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FOREST STEWARDSHIP SERIES 11

Forest Water Quality

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The purity of fresh water is of vital importance to humans, fish, and wildlife. Since forest management and other land use activities have effects on water quality, it is important to understand what water quality actually is, how it is measured, and how to protect it.

Objective

Understand natural and management effects on forest water quality and the concept of nonpoint source water pollution control.

Competencies

- *Define water quality in relation to the beneficial uses of water.*
- *Learn components and measures of water quality.*
- *Understand the concept of nonpoint source water pollution.*
- *Gain familiarity with regulations requiring control of nonpoint source pollution and the methods of pollution prevention through use of best management practices.*
- *Understand issues to consider when developing water sources.*

Related Forest Stewardship Series Publications

- *Forest Streams, ANR Publication 8239*
- *Riparian Vegetation, ANR Publication 8240*
- *Laws and Regulations Affecting Forests, Part I: Timber Harvesting, ANR Publication 8249*

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WATER QUALITY

The quality of water is measured and expressed in many ways. Common indicators include clarity (turbidity), chemical composition (presence or absence of pesticides, nutrients, petroleum products, etc.), bacterial content (presence or absence of bacteria harmful to animals and humans), and temperature (in relation to tolerance levels of organisms living in the water).

The quality of water for human consumption is extremely important, but other uses have water quality requirements as well. Legal standards have been defined to protect water quality based on these requirements.

Beneficial Uses

California and federal laws and regulations define various beneficial uses of water. Each beneficial use requires its own level of water quality. Beneficial uses of water include

- drinking water
- sustaining fish and aquatic life
- irrigation and livestock
- industrial uses
- swimming, water contact sports, and boating
- navigation
- hydropower generation

Drinking water must be of a much higher quality than water used for irrigation or most industrial purposes. The quality of drinking water is impaired by the presence of bacteria, odor, color, and toxic substances that affect human health, but it is not directly affected by water temperature. Water temperature does, however, influence the suitability of water for cold-water fisheries. A human disturbance that increases temperature, such as riparian vegetation clearing, can reduce water quality for fish but might not affect water quality for other purposes. The uses of water for this variety of purposes are legally defined as beneficial uses.

Natural Variation

Water quality varies naturally over time and from place to place, and is determined at a specific time and place in a watershed by the combined effects of natural watershed processes and human activities. For example, water temperature in a small stream naturally increases during the summer when stream flow is reduced. Human or natural disturbances to riparian vegetation that reduce shade on the stream can exacerbate this effect.

Watersheds with soils prone to erosion have higher natural levels of sediment suspended in runoff and stream water than watersheds with less-erosive soils. Soil texture and cohesiveness, along with topographic slope, determine the potential for erosion. Generally, soils most likely to erode tend to be sandy, poorly consolidated, and found on steeper slopes, such as the decomposed granite soils found in many parts of California. Other fine-textured soils, such as silts and clays, may also be very erosive, especially when barren or disturbed. Even moderate levels of human disturbance in watersheds with highly erosive soils may increase sediment loads to levels that impair beneficial uses because sediment is naturally high anyway (fig. 1).

WATER POLLUTION

Water is considered polluted when it is no longer suitable for one or more beneficial uses. Water pollution comes from either "point" or "nonpoint" sources. Point source pollution enters a water body at a known place and typically involves a known quantity and type of pollutant. An example is wastewater discharged by a sewage treatment plant directly into a stream. This type of impairment can be controlled by measures at the source.

Nonpoint source pollution (NPS) comes from sources dispersed over a large area, rather than from a single point. For example, a number of development sites, parking lots, pastures, irrigated fields, and timber harvest sites dispersed throughout a watershed can combine to cause water pollution in a stream. Nonpoint source pollution is more difficult to control because it does not come from a single point and may cause impairment only as a cumulative effect of many activities.

Figure 1. Some watersheds are naturally more erosive than others, and streams draining them have high natural sediment loads. Stream bank erosion commonly occurs when riparian vegetation has been eliminated and when stream sediment loads are high. *Photo:* Richard Harris.

Types of Nonpoint Source Pollution

Point source pollution is rare in forested watersheds, but nonpoint source pollution is relatively common and can result from typical forest management activities. Excessive sediment, bacterial contamination, excessive nutrients and low levels of dissolved oxygen, and elevated water temperatures, and toxic contamination are types of water pollution that may come from nonpoint sources. Controlling nonpoint source pollution has become increasingly important because control of point source pollution alone is not enough to protect or restore water quality in many watersheds.

Sediment

Excessive fine sediment in a stream is a good example of nonpoint source pollution. A stream may have excessive sediment due to the combined contributions of many land uses within a watershed, such as road construction, urban development, cultivated agriculture, and timber harvesting. Reducing sediment is complicated because landowners in many locations may be involved.

Sediment is an essential component of healthy streams; it forms channel features such as point bars and floodplains that are sites for recruitment of riparian vegetation. Sediment inputs are also required to form spawning gravels and rearing habitat for fish. However, excessive sediment may be harmful to aquatic life particularly if it is in the silt- and clay-size ranges. In streams where fish occur, excessive fine sediment may bury eggs and newly hatched fish.

The amount of sediment in a stream varies naturally according to the rock types and soils through which a stream flows. Some streams have high sediment loads while others, such as streams flowing through bedrock, have very low sediment loads.

Causes of sediment impairment in forested watersheds include erosion resulting from poorly constructed roads and stream crossings, uncontrolled grazing, clearing of riparian vegetation, winter use of roads not designed for use in wet periods, and timber harvesting (fig. 2).

Figure 2. Use of unsurfaced roads in the winter can lead to erosion and sediment delivery to streams. *Photo:* Courtesy Angela Wilson.

Does my stream have a sediment problem? Look for:
- streams with little riparian vegetation and barren banks
- streams that become muddy after rainstorms and take a long time to clear up
- A stream that leaves your property muddier than when it entered

Bacteria

Coliform bacteria endanger the use of water for swimming and drinking. These bacteria are found in the wastes of warm-blooded animals, including humans, livestock, and wild mammals and birds. Coliform bacteria typically make their way into water bodies in above-ground or belowground runoff that has been contaminated by sewage, animal feedlots, or grazing animals. Once these bacteria enter water bodies, most settle to the bottom and become attached to sediment particles. When bottom sediments are disturbed, coliform bacteria can be resuspended and continue to affect water quality.

Does my stream have a bacteria problem? Look for:
- streams with unrestricted access by livestock
- streams with manure, sewage, or septic tanks in their 100-year floodplain
- streams that smell of manure or sewage

Nutrients and Dissolved Oxygen

Nitrogen and phosphorus are necessary for the growth of algae and aquatic plants. These plants serve as the primary food source for aquatic insects and macroinvertebrates that in turn are the primary food sources for fish. The concentration of dissolved oxygen (DO) in water is a result of many factors including water temperature, water movement, and velocity. Water can hold more dissolved oxygen at low temperatures than at higher temperatures. Fast-moving water incorporates atmospheric oxygen as it splashes. This is observable as points of whitewater in stream riffles and rapids. Dissolved oxygen in the water column is essential for aquatic life: oxygen is absorbed by fish and insects and used by bacteria to break down or decompose plants.

When excessive nitrogen and phosphorus enter a water body they may stimulate the growth of an overabundance of algae and aquatic plants. This can lead in turn to an oxygen deficiency in the water, because as the algae die and decompose the decomposing organisms consume the available oxygen. Eventually, a slow-moving stream, lake, or pond may be transformed to a marsh or wetland through this process.

The eventual transformation of lakes, ponds, and some portions of streams into marshes or wetlands is a natural process. When the process is accelerated because human sources increase the rate of nutrient input it is called “cultural eutrophication.” Human sources of excessive nitrogen and phosphorus include discharges from municipal sewage treatment plants, fields with heavy applications of fertilizers, and animal waste storage areas. Water pollution control regulations have evolved over time largely in response to observations of cultural eutrophication in major water bodies.

Even without excessive nitrogen and phosphorus inputs, excessive organic matter in a stream, lake, or pond can impact aquatic life especially when temperatures are too high. Either excessive nutrients or high temperatures can reduce dissolved oxygen levels. One reason for restrictions on the amount of logging debris that can enter a stream is to prevent depletion of dissolved oxygen.

Does my stream have a nutrient or dissolved oxygen problem? Look for:
- streams with green water
- streams with thick, stringy clumps of vegetation
- streams with heavy, dirty, brownish, slimy material coating underwater objects

Temperature

Fish such as salmon and trout need cool water temperatures and high dissolved oxygen content at all stages of their life cycle. Water that is too warm or contains too little oxygen may cause fish to become diseased, halt spawning, reduce the survival rate of eggs, reduce the growth and survival rates of juveniles, increase competition for limited habitat and food, and reduce the ability of the fish to compete with other species.

Water temperature is affected by air temperature, water volume, stream channel shape, and incoming solar radiation. The temperature of water fluctuates along with air temperature, although to lesser extremes. Streams with a lot of water in them tend to stay cooler than those with only a small amount. Wide, shallow streams generally have higher temperatures than narrow, deep streams. Shade cast by riparian vegetation onto stream water blocks incoming solar radiation and helps prevent the water from heating. The main causes of temperature impairment (water that is too hot) are reduced stream flow (either natural or due to diversions) and removal of riparian vegetation (fig. 3).

Does my stream have a temperature problem? Look for:
- streams with very few trees or other plants along their banks
- streams with excessive water removed during the summer
- streams with wide shallow channels

Figure 3. Diversions of streamflow must be authorized by the State Water Resources Control Board, Division of Water Rights, to protect downstream beneficial uses. *Photo:* Richard Harris.

Toxic Substances

Toxic contaminants are chemicals from natural or human sources that are harmful to humans and wildlife. These can include pesticides, chemical toxins, and metals. Although there are exceptions, such as properties that have mining "tailings" with high levels of toxic metals, the principal potential toxic pollution problem on forest properties is pesticides. Pesticides are intended to selectively eliminate certain organisms, but when they are improperly applied, they may directly or indirectly affect others. For example, herbicides are commonly used on forest properties to control unwanted vegetation. If applied at too high a level or if herbicide "drifts" to water bodies, there may be unintended impacts on aquatic plants and animals. Several frog species have been shown to be especially susceptible to poisoning by certain herbicides.

Does my stream have a toxic contamination problem? Look for:

- streams with very little aquatic life
- streams flowing through areas treated frequently with herbicides and pesticides
- streams with chemicals or fuel stored within their 100-year floodplains

Judging Water Quality by Analysis of Macroinvertebrates

Aquatic macroinvertebrates, which are animals without backbones such as insects, worms, and snails, are a major food source for many fish. Biologists sometimes use their presence, absence, or species composition as an indicator of water quality and fish habitat suitability. Macroinvertebrates are quite sensitive to the effects of human disturbances such as excessive nutrients, increased water temperature, and excessive sedimentation.

Surveying for Macroinvertebrates

Macroinvertebrates may be surveyed at varying levels of precision and complexity, depending on need. Informal surveys can be done by nonprofessionals using keys to identify the major types of macroinvertebrates. Collect the organisms by disturbing the stream bottom while holding a net downstream of the disturbed area. Empty the net into a large flat container of water. Small creatures in the water and attached to rocks or pebbles in the pan can then be identified using photographs or a key. Your local California Department of Fish and Game (DFG) staff can provide instructions on how to conduct a simple survey for macroinvertebrates.

The macroinvertebrate species that are most sensitive to pollution and human disturbance include mayflies, stoneflies, and caddisflies. These are also the species most used by fish as a food source. Species that are tolerant to pollution and human disturbance include aquatic worms, leeches, blackflies, midges, and snails.

The assemblage of invertebrates, that is, the relative abundances of pollution-sensitive versus pollution-tolerant species, found in a stream can be used to infer its water quality. Finding many aquatic worms, leeches, and snails and very few mayflies, stoneflies, and caddisflies implies that the stream has low water quality for cold-water fisheries. Although collecting and identifying macroinvertebrates may be difficult, consider conducting a simple survey (see box). You might also inquire at the local DFG office to determine whether any related information is available for streams on your property.

CONTROLLING NONPOINT SOURCE POLLUTION

Prevention is the best strategy for controlling nonpoint source pollution. Many forest-based activities, including timber harvesting, road building, construction, mining, livestock grazing, recreation, fire suppression and fuels treatments, and prescribed fire can produce nonpoint source pollution. Management practices that reduce or avoid creation of nonpoint source pollution are known as Best Management Practices (BMPs). BMPs focus on preventing erosion, using pesticides in an environmentally safe manner, reducing storm runoff, and protecting streams and other water bodies. Many BMPs have been developed and are relatively straightforward to implement.

What you can do for water quality

Pollutant	Best Management Practices (BMPs) or preventive measure
Sediment	Maintain riparian vegetation buffer strips during forest harvesting operations to minimize sediment in runoff.
	Restrict livestock access to stream banks and beds.
	Maintain good vegetative cover on slopes to minimize runoff, erosion, and potential for landsliding.
	Prevent road drainage that carries sediment from discharging directly to streams.
	Maintain and inspect roads to eliminate any chronic erosion sources.
	Close and storm-proof unused roads.
	Conduct earth-moving operations in the dry season only, and use erosion and sediment control measures during the rainy season.
Temperature	Maintain riparian vegetation to provide shade to the stream.
	Maintain adequate stream water levels to keep temperatures low by reducing water withdrawals during the summer.
	Maintain natural channel shapes so flow is not spread out and heated.
Bacteria	Maintain dense riparian vegetation buffer strips to intercept contaminated runoff and prevent it from reaching streams or lakes.
	Restrict livestock access to streams.
Nutrients	Exclude livestock and domestic animals from water bodies and wetlands or riparian areas, using fencing if necessary.
Dissolved oxygen	Maintain or upgrade septic systems on your property to ensure that they are working properly.
	Minimize the use of fertilizers.
	Minimize placement of organic matter such as grass clippings or tree trimming debris in streams.
Toxics	Minimize use of herbicides, pesticides, rodenticides, and fungicides.
	Avoid burning or burying garbage that contains toxic compounds, including televisions, refrigerators and cars. Dispose of these properly at a supervised land fill.

The federal Clean Water Act of 1972 requires control of both point and nonpoint source water pollution. In California, enforcement of water quality standards is the responsibility of the State Water Resources Control Board (SWRCB) and nine regional water quality control boards (RWQCBs). The RWQCBs have adopted Basin Plans that identify the beneficial uses of water in California and establish standards for water quality to maintain these uses. They issue permits to restrict the discharge of point source pollutants into a water body. They are increasingly involved in the regulation of nonpoint source pollution as well. For example, timber harvesting is subject to specific regulatory procedures that require implementation of BMPs.

TIMBER HARVEST PLANNING

The California Department of Forestry and Fire Protection (CAL FIRE) is required to protect water quality from degradation due to forest management activities. CAL FIRE does this by requiring landowners to file timber harvest plans (THPs) or nonindustrial timber management plans (NTMPs) prepared by registered professional foresters. THPs contain a listing of the BMPs that will be used during a timber harvest to protect water quality. RWQCBs participate in the review of THPs and may require additional BMPs. These must be implemented during the harvest. Landowners who do not control nonpoint source pollution during harvest may be cited.

TOTAL MAXIMUM DAILY LOADS (TMDLs)

The U.S. Environmental Protection Agency (EPA) and the SWRCB implement a total maximum daily load (TMDL) program to reduce nonpoint source pollution. Under this program, all states must identify and prepare a list of waters that do not meet water quality standards. The list includes hundreds of water bodies in California, each of which has particular pollutants that are impairing water quality. Streams and rivers in California support many beneficial uses of water and as a result have different levels of impairment due to nonpoint source pollution. The water quality and reasons for impairment are given in table 1.

Each state must prioritize and target water bodies for development of TMDL documents that describe a goal and strategy to attain the desired water quality. TMDL reports are regulatory tools that include a description of the total allowable level of the pollutant(s) in question and allocates loads to individual sources or groups of sources. Landowners with property in the vicinity of listed and prioritized impaired water bodies may face water quality protection requirements in addition to those enforced through other means such as timber harvest plans. To find out if your property is in a watershed that either has or is scheduled for a TMDL, contact your local RWQCB.

DEVELOPING WATER SOURCES

Forest landowners often desire to develop the water available on their property for drinking water, irrigation, stock ponds, or fire control. Laws controlling the use of water are fairly complex in California and are administered by the SWRCB as well as county environmental health departments.

In general, anyone may dig a well on their property provided that the proper permits are obtained. It may also be possible to withdraw water from a stream passing through a property utilizing "riparian rights." Any withdrawals or new stream diversions may be subject to regulation by the SWRCB Division of Water Rights. Wells are typically subject to permit requirements by each county's health or environmental health department to ensure that they are properly located and designed. Water in springs and standing pools that have no natural outlet belong to the landowner and may be used without obtaining a permit from the state. Owners of land along streams must share the stream's water and are subject to many legal considerations. Check with the SWRCB Division of Water Rights before diverting stream or spring water. Your county health or environmental health department will also have requirements you must meet if the purpose is domestic use.

Water development is also regulated by the DFG. Since diverting water from a stream alters the amount of water in the stream available for fish or other aquatic life, the diversion may require a streambed alteration agreement from the DFG. Wells that pump water from the streamside zone are considered to alter the stream water available for fish and may also require a streambed alteration agreement.

Table 1. Regional water quality

Region	Reason for impairment								
	Timber	Agriculture	Livestock grazing	Recreation	Mining	Storm drains	Municipal waste	Septic runoff	Land development
North Coast	X	X							
San Francisco Bay		X			X	X	X		X
Central Coast	X	X				X	X		X
Los Angeles		X				X	X		
Central Valley		X			X	X	X		X
Lahontan			X	X	X	X	X	X	X
Colorado River Basin		X					X		
Santa Ana		X				X	X		
San Diego		X				X			

Ponds do not necessarily require a DFG agreement since water may not be diverted from a stream. But if a pond will store water for more than 30 days, landowners must acquire a water right through the Division of Water Rights. The county planning department may also require a permit.

RESOURCES

The main sources of information on water quality and water pollution control are the Regional Water Quality Control Boards (RWQCBs). In addition to regulating water quality, their staff can assist you in diagnosing a water quality problem or abating a water quality violation in your watershed.

Other important sources of information and technical assistance include the California Department of Forestry and Fire Protection, county environmental health departments, Resource Conservation Districts (RCDs) and the Natural Resource Conservation Service (NRCS). Always contact local offices of state and federal agencies to obtain advice from staff familiar with your area.

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