HYDROPOWER AND THE ENVIRONMENT

US. ARMY CORPS OF ENGINEERS- ECO-MEET STUDY PACKET

The Corps of Engineers' station will focus on hydropower and its role in the environment. In particular, students will be expected to understand the benefits of hydropower, the basic function and operation of a hydropower plant, the aquatic and terrestrial impacts of hydropower and dams, and what is being done to reduce those impacts.

STUDENTS SHOULD BE PREPARED TO ANSWER QUESTIONS ON THE FOLLOWING TOPICS:

- Benefits of hydropower
- The water cycle
- Basic types of hydropower dams (impoundment, run-of-river, pumped storage)
- Components of a hydropower dam and their function
- Basic concept of stratification in lakes and its effect on water quality
- Effects of dams and hydropower on water quality
- Effects of dams on fish migration, both upstream and downstream
- Effects of dams on aquatic and terrestrial habitats
- Means of reducing impacts to fish migration
- Methods of improving water quality
- Structural modifications to reduce impacts on habitat

STATE STANDARDS INCLUDE:
GEORGIA: S6E3, S6E4, S6E6; S8P5
SOUTH CAROLINA: 6.E.2A.3, 6.P.3A.4, 6.L.4B3; 7.S.1A.4, 8.S.1A.4, 8.E.5A.1

THE POWER OF WATER

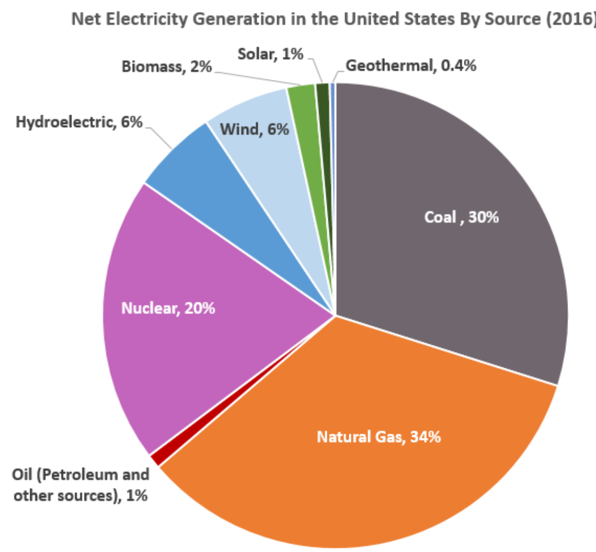
For thousands of years, the power of water has been used throughout the world, for such purposes as grinding grain and operating machinery. More recently, water's energy has been captured and transformed into electricity to help meet the world's ever- growing power demands. Hydropower, the process of converting water's **kinetic energy to mechanical energy, and then to electrical energy**, occurs at thousands of dams around the world and provides a “clean” form of power whose only greenhouse gas emissions are involved in the facility construction process.

There are many benefits to hydropower. Hydropower is one of the most efficient ways to generate electricity, converting as much as 90% of the available energy into electricity. At best, fossil fuel plants, such as conventional coal-burning plants, convert only 50% of available energy into electricity. Additionally, the power generation produces no greenhouse gases or air pollution, and leaves no waste behind.

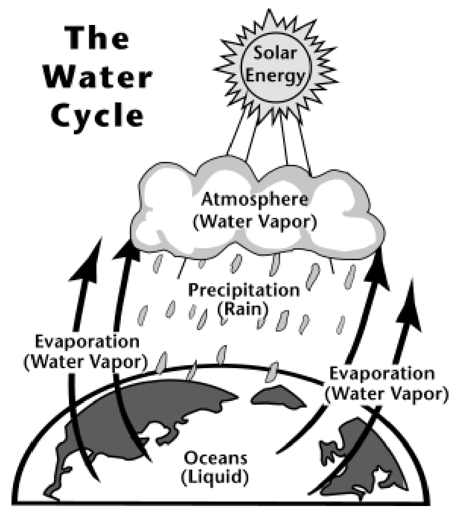
Since the US is one of the world's largest consumer of energy, renewable hydropower is very important and approximately 6% of the power generated in the U.S. comes from hydropower.

Another benefits of hydropower is its ability to come "on line" quickly during rapid increases in energy demand and its ability respond to power emergencies.

Traditional hydropower has been used for centuries, from the simple water wheel that provided power to operate mills to today's large hydropower plants supplying power to industry and homes worldwide.



A RENEWABLE RESOURCE

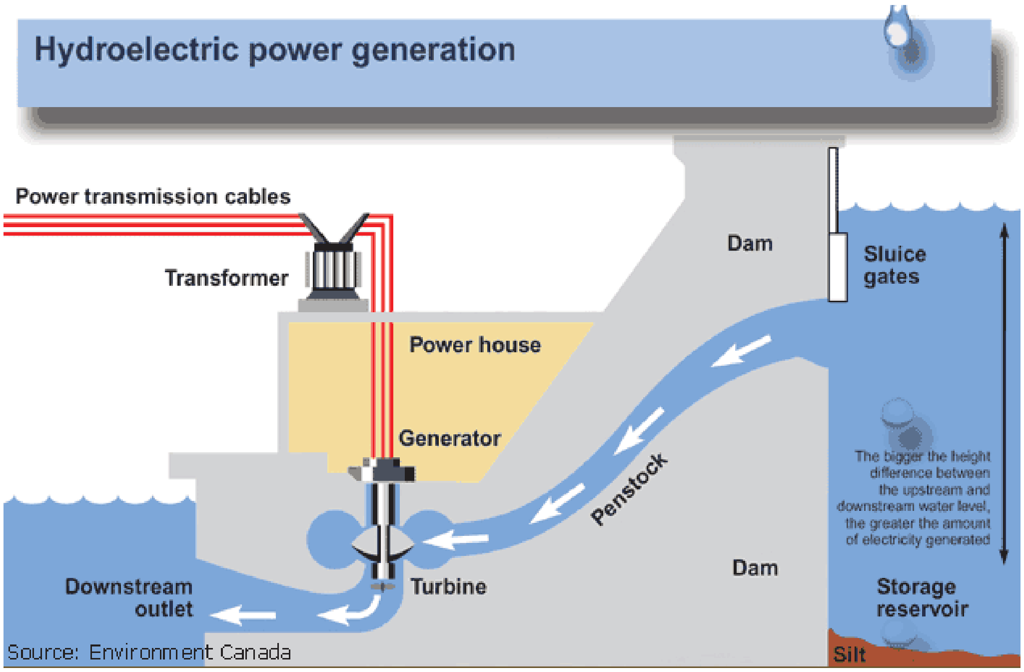


Water is an essential and fundamental element to the creation and evolution of life on our planet. From ancient times to the present, however, the amount of water available on earth remains unchanged. Only 2.8% of the earth's water supply is fresh water. Of this, only 0.01% is in our lakes and streams. Another 0.6% is in the earth's groundwater. Protecting and using this water supply wisely is essential to maintaining life itself. To understand this renewable resource and its value for energy production, we must first understand the hydrologic, or water cycle. The hydrologic cycle begins with the sun's energy, which warms water on earth, causing it to evaporate and rise into the atmosphere. Clouds form as the moisture condenses. Air currents carry clouds over land while transpiration causes the atmosphere to pick up additional moisture from trees and plants. When conditions are right, the clouds release precipitation as rain or snow. Rivers and streams become swollen as they collect rain or melting snow and ice. Gravity carries water down rivers and into the ocean, where the process begins again.

Because water continually cycles through our environment, it is considered a renewable resource – one that can be replenished naturally over time and reused. It is the force of this falling water in particular river locations that allows hydroelectricity, or hydropower, to be generated. To some, hydropower is ideal for power generation because, unlike non-renewable fuels such as coal, oil, and natural gas, it is almost free, there are no waste products, and hydropower does not pollute the water or the air.

HOW HYDROPOWER WORKS

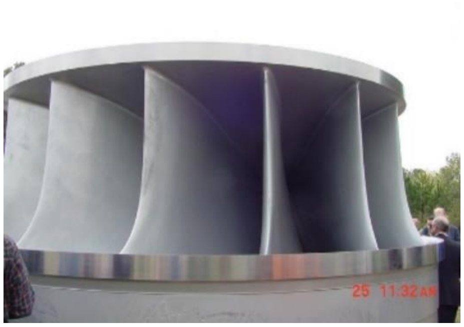
Generating hydroelectricity starts when runoff from rain and snow collects in lakes, streams and rivers and flows to dams downstream. The water funnels along a down gradient or slope, through a pipe in a dam, and into a powerhouse. The kinetic energy of flowing water turns a large wheel called a turbine. The turbine then turns a shaft, above which rotates a series of magnets past copper coils in a structure called a generator. This action creates magnetic energy that is converted to electrical energy by transformers. The water then returns to the river through an outflow. From the transformers, transmission lines carry electricity from the powerhouse to our communities.



The creation of hydroelectricity begins at the dam, where the power plant converts the force of falling water into electricity. The **greater** the height that water falls, the greater kinetic energy and greater potential for producing electricity. Above is a cross-section of a hydropower dam and plant. The following are components of a powerhouse.

THE POWERHOUSE: The turbine, generator, and transformer are located in the powerhouse.

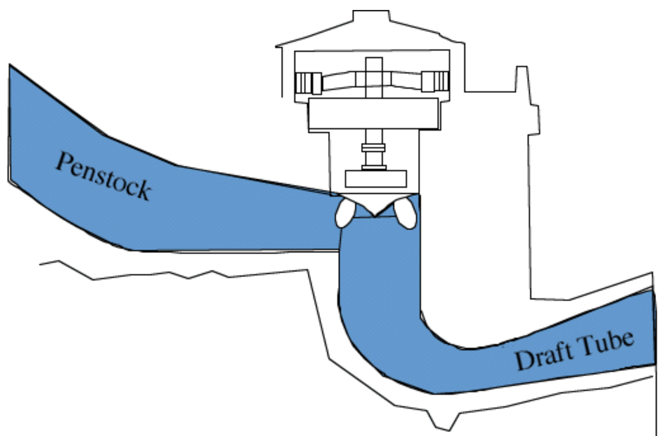
THE PENSTOCK: The pipe that collects water from a lake, reservoir or river and funnels it to the turbine. Penstocks are typically located deep in a lake and can have a large diameter. The penstocks at J. Strom Thurmond Power Plant are large enough to drive a school bus through and collects water from approximately 90 feet below the surface of the lake. This photo was taken during dam construction in the 1940's.



TURBINE: Spins as the force of falling water flows through the penstock and hits the turbine blades. TURBINE BLADES: The blades on some turbines can be adjusted to be as efficient as possible given the amount of water passing through the penstock.

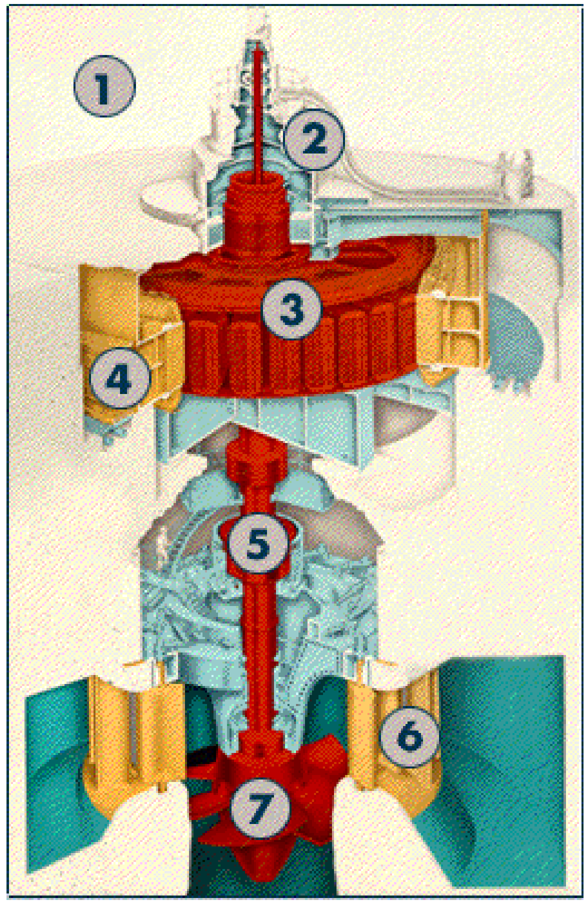
GENERATOR: The generator produces electricity because of the action created by the spinning shaft turning magnets (seen here on a raised rotor) inside a copper coil.

WATER FLOW: Water flows back to the river unpolluted and in the same amount that entered through the penstock. The water leaves the dam though a pipe called the draft tube or outfall.



TRANSFORMER: Transformers convert the voltage of the electricity produced by the generator to levels needed for the journey across the power lines to our communities.

A DETAILED LOOK INSIDE A GENERATOR



Items 3 – 7 in the picture to the right are critical components of a generator. Each part is identified and described below.

3. The rotor is a series of magnets. It's the rotating portion of the generator where the magnetic field is created.

4. The stator is the stationary part of the generator made of coils of copper wire. Electricity is produced as the rotors spin past the stationary wiring.

5. The shaft connects the turbine to the rotor section of the generator. All three elements, the turbine, shaft, and rotor turn at the same speed.

6. The wicket gates are a series of adjustable vanes, resembling vertical blinds. They control the amount of water flowing through the turbine much like a vertical blind controls the amount of light entering a room.

7. The hydraulic turbine resembles a large water wheel. The turbine converts the energy of falling water into mechanical energy to drive the generator. The turbine in this picture has adjustable blades to operate more efficiently in various amounts of water flow.

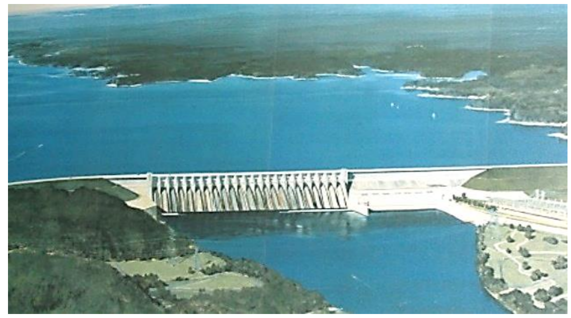
ENVIRONMENTAL IMPACTS OF DAMS AND HYDROPOWER PLANTS

Hydropower is considered environmentally friendly because it is a clean and renewable energy source. The term renewable, in this instance, refers to the fact that water, the resource used to generate power, is replenished in the hydrologic cycle. The term is also used because the production of electricity with hydropower does not pollute the air, contribute to acid rain or ozone depletion because of carbon dioxide emissions, or (like nuclear power) leave highly toxic waste that can pollute soil and water.

Hydropower accounts for 29% of all renewable energy in the United States. Wind, solar and other sources account for the remaining 61%. And while there are many benefits to using hydropower as a renewable source of electricity, it does change the environment by affecting natural habitats. These impacts generally relate to how a hydropower dam affects aquatic ecosystems and wildlife.

Specific ecosystem impacts caused by a hydroelectric dam largely depend on the following variables: (1) the size and flow rate of the river on which the dam is located, (2) the climatic and habitat conditions that exist (drought, flood, etc), (3) the type, size, design and operation of the project, and (4) whether cumulative, or combined, impacts occur because the dam is located upstream or downstream of other dams.

Hydropower dams can generally be classified into three types of facilities: impoundment or storage, diversion, and pumped storage facilities. Impoundment or storage facilities hold water in a reservoir or lake and adjust a river's natural flow pattern to release water when the demand for electricity is highest, called peak demand. More energy can be produced from water falling 100 feet above a turbine than from 10 feet. This height is called "head". That's why hydroelectric projects producing the most electricity also have tall dams and large reservoirs.



J. Strom Thurmond Project, an impoundment project

Run-of-river facility

Run-of-river facilities, often referred to as diversion facilities, channel a portion of a river through a canal or penstock. This type of facility may not require the use of a dam. Run-of-river projects allow water to pass at about the same rate that the river is flowing naturally. Generally, the river level upstream of the project is fairly constant, with daily fluctuations limited to only 3 - 5 feet at the largest projects.

Pumped storage facilities store energy during periods when electricity demand is low by pumping water using a reversible turbine from a lower reservoir to an upper reservoir. During periods of high energy demand, water is released to the lower level to generate electricity. Richard B. Russell dam and lake is a pump storage facility near us.

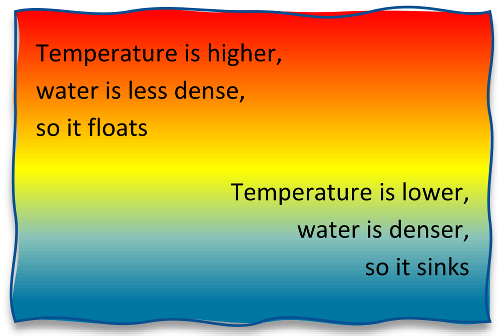
Pump storage facility

While some environmental impacts are a result of power generation, many impacts result from construction of the dam itself. Of the 90,000 dams in the U.S., only 3 percent generate power. Most dams are constructed for flood control, irrigation, navigation, and water supply and many dams support a combination of functions or purposes. One such example is the J. Strom Thurmond Dam on the Savannah River. The purposes of this dam include hydropower generation, flood control, navigation, recreation, and fish & wildlife management.

RESERVOIRS AND LAKE STRATIFICATION

A lake's water quality and ability to support fish are affected by the extent to which water **mixes** in the lake or river. While water mixes well in rapidly moving rivers, this isn't always the case in lakes and Reservoirs (man-made lakes). Surface temperatures tend to become warmer as the slow moving water absorbs heat from the sun. In addition to surface water warming, the colder water sinks toward the bottom because of its higher density. This causes a layering effect called stratification.

To discuss stratification, we need to understand the temperature-density relationship for water. As water increases in temperature, it tends to become less dense. Conversely, water becomes denser as its temperature cools. Denser water will sink below less dense water. Hence, warm water will "float" or settle on top of colder water. The change in water temperature with depth within a lake is called thermal stratification.



Many lakes undergo seasonal changes with regard to their temperature and density called seasonal stratification. These changes directly influence various characteristics and water quality of the lake.

This changes from one season to the next and creates a pattern that is repeated every year. In Spring, the lake water is generally the same temperature from the surface to the bottom. Wind causes circulation and mixes the lake water (surface water can be pushed to the lake bottom and bottom water can rise to the surface) (Figure 1). This circulation allows oxygen to reach the bottom of the lake. Otherwise, oxygen would have to reach the bottom by the relatively slow process of diffusion. The mixing of lake water at this time of year is called Spring turn-over.

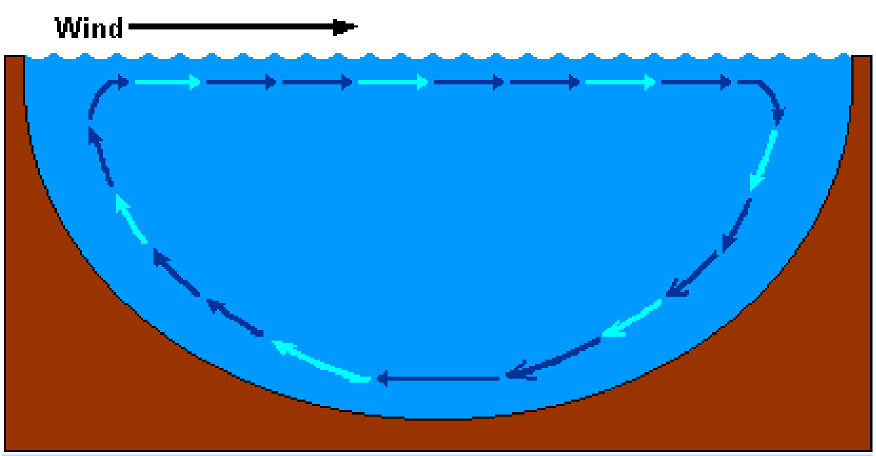


Figure 1 Complete mixing of water can occur when all water within the lake is generally the same temperature. Wind helps to drive this process.

As air temperatures rise in late spring, the heat from the sun begins to warm the lake surface. The lake heats from the surface down and stays cooler at greater depths. The warm water is less dense than the colder water below, resulting in a layer of warm water that floats over the cold water. The layer of warm water at the surface of the lake is called the epilimnion. The cold layer at the bottom of the lake is called the hypolimnion. These two layers are separated by a thin layer of water which rapidly changes temperature with depth. This is called the thermocline. Have you ever been swimming in a deep lake or pond, and when diving under water, suddenly felt much colder water a few feet below the surface? That's the thermocline.

Figure 2 below shows how the depth of the epilimnion increases through the spring and into the early summer as the surface layers warm.

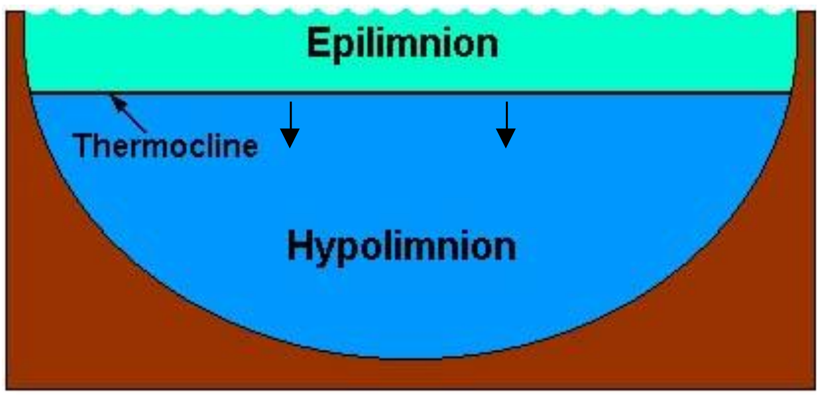


Figure 2 As summer approaches, the surface of the lake begins to get warmer. This creates a relatively warm surface layer over a relatively cool bottom layer. They are separated by a zone that changes temperature very rapidly with depth.

Stratification prevents lake mixing. Wind circulates the surface water, but the warm water of the epilimnion is unable to drive through the thermocline into the cold, dense water of the hypolimnion. As a result, the water is only mixed in the epilimnion (Figure 3).

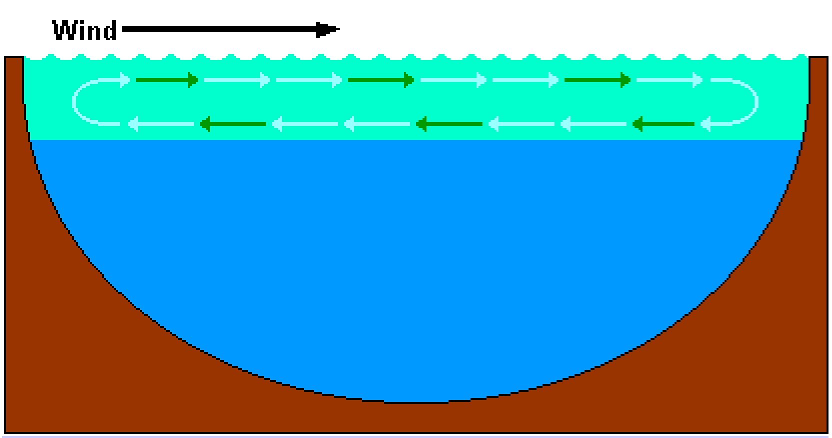


Figure 3 During summer density differences act as a barrier to complete mixing of the lake. This deprives the lake bottom of oxygen.

Without mixing to provide dissolved oxygen, the lake bottom tends to have a very limited supply of oxygen during the summer. As oxygen levels go down in the hypolimnion, the lake bottom can become anoxic (i.e., without oxygen).

As summer ends and temperatures decrease, the epilimnion begins to cool, becomes denser, and decreases in depth (Figure 4).

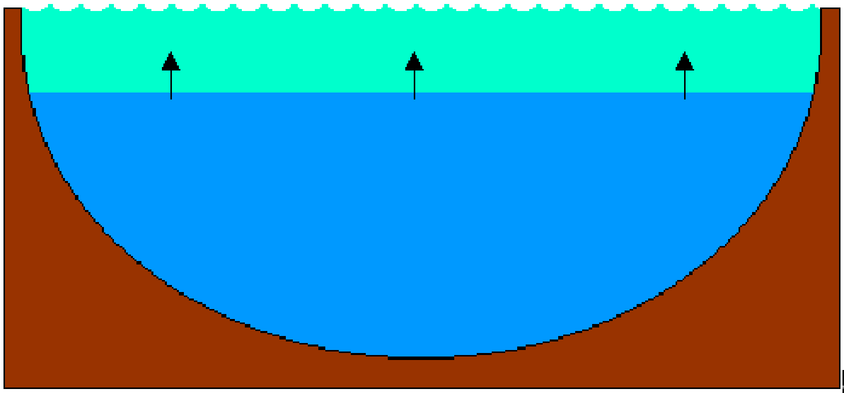


Figure 4 As seasonal temperatures decrease, so does the depth of the warm water layer known as the epilimnion. Conversely, the cold layer known as the hypolimnion increases in thickness.

Eventually the epilimnion gets so shallow that it can't be maintained as a separate layer and the lake loses its stratification.

Just like in the spring, the lake water in the fall has generally uniform temperatures, and wind can once again thoroughly mix the lake water (Figure 5). This process is called autumn turn-over.

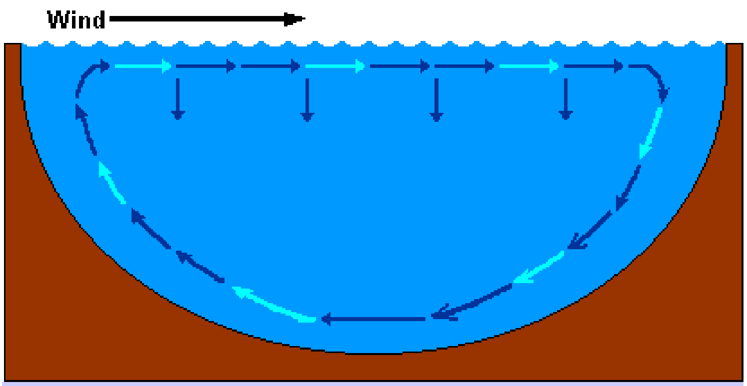


Figure 5 Complete mixing of water can occur when all water within the lake is generally the same temperature. In addition, the atmosphere cools the water at the lake's surface. This dense water sinks to the bottom and further contributes to lake mixing.

In northern climates, lakes undergo a second seasonal stratification in winter, as ice forms on the lake surface. In these situations, the water immediately below the ice is slightly warmer (4°C) but denser than the ice. The ice floats because water is densest at 4°C, just above freezing. Most lakes in southern climates, such as those in Georgia and South Carolina, do not stratify during winter, but remain mixed throughout the depth of the lake.

DISSOLVED OXYGEN CONCENTRATION AND FISH HABITAT

Now that we have a basic understanding of seasonal stratification, let's look at how this stratification affects the environment, particularly fish habitat. Dissolved oxygen**,** the amount of available oxygen dissolved in water, is a basic requirement of a healthy aquatic ecosystem and can be used as one factor in determining the quality of water and its ability to support a balanced aquatic ecosystem. Most fish and beneficial aquatic insects "breathe" oxygen dissolved in the water column. While a few fish are adapted to low oxygen levels, most fish species suffer if dissolved oxygen levels fall below 3 to 4 mg/L (milligrams of oxygen per liter of water). Larvae and juvenile fish are more sensitive and require even higher levels of dissolved oxygen. Prolonged periods of low dissolved oxygen levels $\leq$ 2.0 mg/L can result in "dead" water bodies, those that cannot support living organisms. During the summer months when lakes stratify, levels within the hypolimnion, particularly on the lake bottom, can drop to less than 1.0 mg/L. At this point, very few fish species can survive in this part of the lake.

Not only are the effects of such low oxygen levels seen in the lake, but low oxygen levels can also impact fish habitat in the river below dams. Penstocks in dams often pull water from lakes at depths below the thermocline. They, therefore, can pull anoxic water into the turbines when a lake is stratified. When hydropower plants generate electricity in the summer, particularly with multiple turbines and generators running at one time, a large volume of anoxic water can be released to the river, lowering the overall oxygen level in the river, possibly to levels below which fish can survive. As a result, fish will migrate to downstream portions of the river, leaving the area immediately below the dam void of fish. The level of dissolved oxygen in the Savannah River preferred for fish habitat is $\geq$ 5.0 mg/L. Dissolved oxygen levels in water coming through the penstocks during summer can drop as low as 1.0 mg/L. This can severely impact fish populations immediately below dams on the Savannah River.

SUPERSATURATION

During heavy rainfalls, dams hold back water to protect downstream areas from flooding. Afterwards, dams begin to slowly release that water by spilling it through gates at the top of the dam. Supersaturation occurs when water is spilled over the top of a dam and hits the river below, creating turbulence, and trapping a considerable amount of air in the water. Because air is 78% nitrogen, the level of nitrogen dissolved in the water can increase dramatically. The affected water does not lose the excess nitrogen quickly. For fish and other species, supersaturated water can enter body tissues. If fish swim from an area supersaturated with nitrogen to a lower pressure area in the river, a condition similar to "the bends" in scuba diving can occur. As fish enter lower pressure areas, the nitrogen in the blood and tissues expands, resulting in injury and possibly even death to fish.

CHANGING WATER LEVELS

Building a hydroelectric dam can raise the water level behind a dam from a few feet to several hundred feet. When stream banks and riparian areas become covered by the lake's higher water level, the result is inundation**,** or flooding. Habitat conditions change and a new equilibrium emerges. As this occurs, plants and animals that traditionally grow, nest, feed or spawn in these areas are impacted. As a new balance in the ecosystem emerges, fish and wildlife dependent upon river habitats may not do well in the new environment. These species usually migrate to new habitat and are replaced by different animals that find the lake habitat more attractive. Vegetation in shoreline areas develops while animals re-populate the area. The new environment created around lakes often provides habitat for different birds, insects, small and large mammals that nest and forage in the new habitat. As a result, a new ecosystem takes hold.

Once built, hydroelectric projects can also raise and lower the water level in a reservoir on a daily, weekly or seasonal basis to produce electricity. This occurs when more water is released to meet the high energy demands. For instance, more water may be released in the morning because electricity demands increase as people wake up and begin turning on lights, using kitchen appliances, etc. One term used to describe this process is "power peaking." In a riparian zone (the area where moist soils and plants exist next to a body of water), water levels may fluctuate, resulting in shoreline and shallow aquatic vegetation not being effectively established. This can reduce the habitat available for species that live in these areas. For instance, fish often prefer to spawn in shallow areas with abundant vegetation. The young fish, or fry, live in these areas for the first year or two of their lives. The aquatic plants in these areas provide a food resource (insects that young fish need to thrive often live on the plants) as well as shelter from predators such as larger fish.

SEDIMENTATION

Sediments, which are fine organic and inorganic materials that are typically suspended in water, can collect behind a dam because the dam itself is a physical barrier. From the time a project is built, man-made and natural erosion of lands adjacent to a reservoir can lead to sediment build-up behind a dam. This build-up can vary based on the ability of the river to "flush" the sediments past the dam. It can also vary based on the natural condition of the river and its upstream tributaries. For instance, a greater amount of sediment may collect behind a dam when the sediments in a river and its tributaries are made up of small, fine sands rather than thick, heavy clay or rock.

When sediments collect, the ecosystem can be affected in two ways. First, downstream habitat conditions can decline because there is no inflow of new sediments providing important organic and inorganic nutrients.

Second, where sediment builds up behind a dam, an effect called nutrient loading can cause the supply of oxygen to be depleted. This happens because more nutrients are now available, thus more organisms populate the area to consume the nutrients. As these organisms consume the nutrients, more oxygen is used, depleting the supply of oxygen in the lake.

Similarly, gravel can be trapped behind a dam in the same way as sediment. In cases where the movement of gravel downstream is part of establishing or replenishing spawning areas for fish, important downstream spawning areas can be affected by the lack of gravel in the riverbed.

HYDROPOWER: CHANGING HABITAT CONDITIONS FOR FISH AND WILDLIFE

When ecosystem changes occur at a project, a new pattern of biological activity is likely to emerge. As this happens, a new and dynamic equilibrium takes hold. With this new equilibrium come changes to the plants, fish, and wildlife that populate these areas.

Over time, observation indicates which species continue to do well, which ones become attracted or more attracted to the area around a hydroelectric project, and which species begin a gradual, sharp, or complete decline.

To examine these possible habitat changes, let's begin with fish.

FISH

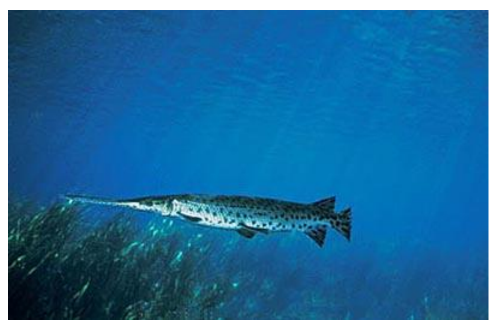
Fish that occur in rivers can be divided into various categories based on where they spend portions of their lives. For the purposes of looking at dams, we will address two of these categories, anadromous and riverine or resident fish. Anadromous fish are fish that spend most of their lives in the saltwater environment of oceans and bays, but return to the freshwater of rivers and streams to spawn, or lay eggs, and then return to saltwater. There are several species of anadromous fish in the southeastern U.S. Some of these are blueback herring, American shad, shortnose sturgeon and Atlantic sturgeon. Perhaps the best known of anadromous fish are Pacific and Atlantic salmon.

Atlantic sturgeon

Atlantic salmon

Riverine fish, on the other hand, spend their entire lives in freshwater streams, tributaries and rivers. Some may migrate from streams to lakes while others may migrate from streams to rivers, and some remain in the same body of water their entire lives. Brook trout, bull trout and gar, for instance, are well-known riverine fish that migrate up and downstream. To reach upstream spawning areas, fish must be allowed to pass around dams.

Brook trout



Longnose gar

Depending on the species, these migration patterns can vary. In the case of salmon, for instance, some species tend to spawn in small streams and prefer shaded pools while others migrate hundreds of miles to spawn in large lakes where their fry live for two years before migrating to the ocean. Fish are called "fry" when they emerge from their spawning area and begin swimming freely and feeding in a stream. As they increase in size and maturity, they become "smolts" or "juveniles". During their time in the ocean, anadromous fish become adults. As a result, adult anadromous fish only exist in a river when they are migrating to and from their spawning grounds.

Based on their life cycle and migration and spawning patterns, fish can face several different and changing ecosystems. Listed below are some fishery impacts that can result from hydropower dams.

1. Slower moving waters in a reservoir can have a strong effect on riverine and anadromous fish for two reasons. First, they can become disoriented in slower moving waters; and second, the length of time it takes anadromous fry and smolts migrate downstream to the ocean may increase. Due to disorientation and lengthened travel time, the fish are more exposed to predators.

2. Fish passing downstream through or around a dam can become stressed, injured, disoriented or die because of contact with turbines, the walls of the dam, or other structures. They then exit into a relatively small area where exposure to predators is increased. Fish that must pass through multiple dams along a river face even greater risk. The situation in which fish pass through the turbines is known as fish entrainment.

3. When fish migrate upstream to spawning grounds, the dam can again be a physical barrier. If a "**fish passage**" does not exist, then adult fish cannot reach spawning grounds. Over time, some fish populations can decrease or even cease to exist in a river because of reduced reproduction as fish settle for less desirable spawning areas.

WILDLIFE

Riparian, or streamside, vegetation and its bordering waters provide critical habitat for songbirds, waterfowl, and small and large mammals. When a hydroelectric dam floods a free-flowing river, the nesting habitat, forage, and shelter provided by these areas can be lost.

When habitat is lost, animals are forced to move to higher ground or other areas where habitat conditions may be less suitable, predators are more abundant, or the territory is already occupied by another species. As an example, ground birds like quail require cover and cannot successfully move to higher, more open ground.

In cases where water levels stabilize at a new height, such as around many lakes, vegetation in riparian zones can re-emerge and species can re-populate an area. With storage projects, the riparian zone that emerges has conditions of a reservoir or lake rather than a free-flowing river. When such conditions occur, certain species may begin to decline, others will become more abundant, and some will move into these areas for the first time.

Ducks and geese are examples of wildlife that are strongly attracted to the habitat conditions found in reservoirs. For some of these species, reservoirs provide an important alternative to the wetland areas that they previously occupied.

MITIGATION OF IMPACTS

Hydropower is considered a favorable alternative for producing electricity because it is a renewable and clean energy resource. Like any energy resource, however, there are environmental effects associated with its use. As described above, impacts can vary greatly from one hydroelectric project to the next. At any given project, governmental agencies, power companies, non-profit groups or others monitor the impacts of hydroelectric dams on the surrounding environment. In some cases, the environmental effects are positive. For instance, reservoirs can provide resting and feeding areas for migrating birds, as well as quality habitat for bass and other fish species.

On the other hand, habitat conditions for some fish, wildlife and plants can be adversely affected. A number of protection and enhancement strategies can be employed, however, to minimize these affects. Structural changes can be utilized to reduce the impact of hydroelectric dams on the environment. The following will address various structural mitigation strategies and the impact or issue they address.

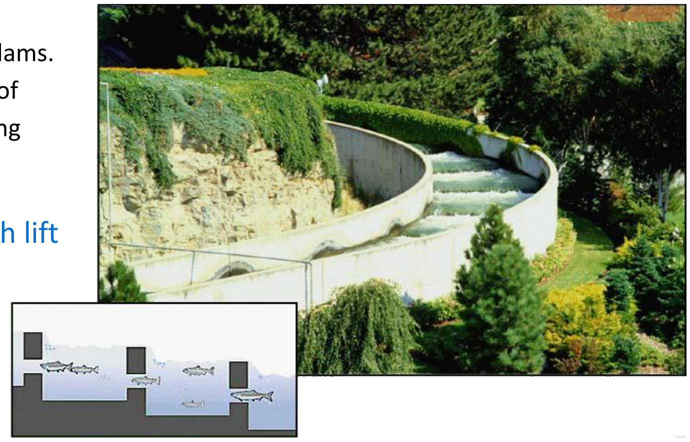
ISSUE: DOWNSTREAM WATER QUALITY, LOW DISSOLVED OXYGEN
STRATEGY: OXYGENATION AND AUTO-VENTING TURBINES

As we have learned, stratification in deep lakes, such as those found at hydroelectric dams, can result in anoxic water entering the penstocks and being released to the tailrace in summer. Dissolved oxygen levels are measured by an instrument called a Hydrolab. In addition to dissolved oxygen content, hydrolabs can measure temperature, pH and conductivity of water. Oxygen profiles are recorded at various depths in the lake throughout the summer. Hydrolabs are also used to measure the dissolved oxygen in water as it enters and leaves the dam. Data from these combined sources can be used to determine whether minimal oxygen limits have been reached, and whether additional oxygen is needed. Technologies such as oxygenation systems and auto-venting turbines have been developed to provide additional oxygen, both in the lake and the river, to improve fish habitat. Oxygenation systems can provide additional oxygen to a lake's hypolimnion during summer by pumping oxygen from liquid oxygen storage tanks located on land through a series of pipes lying on the lake bottom. Depending upon the size of the oxygenation system and the lake, this can increase the dissolved oxygen levels throughout the hypolimnion, or within a smaller area immediately surrounding the pipes. Thurmond Lake now has an oxygenation system in place to attract fish, as mitigation for the effects of the Russell Power Plant. The goal is to encourage the fish to remain in the center of the lake during the summer rather than migrating towards Russell's turbines and experiencing fish entrainment.

Oxygen levels in the tailrace of a dam can be enhanced through the use of auto-venting, or aerating turbines. These are a new class of turbines that are hollow, with holes along the outer edge of the blades. A valve in the top of the turbine, not immersed in water, can pull air from the surrounding environment and force it through the hollow blades of the turbine and into the water as it passes through the turbines. This water then leaves the turbine area and enters the tailrace containing considerably more oxygen than when it entered the turbines. Auto-venting turbines have the capability of raising the dissolved oxygen levels within the tailrace 2-4 mg/L, which can make the difference between habitat void of fish and habitat that fish thrive in. These turbines have been installed at hydropower plants such as the Thurmond Dam and Power Plant on the Savannah River.

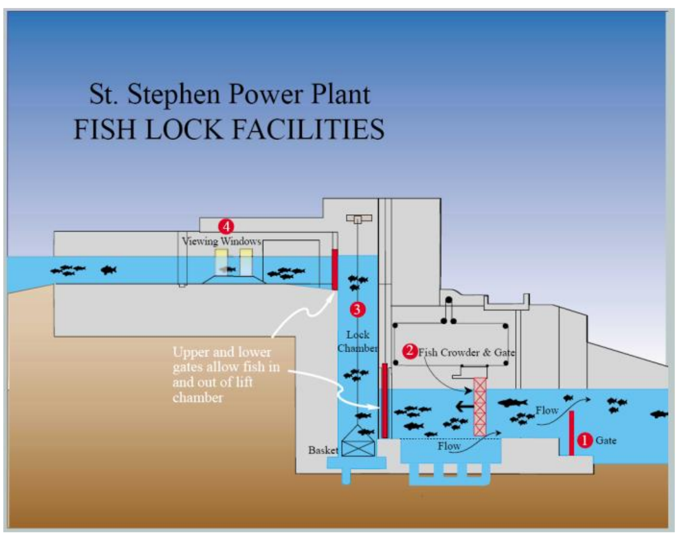
The picture to the left is an auto-venting turbine being installed at J. Strom Thurmond Dam. The small holes along the edge of each turbine blade allow air from inside the power plant to be pulled into the blades and released into the water as it passes by the turbine.

Issue: Upstream Fish Migration
Strategy: Fish Ladders, Fish Lifts



As discussed earlier, fish passage is a significant impact of dams. Engineers and scientists, however, have developed means of providing fish migration around dams to important spawning grounds.

Adult fish migrating upstream can use a fish ladder **or** fish lift to migrate past dams to spawning grounds. A **fish ladder** may look like a series of steps with water flowing over them. Between each step is a pool. Fish are attracted to the swiftly flowing water in the ladder and migrate around dams by jumping from pool to pool up the steps, a natural behavior for fish.



Fish lifts provide a mechanism similar to an elevator. Fish swim into a chamber at river level that then closes and lifts the fish to the lake level, where they are released into the lake. The St. Stephens Hydropower Plant in South Carolina operates a fish lift to move fish from the Cooper River into Lake Marion.

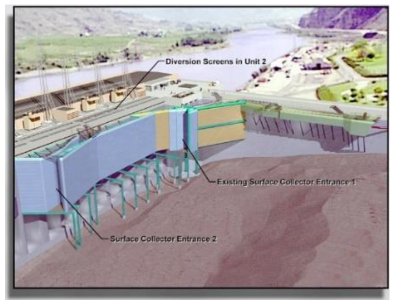
In instances where a dam has a navigation lock, the lock doors can be opened for periods of time when fish are migrating to spawning grounds, allowing them safe passage past a dam. This occurs more often at diversion and run-of-river projects, as well as at lock and dam structures like the New Savannah Bluff Lock and Dam in Augusta, Georgia.

ISSUE: DOWNSTREAM FISH MIGRATION
STRATEGY: SURFACE COLLECTORS, FISH SCREENS, TURBINE MODIFICATIONS, GUIDANCE DEVICES

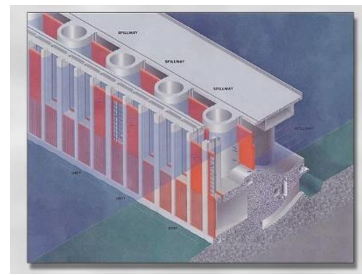
Mechanisms have also been developed to allow fish to migrate downstream safely through dams. When young fish migrate downstream through a hydropower dam, they may enter a bypass system. Downstream migration of fish is aided by fish screens, racks, and fish-friendly turbines. Even the use of underwater lights and sounds can move fish away from intakes, avoiding harmful encounters with turbines.

Fish migrating downstream run the risk of becoming entrained and injured in a dam's turbines. Certain times of the year, fish may gather immediately behind the dam at the opening or intake of the penstocks. This is often in response to water temperatures and oxygen levels in this portion of the lake. If fish enter the penstocks, they may be injured or killed while passing through the turbines. Some hydropower dams use fish screens and collection systems to move these fish downstream. The systems are typically located on the back of the dam, in the lake, where fish are diverted through a screen or surface collector, then moved through a separate channel or pipe to the river below the dam. They pass through the dam safely without contacting the turbines. The diagram below shows different types of fish downstream passage systems, including fish screens, surface collectors, and bypass systems.

This fish screen was lifted from within the structure for cleaning and maintenance



Surface Collector- fish are collected and flow through tubes to the river downstream

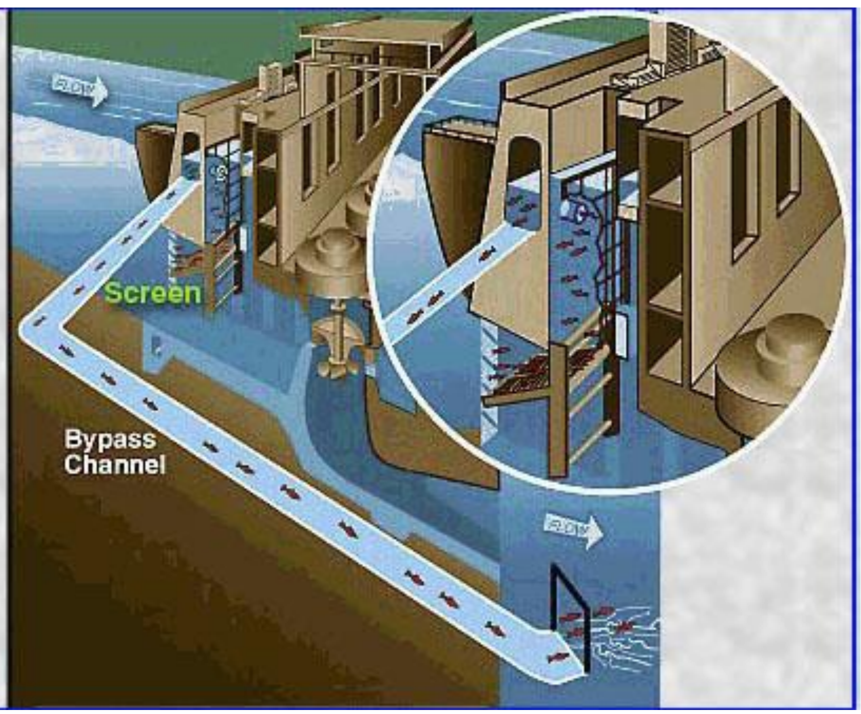


Fish Bypass System-Fish move through openings in the dam to the river downstream

SURFACE COLLECTOR

Surface Collectors are common means of guiding juvenile salmon around a project. Often, screens are used to help guide fish into the bypass system.

Surface collectors are designed to meet the particular river flows, fish passage needs and structural design that is unique to each project.



In some cases, fish are even transported around dams by barge or truck. Along the main stem of the Columbia and Snake rivers in the Pacific Northwest US, some migrating salmon smolts are collected in barges and then transported several miles downstream. They are released below the Bonneville Dam, where they migrate through the estuary and into the ocean.

Even newer technology has led to the development of new turbines that reduce mortality caused by fish being bruised, stressed or disoriented. These "fish friendly" turbines are constructed to operate at a slower speed, without compromising efficiency, to allow fish to pass safely through the power plant.

Lights and underwater sonar can also be used to divert fish away from turbines and intakes. As fish are often attracted to lights, particularly at night, lights located away from the penstocks can attract fish, drawing them away from intakes. Loud noises produced by underwater sonar can be used to scare fish away from intakes. These techniques can be particularly useful at pumped storage projects to prevent fish from being pumped through turbines back into the lake.

ISSUE: LACK OF SHORELINE AQUATIC VEGETATION DUE TO PEAKING ENERGY PRODUCTION
STRATEGY: ESTABLISHING SHORELINE VEGETATION AND ADDING FISH ATTRACTORS.

As discussed earlier, many hydropower plants produce energy based on when the highest demand for energy occurs. This may change hourly, daily, or monthly. With changing energy demands, the lake levels may vary over time, impacting the plants that occur in the shoreline and shallow aquatic areas. To enhance the aquatic vegetation in these shallow areas, and subsequent fish habitat, biologists may re-vegetate shallow areas by planting native aquatic vegetation. The photo to the right shows plants such as Maidencane and Water Willow that were planted by hand in shallow areas. As these plants grow larger and more dense, they will provide habitat for fish. In addition to fish, many aquatic invertebrates, waterfowl and wading birds use the shallow vegetation for food and shelter.

In addition to planting vegetation, biologists may also sink structures that provide shelter for fish. Some structures may be man-made, while others may be natural, such as Christmas trees following the holidays. In time, algae will grow on these structures to provide food for fish, in addition to shelter. Trees may also be cut along the shoreline and left in the water to provide similar habitat. The photos below show biologists and park rangers sinking Christmas trees and cutting trees along the shoreline to provide shallow fish habitat in Thurmond Lake.