 1989). **Pumping** and **Mixing** are also methods used to redistribute oxygen and can be especially effective in destratifying deep impoundments. The appropriate balance of aeration, pumping and/or mixing of water layers can be effective in addressing many water quality problems in water bodies.

Diffusion

Diffusion is accomplished mainly through bubbler systems that pump and release air underwater. This allows the water to gain oxygen as the bubbles rise to the surface.

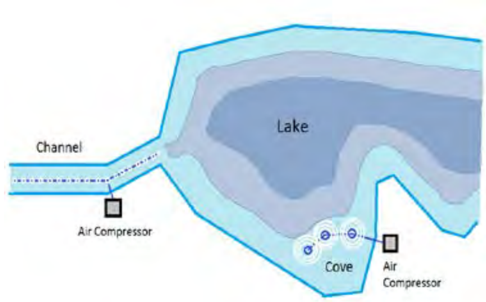


Underwater View
Photo: Air-O-Lator Corporation

Surface View
Photo: Aquatic Management

Diffusion generally occurs below and at the water surface. Diffused air systems provide effective transfer of oxygen to water by forcing compressed air through small pores in a system of diffusers that form bubbles. Systems can be placed at various depths to aerate water at shallow or deeper levels. Pumps can be located on land with tubing that extends to diffusers located in various locations within the impoundment. The pumps can also be located in the water if a power source can be safely extended from the shore or co-located with the pump. Compressed air is typically used in simple systems, while liquid oxygen can be utilized in more complex systems.

The number of diffusers needed for a particular situation is based upon site specific conditions. Different configurations of diffusion systems can be used below the surface of the water.



Diffused Aeration Configurations

Photo: ODNR

Several diffusers can be grouped in cove areas to provide sufficient aeration to areas without adequate circulation of water. Diffusion systems can also be created using lines of bubblers extending into linear channels. Careful consideration should be given to placement of the diffusion systems in areas and channels where boats routinely travel. The lines and diffuser units should be at depths and locations where they will not become tangled with propellers or keels.

Surface Aeration

Surface Aeration occurs by pumping water from the impoundment into the air, causing the water to gain oxygen through contact with the air. Various methods are available to accomplish this, including fountains, splash basins, and constructed waterfalls. Fountain systems usually have pumps located in the water with power provided by electric lines extending from the shore. They can also be power through solar or wind powered units. Intakes for the pumps can be located at various depths to pull water from shallow or deeper zones.

Surface Aeration
Photo: Kasco Pond Aerators

Aeration will elevate levels of dissolved oxygen, but also may redistribute algae that are found in the shallower depths (less than 15 -20 feet) and nutrients that are normally restricted to deeper waters. Surface aeration systems do not return oxygen rich water to lower depths, so they are not always useful at increasing oxygen levels in deeper areas. Destratifying warmer, oxygen rich shallow waters and cooler, oxygen poor deep waters through mixing with pumps can be useful in such circumstances.

Artificial Destratification

Artificial destratification is the term used to describe efforts to destratify all or most of the impounded volume of water. This is done through mixing of shallow and deep layers of water. Mixing of the layers of water through artificial circulation can enhance water quality and increase oxygen levels in deeper water.

Circulation/Mixing

Significant energy can go into destratifying entire reservoirs or other larger bodies of water, so efforts are usually focused on deeper areas. In circumstances where a stream or a river empties into the body of water, natural circulation patterns can be used to enhance efforts to destratify the impoundment. In larger upland reservoirs with no stream or river to create flow patterns, pumping is generally the only way to destratify the deeper areas.

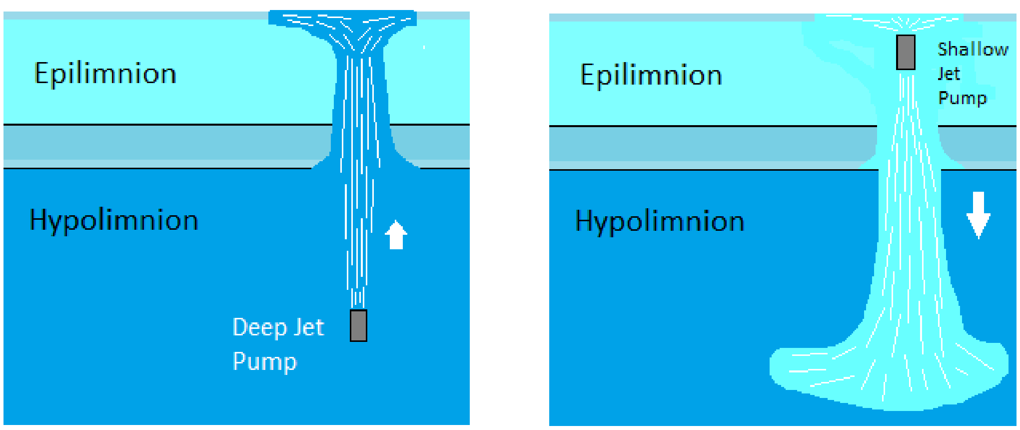


Photo: ODNR

Artificial mixing of deeper water with shallow or surface waters can be accomplished in several ways. One way is to use jet pumps that are located at or near the bottom and directed upward to set up a vertical current of colder, oxygen depleted water from the hypolimnion through the metalimnion and into the epilimnion. Another way is to use the jet pumps in the opposite direction and push oxygen-rich warmer water from the epilimnion through the thermocline into the hypolimnion. Both of these methods can be effective in mixing water directly between shallow and deeper zones.

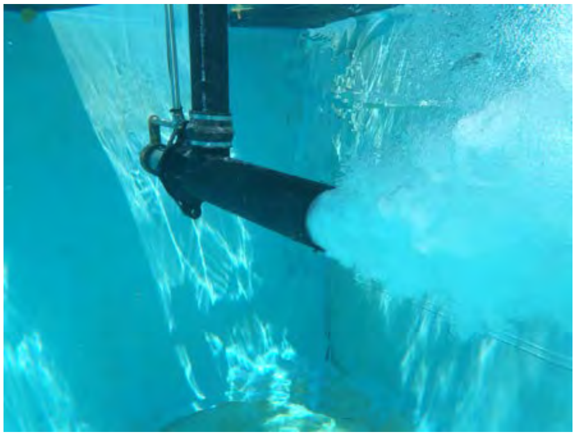
Using the jet pumps to send cooler, oxygen depleted water through the water column to the shallow zones can result in a localized breakup of the stratified layers. This can be helpful in redistributing available oxygen throughout the reservoir, but can result in areas of low oxygen near the surface while the pumping is occurring. This technique is best used in areas where surface wave action frequently occurs so that the cooler oxygen deficient water can mix laterally with the oxygen rich warmer water.

Either of these methods can be used beneficially in deeper impoundments to circulate water and decrease stratification. Caution must be used, however, to prevent stirring of bottom sediments. Intakes for deep jet pumps used to pump water upward must be a sufficient distance from the bottom so that flow into the intakes does not pull sediment off the bottom. Flow directed downward from shallow jet pumps must be in deep enough areas to allow for the energy of the water to dissipate before reaching the bottom and stirring up sediment.

Pumps used to create the jets generally fall into two categories, axial flow propellers and direct drive mixers (Price, 1989). Axial flow pumps usually have a large-diameter propeller (6 to 15 feet) that produces a high-discharge, low-velocity jet. Direct drive mixers have small propellers (1 to 2 feet) that rotate at high speeds and produce a high-velocity jet. The axial flow pumps are suitable for shallow reservoirs because they can force large quantities of water down to shallow depths. The high-momentum jets produced by direct drive mixers are necessary to penetrate deeper reservoirs (Price, 1989).

Aeration with mixing

Aeration combined with mixing can be effective in increasing oxygen levels when destratifying impoundments. Air injection systems operate in a manner similar to that of pumping systems to mix water from different strata in the impoundment, except that air or pure oxygen is injected into the pumping system (Henderson and Shields, 1984).



Aerating mixer pump
Photo: Air-O-Lator Corporation

Jet pumps can be used horizontally or in a slightly downward angle to create low speed currents in the impoundment. Placing the jet pumps in shallow water and directing the flow at a shallow angle down into deeper water can be helpful in breaking up or preventing stratified layers. The warmer oxygen rich water is pushed into the cooler oxygen deficient layers, helping to redistribute oxygen throughout the water column. Other kinds of aeration/mixing systems are divided into two categories: *Partial air lift systems* and *Full air lift systems*.

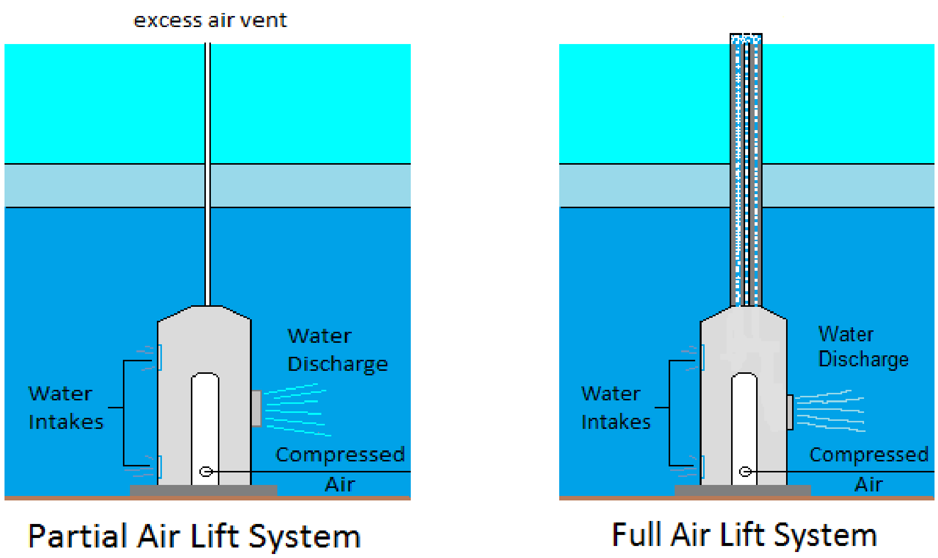


Photo: ODNR

In the partial air lift system, compressed air is injected at the bottom of the unit. The air and water are separated at depth and the air is vented to the surface. The oxygen rich cooler water is discharged in deeper water, avoiding a mixing of stratified layers. In the full air lift system, compressed air is injected at the bottom of the unit (as in the partial air lift system), but the air-water mixture rises to the surface. The full air lift design has a higher efficiency than the partial-air lift and has a lesser tendency to elevate dissolved nitrogen levels (Cooke and Kennedy, 1989).

Photo: USEPA Station 5 outfalls: Chicago Sanitary and Ship Canal (left) and Cal-Sag Channel (right)
From "SIDESTREAM ELEVATED POOL AERATION
(SEPA) STATIONS: EFFECTS ON IN-STREAM DISSOLVED OXYGEN"
T.Butts, D. Shackleford, and T. Bergerhouse

Oxygen injection systems use pure oxygen to increase levels of dissolved oxygen in reservoirs. One type of design, termed *side stream elevated pool systems*, carries water from the impoundment onto the shore and through a piping system into which oxygen is injected. After passing through this system, the water is returned to the impoundment, usually through a series of elongated weirs that create aeration. In Illinois the Metropolitan Water Reclamation District has incorporated these aeration systems into a series of parks along the Chicago Sanitary and Ship Channel.

SEPA Station 3outfall: Blue Island - Chicago Sanitary and Ship Canal
Photo: Metroplanning

Reservoir Nutrient Management

Lakes, ponds and reservoirs accumulate sediment and nutrients from the streams and rivers that flow into them. These impoundments become shallower as sediment accumulates on the bottom. A report on 'Watershed Characteristics and Reservoir Sedimentation in Ohio' (2005, W.Renwick and Z. Andereck, Miami University) details different trends in sedimentation rates based upon agricultural erosion and the efficiency of the stream systems carrying sediment downstream from source areas.

Streams and rivers that are in watersheds associated with urban and agricultural lands may contain phosphorous and nitrogen in the surface water runoff from those lands. The phosphorous and nitrogen attach to the sediment particles and are deposited into the impoundments along with the sediment. Some of the nutrients remain with the sediment until the sediment is stirred up and reintroduced into the water column.

Dredging

Dredging of channels to maintain sufficient water depth for navigation is a common practice dating back centuries. In recent decades dredging activities have been expanded to include removal of sediments to restore reservoir capacity, and in some cases to also remove sediment to prevent re-suspension of phosphorous and nitrogen.

Dredge with Cutting Head
Photo: ODNR

Sediment can be stirred up by power boats, waves, and even bottom feeding fish. As water depth becomes shallower from the accumulated sediment, the sediment on the bottom is more easily disturbed by activity in the water above it. Dredging the accumulated sediment can restore the original depths of the impoundment, and may remove a source of phosphorous and nitrogen that could cause water quality problems.

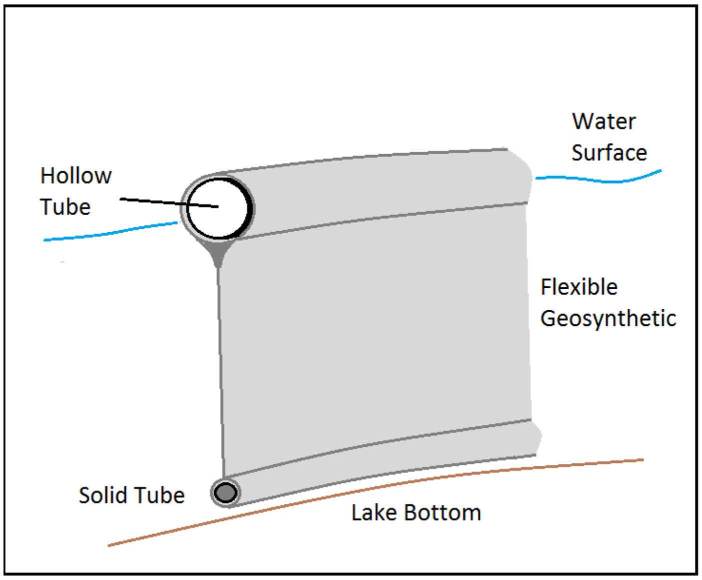
Dredging can be performed in several ways. Specially designed dredge scows with cutting heads can be used in areas where the sediment is fairly free of debris. The sediment can be pumped through lines into barges and taken to deeper areas for disposal. The sediment can alternatively be pumped onto holding areas on shore to dewater the sediment so it can eventually be reused or disposed. In some cases the dredged sediment can be used to create pre-designed wetland areas to enhance habitat in the water body.

Dredge with Clamshell bucket
Photo: Port Canaveral

Dredging can also take place from a floating platform such as a barge or a specially designed dredge scow. Excavators with long hydraulically powered arms and buckets can be used in shallower areas. Deeper areas can be accessed by larger equipment using drag lines with booms and clam shell buckets. Both these types of dredge methods and equipment are well suited to areas where large quantities of debris (wood, brush, garbage, etc.) are mixed in with the sediment.

Floating Booms
Photo: The Australian Boom and Baffle Company

Dredging stirs up sediment and can cause turbidity during the time the dredging is occurring. Floating booms (see section on sediment barriers below) can be placed around the areas being dredged to keep the re-suspended sediment from migrating into other areas.



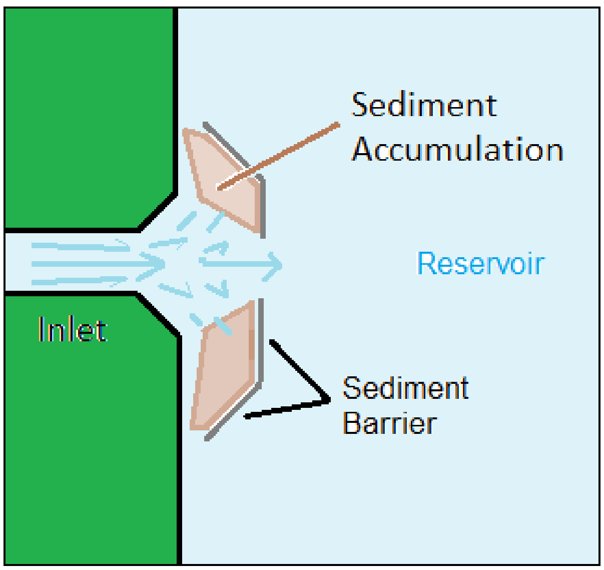
Floating Sediment Barrier
Photo: ODNR

Sedimentation Barriers/Basins

Removal of sediments through dredging in open water can be expensive and difficult. Capturing sediment in basins or behind barriers constructed at inlets before it reaches the lake can result in cost savings and improved water quality. Such barriers and basins can be very effective in collecting sediment before the sediment moves out into the impoundment. If collected close to shore in areas with good land access, the sediment can be routinely removed by using track hoes or other land based equipment.

Sediment is carried along by streams and rivers when the water is moving at a decent pace. Some rivers and streams transport sediment consistently throughout the year, while others only move sediment during significant runoff events. In either circumstance, once the water slows down, sediment starts to fall down through the water and accumulate on the bottom. A sediment barrier or basin is designed to slow water down from the stream or river inlet as it is entering the impoundment. As the water slows down the sediment accumulates in the basin or next to the barrier instead of being transported into the impoundment. Once sufficient amounts of sediment have accumulated, the sediment can be removed from the cleanout area and placed in an upland area.

One type of barrier consists of floating booms with synthetic curtains hanging from the boom and extending to just above the bottom surface. The booms are placed strategically in the impoundment near the inlet in a manner that slows the water.



Sediment Barriers at Inlet
Photo: ODNR

Preferably these booms should be near land based access points to aid in sediment removal. Different configurations may be utilized depending on how the inlet enters the impoundment. An advantage to using floating barriers with sediment curtains is that they can be adjusted to optimize their effectiveness. They can also be easily removed or reconfigured if they are not working efficiently.

A *sediment basin* is a settling pond that releases runoff at a controlled rate. The basin is designed to slowly release runoff, detaining it long enough to allow most of the sediment to settle. Sediment basins typically consist of a smaller dam or embankment, the pool area for water and sediment storage, principal and emergency spillways, and a controlled dewatering device or skimmer.

Sediment basins are usually designed with the intent of collecting sediment laden runoff from construction sites or other areas with exposed soils. They work best when located near the site where the sediment is being eroded from the land surface. They have limited application on streams or rivers, but can be designed adjacent to a stream to collect some of the runoff from smaller precipitation events. The potential volumes of water from larger precipitation events generally preclude the use of sediment basins for rivers. Care needs to be exercised to make sure that the basin does not remove coarser sediments that are valuable to the stream morphology. Such basins may also flood from time to time during out of bank flood events. The impacts of such flooding should be considered in the design of the basin.

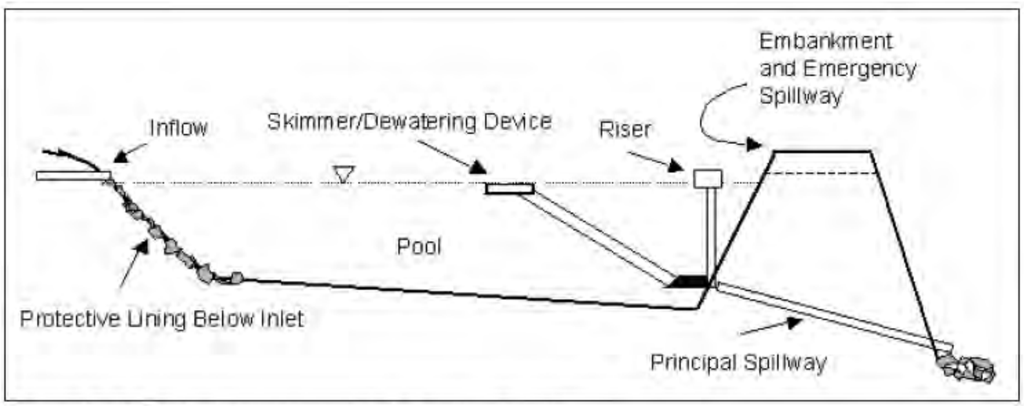


Figure 6.1.2 Typical components of a settling basin

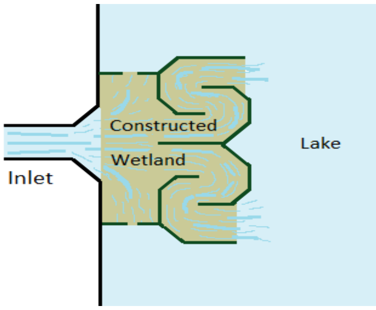
Specific instructions on design of Sedimentation Basins can be found in the Chapter 6 of the *Ohio Rainwater and Land Development Manual*. The Manual is located at: http://epa.ohio.gov/dsw/storm/technical_guidance.aspx

Constructed Wetlands

In contrast with sediment basins, constructed wetlands are designed to assimilate nutrients and contaminants. The wetlands provide sediment removal, but are more suited to capturing pollutants contained in stormwater runoff. Most constructed wetlands are installed to capture runoff from specific urban or rural areas and treat the runoff before it reached the stream, river or water body. Some wetlands are constructed to the side of a stream or river that is already affected by stormwater runoff. Water is diverted into the wetland through gates and channels connected to the stream or river. Once it is treated by the wetland the water is released back to the stream or river.

Harbor Brook CSO Treatment Wetland
Photo: Onondaga County 'Save the Rain'

Wetlands can also be constructed in the impoundment near the inlet of a stream that feeds into the impoundment. The wetlands can be constructed using a set of berms and channels within the impoundment. The water can be routed through the wetland at low velocities, allowing sediment and contaminants to accumulate in the wetland.



Wetland constructed at an inlet
Photo: ODNR

This type of wetland may involve filling and dredging in the impoundment. Approval of such a practice will require a detailed analysis of the benefits of installing the wetland versus the impacts of dredging and filling activities to construct the wetland within the impoundment. Such a wetland may create aquatic habitat that is beneficial to organisms but will alter flow and circulation patterns in the stream and impoundment. The wetland can be expected to accumulate sediment over time, and may need to be dredged in the future to maintain a channel if the stream is used for navigation.

A number of resources are available to learn about wetland restoration. The US EPA, the US Geological Survey, the Natural Resource Conservation Service and the US Fish and Wildlife Service maintain web sites focused on wetland restoration:

USEPA
https://www.epa.gov/wetlands

USGS
http://water.usgs.gov/nwsum/WSP2425/restoration.html

NRCS - Wetland Reserve Program
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/easements/wetlands/?cid=nrcs143_008419

The US Fish and Wildlife Service National Wetland Inventory web site: http://www.fws.gov/wetlands/index.html.

Fish Management

Certain fish species, especially bottom feeders like common carp and gizzard shad, burrow through sediment at the bottom of reservoirs in search of food. These fish can disturb significant amounts of nutrient laden sediment at the bottom of impoundments. The disturbed sediment is re-suspended in the water column, increasing turbidity in the water. The re-suspended sediment may contain nutrients which are reintroduced in the water column along with the sediment. The re-suspended nutrients are then available for aquatic microorganisms such as algae to feed and grow.

Common Carp
Photo: Ohio DNR

Removing fish species that stir up bottom sediments can reduce the amount of turbidity in the water column and reduce the amount of re-suspended nutrients available to aquatic microorganisms. Such reductions may decrease or hold in check the quantity of various algae commonly found in most water bodies.

Local or state fishery managers can be consulted to identify those species that might exist in an impoundment, and can work with dam owners and owners of impoundments to devise strategies to remove or lower the populations of species that tend to stir up bottom sediments. Careful consideration must be given to how to remove or lower the populations of certain species without impacting the other fish or aquatic organisms in the impoundment.

The Ohio Department of Natural Resources Division of Wildlife has experts who can provide advice on management of fish species. They can be contacted at: 1-800-WILDLIFE (1-800-945-3543). Additional information can be found at: http://wildlife.ohiodnr.gov/.

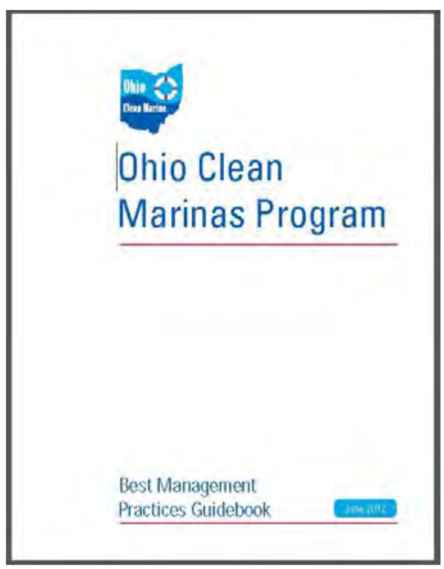
Boating Operations

Many of the surface water impoundments in Ohio are used for recreational boating. Canoeing, kayaking, power boating and sailing are some of the ways used to enjoy the water bodies created by dams. Boat ramps are available at many lakes and reservoirs, and some of the larger water bodies have marinas for longer periods of use by the boating public.

Most boaters recognize the value of the water resources they use for recreational boating. Boating activities can nonetheless create water quality problems in lakes and reservoirs throughout the state. Ohio Sea Grant in coordination with several state agencies and boating organizations has developed the Ohio Clean Boater and Ohio Clean Marina programs to help boaters operate in a way that minimizes water quality impacts associated with boating.

Delaware State Park Marina
Photo: Ohio DNR

The Ohio Clean Boater and the Ohio Clean Marina programs represent a proactive partnership designed to encourage marinas and boaters to use simple, innovative solutions to keep Ohio's coastal and inland waterway resources clean. The programs assist these operators in protecting the resources that provide their livelihood – clean water and fresh air. The basic goal of the programs is environmental stewardship by making marinas and boaters more aware of environmental laws, rules and jurisdictions, and to get as many boaters and marinas as possible to follow best management practices.



The Clean Marinas Program has developed a Best Management Practices Guidebook for use by boaters and marinas in Ohio. The Guidebook and additional information on the Ohio Clean Marinas and Ohio Clean Boaters Programs can be found at: http://ohioseagrant.osu.edu/cleanmarinas/.

Chapter 4

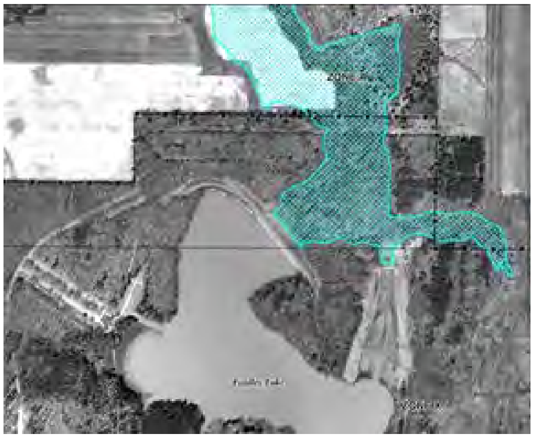
Practices for Improving the Quality of Water Releases

Delaware Dam
Photo: Ohio DNR

Water Quality and Quantity in Releases from Impoundments

As mentioned in Chapter 1, dams range in size and ownership. They are owned by public agencies, homeowner associations, private landowners and others. Dams are located on large river systems or smaller streams, each with their own physical setting and flow regime. Some dams, such as those used for flood control, are actively managed by their owners. Other dams used for recreation or storm water management might be passively managed. A clear understanding of the current and historic conditions of the stream or river where the dam is located, an understanding of the capacity of the owner to manage or change the operation of the dam, and an understanding on how and when water is currently released from the dam are needed before initiating Best Management Practices that might change the dynamics and composition of water releases.

The original physical condition of the stream or river may have undergone significant changes due to the presence of the dam. The impact a particular Best Management Practice may have on the current floodway and floodplain of the stream or river upstream and downstream of the dam is an example of an issue that must be carefully considered. Changes to the frequency and rates of releases can potentially alter the characteristics of the floodway and floodplain. Local flood maps should be consulted and engineering studies performed when appropriate to ensure that the proposed changes do not increase the magnitude or frequency of flooding downstream of the dam. Information on existing flood maps can be found through the Ohio DNR Floodplain Program at:http://water.ohiodnr.gov/water-use-planning/floodplain-management



Findley State Park Dam/Wellington Creek
FEMA Flood Zones

The downstream uses of water also need to be considered. Wide fluctuations in water levels downstream of the dam may affect navigation in waterways and influence the quantity of water available at intakes for public and private water supplies. Excessive sediment in water releases may temporarily impact water quality and spawning areas. Downstream lakes or reservoirs might fill more rapidly with sediment, impacting the long term uses of those water bodies. Excess nutrient levels in the water may cause problems with the quality of water being treated for human consumption, and may cause algal problems in slow moving or stagnant areas within the floodplain of the stream or river.

Water Release from Dam
Photo: Knoxville News Sentinel Company

Limitations on how much water is available for release during certain seasons will be partially dependent on the uses of the water in the impoundment. Impoundments that support water supplies or recreational uses will need to be managed carefully to avoid adverse impacts to those who rely on the impoundment for those uses. Care must be exercised in making sure that the uses and needs of the downstream property owners and communities are considered when determining the potential use of a Best Management Practice. Proper studies of these uses and collaborative discussion with those users are very important in determining whether a particular Best Management Practice is suitable for incorporating into releases from the dam.

Practices to Improve Oxygen Levels in Reservoir Releases

Improving water quality in impoundments and in the waters released from a reservoir often requires consideration of several different factors. Issues related to oxygen levels, pollutants, water quantities, flow rates, sediment loads and types of sediment in the water need to be reviewed and considered in the context of the health of the aquatic ecosystem in the stream or river. For example, achievement of desired dissolved oxygen levels at specific locations may require evaluation of several different technologies and management activities.

Changes to flow rates, quantities of sediment in the water releases, and frequency of releases can have sizeable and positive impacts on the habitat of the stream or river, but may also create conditions that need further analysis. Some options might include:

- Improving water quality in the reservoir near the outlet to create better water quality in releases,
- Modifying the withdrawal outlet location and thereby changing where water is withdrawn and released from the reservoir,
- Treating the release water to eliminate poor water quality as the flow passes through the outlet structure, and
- Treating the release water in the tail water area (Wilhelms and Yates, 1995).

Aeration of water as it passes through the dam or through the portion of the waterway immediately downstream from the dam is an approach to improving dissolved oxygen in water releases from dams. The systems in this category rely on agitation and turbulence to mix the reservoir releases with atmospheric air.

Dam Spillway
Photo: U.S. Department of the Interior

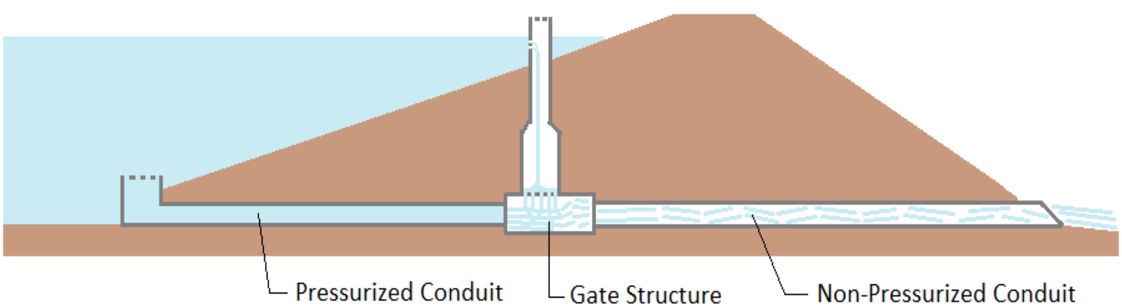
Another approach is to install barriers called weirs in the downstream areas. Weirs are designed to allow water to overtop them, which can increase dissolved oxygen through surface agitation and increased surface area contact. A note of caution is that some of these downstream systems can create supersaturation of dissolved gases which may be harmful to aquatic organisms. Additional modifications to prevent supersaturation may be needed if weirs are utilized. Information on aeration through the use weirs can be found in the following publications:

> Wilhelms, S.C. 1988. Reaeration at Low-Head Gated Structures; Preliminary Results. *Water Operations Technical Support*, Volume E-88-1, July 1988. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.
>
> Wilhelms, S.C., and D. R. Smith. 1981. *Reaeration Through Gated-Conduit Outlet Works*. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS. Technical Report E-81-5.

Some examples of these technologies and management activities are noted below:

Gated Conduits

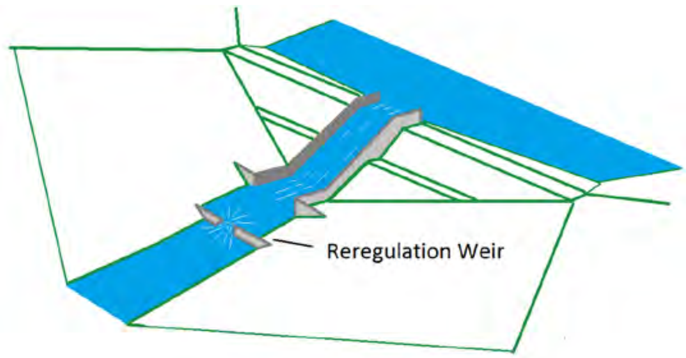
Gated conduits are hydraulic structures that divert the flow of water under the dam. They are designed to create turbulent mixing to enhance the oxygen levels in waters being released downstream. Gates are used to control the cross-sectional area of flow. Gated conduits have been extensively analyzed for their performance and effectiveness (Wilhelms and Smith, 1981), although the available data are mostly from high-head projects (Wilhelms, 1988). In modeling studies, gated conduit structures have been found to achieve 90 percent aeration (Wilhelms and Smith, 1981).



Gated Conduits
Photo: ODNR

Reregulation Weirs

Reregulation weirs have been constructed from stone, wood, concrete and large aggregate. In addition to increasing the levels of dissolved oxygen in the tailwaters, reregulation weirs result in a more constant rate of flow farther downstream during periods when turbines are not in operation.



Reregulation Weir downstream of a Dam

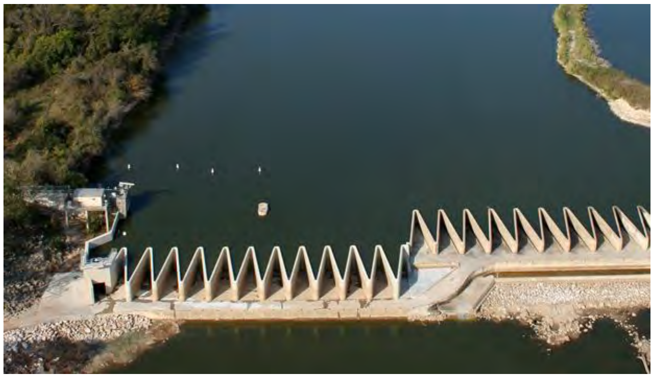
Photo: ODNR

Multiple reregulation weirs can be used in a series to create pools and mixing areas. These sets of weirs use the natural flow of water downstream as a way to aerate the water. Fish passage devices (Chapter 5) often use the concept of modified weir structures to create small pools and rapids for migration of fish upriver. Such devices can serve both to aerate water and enhance migration of aquatic species.

Fish Passage Weirs
Bonneville Dam, Columbia River
Photo: Eric Guinther

Labyrinth Weirs

Labyrinth weirs have an extended crest length and are usually W-shaped. These weirs spread the flow out to prevent dangerous undertows in the plunge pool. They also extend the spillway length, potentially increasing discharge over the spillway during certain flow events. Some labyrinth weirs are constructed for the dual purpose of providing minimum flows and improving dissolved oxygen in reservoir releases. Actual increases in the dissolved oxygen will depend on the temperature and the level of dissolved oxygen of the water going over the weir.



Lake Brazos Labyrinth Weir
Photo: Freese and Nichols, Inc.

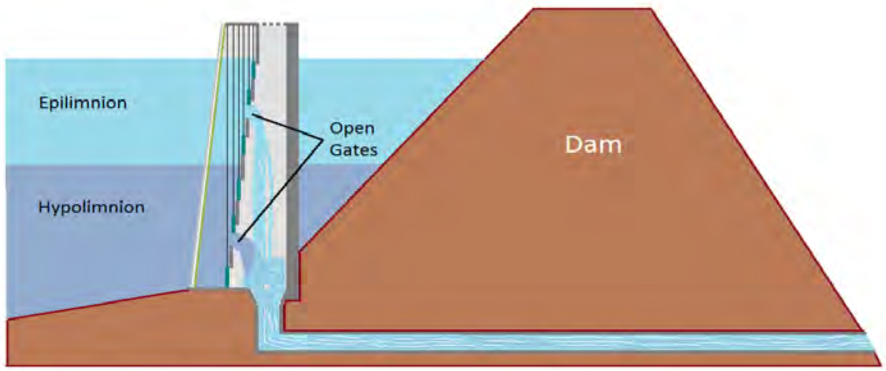
Some dam spillways have been successfully retrofitted with labyrinth weirs. Various configurations have evolved over time, some of which are still in experimental stages. The height of the weirs can vary, allowing low flows to pass over a few weirs while higher flows are distributed across all weirs.

Weir Model
Photo: Utah Center for Water Resources
Utah State University

Designs of labyrinth weirs can be complex and require extensive engineering studies. Careful consideration needs to be given to downstream turbulence to ensure that energy created between each segment by the concentrated flows is properly dissipated.

Multilevel Devices

Multilevel Riser devices in storage reservoirs allow selective withdrawal of water based on temperature and dissolved oxygen levels. These devices can also minimize the withdrawal of surface water containing high concentrations of algae, or of deep water rich in iron and manganese.



Multi Level Riser with multiple openings

Photo: ODNR

Multilevel risers are an option for retrofitting existing ponds and reservoirs to meet temperature requirements in downstream areas. They can require active use of gates and monitoring of temperatures at various depths to ensure proper blending of warmer and cooler temperatures.

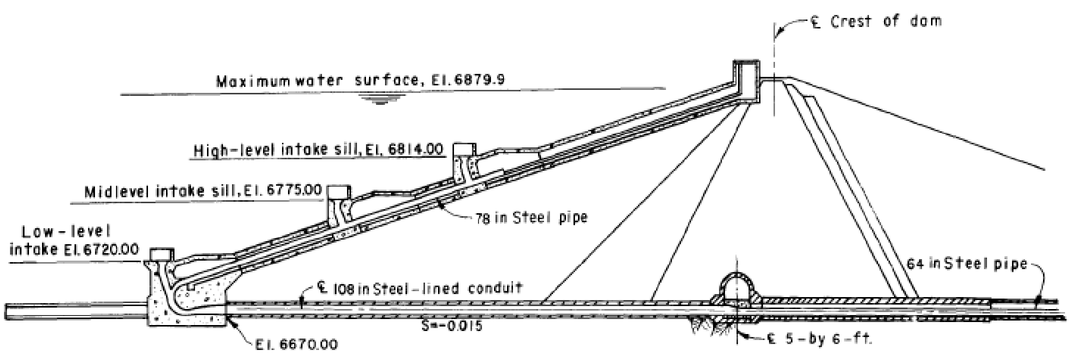
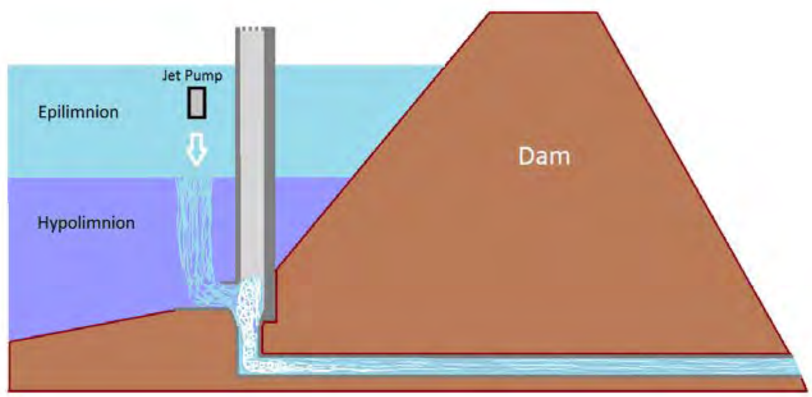


Figure 2. — Ridgway Dam inclined multilevel outlet structure.

Diagram: Hydraulic Model Studies -Ridgeway Dam Outlet Works
Photo: US Department of the Interior – September 1984, Engineering Research Center

Localized Mixing

If the principal objective is to improve dissolved oxygen levels in the reservoir releases and not throughout the entire impoundment, then aeration can be applied selectively through *localized mixing*. Discrete layers of water are aerated through localized mixing in areas immediately surrounding the water intakes or as water passes through outlets or release structures.



Localized Mixing

Photo: ODNR

Localized mixing can improve water quality in thermally stratified reservoirs by destratifying the reservoir in specific areas of the impoundment. This most favorably occurs in the immediate vicinity of the outlet structure. Water pumps are used to move surface water containing higher concentrations of dissolved oxygen downward to mix with deeper waters (or in reverse if the outlet is near the surface) as the two strata are entering the outlet.

Providing Proper Flows to Restore or Maintain Instream Habitat

Several options are available for the restoration or maintenance of aquatic and riparian habitat in a reservoir impoundment or in portions of the waterway downstream from a dam. One set of Best Management Practices is designed to augment existing flows that result from normal operation of the dam. These include operation of the facility to produce flushing flows, minimum flows, or turbine pulsing in the case of hydroelectric dams. Installation of reregulation weirs in the waterway downstream from the dam can also help achieve minimum flows.

Kinzua Dam
Photo: Heather Elmer

The quality of reservoir releases can be improved through adjustments in the operational procedures at dams. These include:

- Scheduling of releases or the duration of shutoff periods to reflect downstream water quality and habitat needs
- Instituting procedures for the maintenance of minimum flows downstream
- Making seasonal adjustments in the pool levels or in the timing and variation of the rate of drawdown
- Timing releases from gate valves or lake drains to avoid impacts during sensitive spawning periods

Dams capable of selectively releasing waters of different temperatures can provide cooler or warmer water temperature downstream at times that are critical for other instream resources such as during periods of fish spawning and development of juvenile (Fontane et al., 1981; Hansen and Crumrine, 1991) fish. Temperature control in reservoir releases depends on:

- The volume of water stored in the reservoir
- The timing of the release relative to storage time
- The level from which the water is withdrawn

Stratified reservoirs can be operated to meet downstream temperature objectives to enhance a cold-water or warm-water fishery or to maintain pre-project stream temperature conditions. Release temperatures may also be important for irrigation (Fontane et al., 1981).

A useful tool for evaluating the effects of operational procedures on the quality of tailwaters is computer modeling. For instance, computer models can describe the vertical withdrawal zone that would be expected under different scenarios of turbine operation (Smith et al., 1987). Zimmerman and Dortch (1989) modeled release operations for a series of dams on a Georgia river and found that procedures that were maintaining cool temperatures in summer were causing undesirable decreases in dissolved oxygen and increases in dissolved iron in autumn. The suggested solution was a seasonal release plan that is flexible and depends on variations in the pool water quality and predicted local weather conditions. Care should be taken with this sort of approach to accommodate the needs of both the fishery resource and people enjoying reservoir recreation, particularly in late summer.

Flow Augmentation

Operational procedures such as flow regulation, flood releases, or fluctuating flow releases all have the potential for detrimental impacts on downstream aquatic and riparian habitat. When evaluating solutions associated with degraded aquatic and riparian habitat, stakeholders must balance operational procedures to address the needs of downstream aquatic and riparian habitat with the requirements of dam operation. There are often legal and jurisdictional requirements for an operational procedure at a particular dam that should be considered (USDOI, 1988).

Flushing Flows

A flushing flow is a high-magnitude, short-duration release for the purpose of maintaining channel capacity and the quality of instream habitat by scouring the accumulation of fine-grained sediments from the streambed. Availability of suitable instream habitat is a key factor limiting spawning success. Flushing flows wash away the sediments without removing the gravel. Flushing flows can also prevent the encroachment of riparian vegetation.

Flushing Flow
Photo: US Department of the Interior

Flushing flows are not recommended in all cases. Flushing flows of a large magnitude may cause flooding in the old floodplain or depletion of gravel in the river or stream below a dam. Routine maintenance of downstream areas generally requires a combination of practices rather than simply relying on flushing or scouring flows (Nelson et al., 1988).

Minimum flows

Several options exist for creating minimum flows downstream of the dam. The selection of any particular technique is site-specific and depends on several factors. These factors include adequate performance to achieve the desired instream and riparian habitat characteristic, availability of sufficient water quantities during periods when the minimum flows are needed, and cost.

Many rivers have minimum flow requirements for maintaining acceptable water levels for downriver water intakes or navigational channels. The requirements are usually translated into minimum thresholds of water releases at dams during certain times of the year.

Minimum flow requirements from dams for temperature or habitat are less common, but may exist if studies of waterways have established the need for such requirements. A good source of information about the need for minimum flows associated with water quality and habitat can be the Total Maximum Daily Limit studies conducted for larger watercourses. http://www.epa.ohio.gov/dsw/tmdl/index.aspx

Chapter 5

Best Management Practices for Fish Passage

Fish Passage Channel
Photo: National Oceanic and Atmospheric Administration

Practices to Maintain Fish Passage

The passage of fish over or around dams is critical to facilitating the migration of certain spawning species to areas upstream of dams and the movement of fish from spawning areas to downstream areas. Migrating fish populations are unable to safely travel upstream or downstream because of the presence of a dam if the dam has not been equipped with special features to accommodate fish passage. Selecting a device or management strategy for optimal fish passage in a stream or river occupied by a dam requires careful analysis of a variety of factors. The types of aquatic species, the type and operation of the dam and the physical characteristics of the river system all play a role in designing a fish passage system.

Examples of Best Management Practices that have been successfully used to maintain fish passage include but are not limited to spill and water budgets, fish ladders, and fish lifts. Transference of fish runs and installation of constructed spawning beds downstream of dams have also been used as alternatives to fish passage. Fish-protection systems such as physical barriers and behavioral barriers are available for hydropower facilities based on their mode of action (Stone and Webster, 1986).

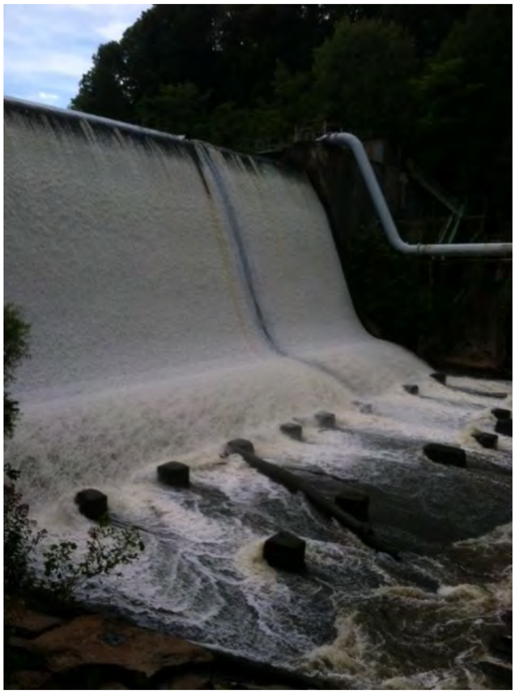
Devices such as fish ladders and bypass channels can help fish travel past dams, but may result in increased mortality due to the hardship and stress involved with passing through these structures (Larinier 2000). In addition, the fish passage structures have to be placed in a suitable entrance location, have a flow that is attractive to the species of concern, be continually maintained, and possess the hydraulic conditions necessary for the target species (Larinier, 2000). With all of these requirements, the success of a fish passage device is often uncertain.

Fish swimming into pipe
Photo: Sydney Morning Herald

The safe passage of fish either upstream or downstream through a dam requires a balance between operation of the facility for its intended uses and implementation of practices that will ensure safe passage of fish. The U.S. Fish and Wildlife Service and its partners have created a database that makes information about barriers to fish passage available to policy makers and the public. The database, known as the Fish Passage Decision Support System (FPDSS), https://ecos.fws.gov/fpdss/index.do, is part of the U.S. Fish and Wildlife Service's National Fish Passage Program, http://www.fws.gov/fisheries/whatwedo/NFPP/nfpp.html.

Hydropower Facilities and Fish Passage

Hydropower generation poses unique risks associated with downstream movement of fish. The use of hydropower in Ohio has diminished over the years due in large part to the availability of other energy sources. Roughly a dozen dams, mainly on rivers such as the Ohio, Auglaize or Scioto supply hydroelectricity to local users. The majority of dams that were once used for hydropower have ceased operation of the power generating facilities. The reduction in the use of turbines has reduced the potential for impacts to the downstream movement of fish populations since the fish no longer have to pass through turbines. The fish still may however pass over spillways and sluice gates that are in place at former hydropower dams. These spillways and sluice gates have their own impacts to fish moving downstream.



Gorge Dam - Cuyahoga Falls (Former Hydroelectric Dam)
Photo: ODNR

The 1995 United States Congress' Office of Technology Assessment (OTA) report on fish passage technologies at hydropower facilities provides an excellent overview of fish passage technologies and discusses some of the economic considerations associated with the safe passage of fish (OTA, 1995). The OTA report can be found at:
http://ota.fas.org/reports/9519.pdf

Managing Aquatic Invasive Species.

Aquatic Invasive species are a prevalent issue of concern for the rivers and streams of Ohio. Aquatic invasive species, including the sea lamprey and Asian carp, can prey on native fish species and diminish the quality of fish species diversity and health within a river or lake system. These are most notable in the Lake Erie rivers and streams. Many factors can influence the vulnerability of a river system for aquatic invasive species, including substrate, water quality, landscape features of the channel and proximity to its river confluences. An evaluation of sea lamprey impacts can be conducted with assistance from Ohio's Division of Wildlife in partnership with U.S. Fish and Wildlife.

The evaluation can assist in identifying the potential vulnerabilities for a removal or modification and design and management options to address the aquatic invasive species for a particular dam structure.

For more information contact: Ohio Department of Natural Resource, Division of Wildlife:
http://wildlife.ohiodnr.gov/about-contacts/contact-information

Additional resources for Sea Lamprey Management:
U.S. Fish and Wildlife: http://www.fws.gov/midwest/Fisheries/sea-lamprey.html

Additional Information pertaining to http://www.glfc.org/sealamp/

Fish Ladders

Fish ladders have been a commonly used structure to enable the safe upstream and downstream passage of mature fish. There are five basic designs: Pool-weir, Denil, Vertical slot, Steep pass and Rock Ramp Channel. Pool-weir fish ladders are one of the oldest and most commonly designed fish passage structures. They consist of stepped pools and weirs that allow fish to pass from pool to pool over the weirs. Pool-weir fish ladders are normally used on slopes of about 10-degrees.

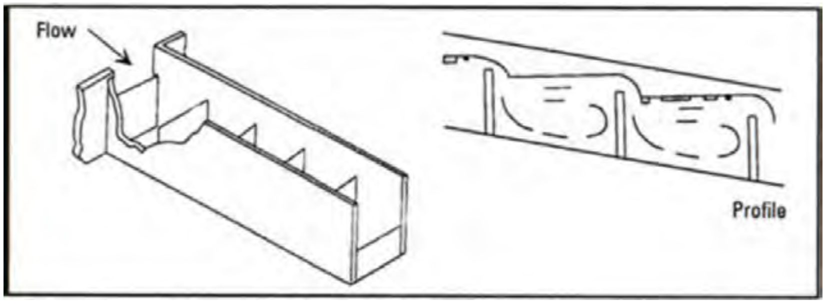


Diagram of a pool and weir fish passage
Photo: The Connecticut River Watershed Council

Some pool-weir fish ladders can be modified to increase the possible number of fish that pass the dam. This is done by including submerged orifices that allow fish to pass the fish ladder without cresting the weirs. OTA (1995) provides details on design and operation of various forms of fish ladders.

Denil fish ladders are elongated rectangular channels that use internal baffles to dissipate flow energy and allow fish passage. They are widely used in the eastern United States due to their ability to pass a wide range of species (from salmonids to riverine) over a wider range of flows than pool-weir ladders. Denil ladders can be used on slopes from 10 to 25 degrees although 10 to 15 degrees is optimal.

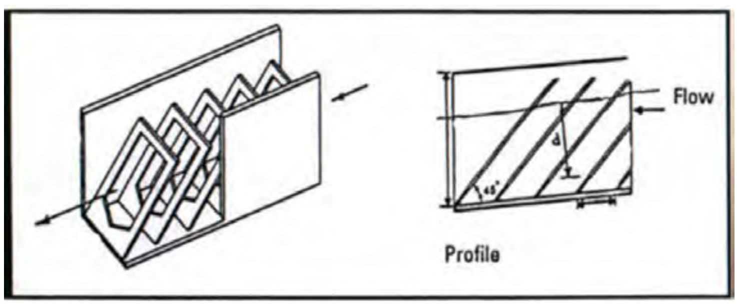
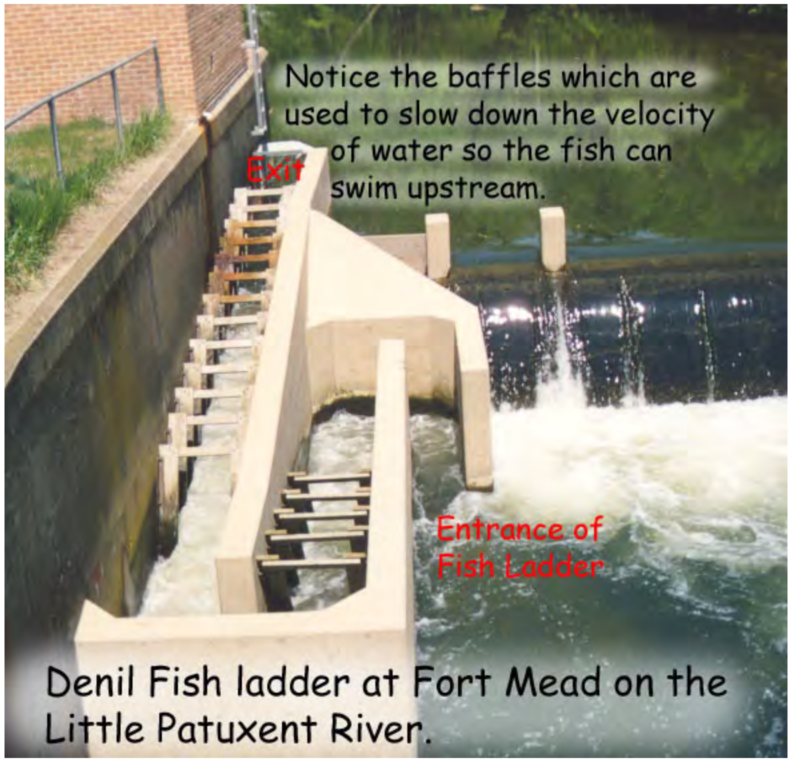


Diagram of a Denil fish passage
Photo: The Connecticut River Watershed Council

Most Denil fish ladders are 2 - 4 feet wide and 4 - 8 feet deep. This fish ladder design allows fish to pass at a preferred depth instead of through a jumping action. Denil ladders do not have resting areas and the fish must either be able to pass the ladder in one burst or resting pools must be provided between sections. Resting pools should be provided every 16 to 50 feet depending upon the species being passed. The high flow rates and turbulence associated with Denil fish ladders reduces the need for concentrated flows to attract fish to the entrance of the ladder.



Denil Fish Passage
Image: Maryland DNR

Vertical slot fish ladders are elongated rectangular channels that use regularly spaced baffles to create steps and resting pools. The vertically oriented slots in the baffles allow fish to pass through the ladder at a preferred depth. Unlike Denil fishways, vertical slot fishways provide a resting area behind each baffle. This allows fish to pass in a "burst-rest" manner instead of one sustained motion. The channel created by the baffles is off-center, making the baffles on one side of the ladder wider than the opposing side. Eddies that form behind longer baffles allow fish to rest and eliminates the need for resting areas.

Vertical Slot Fish Ladder
Photo: Oregon Department of Fish and Wildlife

Although vertical slot ladders are usually operated at slopes of about 10 degrees, they can be operated over a larger variety of flows. The vertical slots create a water jet that is regulated by the pool on the downstream side of it. This creates a uniform, level flow throughout the ladder.

The steep pass fish ladder, often referred to as the "Alaska steeppass," is a modified Denil fish ladder most commonly used in remote areas for the passage of salmonids. Steep pass fish ladders are usually constructed of lightweight materials such as aluminum and can operate on slopes up to 33 percent. The construction materials and design allow this type of fish ladder to be deployed as a single unit to remote areas. The baffles used in steep pass ladders are more aggressively designed, which allow the ladder to more effectively control water flow. Due to their narrow design, steep pass ladders are more susceptible to clogging due to debris and changes in flow upstream or downstream of the ladder.


Steep Pass Fish Ladders
Photo: Maryland DNR, University of Massachusetts

Although fish ladders can be efficient at passing fish, small changes in design have been shown to significantly improve their functionality. A good example of this is the John Day Dam located on the Columbia River. The original design focused on the passage of salmonids and therefore only passed about 17 percent of the American shad (*Alosa sapidissima*) using the ladder. Research indicated that simple design changes could allow for the passage of riverine species such as American shad. By changing the placement of the weirs within the fish ladder, the fish ladder was able to pass 94 percent of the salmonids, and American shad passage increased to 74 percent (Monk et al., 1989).

Fish Ladder – John Day Dam
US Department of the Interior

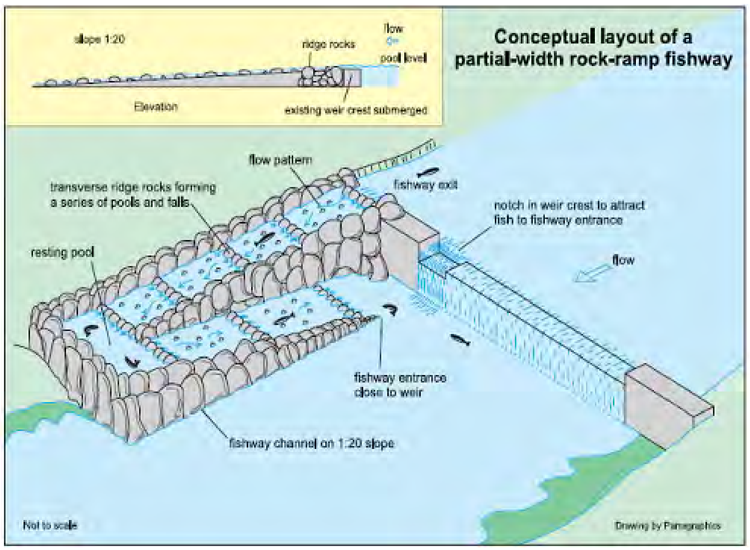
According to the US Army Corps Engineers, Portland District (1997), the success rate for adult fish negotiating fish ladders at dams in the Columbia River Basin is about 95 percent. The U.S. Fish and Wildlife Agency designs fish passages with an assumption that they will achieve a 90 percent efficiency rate. Few studies document actual efficiency of fish ladders, but it is recognized that not all fish passages are equally effective (for various reasons, such as predation or physical damage to passing fish). Some fish passages installed in the last 20 years are less effective than newer ones (when federal licenses began to include fish passage requirements).

Maine Department of Marine Resources (DMR) estimates efficiency between 75 and 90 percent (Presumpscot River Plan Steering Committee, 2002).

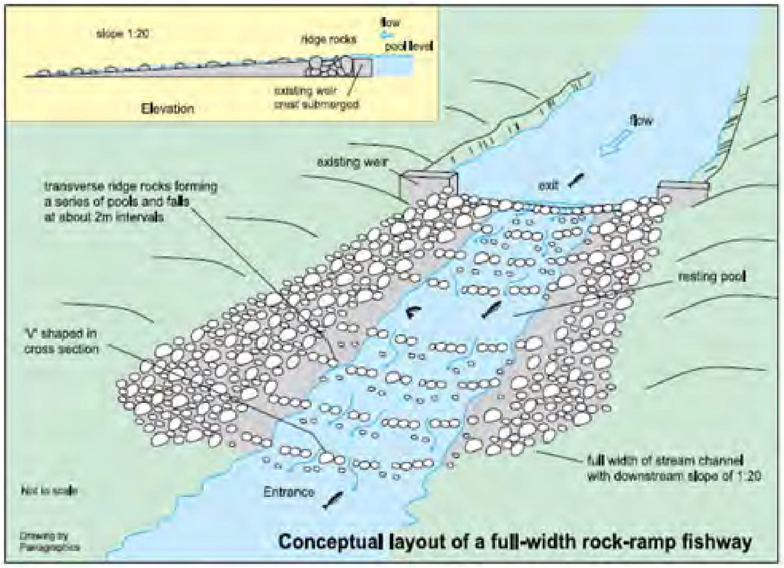
An additional resource on fish ladders can be found at Michigan DNR. *What is a fish ladder?* Michigan Department of Natural Resources, Lansing, MI.

Rock Ramp Channels

Rock ramp channels can be utilized with many types of dams, but may be most useful with lowhead or channel dams. The rock ramp channels may extend partially across the dam or can potentially extend across the entire width of the channel with smaller dams.



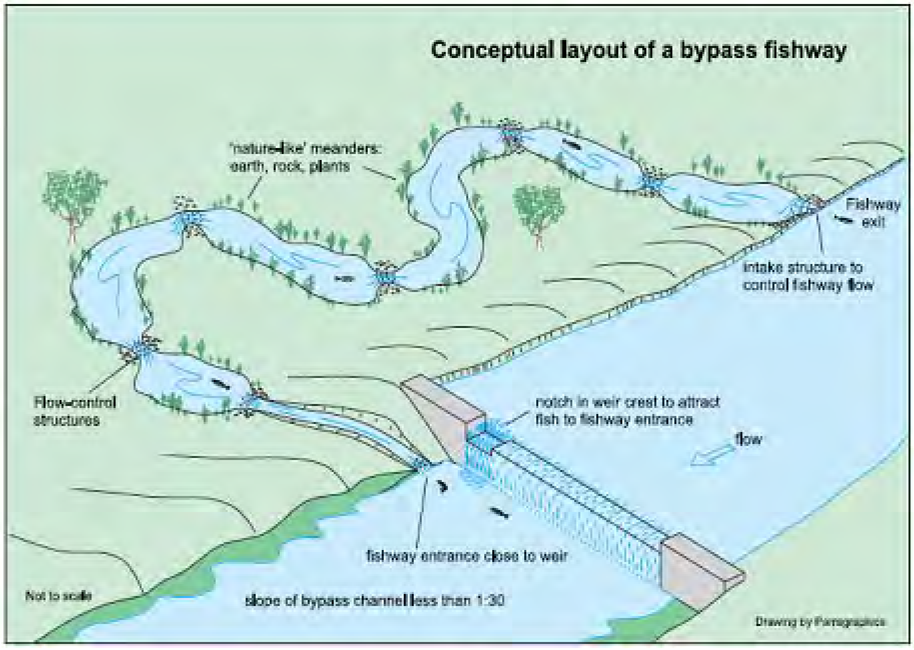
Conceptual Layout of a Partial-Width Rock Ramp Fishway
Photo: Thorncraft and Harris 2000, USACE



Conceptual Layout of Full-Width Rock Ramp Fishway
Photo: Thorncraft and Harris 2000, USACE

Adequate room must be available below the dam to account for an approximate slope of 1 foot vertical to 20 feet horizontal along the ramp. Stone sizes in the main channel of the stream or river must be adequate to withstand the forces of the water during high flow events. Room to incorporate resting pools for fish swimming upstream is important in the design, and in the case of partial width dam a notch in the dam or some other device to provide flow over the top of the dam is needed near the entrance of the channel to attract fish to the channel.

An alternative design is to contruct a bypass fishway along the side of the dam. Such a fishway can be designed with a shallower slope (1 vertical to 30 horizontal), and be designed to more closely resemble a stream with larger riffle and pool settings. More lateral room is needed for a bypass fishway, and surrounding topography may limit the potential use of this Best Management Practice. An advantage to installing a bypass fishway is that the lower slope and more natural system of pools and riffles will enhance the ability other aquatic organisms to travel up the fishway and upriver of the dam.



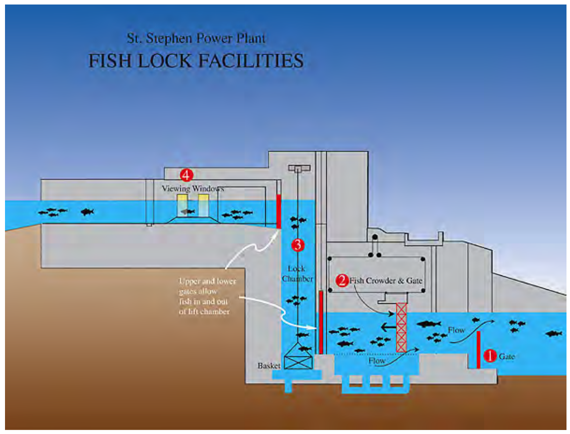
Conceptual Layout of Bypass Fishway
Photo: Thorncraft and Harris 2000, USACE

Fish Lifts

Fish lifts describe both fish elevators and locks which are used to capture fish at the downstream side of a structure and then move them above the structure. Like fish ladders, these systems require sufficient attraction flow to move fish into the lift area. Lift systems can be advantageous because they are not specific to species or flows. They can also be employed at structures too tall for fish ladders and to pass species with reduced swimming ability.

Fish Lift
Photo: South Carolina DNR

Lift systems have the potential to move large numbers of fish if they are operated efficiently. These systems can be automated to allow operation much like fish ladders. Fish lift systems do require additional operation and maintenance costs and are subject to mechanical failures not associated with fish ladders.



Fish Lift system
St. Stephen Power Plant

Most lift systems require either an active or passive bypass system to move fish far enough upstream to avoid entrainment in the flow through the dam. Passive bypass systems may include constructed waterways or pipes that discharge the passed fish sufficiently up-stream of the structure.

Active Bypass Systems

Active bypass systems include trucking and pumping operations that discharge the fish safely upstream of the structure. Active bypass systems, especially pumping systems, have come under scrutiny for fish behavior and health reasons. During the pumping process, fish may be subject to descaling and/or death due to overcrowding. After release, the fish may have orientation problems and therefore be subject to higher rates of predation mortality. Due to these concerns the United States Fish and Wildlife service has generally opposed the use of fish pumps (OTA, 1995)

Alternatives to Fish Passage

Spill and Water Budgets

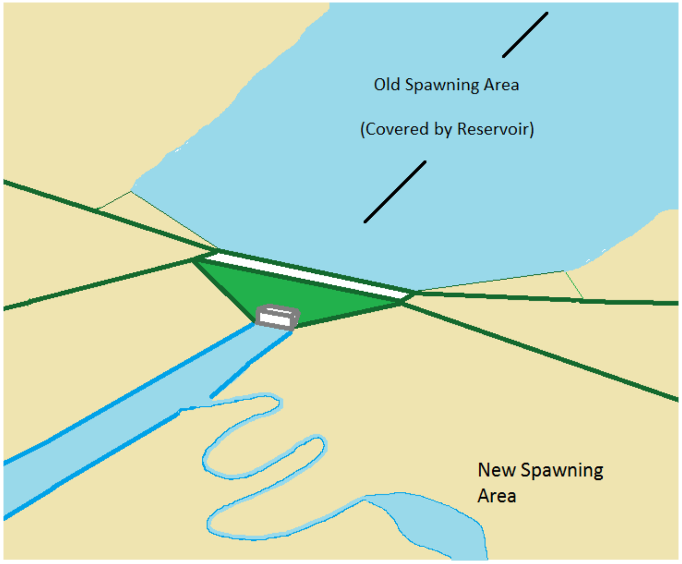
Most of the focus on movement of aquatic lifeforms at dams is on creating opportunities for passage upstream. Spill and water budgets focus on the safe migration of aquatic species from upstream to downstream of a dam. Although often used together, spill and water budgets are independent methods of facilitating downstream fish migration.

Spill budgets provide alternative methods for fish passage that are less dangerous than passage through turbines. Spillways are used to allow fish to leave the reservoir by passing over the dam rather than through the turbines. The spillways must be designed to ensure that hydraulic conditions do not induce injury to the passing fish from scraping and abrasion, turbulence, rapid pressure changes, or supersaturation of dissolved gases in water passing through plunge pools (Stone and Webster, 1986).

Water budgets increase flows through dams during the out-migration of fish species. They are used to speed smolt migration through reservoirs and dams. Water normally released from the impoundment during the winter period to generate power is instead released in May or June, when it can be sold only as secondary energy. This concept has been used in some regions of the United States, although quantification of the overall benefits is lacking (Dodge, 1989).

Transference of Fish Runs

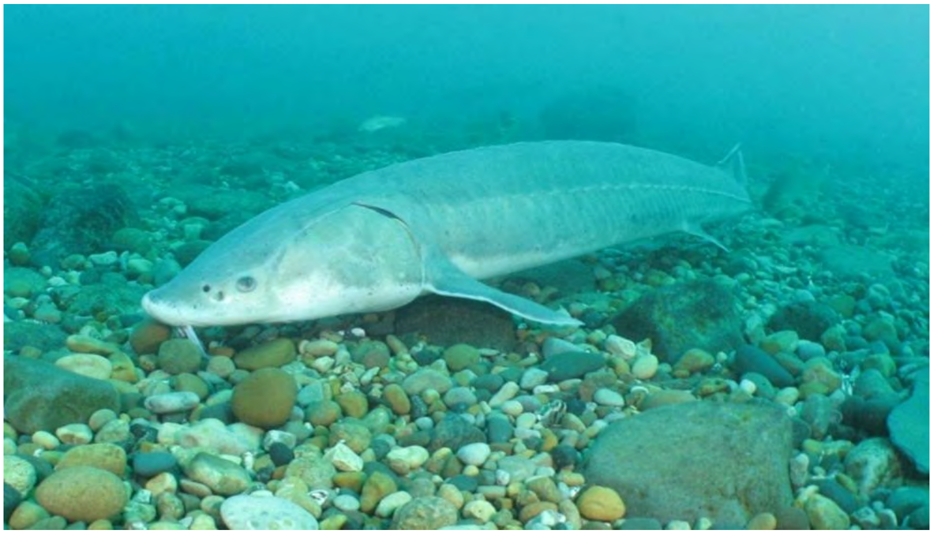
Transference of fish runs involves persuading fish species to use different spawning grounds in the vicinity of an impoundment. To implement this practice, the nature and extent of the spawning grounds that were lost due to the blockage in the river need to be assessed, and suitable alternative spawning grounds need to be identified and created.



Creating alternative spawning areas
Photo: ODNR

The feasibility of successfully collecting the fish and transporting them to alternative tributaries also needs to be carefully determined. One strategy for mitigating the impacts of diversions on fisheries is the use of ephemeral streams as conveyance channels for all or a portion of the diverted water. If flow releases are controlled and uninterrupted, a perennial stream can be created along with new instream and riparian habitat. However, the aquatic organisms that had been adapted to preexisting conditions in the ephemeral stream will probably be eliminated.

Constructed Spawning Grounds



Constructed Spawning Reefs
St Clair River
Photo: Michigan Sea Grant

A spawning bed or reef is an underwater location where fish spawn for reproduction purposes. When dams are constructed across streams and rivers, the dam may block access to spawning areas upstream of a dam. Spawning beds and reefs have been created in ponds, streams, reservoirs, lakes and rivers to address these concerns.

One way to partially address the loss of access to upstream spawning areas is to create or enhance spawning beds in the areas downstream of the dam. While the newly created or enhanced spawning beds may not be able to replicate the original spawning beds, they may be able to partially offset the impact caused by loss of access to the original areas. Knowledge of the native fish populations in the stream or river, the current and previous morphology of the watercourse, the flow patterns and water depths associated with various flows, and the amount and composition of sediment resources in the river are all essential in determining where spawning beds might be viable.

Different fish species utilize different areas for spawning. Some prefer ponded areas with low velocity or still water, while others prefer fast moving water with high oxygen levels. Coarse gravel or cobble substrates attract certain fish species, while other species lay eggs in mud, sand or silt. Spawning beds may be in sheltered areas with debris such as fallen timber, brush or stumps. Other beds are located in the open with direct exposure to sunlight. Some beds are best located in shallow water, while others are more viable in deeper water. Restoring a stream to a natural channel system with riffles and pools can play a large role in creating or enhancing fish spawning beds (see Chapter 4).

Fish Protection Systems

Physical Barriers

Physical barriers are diversion systems that lead or guide fish to bypass systems that transport the fish above or below the dam (FAO, 2001). Physical diversion structures deployed at dams include angled screens, drum screens, inclined plane screens, louvers, and traveling screens. The success and effectiveness of physical barriers has been found to be specific to individual hydropower facilities (Mattice, 1990).

Angled screens are used to guide fish to a bypass by guiding them through the channel at some angle to the flow. Coarse-mesh angled screens have been shown to be highly effective with numerous warm- and cold-water species at adult life stages. Fine-mesh angled screens have been shown in laboratory studies to be highly effective in diverting larval and juvenile fish to a bypass with resultant high survival. Performance of angled screens can vary by species, stream velocity, fish length, screen mesh size, screen type, and temperature (Stone and Webster, 1986). Clogging from debris and fouling organisms is a maintenance problem associated with angled screens.

Angled rotary drum screens oriented perpendicular to the flow direction have been used extensively to lead fish to a bypass. Angled rotary drum screens tend not to experience the major operational and maintenance clogging problems of stationary screens, such as angled vertical screens. Maintenance of angled rotary drum screens typically consists of routine inspection, cleaning, lubrication, and periodic replacement of the screen mesh (Stone and Webster, 1986).

An inclined plane screen is used to divert fish upward in the water column into a bypass. Once concentrated, the fish are transported to a release point below the dam. An inclined plane pressure screen at the T.W. Sullivan Hydroelectric Project (Willamette Falls, Oregon) is located in the penstock of one unit. The design is effective in diverting fish, with a high survival rate. However, this device has been linked to injuries in some species of migrating fish, and it has not been accepted for routine use (Stone and Webster, 1986).

Louvers consist of an array of evenly spaced, vertical slats aligned across a channel at an angle leading to a bypass. The turbulence they create is sensed and avoided by the fish (Stone and Webster, 1986). Louver systems rely on a fish's instincts to use senses other than sight to move around obstacles. Once the louver is sensed, the fish tend to reverse their head first downstream orientation (to head upstream, tail to the louver) and move laterally along it until they reach the bypass (OTA, 1995).

Submerged traveling screens are used to divert downstream migrating fish out of turbine intakes to adjoining gatewell structures, where the fish are concentrated for release downstream. This device has been tested extensively at hydropower facilities on the Snake and Columbia Rivers. Because of their complexity, submerged traveling screens must be continually maintained. The screens must be serviced seasonally, depending on the debris load, and trash racks and bypass orifices must be kept free of debris (Stone and Webster, 1986).

Physical barrier fish diversion systems have been found to work best when specifically designed to the structure and fish being passed. Small differences in design, such as the spacing or depth of the louvers, can mean the difference in success and failure. A successful louver system has been installed at the Holyoke Hydroelectric Power Station, on the Connecticut River. This partial depth louver system was installed in the intake channel at the power plant and successfully passed 86 percent of the juvenile clupeids and 97 percent of the Atlantic salmon (*Salmo salar*) smolts (Marmulla, 2001). Another partial depth louver system on the same river has experienced less successful results. The system installed at the Vernon Dam on the Connecticut River is successfully passing about 50 percent of the Atlantic salmon smolts (OTA, 1995).

Behavioral Barriers

Behavioral barriers use fish responses to external stimuli to keep fish away from intakes or to attract them to a bypass. Since fish behavior is notably variable both within and among species, behavioral barriers cannot be expected to prevent all fish from entering hydropower intakes.

Environmental conditions such as high turbidity levels can obscure some behavioral barriers, such as lighting systems and curtains. Competing behaviors such as feeding or predator avoidance can also be a factor influencing the effectiveness of behavioral barriers at a particular time.

Electric screens, bubble and chain curtains, light, sound, and water jets have been evaluated in laboratory or field studies and show mixed results. Despite numerous studies, very few permanent applications of behavioral barriers have been realized (EPRI, 1999). Some authors suggest using behavioral barriers in combination with physical barriers (Mueller et al., 1999).

Electrical screens keep fish away from structures and guide them into bypass areas for removal. Fish seem to respond to the electrical stimulus best when water velocities are low. Tests of an electrical guidance system at the Chandler Canal diversion (Yakima River, Washington) showed efficiency ranging from 70 to 84 percent for velocities of less than 1 ft/sec. efficiencies decreased to less than 50 percent when water velocities were higher than 2 ft/sec (Pugh et al, 1971). Success of electrical screens may be specific to species and fish size. An electrical field strength suitable to deter small fish may result in injury or death to large fish, since total fish body voltage is directly proportional to fish body length (Stone and Webster, 1986). Electrical screens require constant maintenance of electrodes and associated underwater hardware to maintain effectiveness. Surface water quality can affect the life and performance of electrodes.

Bubble and chain curtains are created by pumping air through a diffuser to create a continuous, dense curtain of bubbles, which can cause an avoidance response. Many factors affect fish response to the curtains, including temperature, turbidity, light, and water velocity. Bubbler systems should be constructed from corrosion-resistant materials and be installed with adequate positioning of the diffuser away from areas where siltation might clog the air ducts. Hanging chains provide a physical, visible obstacle that fish avoid. They are species-specific and life stage-specific. Efficiency of hanging chains is affected by such variables as velocity, instream flow, turbidity, and illumination levels. Debris can limit their performance. In particular, buildup of debris can deflect chains into a nonuniform pattern and disrupt hydraulic flow patterns.

Strobe lights repel fish by producing an avoidance response. A strobe light system at Saunders Generating Station in Ontario, Canada was found to be 67 to 92 percent effective at repelling or diverting eels (EPRI, 1999). Turbidity levels can affect strobe light efficiency. The intensity and duration of the flash can also affect the response of the fish; for instance, an increase in flash duration has been associated with less avoidance. Strobe lights have the potential for far-field fish attraction, since they can appear to fish as a constant light source due to light attenuation over a long distance (Stone and Webster, 1986). Strobe lights at Hiram M. Chittenden Locks in Seattle, Washington were examined to determine how fish respond, depending on strobe light distance. Vertical avoidance was 90 to 100 percent when lights were 0.5 meters away, 45 percent when 2.5 meters away, and 19 percent when 4.5 to 6.5 meters away (EPRI, 1999).

Mercury lights have successfully attracted fish to passage systems and repelled them from dams. Studies suggest their effectiveness is species-specific; alewives (*Alosa pseudoharengus*) were attracted to mercury light, whereas coho salmon (*Oncorhynchus kisutch*) and rainbow trout (*Oncorhynchus mykiss*) displayed no attraction to the light (Stone and Webster, 1986). In a test on the Susquehanna River (Maryland, Pennsylvania, and New York), mercury lights attracted gizzard shad (OTA, 1995). Although results have been mixed, low overall cost of the systems has led to continued research on their effectiveness (Duke Engineering & Services, Inc., 2000).

Underwater sound, broadcast at different frequencies and amplitudes, has been effective in attracting fish away from dams or repelling fish from dangers around dams, although the results of field tests are not consistent. Fish have been attracted, repelled, or guided by the sound. Not all fish possess the ability to perceive sound or localized acoustical sources (Harris and Van Bergeijk, 1962). Fish also frequently seem to become habituated to the sound source.

Poppers are pneumatic sound generators that create a high-energy acoustic output to repel fish. Poppers have effectively repelled warm-water fish from water intakes. Laboratory and field studies in California indicate avoidance by several freshwater species such as alewives (*Alosa pseudoharengus*), perch, and smelt. Operation and maintenance considerations include frequent replacement of "O" rings, air entrainment in water inlets, and vibration of structures associated with the inlets.

Water jet curtains create hydraulic conditions that repel fish. Effectiveness is influenced by the angle at which water is jetted. Although effectiveness averages 75 percent (Stone and Webster, 1986), not enough is known to determine what variables affect performance of water jet curtains. Important operation and maintenance concerns would be clogging of the jet nozzles by debris or rust and the acceptable range of stream flow conditions, which contribute to effective results.

Hybrid barriers or combinations of different barriers can enhance the effectiveness of individual behavioral barriers. Laboratory studies showed a chain net barrier combined with strobe lights to be up to 90 percent effective at repelling some species and sizes of fish. Tests of combining rope net and chain-rope barriers have shown good results. Barriers with horizontal and vertical components in the water column are more effective than those with vertical components alone.

Barriers with a large diameter are more effective than those with a small diameter, and thicker barriers are more effective than thinner barriers. Effectiveness of hanging chains was increased when used in combination with strobe lights. Effectiveness also increased when strobe lights were added to air bubble curtains and poppers (Stone and Webster, 1986).

Chapter 6

Best Management Practices for Dam Modification/Removal

Dam Removal
Photo: Ohio DNR

Exploring Dam Removal

Ohio has dams that have been in service for well over a century. Many of these dams still provide flood control, stormwater management, water supplies, and in a few cases power generation. These and many other dams built in the last century provide recreational boating and fishing opportunities to Ohio's citizens, and in some circumstances have helped create and restore wetland habitats.

Other dams in Ohio have outlived their original purposes. Many dams constructed to create pools for grist mills are no longer needed. Dams constructed to collect and distribute water for canals and other waterways are no longer used to support water commerce. Lowhead dams constructed to provide pools for recreational fishing have been found to create barriers to fish migration and impacts to aquatic habitats.

Former Coho Dam – Huron, Ohio
Photo: ODNR

The cost of maintenance and repairs, the age of many dams, and the usefulness of the dams in serving their original purposes are all factors in reviewing whether a dam might be modified or removed. Navigational safety, liability issues associated with dam ownership, and opportunities to restore fisheries, stream health and water quality are additional factors that play a role in determining whether to maintain, upgrade, repair, modify or remove dams in Ohio's streams and rivers.

Collecting Information about a Dam

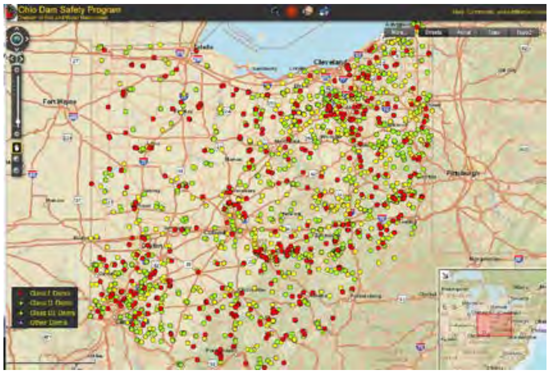
Decisions about removing or modifying a dam are complex. Removal of a dam can have wide ranging consequences for users of the watercourse and the impoundments associated with a dam. The physical environment of the stream, river and associated floodplains may undergo substantial changes if a dam is removed or modified. Decisions about whether to proceed with a dam modification or removal are based upon a number of factors, and as much information as possible should be collected to assist in determining whether to remove or modify a dam.

Decisions about dam removal or modification generally occur through consideration of a series of issues. These issues contribute to a weighing of the benefits and drawbacks for removing or modifying a dam. The following categories of issues (The Heinz Center 2002, The Aspen Institute, 2002) cover topics pertinent to dam removals:

- Social Issues
- Economic Issues
- Safety and Security Issues
- Environmental Issues
- Legal and Administrative Issues

Each of these categories of issues is explored in more detail later in this chapter. A series of questions have been developed for each category to assist in obtaining further information about the issues.

Information about a dam can be collected through a variety of sources, including public agencies involved in watershed management or dam safety permitting an inspection. Obtaining basic information about the dam and waterway where is it located provides a foundation for further collection of information.



https://gis.ohiodnr.gov/MapViewer/?config=ohiodams

The Ohio Department of Natural Resources Dam Safety Program has information regarding all the dams regulated under the Ohio Dam Safety Laws. It also has information about many of the smaller dams that are exempt from regulation under dam safety laws. A web based GIS program is available through the dam safety program for identifying dams and collecting information. A listing such information may include:

Basic Dam Information:

Name of Dam:
Dam Owner:
City/Village/Township:
County:
x-y coordinates (Latitude/Longitude):
Reservoir/River/Stream Name(s):
Approximate River mile:
Stream/River classification
Stream Order :
Hydrologic Unit Code:
Type of Structure: (Low head dam, earth embankment, arch concrete dam, etc.)
Class (I, II, III, IV, unclassified, exempt):
Year constructed:
Year modification(s) made (if applicable):
Original Purpose of Dam/Reservoir:
Current uses of Dam/Reservoir:

This information can be used as the foundation for acquiring further information and developing answers to questions about the dam and the watershed influenced by the dam. Many questions need to be investigated and answered as the future of the dam is explored. The following set of general questions should be answered to reinforce the basic information collected about the dam:

General Questions

What is the Basic Purpose/Reason for considering the modification or removal of the dam?
What are the past, current, and future potential uses of the dam and the impoundment?
What are the future potential uses of the stream/river if the dam is removed?
How does the existing structure fit into the overall management plan for the river system? Do the operations of the dam and associated water controls fit into a broader context of a river basin control plan?
Is the dam or pool a critical element to meeting any legal agreements and/or providing a service to the local economy? Examples include but are not limited to flood control, water supply, power production, irrigation, fire protection, or recreation?
Will modifications need to be made to structures such as bridges, road culverts or other dams upstream or downstream of the dam is the dam is modified or removed?

Social Issues

The following social issues may be associated with the existing dam as well as with its removal. Examples of questions that might be addressed include the following:

Are there changes that might occur to the types of and access to recreational opportunities?
How many boaters, anglers, or other recreational users might be impacted by a removal?
What types of impacts are anticipated? Are the impacts to those users positive or negative?
Are there effects on local and regional populations in terms of economics or economic stability (or lack thereof), water supply, and/or loss of access to traditional uses of areas?
Are there direct and indirect effects on the cultural relationships of the people to the river?
Are there direct and indirect impacts related to any necessary service that was provided by the dam, and how will this service be replaced?
How will dam removal affect aesthetic values in the area for individual property owners or the public in general?
Does the dam honor a person, group or organization?
Are there historical values associated with the dam or the impoundment it creates?

Economic Issues

A variety of economic issues may be associated with the dam removal project. Examples of questions to be asked include the following:

What are the long-term and short-term costs of maintaining the dam versus the cost of removal?
What are the potential costs (estimates) of repair and annual maintenance of the existing facility? Have accurate cost and time estimates been developed for the removal project?
Have all costs and benefits been identified?
What are the sources of funding that have been identified for removal or restoration efforts?
Who is financially responsible for the dam and for any damage that might occur if the dam were breached (intentionally breached or breached during a flood event)?
Is the dam providing a service that will need to be replaced by some alternative?
What are the costs of alternative measures to mitigate project impacts?
Are there financial criteria that must be met or maintained if the project utilizes public funds?
What is the status of the repayment on the debt for the project? Has it met the financial criteria defined in its authorization language if it was a public project?

Safety and Security Issues

Issues associated with safety and security at a dam keeping or removing the existing structure. Questions to address include the following:

Is the dam regulated by the Ohio Dam Safety Program? Does the dam currently meet Dam Safety standards?
Is there a significant potential for loss of life, injury, and/or property damage if the dam should fail or be removed?
Is the dam vulnerable to failure because of either aging or inadequate maintenance? What are the major deficiencies?
Are people safe around the dam (playing on dam (broken concrete, slipping off, etc.))? Have there been any known injuries or deaths caused by the presence or condition of the dam?
Are there Boating Safety issues (hydraulics, rollers, etc.)? Would safety be improved if the dam is removed?
Is there a safe portage around the dam?

Environmental Issues

Identify environmental issues associated with keeping or removing the existing structure. Depending on the site, the following questions should be addressed:

What water quality and habitat assessments have been completed?
Will removal of the structure help to enhance the recovery of threatened or endangered species?
If yes, what species would benefit?
If yes, how will dam removal enhance the recovery of the species?
What species may need to be reintroduced or relocated to the exposed mudflats/bank areas after dam removal?
What costs would be associated with the reintroduction/relocation effort?
Will removal of the structure lead to changes in the distribution of unwanted invasive species?
If yes, what invasive species?
If yes, how will the removal of this dam lead to an increase in or migration of invasive species?
What is the natural ability of the stream or river to carry sediments and how does this relate to the sediment currently deposited behind the dam?
Will removing the dam cause sediment to move downstream? What impacts will the sediment have on stream or river morphology?
Are there likely to be problems associated with contaminated sediments currently contained behind the dam if the dam is removed? If yes, what contaminated sediments are of concern?
Are there other potential beneficial uses for the removed sediments?
Will dam removal lead to a net gain or loss in wetland areas?
Have so many other changes occurred in addition to the dam that removal of the dam will not achieve the desired ecosystem restoration goals?
What is the relationship of the dam and its removal to other parts of the watershed?
Will drinking water surface or groundwater supplies be affected?
What time of year would be ideal for the dam removal, considering safety, weather, and environmental issues such as fish spawning, flooding, etc.?

Legal and Administrative Issues

Evaluate concerns and needs from a legal and process perspective. Questions that should be addressed include the following:

Are there current existing or potential conflicts with laws and regulations designed to protect natural systems or address safety issues? • Clean Water Act • Endangered Species Act • National Flood Insurance Program • Federal Energy Regulatory Commission • Rivers and Harbors Act (Section 9, 10) • OEPA Section 401 Water Quality Certification • Ohio DNR Dam Safety Program
Are there current existing or potential conflicts with laws and regulations designed to protect social, historical, or cultural values? (e.g., Section 106 National Historic Preservation Act, tribal water rights)
Are there existing contracts for water supply and delivery that would be affected by dam removal?
Are there issues related to removal or modification that might be a factor if certain Federal funds were used in the construction?

Collecting information about the dam and the waterway on which it sits, and developing answers to questions about the Economic, Social, Safety, Security, Environmental, Legal and Administrative issues, will help prepare the foundation for the next steps. Decisions about whether to modify or remove a dam can be complex and involve many stakeholders. A competent public involvement process and well defined pathways for making decisions are also essential tools in reaching a consensus on whether action is needed with respect to a dam removal or modification. Having basic information about the dam, the watershed and the issues surrounding the dam will help facilitate the Public Involvement Process and lead to informed decisions.

Public Involvement and Decision Making

In addition to the issues that should be investigated through the questions posed above, consideration should be given to the role of the public and the process of deciding to remove or modify a dam. Those in charge of considering a dam for removal or modification should identify the public involvement issues and planning associated with the dam removal project.

Examples of questions to be considered include the following:

Who are the primary local, regional, state and federal political stakeholders?
What plans have been made to involve stakeholders in the discussion?
What are the stakeholders opinions about dam removal (if known)?
How will their opinions be sought throughout the process?
What plans have been made to involve the public? Has the public been notified?
What is the general public opinion about the project?
How will information on the project be communicated to all interested parties?
What are the main factors in the decision making process?
How will the final decision be made?

Removal or Modification of the Dam

In addition to collecting information and answering questions about social, environmental, legal, economic, safety and security issues, the practicality of safely removing the dam must be carefully considered. Dams range in size, composition, purpose, location and amount of water impounded. The removal of a small lowhead dam on a stream can be significantly different in scope and complexity than removal of a large dam on a major river.

Key issues about dam removal include

- Dewatering of the impoundment upstream of the dam
- Access to the dam by construction equipment
- Deconstruction of the dam
- Removal and disposal of accumulated sediment and debris
- Restoration of exposed mud flats and banks upriver of the dam

These issues are explored in more detail below.

Dewatering

Before removal of the actual dam begins, the water impounded upstream of the dam needs to be drained. This removes the pressure of the water on the dam, allowing the dam to be removed safely while decreasing the risk of flooding areas downstream. Most dams can be dewatered by releasing water through lake drains, spillways, gates, and in some cases through the use of pumps. Water levels upstream of lowhead dams with constant flows across the top of the dams may be lowered by continuous notching a section of the dam, slowly allowing the water surface to readjust to a lower level.

Lowering of water levels upstream of Lefever Dam
Photo: Ohio DNR

Lowering the water level upstream of a dam must be done carefully, and it may take days if not weeks to safely drain the impoundment. Earthen dams are susceptible to instability in the upstream slope face when water levels are lowered, and conditions must be carefully monitored when draining the water. Impoundments that are fed by rivers and streams will accumulate water while the water levels are lowered, and the amount of water delivered by the stream or river needs to be accounted for in estimating the time it will take to dewater the impoundment.

Managing the water impounded by the dam and flowing through the site is a key component of dam removal. After dewatering the impoundment there is still a risk that meteorological events might supply large volumes of water to the impoundment while deconstruction is occurring. The risk of water filling up the impoundment while the dam is being deconstructed and subsequently causing the remaining dam to breach should be carefully considered and accounted for in the sequence of deconstruction activities.

Access

Many dams were constructed decades and even centuries ago. Access points that were used to construct the dam may no longer be available for deconstruction of the dam. Permissions from adjoining property owners might be needed in order to gain access to the dam by heavy equipment. Some dams are located in remote areas, and roadways leading to these areas may be unable to handle the loading from the heavy equipment needed to remove the dam. Other dams are located in highly developed urban areas with limited opportunities for access.

Access road constructed under bridge
Photo: ODNR

Access locations may be needed to remove the remains of the dam, and also might be used to transport accumulated sediment and debris from the site. Constructing access roads that can handle the expected loads and frequency of use must be carefully considered. Travel by vehicles from access locations onto local, state and federal roadways must be approved by the entity in charge of the roadway. Permits for entry from access roads to public roadways may be needed, and temporary traffic controls may be required for vehicles entering and exiting the road at the access points.

Deconstruction

The deconstruction of the dam must be carefully evaluated and planned. The approach to deconstructing the dam will be partially dictated by the design of the dam and the methods used to initially construct the dam. A dam built mainly with reinforced concrete will be disassembled in a different manner than a dam built mainly out of compacted earth. Concrete with reinforcing steel may need to be drilled and/or jackhammered, and can be difficult to pull apart into manageable pieces of debris. Excavators and large earthmoving equipment will most likely be used to deconstruct an earthen dam.

Dam Removal – Cuyahoga Falls
Photo: ODNR

Removal and disposal of dam debris can be a significant part of the cost of removal of the dam. Substantial quantities of earth, concrete, steel and stone may need to be transported to other on site or off site locations. Reuse of stone and concrete pieces (that have been cleared of reinforced steel) for stream or river restoration efforts can reduce the costs of transporting material off site.

Sediment Removal

Once a dam is installed, sediment tends to accumulate upstream of the dam. Most of the sediment will come from streams and rivers that empty into the impoundment created by the dam. The sediment can accumulate where streams and rivers enter the impoundment, at the upstream base of the dam, and over time throughout the impoundment.

The quantity of sediment and the time it takes to accumulate upstream of the dam in the impoundment can vary greatly. Streams and rivers traveling through areas of erodible soils may supply substantially more sediment to an impoundment than areas with less erodible soils. Rapidly moving waters in streams and rivers may carry more sediment and may cause erosion of the bed of a stream or river, resulting in more sediment moving into the impoundment. Water that moves that moves slowly through the impoundment may drop more sediment in the impoundment than water that moves quickly through the impoundment

The types of soils in the watershed upriver of the dam can have a direct relationship on the types of sediment found in the bottom of the impoundment. The sediment that accumulates upstream of a dam can vary greatly in gradation, composition and location. Fine grained soils such as silt and clays from streams and rivers will disperse throughout the impoundment. If the soils remain in impoundment for enough time they will settle out of the water and fall to the bottom. Coarser grained sand and gravels will drop out of the water and onto the bottom of the impoundment when streams and rivers slow down as they enter the impoundment. Some of the sediment may also contain organic material such as trees, branches, leaves, grasses and aquatic vegetation.

Sequiota Park Lake Sediment removal
Photo: City of Springfield

Determining whether to remove the accumulated sediment, leave it in place, or allow some of the sediment to move downstream is based upon many factors. If the sediment contains contaminants, it may need to be stabilized in place or removed and deposited off site. The costs of removal and off-site disposal can be substantial depending upon the type and level of contamination. If the sediment is free of contamination then stabilization in place or allowing some or all of the sediment to move downstream are viable options. The need to resupply downstream areas with sediment for restoration of natural stream functions should be carefully weighed. The amount of sediment available in the impoundment should be compared to the capacity of the downstream areas to handle the influx of sediment. If releasing accumulated sediment to downstream areas will enhance or restore the functionality of the stream, some of the sediment could be allowed to be transported downstream through the natural flows and functions of the stream or river. Too much sediment accumulating in downstream areas could reduce downstream channel capacity and increase the risk of localized flooding. Sediment removal can occur before or after the removal of the dam. Unconsolidated sediments generally cannot support the weight of heavy equipment until thoroughly dried. The removal of sediments by floating dredges before lowering of the pool and subsequent dam removal can be a cost effective way to remove substantial portions of sediment in the impoundment.

Removal of Sediment/Debris
Photo: Ohio DNR

Removal of sediment after dam removal usually involves the use of excavators and trucks to dig and transport the material to another location. The sediment in the impoundment is generally unconsolidated and saturated, and may take a long time to drain enough to be handled. Sediment comprised of sand and gravel will drain more quickly than sediment comprised of silts and clays. The material will be wet, may have odor, and has the potential create problems along the route between the impoundment and disposal location.

Stabilization of Remaining Sediment

If all or a portion of the sediment is to remain in place, it will need to be stabilized. Chapter 7 of the Ohio Rainwater and Development Manual contains information on soil stabilization techniques that will be useful in stabilizing exposed lakebed areas. The manual can be referenced at: http://epa.ohio.gov/dsw/storm/technical_guidance.aspx

The exposure of the lakebed provides an opportunity to establish native plant species on the expanse of unconsolidated sediment. The Ohio DNR maintains a listing of Ohio Native Species for Landscape and Restoration Use. The listing includes categories for Floodplains, Wet Fields and Prairies, Wet Woods, and Wetlands. http://ohiodnr.gov/gonative

The removal of the dam may also allow the original stream or riverbed to reestablish itself in the bed of the lake. Many of the guides referenced in Chapter 3 of this Guidebook related to stream restoration are applicable when looking for methods to reestablish the banks of rivers and streams that were submerged in the impoundments. The formerly submerged stream or river will react to the removal of the dam by trying to reestablish a dynamic equilibrium within the newly reopened waterway.

It may take several flow events over time for the channel to reform and adjust to the change in energy present in channel. It is important to not overstabilize the stream or river by prematurely installing control structures that limit the ability of the channel to respond to the new flow regime. Structures placed to control channel formation may cause unanticipated consequences that could result in unintended erosion of the sediment.

Summary

Many of the dams in Ohio still serve useful purposes and will continue to do so into the future. Other dams that are no longer needed for their original purpose have seen extended life by meeting the needs of new users. Some dams have completed their purpose, have high maintenance needs and costs, and are no longer needed. These dams and others whose removal would enhance water quality and habitat and restore natural stream and river systems may be candidates for modification or removal.

The issue areas described in this chapter will help readers in reviewing the potential options for dam modification or removal. The issues and the questions associated with each issue do not provide a comprehensive list of items to address when considering a modification or removal of a dam, and should not be used as a complete checklist of items that might be encountered when considering a removal. They can, however, provide a guide to the complexity of a dam modification or removal and assist dam owners, consultants, public officials and other interested parties with a framework for considering the costs, implications and benefits of a dam modification or removal.

Glossary

Best Management Practices for Dams

Aeration - To dissolve or integrate air into water for the primary purpose of increasing oxygen levels in the water.

Accretion - The gradual process of sediment accumulation in a lake, river or stream.

Algae - A plant or plantlike organism of any of several phyla, divisions, or classes of aquatic organisms that usually include green, yellow-green, brown, and red algae.

Arch Dams - A structure made primarily of concrete that is designed to curve upstream in an arch. The force of the water pushing against the dam presses against the arch and is transferred through the arch into the foundation or side walls (abutments) of the dam.

Aquatic Organisms – Organisms such as fish, bivalves, amphibians, reptiles, insects or other life forms that primarily or wholly live in or around water.

Bank – The land found at the edge of a stream or river.

Benthic – A term used to describe aquatic organisms that inhabit the bottom of the water body.

Best Management Practices – Activities or efforts that represent effective and practical ways of achieving an objective.

Buffer Zones - An area that can be created or maintained along waterways to preserve and restore the functions of the waterway and minimize impacts of adjacent land uses to the waterway.

Buttress Dam - A solid structure (usually made of concrete or steel) that relies upon a series of supports called buttresses to offset the force of water against the upstream side of the dam.

Channelization - Navigation or flood control projects that widen, deepen, or straighten streams, canals, or rivers. Environmental consequences associated with channelization include bank erosion, increased sedimentation, flooding, and a decrease in biomass available to aquatic organisms.

Conservation Development: The development of land using alternative layout and building arrangements in order to better conserve open space and retain natural resources.

Conservation Tillage - Any sequence of tillage that reduces loss of water or soil relative to conventional tillage.

Dam and Lock System - A series of dams and locks that are used to maintain adequate water depths for navigation on a river or canal. The dams are used to create pools of water within the river. The water levels upstream of each dam are higher that the downstream elevation at the base of the dam. The locks are usually located at the dams and are used to transfer vessels between the pools maintained by the dams.

Destratification - The process of breaking up different horizontal layers of water within an impoundment.

Discharge – The volume of water flowing past a point in a water system for a specific time interval.

Diversion Dam – A dam with the primary purpose of diverting all or a portion of the flow of a river. The dam is used to raise the water level of the water body so the water can be redirected. The style of the dam can be an Embankment Dam, Buttress Dam, Arch Dam or Gravity Dam.

Ecosystem - A biological community and the local surrounding non-biological features associated with it.

Embankment Dam - Embankment dams are designed to counteract the force of the water pushing on the dam by building a dam with enough weight to withstand the force. Embankment dams are commonly made from materials in the surrounding area where the dam is being built. The materials generally include: sand, gravel, and rocks. The combination of these building materials along with either a clay or an impervious membrane gives the embankment dam its integrity.

Emergency Spillway - A chute, weir, channel or conduit that provides additional flow capacity for water to pass over, around or through a dam during large flood events.

Ephemeral Stream – A stream that flows after precipitation or snowmelt within the watershed draining to the stream. The primary source of the water in the stream is surface water runoff from rainfall or melting snow, although some flow may occur from groundwater springs that discharge after filling up with rainwater or snowmelt.

Epilimnion – The top layer of water in a thermally stratified body of water. The epilimnion is generally warmer than the layers of water beneath it.

Erosion – The process of wearing away of a surface by physical means (water, wind, ice).

Eutrophication – The addition of excessive nutrients (usually nitrates or phosphates) to a body of water, leading to overgrowth of aquatic plants.

Floodgates – Moveable gates that can be used to divert or control the flow of water at dams and other similar structures such as levees or dikes. The gates can be used to hold back floodwaters in reservoirs, or conversely used to lower waters levels or bypass water to other channels to alleviate the impact of flooding on rivers or other channels.

Floodwalls – a barrier along a river or stream that is designed to contain floodwaters within a waterway. The floodwall serves a function similar to a levee, but is designed to have a smaller footprint than a levee. Floodwalls are generally used in circumstances such as in urban areas where there is limited space for flood control measures.

Freeboard – The difference in height between the normal water level in an impoundment and the elevation of the top of the dam.

Floodplain – Areas where flooding occurs near or adjacent to a river or stream. The floodplain usually includes lower lying areas which are at elevations that are close to the elevation of the water in the steam or river.

Fluvial Geomorphology - A specialized discipline involving the study of how rivers and streams shape landforms through physical processes. Synonymous with river or stream morphology

Forbs – A herbaceous broad leaved flowering plant found in fields, grasslands or meadows. A Forb is not a grass, sedge or rush**.**

Forebay - an area upstream of a larger body of water that can be used to collect sediment or debris before the material enters the larger body of water. The forebay can be natural or man-made and usually has a pool of water.

Gravity dam - Gravity style dams are built to counteract the force of the water pushing on the dam by building a dam with enough weight to withstand the force. Gravity dams are commonly constructed using masonry or cement.

Grist Mill – A building that houses a grinding mechanism used to crush grains into flour. Many grist mills were constructed along rivers or streams to take advantage of hydropower for driving the grinding mechanism.

Homeowners Association – A corporation formed for purposes of managing and selling homes and lots within a subdivided residential area. Membership in the corporation is generally held by the developer and owners of the lots within the area covered by the corporation.

Home Septic System – A combination of treatment devices used as a system to collect, filter and treat wastewater from a single residence. The system generally consists of a septic tank, an aeration device, filters and a drain (leach) field to disperse the treated wastewater.

Hydroelectricity – Electricity that is created by using generators attached to turbines that capture the power of falling or flowing water and convert it to electrical energy.

Hydrologic cycle - The processes of precipitation, evaporation, transpiration, condensation, and surface water runoff within the atmosphere of the earth.

Hypolimnion - The colder and deeper portion of a lake beneath the thermocline. The water in the hypolimnion is denser of relatively uniform temperature with potentially lower oxygen levels.

Hypoxia – A condition where oxygen levels in water are reduced to or below a level necessary to sustain aquatic life.

Impervious Core - Description of a material that prevents passage of a fluid (i.e., asphalt surfaces)

Impoundment – an area created by the construction of a dam or other barrier that can be filled with water or other materials on a temporary or more permanent basis.

Infiltration – The downward migration of water into the soil profile.

Inundation – The submergence of an area by flooding, either by natural or man-made processes.

Irrigation – The application of water to assist with the production of agricultural crops and products.

Lagoon – A shallow area used to collect and hold wastewater or other liquids that may need processing or treatment.

Legume – An family of flowering plants that can be grown for agricultural purposes which can be used for land cover to prevent or control erosion of soil. Examples include beans, peas, alfalfa, clover, peanuts, and other flowering plants.

Lock System – A series of gates, pumps, impoundments and other devices used to raise or lower water levels within a river or canal system. Use of the locks allow the raising and lowering of boats and other vessels between different water levels within the river or canal system.

Metalimnion - A layer of water in a lake between the warmer shallow water of the epilimnion and the deeper colder water of the hypolimnion. Also referred to as a thermocline.

Mill Pond - An impoundment where water is collected for the purpose of supplying water to power a mill.

Mill Race - A channel or waterway leading from a mill pond to a mill.

Mulch Till – The conservation practice of leaving crop residues on the surface of the ground to protect the soil from erosion. Subsurface tillage is performed in a manner that leaves the crop residues relatively undisturbed.

No Till - A method of growing crops or pasture without disturbing the soil through tillage. No Till can increase the amount of water that infiltrates soil, and can reduce surface water runoff and soil erosion.

Nutrients – A description of pollutants such as nitrogen and phosphorous that may be contained in surface waters that run off from urban or agricultural lands. Such pollutants may also originate from sources such as untreated or partially treated wastewater or discharges from improperly maintained septic systems.

Overtopping - A situation where the level of water in the impoundment rises to the top elevation of the dam and starts to flow over the crest of the dam.

Percolation - Downward movement of water within the soil profile.

Permanent Pool – The amount of the water maintained in an impoundment on a continuous basis.

Permeability – The rate at which water will filter into and through a layer of soil or other material

Phytoplankton - Microscopic plants, such as algae, suspended in aquatic environments.

Principal Spillway – The primary outlet for an impoundment consisting of either a riser structure in combination with a conduit that extends through the embankment or a weir control structure cut through the embankment. The spillway is designed to safely release water accumulating from storm events of a certain frequency.

Ridge Till – Planting of crops on rows of tilled ridges left in the field from previous crops. The depressions between the ridges can sometimes be used for irrigation, and when combined with contour farming can be very effective in reducing soil erosion and increasing infiltration of rainfall or irrigated water.

Riparian - Type of wetland transition zone between upland habitats and aquatic habitats. Lush vegetation along a stream is usually associated with a riparian area.

Rip Rap - Rock, stone or concrete pieces used to control erosion or scour from water or ice. The sizes of the individual pieces are based upon the expected forces of the water or ice and the ability of the forces to move the pieces.

Runoff - The portion of storm water or snow melt that enters a water system instead of entering the ground through infiltration.

Sea Lamprey – A jawless parasitic fish that resembles an eel. The Sea Lamprey attaches to other fish and feed on their blood, weakening or killing the fish.

Sediment Trap – A small basin where sediment laden runoff can be collected and retained long enough for sediment to settle out of the water before the water is released to a stream. Sediment traps are temporary devices that are usually created during construction projects for short periods of time until the upland areas are stabilized.

Sheet Flow - A thin continuous flow of water moving downslope at a slow velocity.

Slope - The degree of deviation of a surface from the horizontal plane, usually measured in a percent, degrees or numerical ratio.

Species Richness - A measure of the number of species in relation to the total number of individuals in a particular community.

Substrate - In terms of river/stream characteristics, substrate usually refers to both inorganic and organic particles on the stream bed. Examples of substrates include: bedrock, boulder, cobble, gravel, silt, sand, detritus, muck, and artificial.

Stream Habitat – A term used to describe the places at the surface, within the water column, at the bottom and in the sediment underneath the stream that provide habitat for aquatic organisms. Classifications can include pools, runs, riffles cascades and falls.

Storage Dam - A dam used primarily for the collection and holding of water for various purposes including water supply, stormwater management and flood protection.

Stratification – The formation of layers of water based upon different properties such as temperature, oxygen, density, and salinity. Stratification can create barriers to the mixing of nutrients, causing problems with the availability of phytoplankton.

Strip Till – a conservation practice that disturbs only the portion of the soil contained in the row of seeds. This practice leaves the area between seed rows intact, reducing the potential for erosion and increasing the soils ability to absorb rainfall.

Storm water Management - The practice of collecting, diverting and holding stormwater to prevent flooding and erosion downstream. Stormwater retention can enhance water quality by collecting pollutants and sediment before they reach a stream or river.

Tillage - Mechanical manipulation of soil with disks, plows, cultivators or other devices associated with agriculture for the purpose of crop production.

Thermocline - A thin layer of water between shallow and deeper waters within a larger water body. Also referred to as a metalimnion.

Trapezoidal Dams – A dam with a trapezoidal cross section built primarily from soil materials.

Turbidity - A measure of the amount of suspended material (sediment) in water based on the relative ability of light to penetrate the water's surface.

Tributary – A waterbody such as a stream or river that flows into a larger waterbody such as a river or lake.

Upground Reservoir – An aboveground impoundment of water held in place by a continuous dam around all sides of the impoundment.

Wastewater Treatment Facility – A series of water control and treatment structures that are designed and operated for the purpose of filtering or otherwise treating wastewater to remove pollutants in the water.

Watershed - The area of land that drains into a stream or lake. Also referred to as a drainage basin.

Wetland Mitigation – Offsetting the loss of a wetland by creating or restoring another wetland in a different location.

Weir – A structure placed in a stream, river or waterway to passively control the level of the water in the channel.

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Chapter 1

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3) Typical Dam Diagram	Ohio DNR
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Chapter 2

1) Wellington Creek	Angela Schaeffer
2) Ohio Watershed Programs	Ohio DNR
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21) Home Septic System	The Natural Home
22) Natural Stream System	Medina County SWCD
23) Channelized Stream	US Fish and Wildlife Service

Chapter 3

1) Findley State Park Lake	Angela Schaeffer
2) Sediment in Lake	USGS
3) Pond Aeration System	Living Water Aeration
4) Diffusion Underwater View	Air-O-Lator Corporation
5) Diffusion Surface View	Aquatic Management
6) Diffused Aeration Configurations	Ohio DNR
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20) Wetland at Inlet	Ohio DNR
21) Common Carp	Ohio DNR
22) Delaware State Park Marina	Ohio DNR

Chapter 4

1) Delaware Dam	Ohio DNR
2) FEMA Floodmap	FEMA
3) Water Release from a Dam	Knoxville News Sentinel Company
4) Dam Spillway	US Department of the Interior
5) Gated Conduit	Ohio DNR
6) Reregulation Weir	Ohio DNR
7) Fish Passage Weir	Eric Guinther
8) Lake Brazos Labyrinth Weir	Freese and Nichols, Inc.
9) Weir Model	Utah Center for Water Resources
10) Multi-Level Riser	Ohio DNR
11) Ridgeway Dam Outlet Works	US Department of the Interior
12) Localized Mixing	Ohio DNR
13) Kinzua Dam	Heather Elmer

14) Flushing Flow	US Department of the Interior

Chapter 5

1) Fish Passage Channel	National Oceanic & Atmospheric Admin
2) Fish swimming into pipe	Sydney Morning Herald
3) Gorge Dam	Ohio DNR
4) Diagram Pool and Weir Fish Passage	The Connecticut River Watershed Council
5) Diagram of Denil Fish Passage	The Connecticut River Watershed Council
6) Denil Fish Passage	Maryland DNR
7) Vertical Slot Fish Ladder	Oregon Department of Fish and Wildlife
8) Steep Pass Fish Ladders	Maryland DNR, University of Massachusetts
9) Fish Ladder – John Day Dam	US Department of the Interior
10) Partial Width Rock Ramp Fishway	Thorncraft and Harris/USACE
11) Full Width Rock Ramp Fishway	Thorncraft and Harris/USACE
12) Bypass Fishway	Thorncraft and Harris/USACE
13) Fish Lifts	South Carolina DNR
14) Alternative Spawning Areas	Ohio DNR
15) Constructed Spawning Reef	Michigan Sea Grant

Chapter 6

1) Dam Removal	Ohio DNR
2) Former Coho Dam	Ohio DNR
3) Charles Mill Dam	Muskingum Watershed Conservancy District
4) Lefever Dam Removal	Ohio DNR
5) Access Road under Bridge	Ohio DNR
6) Dam Deconstruction	Ohio DNR
7) Sequiota Park Lake	City of Springfield Missouri
8) Removal of sediment/debris	Ohio DNR

Financial Resources

Best Management Practices for Dams

National Sources

National Fish Passage Program (U.S. Fish and Wildlife Service)

http://www.fws.gov/fisheries/whatwedo/NFPP/nfpp.html

The U.S. Fish and Wildlife Service's National Fish Passage Program is a non-regulatory program that provides funding and technical assistance toward removing or bypassing barriers to fish movement.

U.S. Fish and Wildlife Service Partners

http://www.fws.gov/partners/

The U.S. Fish and Wildlife Service's Partners for Fish and Wildlife program offers technical and financial assistance to private (non-federal) landowners to voluntarily restore wetlands and other fish and wildlife habitats on their land. Restoration projects include reestablishing fish passage for migratory fish by removing barriers (dams) to movement.

National Fish Habitat Initiative (NFHI) Habitat Restoration Program

www.fishhabitat.org

NFHI is a nationwide strategy that harnesses the energies, expertise and existing partnerships of state and federal agencies and conservation organizations. The goal is to focus national attention and resources on common priorities to improve aquatic habitat health.

General Matching Grant Program (National Fish and Wildlife Foundation)

http://www.nfwf.org/whatwedo/grants/Pages/home.aspx

The National Fish and Wildlife Foundation operates a conservation grants program that awards matching grants to projects that: address priority actions promoting fish and wildlife conservation and the habitats on which they depend; work proactively to involve other conservation and community interests; leverage available funding; and evaluate project outcomes.

Open Rivers Initiative (NOAA)

http://www.habitat.noaa.gov/funding/ori.html

NOAA oversees a competitive grant program focused on community-driven, small dam and river barrier removals in coastal states to help repair vital riverine ecosystems, to benefit communities, and to enhance populations of key trust species.

NOAA/Ocean Trust/National Fisheries Institute

http://www.nmfs.noaa.gov/

NOAA partners with Ocean Trust to fund habitat restoration projects that enhance living marine resources around the coastal U.S. The applicant must be an individual, association or company in the fish and seafood industry.

The Nature Conservancy/NOAA Habitat Restoration Partnership

http://www.nature.org/ourinitiatives/habitats/oceanscoasts/howwework/noaa-partnership.xml

NOAA partners with The Nature Conservancy (TNC) to fund marine and anadromous fish habitat restoration projects around the coastal U.S. *The applicant must be a TNC local chapter*. Organizations that have project ideas should contact their local TNC chapter to discuss forming a partnership to apply for project funds under this request for proposals.

Trout Unlimited/NOAA Partnership

http://www.tu.org/conservation/outreach-education/veterans-service-partnership

Provides matching grants that require 1:1 match from a non-federal source or sources. Typical awards can cover any aspect of a habitat restoration project, including construction, engineering, planning, or outreach. There is no formal application process. Project must be sponsored by a TU chapter or State Council, or by TU staff.

NOAA Community-Based Habitat Restoration Project Grants

http://www.habitat.noaa.gov/restoration/programs/index.html

The program invites the public to submit proposals for available funding to implement grass-roots habitat restoration projects that will benefit living marine resources, including diadromous fish, under the NOAA Community-based Restoration Program.

FishAmerica Foundation/NOAA

http://www.fishamerica.org/grants/

FishAmerica, in partnership with the NOAA Restoration Center provides funding for on-the-ground, community based projects to restore habitat for marine and diadromous fish in the United States.

Wildlife Habitat Improvement Program (Natural Resources Conservation Service)

http://www.nrcs.usda.gov/programs/whip/

Funding awarded to projects that work to establish and improve fish and wildlife habitat. Contact local USDA Service Center for more information.

Aquatic Ecosystem Restoration Foundation

http://www.aquatics.org/

Aquatic Ecosystem Restoration – Section 206, Water Resources Development Act of 1996. Funds from this program can be utilized to remove lowhead dams as a way to improve water quality and fish and wildlife habitat. This funding source is listed under the Continuing Authorities Program.

Wildlife Restoration Act (Pittman-Robertson Act) Dept. of Interior-Fish and Wildlife Service

http://www.fws.gov/midwest/fisheries/glfwra-grants.html

The purpose of this Act was to provide funding for the selection, restoration, rehabilitation and improvement of wildlife habitat, wildlife management research, and the distribution of information produced by the projects. **Contact**: The Division of Federal Assistance, FederalAid@fws.gov

Regional Sources

Great Lakes Protection Fund

http://www.glpf.org/

The Great Lakes Protection Fund provides grants to further development of new technologies, innovative methods, and practical tools to improve the natural and economic vitality of the Great Lakes. Previous grants have been provided to review and modify operations at over 90 dams draining into the Great Lakes in hopes of restoring dissolved oxygen levels to those required to support fishery uses, restoring thermal regimes to those required to support fishery uses, returning the timing of flows to a pattern more like a free flowing stream, and increasing the population, distribution and health of fish in the tributaries and open lakes.

Sustain Our Great Lakes

http://www.sustainourgreatlakes.org/

Sustain Our Great Lakes works to restore, protect and preserve the fragile habitats and ecosystems that form the world's largest freshwater system. Sustain Our Great Lakes partners with conservation organizations, governments and groups on the local level to support programs dedicated to protecting and restoring the Great Lakes watershed.

The George Gund Foundation

http://www.gundfdn.org/

The Foundation provides grants to organizations that address environmental issues in Northeast Ohio and efforts to restore and preserve the Lake Erie ecosystem. The Foundation focuses on promoting alternatives to urban sprawl, decreasing energy consumption and waste, conserving ecosystems and biodiversity, reducing environmental health hazards, increasing public awareness of environmental issues and building the skills of nonprofit environmental leaders.

The Charles Stewart Mott Foundation

http://www.mott.org/FundingInterests/programs/environment.aspx

Grants are provided to advance the conservation and restoration of freshwater ecosystems in North America, with emphasis on the Great Lakes and, to a lesser extent, portions of the southeastern U.S. Projects can be funded to protect and restore freshwater ecosystems through place-based conservation activities.

US EPA Great Lakes National Program Office

http://www2.epa.gov/great-lakes-funding

Funding is provided for the Great Lakes Restoration Initiative through the Great Lakes National Program Office. Grant amounts are based upon annual congressional appropriations each federal fiscal year. Funds are available for a variety of restoration initiatives throughout the Great Lakes.

State Sources

Ohio EPA

Water Quality Trading Program:

http://www.epa.ohio.gov/dsw/WQ_trading/index.aspx

Water Quality Trading is a voluntary program that would allow a National Pollutant Discharge Elimination (NPDES) permit holder (point source) to meet its regulatory obligations by using pollutant reductions generated by another wastewater point source or nonpoint source. The program follows U.S. EPA's 2003 Water Quality Trading Policy and is reflected in Ohio Administrative Code Rule 3745-5-01 through -14. Installation of Best Management Practices at dams to improve water quality, including removal or modification of dams, may qualify for credits as part of a water quality trading program. Such credits could be used under an approved water quality trading plan to offset costs of the Best Management Practices at the dam.

Clean Water Act Section 319 Program:

http://www.epa.ohio.gov/dsw/nps/319Program.aspx

In 1987 the federal Clean Water Act amendments created a national program to control Nonpoint Source Pollution (NPS) under Section 319 of the Clean Water Act. Ohio EPA is the designated water quality agency responsible for administering the Ohio Section 319 program. Since 1990, Ohio EPA has annually applied for, received, and distributed Section 319 grant funds to correct NPS caused water quality impairment to Ohio's surface water resources.

Programs such as the Section 319(h) grants program provides funding that is targeted to Ohio waters where NPS pollution is a significant cause of aquatic life use impairments. The cornerstone of Ohio's 319 program is working with watershed groups and others who are implementing locally developed watershed management plans and restoring surface waters impaired by NPS pollution. Section 319 funds are a good source for providing assistance with restoration of a stream following dam removal.

Water Resources Restoration Sponsor Program:

http://epa.ohio.gov/defa/EnvironmentalandFinancialAssistance.aspx

The goal of Ohio EPA/Division of Environmental and Financial Assistance is to offer access to technical and financial assistance for implementable solutions to environmental needs. The Water Resource Restoration Sponsor Program (WRRSP) was created to counter the loss of ecological function and biological diversity that jeopardizes the health of Ohio's water resources. This program funds both preservation and restoration of aquatic habitat.

Water Pollution Control Fund:

http://www.epa.ohio.gov/defa/EnvironmentalandFinancialAssistance.aspx

The Water Pollution Control Loan Fund (WPCLF) is a revolving fund designed to operate in perpetuity to provide low interest loans and other forms of assistance for water resource protection and restoration projects. The WPCLF provides financial and technical assistance for a wide variety of actions to protect or improve the quality of Ohio's rivers, streams, lakes, and other water resources. The WPCLF offers opportunities for both public and private entities.

Surface Water Improvement Fund (SWIF) Grants Program

http://www.epa.state.oh.us/dsw/nps/swif.aspx

The Surface Water Improvement Fund was created in 2008 and authorizes the Ohio Environmental Protection Agency to provide grant funding to applicants such as local governments, park districts, conservation organizations and others. Resources from the Surface Water Improvement Fund can be utilized to assist with the removal of small dams.

Ohio Department of Natural Resources

Division of Natural Areas and Preserves

The Division has utilized funds generated by the sale of specialized license plates to help fund dam removal on Ohio's scenic rivers. For more information concerning dam removal along Ohio's Scenic Rivers contact (614) 265-6814 or visit the division of Natural Areas and Preserves website at http://naturepreserves.ohiodnr.gov/.

Division of Wildlife

From time to time the Division has funds available for the removal of lowhead dams. All inquiries regarding lowhead dam removal should contact 1-800-WILDLIFE or visit the Division of Wildlife website at: http://wildlife.ohiodnr.gov/.

Ohio Department of Transportation (ODOT)

Office of Environmental Services

To offset the environmental impact of transportation projects, ODOT has approved the removal of lowhead dams as a viable way to mitigate project impacts. One lowhead dam removal project has been approved. ODOT is looking for additional projects to be considered. Once a project has been approved ODOT oversees the project from beginning to end. For more information, contact Tim Hill, Environmental Administrator at (614) 644-0377 or visit their website at http://www.dot.state.oh.us/Divisions/Planning/Environment/Pages/default.aspx.

Ohio Water Development Authority (OWDA)

The OWDA offers loans to local governments to finance improvements and repairs to dams as mandated by the Ohio Department of Natural Resources (ODNR). These types of projects are eligible to receive OWDA financing as long as plans have been approved by and an inspection report has been obtained from ODNR.

Sources of information:

Commonwealth of Massachusetts, Riverways Program, Fact Sheet: Funding Sources for Dam Removal
http://www.mass.gov/eea/waste-mgnt-recycling/water-resources/preserving-water-resources/water-laws-and-policies/water-laws/draft-regs-re-dam-and-sea-wall-repair-or-removal-fund.html

American Rivers https://www.americanrivers.org/

Wisconsin River Alliance : http://www.wisconsinrivers.org/

The River Network list of Funding Sources
https://www.rivernetwork.org/