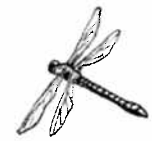
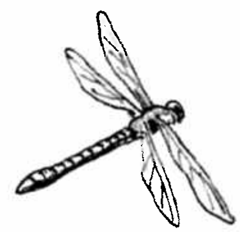
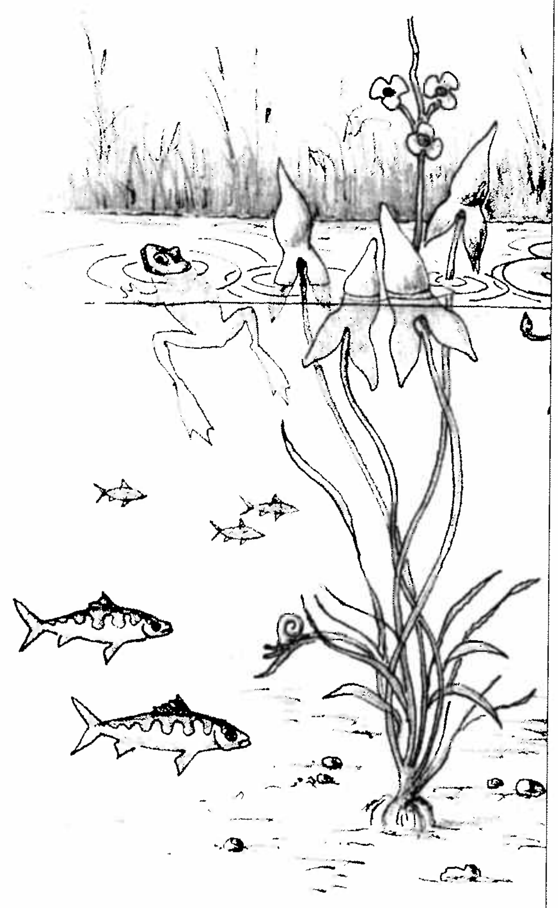
AQUATIC ECOLOGY KEY POINTS



Students should be able to:

- Identify the processes and phases for each part of the water cycle.
- Describe the chemical and physical properties of water and explain their implications for freshwater and saltwater ecosystems.
- Analyze the interaction of competing uses of water for water supply, hydropower, navigation, wildlife, recreation, waste assimilation, irrigation, industry, and others.
- Discuss methods of conserving water and reducing point and non-point source pollution.
- Identify common aquatic organisms through the use of a key.
- Delineate the watershed boundary for a small water body.
- Explain the different types of aquifers and how each type relates to water quantity and quality.
- Briefly describe the benefits of wetlands, including both function and value.
- Describe the benefits of riparian areas, including both function and value.
- Describe the changes to the aquatic ecosystem based on alteration to the aquatic habitat.
- Know methods used to assess and manage aquatic environments and be able to utilize water quality information to assess the general water quality of a specific body of water. This includes sampling, technique, and water quality parameters used to monitor point and non-point source pollution.
- Be familiar with major methods and laws used to protect water quality (i.e., both surface and ground water) and utilize this information to make management decisions to improve the quality of water in a given situation.





Canon ENVIROTHON

For more information about the Canon Envirothon, please visit us on the web at **www.envirothon.org**

Note to students:

This glossary is to help you better understand some of the terms used in the study material. You will not be tested on all these terms. However, you should know the definitions of the follow key terms:

Aquifer
Condensation
Dissolved oxygen
Drainage basin
Estuary
Ground water
Hardness
Hydrologic cycle
Infiltration
Non-point source pollution
pH
Point-source pollution
Riparian area
Sediment
Tributary
Turbidity
Wastewater
Water cycle
Water quality
Watershed

Water Science for Schools

Water Science Glossary of Terms

Here's a list of water-related terms that might help you understand our site better. It is compiled from a number of sources and should not be considered an "official" U.S. Geological Survey water glossary. A detailed water glossary is kept by the Water Quality Association, and an **extremely detailed** water dictionary is offered by the Nevada Division of Water Resources).

Top

A

acequia--acequias were important forms of irrigation in the development of agriculture in the American Southwest. The proliferation of cotton, pecans and green chile as major agricultual staples owe their progress to the acequia system.

acid--a substance that has a pH of less than 7, which is neutral. Specifically, an acid has more free hydrogen ions (H^+) than hydroxyl ions (OH^-).

acre-foot (acre-ft)--the volume of water required to cover 1 acre of land (43,560 square feet) to a depth of 1 foot. Equal to 325,851 gallons or 1,233 cubic meters.

alkaline--sometimes water or soils contain an amount of alkali (strongly basic) substances sufficient to raise the pH value above 7.0 and be harmful to the growth of crops.

alkalinity--the capacity of water for neutralizing an acid solution.

alluvium--deposits of clay, silt, sand, gravel, or other particulate material that has been deposited by a stream or other body of running water in a streambed, on a flood plain, on a delta, or at the base of a mountain.

appropriation doctrine--the system for allocating water to private individuals used in most Western states. The doctrine of Prior Appropriation was in common use throughout the arid west as early settlers and miners began to develop the land. The prior appropriation doctrine is based on the concept of "First in Time, First in Right." The first person to take a quantity of water and put it to Beneficial Use has a higher priority of right than a subsequent user. Under drought conditions, higher priority users are satisfied before junior users receive water. Appropriative rights can be lost through nonuse; they can also be sold or transferred apart from the land. Contrasts with Riparian Water Rights.

aquaculture--farming of plants and animals that live in water, such as fish, shellfish, and algae.

aqueduct--a pipe, conduit, or channel designed to transport water from a remote source, usually by gravity.

aquifer--a geologic formation(s) that is water bearing. A geological formation or structure that stores and/or transmits water, such as to wells and springs. Use of the term is usually restricted to those water-bearing formations capable of yielding water in sufficient quantity to constitute a usable supply for people's uses.

aquifer (confined)--soil or rock below the land surface that is saturated with water. There are layers of impermeable material both above and below it and it is under pressure so that when the aquifer is penetrated by a well, the water will rise above the top of the aquifer.

aquifer (unconfined)--an aquifer whose upper water surface (water table) is at atmospheric pressure, and thus is able to rise and fall.

artesian water--ground water that is under pressure when tapped by a well and is able to rise above the level at which it is first encountered. It may or may not flow out at ground level. The pressure in such an aquifer commonly is called artesian pressure, and the formation containing artesian water is an artesian aquifer or confined aquifer. See *flowing well*

artificial recharge--an process where water is put back into ground-water storage from surface-water supplies such as irrigation, or induced infiltration from streams or wells.

Top

B

base flow--sustained flow of a stream in the absence of direct runoff. It includes natural and human-induced streamflows. Natural base flow is sustained largely by ground-water discharges.

base--a substance that has a pH of more than 7, which is neutral. A base has less free hydrogen ions (H^+) than hydroxyl ions (OH^-).

bedrock--the solid rock beneath the soil and superficial rock. A general term for solid rock that lies beneath soil, loose sediments, or other unconsolidated material.

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C

capillary action--the means by which liquid moves through the porous spaces in a solid, such as soil, plant roots, and the capillary blood vessels in our bodies due to the forces of adhesion, cohesion, and surface tension. Capillary action is essential in carrying substances and nutrients from one place to another in plants and animals.

commercial water use--water used for motels, hotels, restaurants, office buildings, other commercial facilities, and institutions. Water for commercial uses comes both from public-supplied sources, such as a county water department, and self-supplied sources, such as local wells.

condensation--the process of water vapor in the air turning into liquid water. Water drops on the outside of a cold glass of water are condensed water. Condensation is the opposite process of evaporation.

consumptive use--that part of water withdrawn that is evaporated, transpired by plants, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment. Also referred to as water consumed.

conveyance loss--water that is lost in transit from a pipe, canal, or ditch by leakage or evaporation. Generally, the water is not available for further use; however, leakage from an irrigation ditch, for example, may percolate to a ground-water source and be available for further use.

cubic feet per second (cfs)--a rate of the flow, in streams and rivers, for example. It is equal to a volume of water one foot high and one foot wide flowing a distance of one foot in one second. One "cfs" is equal to 7.48 gallons of water flowing each second. As an example, if your car's gas tank is 2 feet by 1 foot by 1 foot (2 cubic feet), then gas flowing at a rate of 1 cubic foot/second would fill the tank in two seconds.

Top

D

desalinization--the removal of salts from saline water to provide freshwater. This method is becoming a more popular way of providing freshwater to populations.

discharge--the volume of water that passes a given location within a given period of time. Usually expressed in cubic feet per second.

domestic water use--water used for household purposes, such as drinking, food preparation, bathing, washing clothes, dishes, and dogs, flushing toilets, and watering lawns and gardens. About 85% of domestic water is delivered to homes by a public-supply facility, such as a county water department. About 15% of the Nation's population supply their own water, mainly from wells.

drainage basin--land area where precipitation runs off into streams, rivers, lakes, and reservoirs. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large drainage basins, like the area that drains into the Mississippi River contain thousands of smaller drainage basins. Also called a "watershed."

drip irrigation--a common irrigation method where pipes or tubes filled with water slowly drip onto crops. Drip irrigation is a low-pressure method of irrigation and less water is lost to evaporation than high-pressure spray irrigation.

drawdown--a lowering of the ground-water surface caused by pumping.

Top

E

effluent--water that flows from a sewage treatment plant after it has been treated.

erosion--the process in which a material is worn away by a stream of liquid (water) or air, often due to the presence of abrasive particles in the stream.

estuary--a place where fresh and salt water mix, such as a bay, salt marsh, or where a river enters an ocean.

evaporation--the process of liquid water becoming water vapor, including vaporization from water surfaces, land surfaces, and snow fields, but not from leaf surfaces. See transpiration

evapotranspiration--the sum of evaporation and transpiration.

Top F

flood--An overflow of water onto lands that are used or usable by man and not normally covered by water. Floods have two essential characteristics: The inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river, stream, lake, or ocean.

flood, 100-year--A 100-year flood does not refer to a flood that occurs once every 100 years, but to a flood level with a 1 percent chance of being equaled or exceeded in any given year.

flood plain--a strip of relatively flat and normally dry land alongside a stream, river, or lake that is covered by water during a flood.

flood stage--The elevation at which overflow of the natural banks of a stream or body of water begins in the reach or area in which the elevation is measured.

flowing well/spring--a well or spring that taps ground water under pressure so that water rises without pumping. If the water rises above the surface, it is known as a flowing well.

freshwater, freshwater--water that contains less than 1,000 milligrams per liter (mg/L) of dissolved solids; generally, more than 500 mg/L of dissolved solids is undesirable for drinking and many industrial uses.

Top G

gage height--the height of the water surface above the gage datum (zero point). Gage height is often used interchangeably with the more general term, stage, although gage height is more appropriate when used with a gage reading.

gaging station--a site on a stream, lake, reservoir or other body of water where observations and hydrologic data are obtained. The U.S. Geological Survey measures stream discharge at gaging stations.

geyser--a geothermal feature of the Earth where there is an opening in the surface that contains superheated water that periodically erupts in a shower of water and steam.

giardiasis--a disease that results from an infection by the protozoan parasite Giardia Intestinalis, caused by drinking water that is either not filtered or not chlorinated. The disorder is more prevalent in children than in adults and is characterized by abdominal discomfort, nausea, and alternating constipation and diarrhea.

glacier--a huge mass of ice, formed on land by the compaction and recrystallization of snow, that moves very slowly downslope or outward due to its own weight.

greywater--wastewater from clothes washing machines, showers, bathtubs, hand washing, lavatories and sinks.

ground water--(1) water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper surface of the saturate zone is called the water table. (2) Water stored underground in rock crevices and in the pores of geologic materials that make up the Earth's crust.

ground water, confined--ground water under pressure significantly greater than atmospheric, with its upper limit the bottom of a bed with hydraulic conductivity distinctly lower than that of the material in which the confined water occurs.

ground-water recharge--inflow of water to a ground-water reservoir from the surface. Infiltration of precipitation and its movement to the water table is one form of natural recharge. Also, the volume of water added by this process.

ground water, unconfined--water in an aquifer that has a water table that is exposed to the atmosphere.

Top

H

hardness--a water-quality indication of the concentration of alkaline salts in water, mainly calcium and magnesium. If the water you use is "hard" then more soap, detergent or shampoo is necessary to raise a lather.

headwater(s)--(1) the source and upper reaches of a stream; also the upper reaches of a reservoir. (2) the water upstream from a structure or point on a stream. (3) the small streams that come together to form a river. Also may be thought of as any and all parts of a river basin except the mainstream river and main tributaries.

hydroelectric power water use--the use of water in the generation of electricity at plants where the turbine generators are driven by falling water.

hydrologic cycle--the cyclic transfer of water vapor from the Earth's surface via evapotranspiration into the atmosphere, from the atmosphere via precipitation back to earth, and through runoff into streams, rivers, and lakes, and ultimately into the oceans.

Top

I

impermeable layer--a layer of solid material, such as rock or clay, which does not allow water to pass through.

industrial water use--water used for industrial purposes in such industries as steel, chemical, paper, and petroleum refining. Nationally, water for industrial uses comes mainly (80%) from self-supplied sources, such as a local wells or withdrawal points in a river, but some water comes from public-supplied sources, such as the county/city water department.

infiltration--flow of water from the land surface into the subsurface.

injection well--refers to a well constructed for the purpose of injecting treated wastewater directly into the ground. Wastewater is generally forced (pumped) into the well for dispersal or storage into a designated aquifer. Injection wells are generally drilled into aquifers that don't deliver drinking water, unused aquifers, or below freshwater levels.

irrigation--the controlled application of water for agricultural purposes through manmade systems to supply water requirements not satisfied by rainfall. Here's a quick look at some types of irrigation systems.

irrigation water use--water application on lands to assist in the growing of crops and pastures or to maintain vegetative growth in recreational lands, such as parks and golf courses.

Top K

kilogram--one thousand grams.

kilowatthour (KWH)--a power demand of 1,000 watts for one hour. Power company utility rates are typically expressed in cents per kilowatt-hour.

Top L

leaching--the process by which soluble materials in the soil, such as salts, nutrients, pesticide chemicals or contaminants, are washed into a lower layer of soil or are dissolved and carried away by water.

lentic waters--ponds or lakes (standing water).

levee--a natural or manmade earthen barrier along the edge of a stream, lake, or river. Land alongside rivers can be protected from flooding by levees.

livestock water use--water used for livestock watering, feed lots, dairy operations, fish farming, and other on-farm needs.

lotic waters--flowing waters, as in streams and rivers.

Top M

maximum contaminant level (MCL)--the designation given by the U.S. Environmental Protection Agency (EPA) to water-quality standards promulgated under the Safe Drinking Water Act. The MCL is the greatest amount of a contaminant that can be present in drinking water without causing a risk to human health.

milligram (mg)--One-thousandth of a gram.

milligrams per liter (mg/l)--a unit of the concentration of a constituent in water or wastewater. It represents 0.001 gram of a constituent in 1 liter of water. It is approximately equal to one part per million (PPM).

million gallons per day (Mgd)--a rate of flow of water equal to 133,680.56 cubic feet per day, or 1.5472 cubic feet per second, or 3.0689 acre-feet per day. A flow of one million gallons per day for one year equals 1,120 acre-feet (365 million gallons).

mining water use--water use during quarrying rocks and extracting minerals from the land.

municipal water system--a water system that has at least five service connections or which regularly serves 25 individuals for 60 days; also called a public water system

Top N

nephelometric turbidity unit (NTU)--unit of measure for the turbidity of water. Essentially, a measure of the cloudiness of water as measured by a nephelometer. Turbidity is based on the amount of light that is reflected off particles in the water.

NGVD--National Geodetic Vertical Datum. (1) As corrrected in 1929, a vertical control measure used as a reference for establishing varying elevations. (2) Elevation datum plane previously used by the Federal Emergency Management Agency (FEMA) for the determination of flood elevations. FEMA current uses the North American Vertical Datum Plane.

NGVD of 1929--National Geodetic Vertical Datum of 1929. A geodetic datum derived from a general adjustment of the first order level nets of the United States and Canada. It was formerly called "Sea Level Datum of 1929" or "mean sea level" in the USGS series of reports. Although the datum was derived from the average sea level over a period of many years at 26 tide stations along the Atlantic, Gulf of Mexico, and Pacific Coasts, it does not necessarily represent local mean sea level at any particular place.

non-point source (NPS) pollution--pollution discharged over a wide land area, not from one specific location. These are forms of diffuse pollution caused by sediment, nutrients, organic and toxic substances originating from land-use activities, which are carried to lakes and streams by surface runoff. Non-point source pollution is contamination that occurs when rainwater, snowmelt, or irrigation washes off plowed fields, city streets, or suburban backyards. As this runoff moves across the land surface, it picks up soil particles and pollutants, such as nutrients and pesticides.

Top

O

organic matter--plant and animal residues, or substances made by living organisms. All are based upon carbon compounds.

osmosis--the movement of water molecules through a thin membrane. The osmosis process occurs in our bodies and is also one method of desalinizing saline water.

outfall--the place where a sewer, drain, or stream discharges; the outlet or structure through which reclaimed water or treated effluent is finally discharged to a receiving water body.

oxygen demand--the need for molecular oxygen to meet the needs of biological and chemical processes in water. Even though very little oxygen will dissolve in water, it is extremely important in biological and chemical processes.

Top

P

pH--a measure of the relative acidity or alkalinity of water. Water with a pH of 7 is neutral; lower pH levels indicate increasing acidity, while pH levels higher than 7 indicate increasingly basic solutions.
View a diagram about pH.

particle size--the diameter, in millimeters, of suspended sediment or bed material. Particle-size classifications are:
[1] Clay—0.00024-0.004 millimeters (mm);
[2] Silt—0.004-0.062 mm;
[3] Sand—0.062-2.0 mm; and
[4] Gravel—2.0-64.0 mm.

parts per billion--the number of "parts" by weight of a substance per billion parts of water. Used to measure extremely small concentrations.

parts per million--the number of "parts" by weight of a substance per million parts of water. This unit is commonly used to represent pollutant concentrations.

pathogen--a disease-producing agent; usually applied to a living organism. Generally, any viruses, bacteria, or fungi that cause disease.

peak flow--the maximum instantaneous discharge of a stream or river at a given location. It usually occurs at or near the time of maximum stage.

per capita use--the average amount of water used per person during a standard time period, generally per day.

percolation--(1) The movement of water through the openings in rock or soil. (2) the entrance of a portion of the streamflow into the channel materials to contribute to ground water replenishment.

permeability--the ability of a material to allow the passage of a liquid, such as water through rocks. Permeable materials, such as gravel and sand, allow water to move quickly through them, whereas unpermeable material, such as clay, don't allow water to flow freely.

point-source pollution--water pollution coming from a single point, such as a sewage-outflow pipe.

polychlorinated biphenyls (PCBs)--a group of synthetic, toxic industrial chemical compounds once used in making paint and electrical transformers, which are chemically inert and not biodegradable. PCBs were frequently found in industrial wastes, and subsequently found their way into surface and ground waters. As a result of their persistence, they tend to accumulate in the environment. In terms of streams and rivers, PCBs are drawn to sediment, to which they attach and can remain virtually indefinitely. Although virtually banned in 1979 with the passage of the Toxic Substances Control Act, they continue to appear in the flesh of fish and other animals.

porosity--a measure of the water-bearing capacity of subsurface rock. With respect to water movement, it is not just the total magnitude of porosity that is important, but the size of the voids and the extent to which they are interconnected, as the pores in a formation may be open, or interconnected, or closed and isolated. For example, clay may have a very high porosity with respect to potential water content, but it constitutes a poor medium as an aquifer because the pores are usually so small.

potable water--water of a quality suitable for drinking.

precipitation--rain, snow, hail, sleet, dew, and frost.

primary wastewater treatment--the first stage of the wastewater-treatment process where mechanical methods, such as filters and scrapers, are used to remove pollutants. Solid material in sewage also settles out in this process.

prior appropriation doctrine--the system for allocating water to private individuals used in most Western states. The doctrine of Prior Appropriation was in common use throughout the arid West as early settlers and miners began to develop the land. The prior appropriation doctrine is based on the concept of "First in Time, First in Right." The first person to take a quantity of water and put it to beneficial use has a higher priority of right than a subsequent user. The rights can be lost through nonuse; they can also be sold or transferred apart from the land. Contrasts with riparian water rights.

public supply--water withdrawn by public governments and agencies, such as a county water department, and by private companies that is then delivered to users. Public suppliers provide water for domestic, commercial, thermoelectric power, industrial, and public water users. Most people's household water is delivered by a public water supplier. The systems have at least 15 service connections (such as households, businesses, or schools) or regularly serve at least 25 individuals daily for at least 60 days out of the year.

public water use--water supplied from a public-water supply and used for such purposes as firefighting, street washing, and municipal parks and swimming pools.

Top

R

rating curve--A drawn curve showing the relation between gage height and discharge of a stream at a given gaging station.

recharge--water added to an aquifer. For instance, rainfall that seeps into the ground.

reclaimed wastewater--treated wastewater that can be used for beneficial purposes, such as irrigating certain plants.

recycled water--water that is used more than one time before it passes back into the natural hydrologic system.

reservoir--a pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water.

return flow--(1) That part of a diverted flow that is not consumptively used and returned to its original source or another body of water. (2) (Irrigation) Drainage water from irrigated farmlands that re-enters the water system to be used further downstream.

returnflow (irrigation)--irrigation water that is applied to an area and which is not consumed in evaporation or transpiration and returns to a surface stream or aquifer.

reverse osmosis--(1) (Desalination) The process of removing salts from water using a membrane. With reverse osmosis, the product water passes through a fine membrane that the salts are unable to pass through, while the salt waste (brine) is removed and disposed. This process differs from electrodialysis, where the salts are extracted from the feedwater by using a membrane with an electrical current to separate the ions. The positive ions go through one membrane, while the negative ions flow through a different membrane, leaving the end product of freshwater. (2) (Water Quality) An advanced method of water or wastewater treatment that relies on a semi-permeable membrane to separate waters from pollutants. An external force is used to reverse the normal osmotic process resulting in the solvent moving from a solution of higher concentration to one of lower concentration.

riparian water rights--the rights of an owner whose land abuts water. They differ from state to state and often depend on whether the water is a river, lake, or ocean. The doctrine of riparian rights is an old one, having its origins in English common law. Specifically, persons who own land adjacent to a stream have the right to make reasonable use of the stream. Riparian users of a stream share the streamflow among themselves, and the concept of priority of use (Prior Appropriation Doctrine) is not applicable. Riparian rights cannot be sold or transferred for use on nonriparian land.

river--A natural stream of water of considerable volume, larger than a brook or creek.

runoff--(1) That part of the precipitation, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers. Runoff may be classified according to speed of appearance after rainfall or melting snow as direct runoff or base runoff, and according to source as surface runoff, storm interflow, or ground-water runoff. (2) The total discharge described in (1), above, during a specified period of time. (3) Also defined as the depth to which a drainage area would be covered if all of the runoff for a given period of time were uniformly distributed over it.

Top

S

saline water--water that contains significant amounts of dissolved solids.

Here are our parameters for saline water:
Fresh water - Less than 1,000 parts per million (ppm)
Slightly saline water - From 1,000 ppm to 3,000 ppm
Moderatly saline water - From 3,000 ppm to 10,000 ppm
Highly saline water - From 10,000 ppm to 35,000 ppm

secondary wastewater treatment--treatment (following primary wastewater treatment) involving the biological process of reducing suspended, colloidal, and dissolved organic matter in effluent from primary treatment systems and which generally removes 80 to 95 percent of the Biochemical Oxygen Demand (BOD) and suspended matter. Secondary wastewater treatment may be accomplished by biological or chemical-physical methods. Activated sludge and trickling filters are two of the most common means of secondary treatment. It is accomplished by bringing together waste, bacteria, and oxygen in trickling filters or in the activated sludge process. This treatment removes floating and settleable solids and about 90 percent of the oxygen-demanding substances and suspended solids. Disinfection is the final stage of secondary treatment.

sediment--usually applied to material in suspension in water or recently deposited from suspension. In the plural the word is applied to all kinds of deposits from the waters of streams, lakes, or seas.

sedimentary rock--rock formed of sediment, and specifically: (1) sandstone and shale, formed of fragments of other rock transported from their sources and deposited in water; and (2) rocks formed by or from secretions of organisms, such as most limestone. Many sedimentary rocks show distinct layering, which is the result of different types of sediment being deposited in succession.

sedimentation tanks--wastewater tanks in which floating wastes are skimmed off and settled solids are removed for disposal.

self-supplied water--water withdrawn from a surface- or ground-water source by a user rather than being obtained from a public supply. An example would be homeowners getting their water from their own well.

seepage--(1) The slow movement of water through small cracks, pores, Interstices, etc., of a material into or out of a body of surface or subsurface water. (2) The loss of water by infiltration into the soil from a canal, ditches, laterals, watercourse, reservoir, storage facilities, or other body of water, or from a field.

septic tank--a tank used to detain domestic wastes to allow the settling of solids prior to distribution to a leach field for soil absorption. Septic tanks are used when a sewer line is not available to carry them to a treatment plant. A settling tank in which settled sludge is in immediate contact with sewage flowing through the tank, and wherein solids are decomposed by anaerobic bacterial action.

settling pond (water quality)--an open lagoon into which wastewater contaminated with solid pollutants is placed and allowed to stand. The solid pollutants suspended in the water sink to the bottom of the lagoon and the liquid is allowed to overflow out of the enclosure.

sewage treatment plant--a facility designed to receive the wastewater from domestic sources and to remove materials that damage water quality and threaten public health and safety when discharged into receiving streams or bodies of water. The substances removed are classified into four basic areas:
[1] greases and fats;
[2] solids from human waste and other sources;
[3] dissolved pollutants from human waste and decomposition products; and
[4] dangerous microorganisms.
Most facilities employ a combination of mechanical removal steps and bacterial decomposition to achieve the desired results. Chlorine is often added to discharges from the plants to reduce the danger of spreading disease by the release of pathogenic bacteria.

sewer--a system of underground pipes that collect and deliver wastewater to treatment facilities or streams.

sinkhole--a depression in the Earth's surface caused by dissolving of underlying limestone, salt, or gypsum. Drainage is provided through underground channels that may be enlarged by the collapse of a cavern roof.

solute--a substance that is dissolved in another substance, thus forming a solution.

solution--a mixture of a solvent and a solute. In some solutions, such as sugar water, the substances mix so thoroughly that the solute cannot be seen. But in other solutions, such as water mixed with dye, the solution is visibly changed.

solvent--a substance that dissolves other substances, thus forming a solution. Water dissolves more substances than any other, and is known as the "universal solvent".

specific conductance--a measure of the ability of water to conduct an electrical current as measured using a 1-cm cell and expressed in units of electrical conductance, i.e., Siemens per centimeter at 25 degrees Celsius. Specific conductance can be used for approximating the total dissolved solids content of water by testing its capacity to carry an electrical current. In water quality, specific conductance is used in ground water monitoring as an indication of the presence of ions of chemical substances that may have been released by a leaking landfill or other waste storage or disposal facility. A higher specific conductance in water drawn from downgradient wells when compared to upgradient wells indicates possible contamination from the facility.

spray irrigation--an common irrigation method where water is shot from high-pressure sprayers onto crops. Because water is shot high into the air onto crops, some water is lost to evaporation.

storm sewer--a sewer that carries only surface runoff, street wash, and snow melt from the land. In a separate sewer system, storm sewers are completely separate from those that carry domestic and commercial wastewater (sanitary sewers).

stream--a general term for a body of flowing water; natural water course containing water at least part of the year. In hydrology, it is generally applied to the water flowing in a natural channel as distinct from a canal.

streamflow--the water discharge that occurs in a natural channel. A more general term than runoff, streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

subsidence--a dropping of the land surface as a result of ground water being pumped. Cracks and fissures can appear in the land. Subsidence is virtually an irreversible process.

surface tension--the attraction of molecules to each other on a liquid's surface. Thus, a barrier is created between the air and the liquid.

surface water--water that is on the Earth's surface, such as in a stream, river, lake, or reservoir.

suspended sediment--very fine soil particles that remain in suspension in water for a considerable period of time without contact with the bottom. Such material remains in suspension due to the upward components of turbulence and currents and/or by suspension.

suspended-sediment concentration--the ratio of the mass of dry sediment in a water-sediment mixture to the mass of the water-sediment mixture. Typically expressed in milligrams of dry sediment per liter of water-sediment mixture.

suspended-sediment discharge--the quantity of suspended sediment passing a point in a stream over a specified period of time. When expressed in tons per day, it is computed by multiplying water discharge (in cubic feet per second) by the suspended-sediment concentration (in milligrams per liter) and by the factor 0.0027.

suspended solids--solids that are not in true solution and that can be removed by filtration. Such suspended solids usually contribute directly to turbidity. Defined in waste management, these are small particles of solid pollutants that resist separation by conventional methods.

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T

tertiary wastewater treatment--selected biological, physical, and chemical separation processes to remove organic and inorganic substances that resist conventional treatment practices; the additional treatment of effluent beyond that of primary and secondary treatment methods to obtain a very high quality of effluent. The complete wastewater treatment process typically involves a three-phase process: (1) First, in the primary wastewater treatment process, which incorporates physical aspects, untreated water is passed through a series of screens to remove solid wastes; (2) Second, in the secondary wastewater treatment process, typically involving biological and chemical processes, screened wastewater is then passed a series of holding and aeration tanks and ponds; and (3) Third, the tertiary wastewater treatment process consists of flocculation basins, clarifiers, filters, and chlorine basins or ozone or ultraviolet radiation processes.

thermal pollution--a reduction in water quality caused by increasing its temperature, often due to disposal of waste heat from industrial or power generation processes. Thermally polluted water can harm the environment because plants and animals can have a hard time adapting to it.

thermoelectric power water use--water used in the process of the generation of thermoelectric power. Power plants that burn coal and oil are examples of thermoelectric-power facilities.

transmissibility (ground water)--the capacity of a rock to transmit water under pressure. The coefficient of transmissibility is the rate of flow of water, at the prevailing water temperature, in gallons per day, through a vertical strip of the aquifer one foot wide, extending the full saturated height of the aquifer under a hydraulic gradient of 100-percent. A hydraulic gradient of 100-percent means a one foot drop in head in one foot of flow distance.

transpiration--process by which water that is absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface, such as leaf pores. See evapotranspiration.

Tributary--a smaller river or stream that flows into a larger river or stream. Usually, a number of smaller tributaries merge to form a river.

turbidity--the amount of solid particles that are suspended in water and that cause light rays shining through the water to scatter. Thus, turbidity makes the water cloudy or even opaque in extreme cases. Turbidity is measured in nephelometric turbidity units (NTU).

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U

unsaturated zone--the zone immediately below the land surface where the pores contain both water and air, but are not totally saturated with water. These zones differ from an aquifer, where the pores are saturated with water.

Top

W

wastewater--water that has been used in homes, industries, and businesses that is not for reuse unless it is treated.

wastewater-treatment return flow--water returned to the environment by wastewater-treatment facilities.

water cycle--the circuit of water movement from the oceans to the atmosphere and to the Earth and return to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transportation.

water quality--a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

water table--the top of the water surface in the saturated part of an aquifer.

water use--water that is used for a specific purpose, such as for domestic use, irrigation, or industrial processing. Water use pertains to human's interaction with and influence on the hydrologic cycle, and includes elements, such as water withdrawal from surface- and ground-water sources, water delivery to homes and businesses, consumptive use of water, water released from wastewater-treatment plants, water returned to the environment, and instream uses, such as using water to produce hydroelectric power.

watershed--the land area that drains water to a particular stream, river, or lake. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large watersheds, like the Mississippi River basin contain thousands of smaller watersheds.

watthour (Wh)--an electrical energy unit of measure equal to one watt of power supplied to, or taken from, an electrical circuit steadily for one hour.

well (water)--an artificial excavation put down by any method for the purposes of withdrawing water from the underground aquifers. A bored, drilled, or driven shaft, or a dug hole whose depth is greater than the largest surface dimension and whose purpose is to reach underground water supplies or oil, or to store or bury fluids below ground.

withdrawal--water removed from a ground- or surface-water source for use.

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X

xeriscaping--a method of landscaping that uses plants that are well adapted to the local area and are drought-resistant. Xeriscaping is becoming more popular as a way of saving water at home.
More on xeriscaping: Colorado WaterWise Council

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Y

yield--mass per unit time per unit area

Some of this information is courtesy of the the Nevada Division of Water Resources.

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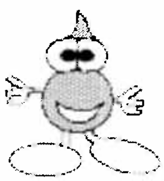
USGS
science for a changing world
Water Science Basics

U.S. Geological Survey: The water cycle
Back • Water-cycle home

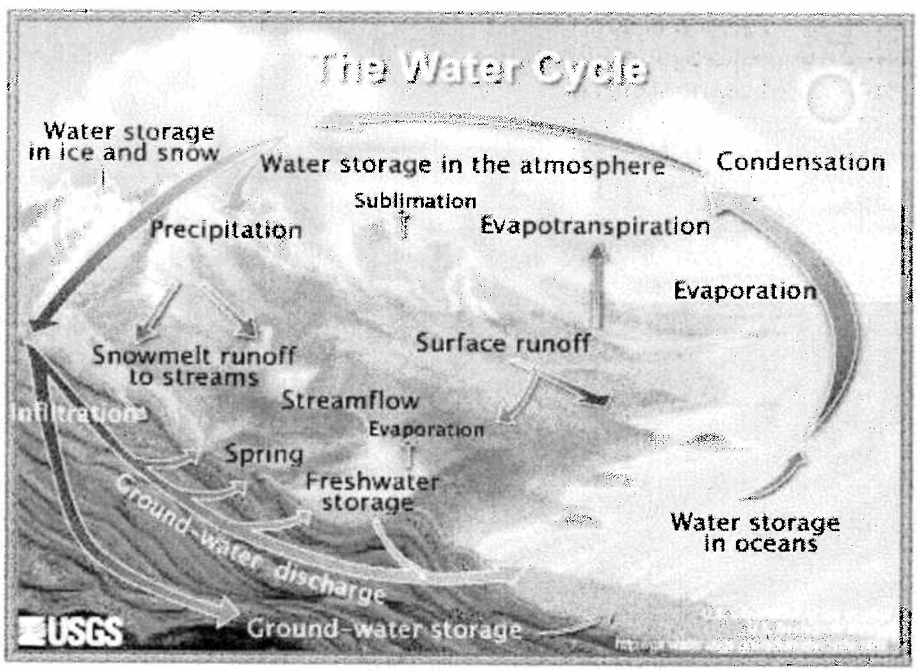
What is the water cycle?



What is the water cycle? I can easily answer that—it is "me" all over! The water cycle describes the existence and movement of water on, in, and above the Earth. Earth's water is always in movement and is always changing states, from liquid to vapor to ice and back again. The water cycle has been working for billions of years and all life on Earth depends on it continuing to work; the Earth would be a pretty stale place to live without it.

Where does all the Earth's water come from? Primordial Earth was an incandescent globe made of magma, but all magmas contain water. Water set free by magma began to cool down the Earth's atmosphere, until it could stay on the surface as a liquid. Volcanic activity kept and still keeps introducing water in the atmosphere, thus increasing the surface- and ground-water volume of the Earth.

A quick summary of the water cycle



Here is a quick summary of the water cycle. The links in this paragraph go to the detailed Web pages in our Web site for each topic. A shorter summary of each topic can be found further down in this page, though.

The water cycle has no starting point. But, we'll begin in the oceans, since that is where most of Earth's water exists. The sun, which drives the water cycle, heats water in the oceans. Some of it evaporates as vapor into the air. Ice and snow can sublimate directly into water vapor. Rising air currents take the vapor up into the atmosphere, along with water from evapotranspiration, which is water transpired from plants and evaporated from the soil. The vapor rises into the air where cooler temperatures cause it to condense into clouds. Air currents move clouds around the globe, cloud particles collide, grow, and fall out of the sky as precipitation. Some precipitation falls as snow and can accumulate as ice caps and glaciers, which can store frozen water for thousands of years. Snowpacks in warmer climates often thaw and melt when spring arrives, and the melted water flows overland as snowmelt. Most precipitation falls back into the oceans or onto land, where, due to gravity, the precipitation flows over the ground as surface runoff. A portion of runoff enters rivers in valleys in the landscape, with streamflow moving water towards the oceans. Runoff, and ground-water seepage, accumulate and are stored as freshwater in lakes. Not all runoff flows into rivers, though. Much of it soaks into the ground as infiltration. Some water infiltrates deep into the ground and replenishes aquifers (saturated subsurface rock), which store huge amounts of freshwater for long periods of time. Some infiltration stays close to the land surface and can seep back into surface-water bodies (and the ocean) as ground-water discharge, and some ground water finds openings in the land surface and emerges as freshwater springs. Over time, though, all of this water keeps moving, some to reenter the ocean, where the water cycle "ends" ... oops - I mean, where it "begins."

Components of the water cycle

The U.S. Geological Survey (USGS) has identified 16 components of the water cycle:

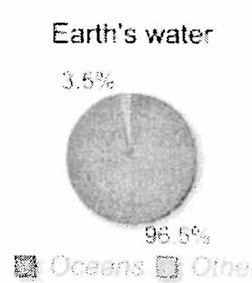
- Water storage in oceans
- Evaporation
- Sublimation
- Evapotranspiration
- Water in the atmosphere
- Condensation
- Precipitation
- Water storage in ice and snow
- Snowmelt runoff to streams
- Surface runoff
- Streamflow
- Freshwater storage
- Infiltration
- Ground-water storage
- Ground-water discharge
- Springs

Global water distribution

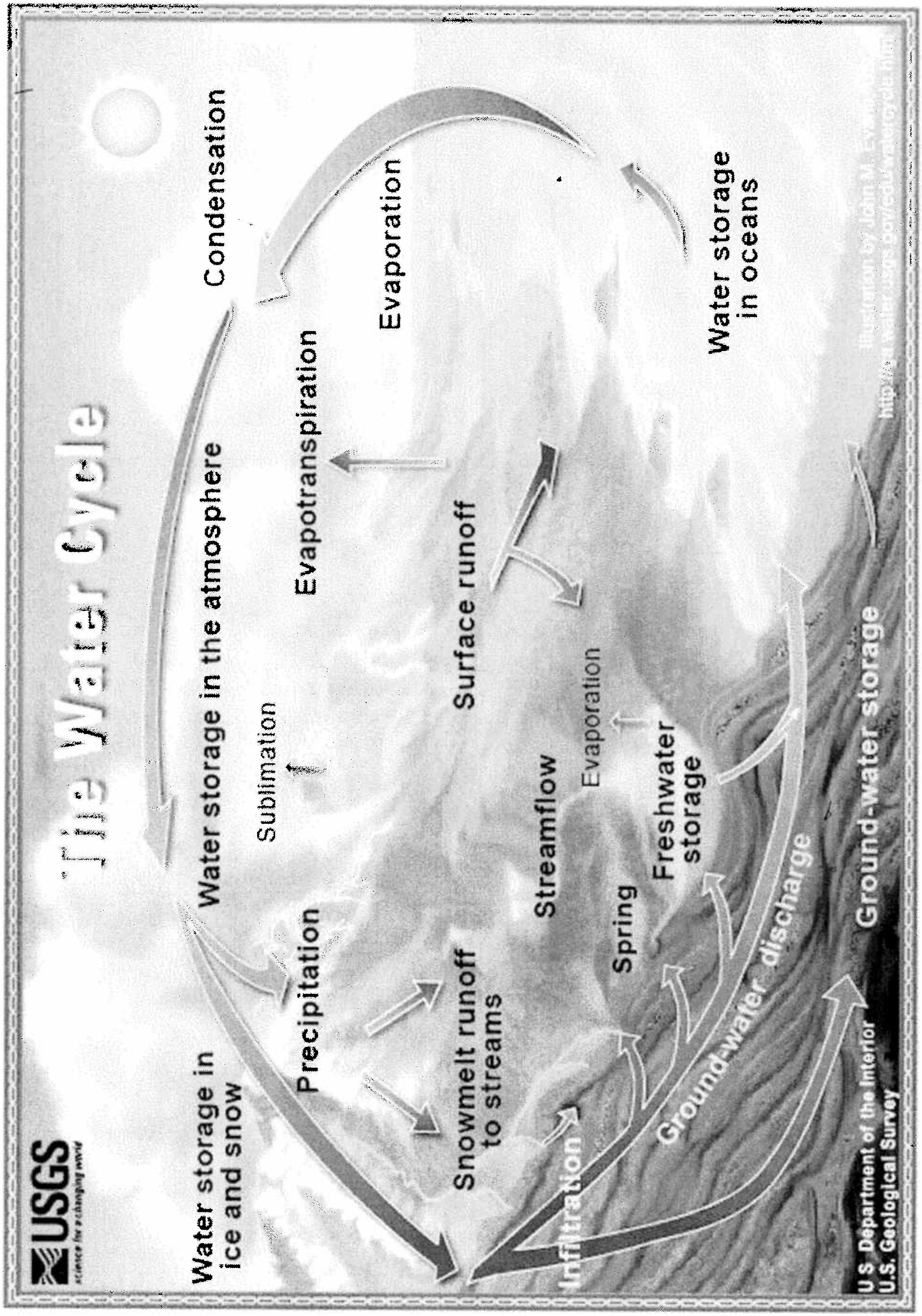
Also, find out how much water exists on (and in) the Earth and where it is located.

Water storage in oceans: Saline water existing in oceans and inland seas

The ocean as a storehouse of water



The water cycle sounds like it is describing how water moves above, on, and through the Earth ... and it does. But, in fact, much more water is "in storage" for long periods of time than is actually moving through the cycle. The storehouses for the vast majority of all water on Earth are the oceans. It is estimated that of the 332,500,000 cubic miles (mi^3) (1,386,000,000


The Water Cycle
USGS
science for a changing world
Water storage in ice and snow
Water storage in the atmosphere
Condensation
Sublimation
Precipitation
Evapotranspiration
Evaporation
Snowmelt runoff to streams
Surface runoff
Streamflow
Evaporation
Spring
Freshwater storage
Infiltration
Ground-water discharge
Ground-water storage
Water storage in oceans
U.S. Department of the Interior
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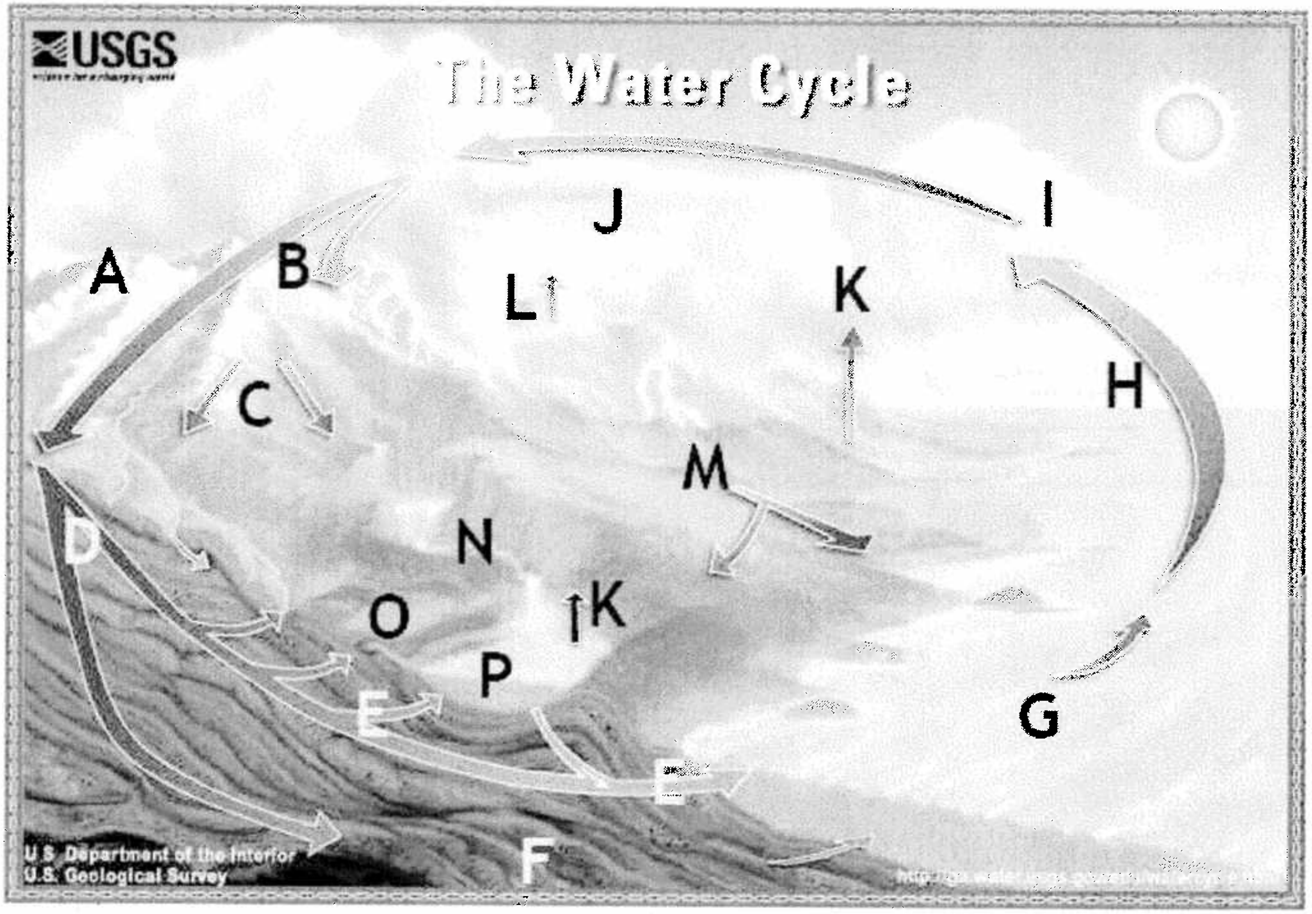
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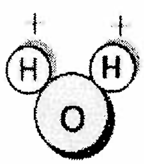
U.S. Department of the Interior
U.S. Geological Survey

Water properties

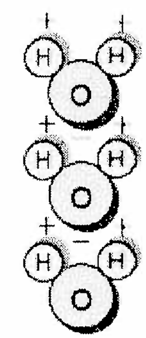
Before we begin looking at the properties of water, maybe you'd like to take our True/False quiz about water properties. Some of the answers may surprise you.

What are the physical and chemical properties of water that make it so unique and necessary for living things? When you look at water, taste and smell it - well, what could be more boring? Pure water is virtually colorless and has no taste or smell. But the hidden qualities of water make it a most interesting subject.

Water's Chemical Properties



You probably know water's chemical description is H_2O. As the diagram to the left shows, that is one atom of oxygen bound to two atoms of hydrogen. The hydrogen atoms are "attached" to one side of the oxygen atom, resulting in a water molecule having a positive charge on the side where the hydrogen atoms are and a negative charge on the other side, where the oxygen atom is. Since opposite electrical charges attract, water molecules tend to attract each other, making water kind of "sticky." As the right-side diagram shows, the side with the hydrogen atoms (positive charge) attracts the oxygen side (negative charge) of a different water molecule. (If the water molecule here looks familiar, remember that everyone's favorite mouse is mostly water, too).



All these water molecules attracting each other mean they tend to clump together. This is why water drops are, in fact, drops! If it wasn't for some of Earth's forces, such as gravity, a drop of water would be ball shaped -- a perfect sphere. Even if it doesn't form a perfect sphere on Earth, we should be happy water is sticky.

- Water is called the "universal solvent" because it dissolves more substances than any other liquid. This means that wherever water goes, either through the ground or through our bodies, it takes along valuable chemicals, minerals, and nutrients.
- Pure water has a neutral pH of 7, which is neither acidic nor basic.

Diagram about pH

Water's Physical Properties

- Water is unique in that it is the only natural substance that is found in all three states -- liquid, solid (ice), and gas (steam) -- at the temperatures normally found on Earth. Earth's water is constantly interacting, changing, and in movement.

- Water freezes at 32° Fahrenheit (F) and boils at 212° F (at sea level, but 186.4° at 14,000 feet). In fact, water's freezing and boiling points are the baseline with which temperature is measured: 0° on the Celsius scale is water's freezing point, and 100° is water's boiling point. Water is unusual in that the solid form, ice, is less dense than the liquid form, which is why ice floats.
- Water has a high specific heat index. This means that water can absorb a lot of heat before it begins to get hot. This is why water is valuable to industries and in your car's radiator as a coolant. The high specific heat index of water also helps regulate the rate at which air changes temperature, which is why the temperature change between seasons is gradual rather than sudden, especially near the oceans.
- Water has a very high surface tension. In other words, water is sticky and elastic, and tends to clump together in drops rather than spread out in a thin film. Surface tension is responsible for capillary action, which allows water (and its dissolved substances) to move through the roots of plants and through the tiny blood vessels in our bodies.
- Here's a quick rundown of some of water's properties:
  - Weight: 62.416 pounds per cubic foot at 32°F
  - Weight: 61.998 pounds per cubic foot at 100°F
  - Weight: 8.33 pounds/gallon, 0.036 pounds/cubic inch
  - Density: 1 gram per cubic centimeter (cc) at 39.2°F, 0.95865 gram per cc at 212°F

Here are some water volume comparisons:
1 gallon = 4 quarts = 8 pints = 128 fluid ounces = 231 cubic inches
1 liter = 0.2642 gallons = 1.0568 quart = 61.02 cubic inches
1 million gallons = 3.069 acre-feet = 133,685.64 cubic feet

Related Topics
Common water measurements · Water properties true/false quiz
Water basics · Water Science home page

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Challenge question #3

What are some of the physical and chemical properties of water?

Water is more than just plain old water - it actually has some very unusual properties. It would be boring if I just told you that water is wet and clear. So, instead, let me show you a list of water properties and see if you know which ones are true and which are false.

(1) Like most liquids, water contracts (gets smaller) when it freezes.

Your Answer	Correct Answer	Explanation
--	False	Actually, water expands (gets less dense) when it freezes, which is unusual for liquids. Think of ice -- it is one of the few items that floats as a solid. If it didn't, then lakes would freeze from the bottom up (that would mean we'd have to wear wet suits when ice skating!), and some lakes way up north would be permanent blocks of ice.

(2) Water has a high surface tension.

Your Answer	Correct Answer	Explanation
--	True	Water has the highest surface tension among common liquids (mercury is higher). Surface tension is the ability of a substance to stick to itself (cohere). That is why water forms drops, and also why when you look at a glass of water, the water "rises" where it touches the glass (the "meniscus"). Plants are happy that water has a high surface tension because they use capillary action to draw water from the ground up through their roots and stems.

(3) Condensation is water coming out of the air.

Your Answer	Correct Answer	Explanation
		This is actually true -- water that forms on the outside of a cold glass or on the inside of a window in winter is

--	True	liquid water condensing from water vapor in the air. Air contains water vapor (humidity). In cold air, water vapor condenses faster than it evaporates. So, when the warm air touches the outside of your cold glass, the air next to the glass gets chilled, and some of the water in that air turns from water vapor to tiny liquid water droplets. Clouds in the sky and the "cloud" you see when you exhale on a cold day are condensed water-vapor particles. (It is a myth that clouds form because cold air cannot hold as much water vapor as warm air!)

(4) More things can be dissolved in sulfuric acid than in water.

Your Answer	Correct Answer	Explanation
--	False	Not true. Sulfuric acid might be able to dissolve a car, but water isn't known as the "Universal Solvent" for nothing! It can dissolve more substances than any other liquid. This is lucky for us... what if all the sugar in your soft drink ended up as a pile at the bottom of the glass? The water you see in rivers, lakes, and the ocean may look clear, but it actually contains many dissolved elements and minerals, and because these elements are dissolved, they can easily move with water over the surface of the earth.

(5) Rainwater is the purest form of water.

Your Answer	Correct Answer	Explanation
--	False	I was surprised at this, but, actually, distilled water is "purer." Rainwater contains small amounts of dissolved minerals that have been blown into the air by winds. Rainwater contains tiny particles of dust and dissolved gasses, such as carbon dioxide and sulfur dioxide (yep, acid rain). That doesn't mean rainwater isn't very clean -- normally only about 1/100,000th of the weight of rain comes from these substances. In a way, the distillation process is responsible for rainwater. Distilled water comes from water vapor condensing in a closed container (such as a glass jar). Rain is produced by water vapor evaporating from the earth and condensing in the sky. Both the closed jar and the earth (via its atmosphere) are "closed systems," where water is neither added or lost.

(6) It takes more energy to heat cold water to 212° F than it does to change 212° F water to steam.

Your Answer	Correct Answer	Explanation
--	False	First, water at boiling temperature (212° F at sea level) is not really the same as boiling water. When water first reaches boiling it has not begun to turn to steam yet. More energy is needed to begin turning the boiling liquid water into gaseous water vapor. The bonds holding water molecules as a liquid are not easily broken. If I remember correctly, it takes about seven times as much energy to turn boiling water into steam as it does to heat water at room temperature to the boiling point.

(7) If you filled a glass full of water from the Great Salt Lake, when it evaporated there would be 1 inch of salt left.

Your Answer	Correct Answer	Explanation
--	True	They don't call it the Great SALT Lake for nothing. Water in the Great Salt Lake varies in salinity both by location and in time. In this example, we are assuming about a 20-percent salt concentration. In other words, about one-fifth of the weight of the water comes from salt. And how much saltier is Great Salt Lake water than seawater? Quite a bit. Seawater has a salt concentration of about 3 1/2 percent.

(8) Sea water is slightly more basic (the pH value is higher) than most natural fresh water.

Your Answer	Correct Answer	Explanation
--	True	Neutral water (such as distilled water) has a pH of 7, which is in the middle of being acidic and alkaline. Seawater happens to be slightly alkaline (basic), with a pH of about 8. Most natural water has a pH of between 6-8, although acid rain can have a pH as low as 4.

(9) Raindrops are tear-shaped.

Your Answer	Correct Answer	Explanation
--	False	When you think of a drop of falling water you probably think it looks like . When a drop of water comes out of a faucet, yes, it does have a tear shape. That is because the back end of the water drop sticks to the water still in the faucet until it can't hold on any more. But, using high-speed cameras, scientists have found that falling raindrops look more like a small hamburger bun! Gravity and surface tension come into play here. As rain falls, the air below the drop pushes up from the bottom, causing the drop to flatten out somewhat. The strong surface tension of water holds the drop together, resulting in a bun shape (minus the sesame seeds). Here's another explanation.

(10) Water boils quicker at Denver, Co. than at the beach.

Your Answer	Correct Answer	Explanation
--	True	The boiling point of water gets lower as you go up in altitude. At beach level, water boils at 212° Fahrenheit. But at 5,000 feet, about where Denver is located, water boils at 202.9° F, and up at 10,000 feet it boils at 193.7° F. This is because as the altitude gets higher, the air pressure (the weight of all that air above you) becomes less.

Since there is less pressure pushing on a pot of water at a higher altitude, it is easier for the water molecules to break their bonds and attraction to each other and, thus, it boils more easily.

Related Topics

Opinion surveys ✧ Questionnaires ✧ Challenge questions
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TAKE PRIDE IN AMERICA

Encyclopedia of Earth

Water resources

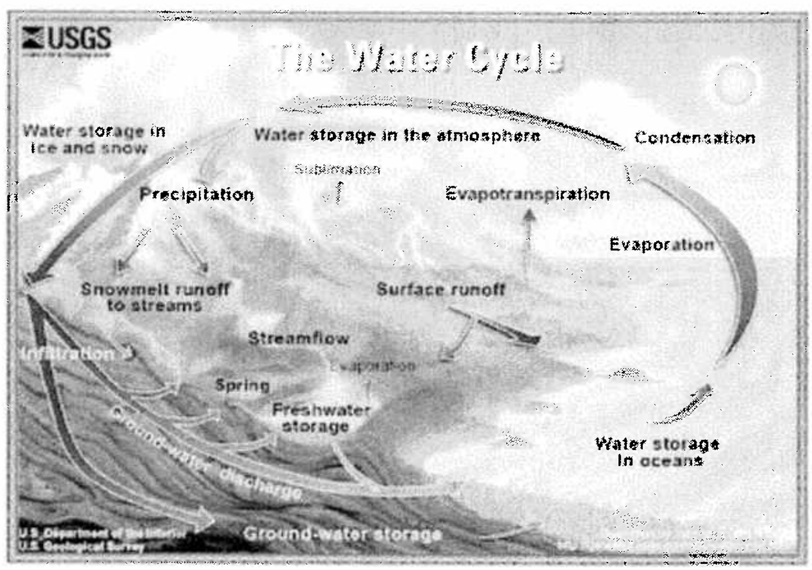
Lead Authors: **Jacqueline Medalye (other articles)** *and* **Jason A. Hubbart (other articles)**
Article Topics: **Water** *and* **Environmental and resource management**
This article has been **reviewed and approved** *by the following Topic Editor:* **Jim Kundell (other articles)**
Last Updated: May 21, 2007

Table of Contents

Introduction

Water resources are used in various ways including direct consumption, agricultural irrigation, fisheries, hydropower, industrial production, recreation, navigation, environmental protection, the disposal and treatment of sewage, and industrial effluents. Water has sources and supplies, economic, social, and political characteristics which make it a unique and challenging natural resource to manage.

Sources and Supplies



Water resources refer to the supply of groundwater and surface water in a given area. Water resources may also reference the current or potential value of the resource to the community and the environment. The maximum rate that water is potentially available for human use and management is often considered the best measure of the total water resources of a given region. Approximately 30 percent of the world's fresh water is in liquid form and therefore potentially accessible for human use and management at any given time. The rest is either locked up in polar or glacial ice or water vapor. Of the 30 percent of fresh water in liquid form, almost all is held in groundwaters.

Historically, attempts to develop global assessments of available water resources have resulted in limited applicability. The usefulness of resulting aggregated quantities, based upon streamflow and population calculations, which lead to measurements in terms of relative abundance and shortages of water regionally, have often been unreliable. The extreme difficulty in preparing a global assessment stems from the general lack of sufficient and reliable information on water availability, quality, and water use in many areas of the world. Efforts to balance supply and demand, and plans for a sustainable future are severely hampered by this lack of reliable information. Studies of water resources leading to meaningful assessments have been found to be realistic only if conducted on a regional or local basis. Only then has [illegible] groundwater [illegible]

[illegible] evapotranspiration [illegible] and sometimes through genetic manipulation. [illegible] and most often temporary, and unfortunately often have serious environmental, social, economic, and legal ramifications.

Physical characteristics

[illegible] not affected by [illegible] However, [illegible] for human and other animal and plant health. Water bodies provide habitats for aquatic life and riparian systems provide moisture for vegetation and terrestrial biota, transporting nutrients between one ecosystem and another (Gleick, 2002). As well, large water systems provide regional and climatic weather services. Large-scale withdrawals or transfers of water can change ecological conditions and thus the in situ benefits of a water body.

Water use has grown rapidly in modern times. The first 80 years of the 20th century saw a 200 percent increase in the world's average per capita water use, which accounted for a remarkable 566 percent increase in withdrawals from the world's freshwater resources (ITT, 2003). In addition, a significant portion of water resources have become unusable due to industrial and agriculture pollution. Diversions or transfers of water from watersheds to other regions have led to many ecological and human health disasters. For example, the diversion of water from the Amu Darya and Syr Darya rivers in Central Asia has caused the destruction of the Aral Sea ecosystem, the extinction of the Sea's endemic fish populations, the dramatic shrinking of the Sea itself, and widespread local health problems associated with the exposure to atmospheric salts (Gleick, 2002). Similar withdrawals of water from North American and European rivers have lead to a decline in ecosystem integrity. Worldwide, more than 20 percent of all freshwater fish species are now threatened or endangered because of dams and water withdrawals. Also, groundwater aquifers are threatened by exhaustion and saltwater intrusions from overuse worldwide in places as far apart as India, China, and the United States. These [illegible] uses of water [illegible] to concerns that its physical value is not reflected in its cost, [illegible]

Economic characteristics

[illegible]

[illegible]

[illegible] ... new industries can be constrained by lack of [illegible] water. Currently, [illegible] developed countries industry uses more than [illegible] percent of total [illegible] water withdrawals [illegible] percent in developing countries [illegible]. Lack of control on pollution and consumption of water could lead to greater scarcity as developing countries pursue industrial growth.

Theoretically, recognizing water as an economic good entails that water can be allocated across competing uses in a way that maximizes the net benefit from the amount of water in question. Practically, the increasing financial burden on users to pay for clean water has social and political implications. For example, more than three thousand million people worldwide have daily incomes of less than US$ 2, which places a severe limit on their capacity to pay the full economic costs of water services (FAO, [illegible]). There has been growing controversy over the privatization of water worldwide as the economic principals of [illegible] and efficiency [illegible] applied to water, a resource that many consider a basic human need and right.

Social characteristics

It is commonly accepted that access to water is a basic human right. The Dublin Conference in 1992 asserted that "it is vital to recognize first the basic right of all human beings to have access to clean water and sanitation at an affordable price" (ICWE, 1992). Moreover, it is argued that water is a social good in that the widespread availability of clean and affordable water improves both individual and social well-being. Clean water reduces the prevalence of water-related diseases, a social benefit shared by all users of the same water source. The public health impacts of inadequate water supply and sanitation has serious social and economic consequences for all. Being a social good and private good are not mutually exclusive conditions. In fact, more water for one individual can mean less water for other individuals who share a water-supply system. Ensuring that the public receives an adequate supply of social goods requires some level of governmental action, since purely private markets often do not find it profitable to provide social goods (Gleick, 2002).

Classifying water as a basic human right introduces further social complications in terms of equitable distribution. Only a fraction of water consumption is actually used for preserving life. A large portion of urban water is used for convenience and comfort. For example in the arid western United States, the per capita water withdrawal by households frequently exceeds 400 liters per day, about half of which is used to irrigate lawns and gardens, the remainder being used for toilets, bathing, and washing cars (FAO, 1995). Clearly with 1.1 billion people still lacking access to safe drinking water the allowance for such frivolous usage is inequitable. Moreover, the moral dimensions of water management intersect with the property rights issues that underlie the economic allocation of water. If [illegible] have a right to water [illegible] natural place (Gleick, 2002). [illegible] In addition, [illegible]

[illegible]

Political characteristics

[illegible] mountain [illegible]

[illegible] Disputes over shared water resources can lead to violence and continue to raise local, national, and even international tensions (Gleick 2002). [illegible] may be willing to go to war to defend their interests. There is a serious risk of water becoming a casus belli in some of the arid parts of the world (FAO 1995). Rising conflict is expected as populations expand, economies grow, and the competition for limited water supplies intensifies. Competition for and conflicts over water are not new, although the [illegible] between [illegible] supplies and expected demand is historically unprecedented.

[illegible] agriculture, [illegible] industrial [illegible] such as fishing, navigation and recreation, and for the environment, including wetlands, deltas and game park [illegible] regarding water management and [illegible] among competing water uses.

The above physical, economic, social and political characteristics of water make it a unique resource in which a degree of government involvement is inevitable. The discussion will now turn to the governance structures which have been implemented in order to manage and provide this complicated and vital resource.

Further Reading

Food and Agriculture Organization (FAO). 1995. Water sector policy review and strategy formulation: A general framework. Food and Agriculture Organization of the United Nations, Rome, Italy.

[illegible], P.H., Wolff, G., Chalecki, E.L., Reyes, R. 2002. The New Economy of Water: The Risks and Benefits of Globalization and the Privatization of Fresh Water. Pacific Institute, Oakland, California.

[illegible] 1998. Water: source of life. In: FORUM: War and Water. International Committee of the Red Cross, Geneva, Switzerland, pp. [illegible].

International Conference on Water and the Environment (ICWE). 1992. The Dublin Principles.

[illegible]

[illegible]

Citation

Medalye, Jacqueline and Jason A. Hubbart (Lead Authors); Jim Kundell (Topic Editor). 2007. "Water resources." In: Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). [First published in the Encyclopedia of Earth May 20, 2007; Last revised May 21, 2007; Retrieved January 8, 2008]. <http://www.eoearth.org/article/Water_resources>

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WATER CONSERVATION TIPS

Household Hints to Conserve Water and Money

Why Conserve?
Water conservation is the most cost-effective and environmentally sound way to reduce our demand for water. This stretches our supplies farther, and protects places like Mono Lake. For example, the City of Los Angeles has grown by 1 million people since the 1970s, but still uses the same amount of water. The entire U.S. uses less water than it did 25 years ago, even though there are more people! Using less water also puts less pressure on our sewage treatment facilities, and uses less energy for water heating. More California water facts from Friends of the River.

The Water and Energy Connection
Saving water also saves energy. 6.5% of the energy used in the state of California is for pumping and treating water--in fact, pumping water south (and uphill) in the State Water Project accounts for 2-3% of all the electricity used in the state. And for your personal energy bill, using less hot water saves on water heating. On the flip side, saving energy and using alternative energy saves water--electricity production from fossil fuels and nuclear energy is responsible for 39% of all freshwater withdrawals in the nation.

What Can I Do?
There are many effective ways to conserve water in and around your home. Look through this list for ways that will work for you. Many of these tips were gleaned from materials published by the Metropolitan Water District of Southern California (MWD). Indoor savings are based on a family of two adults and one child.

- Ten ways that will save the most
- In the bathroom
- In the kitchen and laundry
- Outside
- While shopping

Ten ways that will save the most:

1. Water your lawn only when it needs it. Step on your grass. If it springs back, when you lift your foot, it doesn't need water. So set your sprinklers for more days in between watering. **Saves 750-1,500 gallons** per month. Better yet, especially in times of drought, water with a hose. And best of all, convert your lawn to native plants.

2. Fix leaky faucets and plumbing joints. **Saves 20 gallons** per day for every leak stopped.

3. Don't run the hose while washing your car. Use a bucket of water and a quick hose rinse at the end.

Saves 150 gallons each time. For a two-car family that's **up to 1,200 gallons** a month.

4. Install water-saving shower heads or flow restrictors. **Saves 500 to 800 gallons** per month.

5. Run only full loads in the washing machine and dishwasher. **Saves 300 to 800 gallons** per month.

6. Shorten your showers. Even a one or two minute reduction can **save up to 700 gallons** per month.

7. Use a broom instead of a hose to clean driveways and sidewalks. **Saves 150 gallons** or more each time. At once a week, that's **more than 600 gallons** a month.

8. Don't use your toilet as an ashtray or wastebasket. **Saves 400 to 600 gallons** per month.

9. Capture tap water. While you wait for hot water to come down the pipes, catch the flow in a watering can to use later on house plants or your garden. **Saves 200 to 300 gallons** per month.

10. Don't water the sidewalks, driveway or gutter. Adjust your sprinklers so that water lands on your lawn or garden where it belongs--and only there. **Saves 500 gallons** per month.

In the bathroom:

1. Put a plastic bottle or a plastic bag weighted with pebbles and filled with water in your toilet tank. Displacing water in this manner allows you to use less water with each flush. **Saves 5 to 10 gallons** a day. That's **up to 300 gallons** a month, even more for large families. Better yet, for even greater savings, replace your water-guzzling five to seven gallon a flush toilet with a one and a half gallon, ultra-low flush model.

2. If you're taking a shower, don't waste cold water while waiting for hot water to reach the shower head. Catch that water in a container to use on your outside plants or to flush your toilet. **Saves 200 to 300 gallons** a month.

3. Check toilet for leaks. Put dye tablets or food coloring into the tank. If color appears in the bowl without flushing, there's a leak that should be repaired. **Saves 400 gallons** a month.

4. Turn off the water while brushing your teeth. **Saves three gallons** each day.

5. Turn off the water while shaving. Fill the bottom of the sink with a few inches of water to rinse your razor. **Saves three gallons** each day.

In the kitchen:

1. If you wash dishe by hand -- and that's the best way-- don't leave the water running for rinsing. If you have two sinks, fill one with rinse water. If you only have one sink, use a spray device or short blasts instead of letting the water run. **Saves 200 to 500 gallons** a month.

2. When washing dishes by hand, use the least amount of detergent possible. This minimizes rinse water needed. **Saves 50 to 150 gallons** a month.

3. Keep a bottle of drinking water in the refrigerator. This beats the wasteful habit of running tap water to cool it for drinking. **Saves 200 to 300 gallons** a month.

4. Don't defrost frozen foods with running water. Either plan ahead by placing frozen items in the refrigerator overnight or defrost them in the microwave. **Saves 50 to 150 gallons** a month.

5. Don't let the faucet run while you clean vegetables. Rinse them in a filled sink or pan. **Saves 150 to 250 gallons** a month.

6. Use the garbage disposal less and the garbage more (even better--compost!). **Saves 50 to 150 gallons** a month.

Outside:

1. Put a layer of mulch around trees and plants. Chunks of bark, peat moss or gravel slows down evaporation. **Saves 750 to 1,500 gallons** a month.

2. If you have a pool, use a pool cover to cut down on evaporation. It will also keep your pool cleaner and reduce the need to add chemicals. **Saves 1,000 gallons** a month.

3. Water during the cool parts of the day. Early morning is better than dusk since it helps prevent the growth of fungus. **Saves 300 gallons**.

4. Don't water the lawn on windy days. There's too much evaporation. **Can waste up to 300 gallons** in

one watering.

5. Cut down watering on cool and overcast days and don't water in the rain. Adjust or deactivate automatic sprinklers. **Can save up to 300 gallons** each time.

6. Set lawn mower blades one notch higher. Longer grass means less evaporation. **Saves 500 to 1,500 gallons** each month.

7. Have an evaporative air conditioner? Direct the water drain line to a flower bed, tree base, or lawn.

8. Drive your car onto a lawn to wash it. Rinse water can help water the grass.

9. Tell your children not to play with the garden hose. **Saves 10 gallons** a minute.

10. If you allow your children to play in the sprinklers, make sure it's only when you're watering the yard--if it's not too cool at that time of day.

11. Xeriscape--replace your lawn and high-water-using trees and plants with less thirsty ones. But do this only in wet years. Even drought resistant plantings take extra water to get them going. That'll **save 750 to 1,500 gallons** a month.

12. When taking your car to a car wash--a good idea for saving water--be sure it's one of the many that recycles its wash water.

13. Dispose of hazardous materials properly! One quart of oil can contaminate 250,000 gallons of water, effectively eliminating that much water from our water supply. Contact your city or county for proper waste disposal options. And don't flush prescription medications!

While Shopping

(Information below from *Last Oasis*, by Sandra Postel, and *California Water Facts*, by the Water Education Foundation)

Water is an essential ingredient in most manufacturing operations. Especially for those 1 billion of us in the high-consumption class, cutting down on our purchases of material things--from clothes and shoes to paper and appliances--**conserves and protects water supplies as effectively as installing a low-flush toilet does.** As with so many natural resources, as long as prices in the marketplace fail to reflect full social and ecological costs, voluntary changes in consumption patterns will play an important role in the quest for sustainability.

- We rarely think about water when we see an automobile, for example, but producing a typical U.S. car requires more than 50 times its weight in water (39,090 gallons)! Choosing a fuel-efficient model will help--it takes 44 gallons of water to refine one gallon of crude oil and up to 1,700 gallons of water to produce a gallon of ethanol.
- A kilogram (2.2 lbs) of hamburger or steak produced by a typical California beef cattle operation, for instance, uses some 20,500 liters (5,400 gal.) of water.
- Producing 1 lb of bread requires 500 gallons of water.

- Producing 1 serving (8 oz.) of chicken requires 330 gallons of water.
- Growing one cotton T-shirt requires 256 gallons of water (source: *The King of California*, by Arax and Wartzman)
- Producing 1 egg requires over 100 gallons of water.
- Producing 1 serving (8 fl. oz.) of milk requires 48 gallons of water.
- Producing 1 serving (2 oz.) of pasta requires 36 gallons of water.
- Producing 1 serving (4.6 oz.) of oranges requires 14 gallons of water.
- Producing 1 serving (4.3 oz.) of tomatoes requires 8 gallons of water.
- A typical American Thanksgiving dinner for six people requires over 30,000 gallons of water.

Other Web sites of interest:

Water Saver Home

- Watering Calculator
- The Water Family - online conservation game
- Water Conserve - A Water Conservation Portal
- Home Gardening Tips
- Backyard Conservation
- EPA WaterSense: Efficiency Made Easy
- Watermiser - Water Conservation Supplies
- Water Conservation Products (and more tips!)
- Auto-shut-off Faucet Foot Pedals (faucetfootvalve , footfaucet)
- Waterless Co. (waterless urinals)
- How to Repair Toilets
- Greywater Use Guidelines (for Arizona)

Note: The Mono Lake Committee does not endorse any companies or products listed here. These links are provided for information only.

- Southern California Water Main Page
- Los Angeles Water Conservation Council

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Last Updated January 29, 2007

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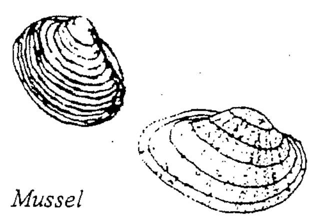
Taxonomic Key to Benthic Macroinvertebrates

The purpose of this taxonomic key is to assist volunteer monitors, who are not trained in taxonomy, with the identification of benthic macroinvertebrates found in Indiana. This key is a simplified version of more complex keys. The taxonomic level of this key is intended for use by citizen monitoring groups. When using this key please note that each couplet offers two or three options. Each couplet is numbered and the numbers in bold refer to the next couplet (the next set of numbers that you proceed to).

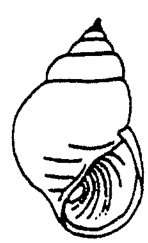
Please be aware that some macroinvertebrates may have missing body parts so you should look at more than one organism!

CHOOSE ONE:	GO BELOW TO:
(1)a Has a shell(s)	**2**
(1)b Has no shell	**5**
(2)a Has a hinged double shell	**3**
(2)b Has a single shell	**4**
(3)a Adult under 2 inches long	**19**
(3)b About 2-4 inches long	MUSSEL



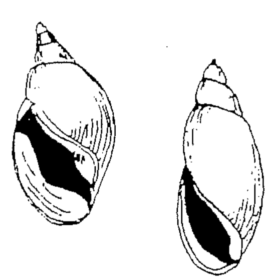
Mussel

(4)a Right-handed opening	RIGHT-HANDED SNAIL



Right-Handed Snail

(4)b Left-hand opening	LEFT-HANDED SNAIL

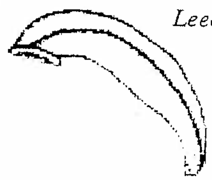


Left-Handed Snail

CHOOSE ONE:	GO BELOW TO:
(5)a Has a segmented body or looks like a tiny tick	6
(5)b Has an unsegmented body and has an "arrow shaped" head; 2 pigment spots (eyes)	PLANARIA

Planaria

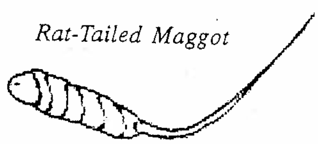
(6)a No obvious legs	7
(6)b Obvious legs	12
(7)a Has no obvious appendages (long, tubular body)	8
(7)b Has some appendages (small tubes, tiny bumps, or feathery structures)	9
(8)a Has a smooth body and suckers	LEECH



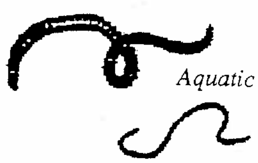
Leech

(8)b Has a round body and a rat tail	RAT-TAILED MAGGOT

Rat-Tailed Maggot



(8)c Has a rounded body	AQUATIC WORMS

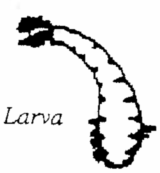


Aquatic Worms

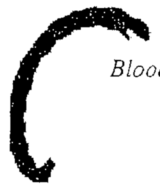
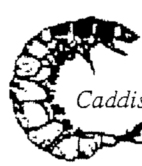
(9)a Body black or brown; more than 1/3 inch long; plump and catepillar-like	CRANE FLY LARVA

Crane Fly Larva

(9)b Has a distinct head	10
(10)a One end of body wider than other end; two tiny feather structures on smaller end	BLACK FLY LARVA



Black Fly Larva

CHOOSE ONE:	GO BELOW TO:
(10)b No difference in diameter along body	**11**
(11)a Bright red body  *Blood Midge*	BLOOD MIDGES
(11)b Grey Body	OTHER MIDGES
(12)a Has four pairs of legs  *Water Mite*	WATER MITE
(12)b Has three pairs of legs	**13**
(12)c Has many pairs of legs	**26**
(13)a Has no wings or short wing pads on back	**14**
(13)b Has two pairs of wings that cover the abdomen	**23**
(14)a Has a flat, round body with legs underneath (wings are not obvious)  *Water Penny*	WATER PENNY BEETLE LARVA
(14)b Not flat, has long body with legs	**15**
(15)a Lives in a tube or a case or has two hooks in its last segment and is green with 3 plates on back behind head. (The "green caddisfly" builds a net & tube, but will be washed into the kick net as "free living")  *Caddisfly Larva* 	CADDISLY LARVA
(15)b Free-living	**16**

CHOOSE ONE:	GO BELOW TO:
(16)a Abdomen possesses lateral filaments similar in size to legs	21
(16)b Abdomen does not have "leg-like" filaments (may have feathery "gills")	17
(17)a Always with only two tail appendages and no abdominal gills	STONEFLY NYMPH

Stonefly Nymph

(17)b Usually has three tail appendages, and with no lateral gills on abdominal segments	18
(17)c Tail has no appendages	25
(18)a Has long, bristle-like tail appendages, sometimes 2 or 3	MAYFLY NYMPH

Mayfly Nymph

(18)b Lower lip formed into extensible scoop-like structure and has leaf-like tail appendages	DAMSELFLY NYMPH

Damselfly Nymph

(19)a Small rounded shell (< 2 inches)	20
(19)b Small triangular shell with alternating cream and dark brown bands	ZEBRA MUSSEL (EXOTIC)

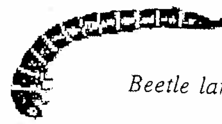
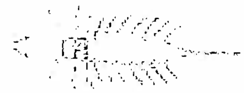
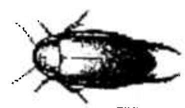
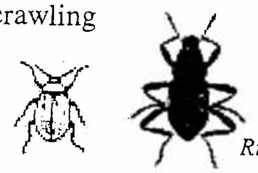
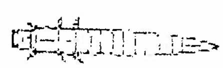
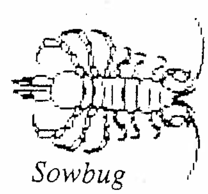
Zebra Mussel

(20)a Numerous very fine concentric rows of elevated lines, white or cream colored, with smooth lateral teeth (ridge lines on inside near point)	FINGERNAIL CLAM

Fingernail Clam

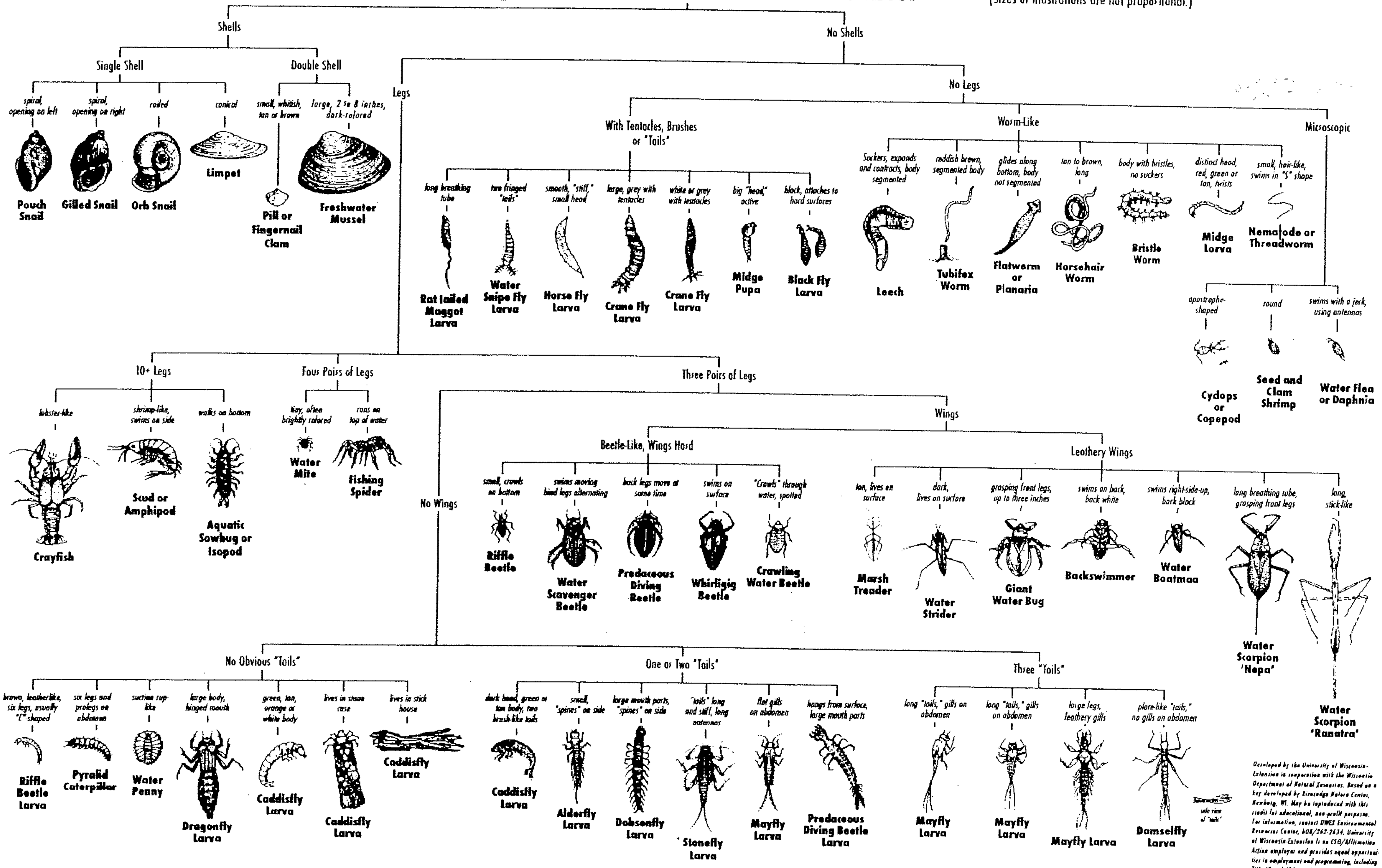
(20)b Numerous concentric elevated ridges, yellowish brown to black shell with serrated lateral teeth	ASIATIC CLAM (EXOTIC)

Asiatic Clam

CHOOSE ONE:		**GO BELOW TO:**
(21)a Head narrower than widest body segments	 *Beetle larva*	BEETLE LARVA
(21)b Head as wide or wider than other body segments		22
(22)a Abdomen with single long filament at end	 *Alderfly*	ALDERFLY
(22)b Abdomen ending with a pair of tiny hooked legs, large head with pincer-like jaws	 *Dobsonfly Larva*	DOBSONFLY OR FISHFLY
(23)a Oval shaped body, legs with feathery swimming hairs	 *Water bug*	ADULT WATER BUGS AND WATER BEETLES
(23)b All legs smooth, without hairs, crawling	 *Riffle Beetle Adult*	RIFFLE BEETLE ADULT
(25)a Lower lip formed into scoop like structure	 *Dragonfly Nymph*	DRAGONFLY NYMPH
(25)b Looks like a tiny millipede	 *Riffle Beetle Larva*	RIFFLE BEETLE LARVA
(26)a Flattened top to bottom, crawling looks like "roly-poly" or a "pill bug"	 *Sowbug*	SOWBUG
(26)b Flattened side to side, swimming looks like tiny shrimp	 *Scud or Side-swimmer*	SCUD

Key to Macroinvertebrate Life in the River

(Sizes of illustrations are not proportional.)



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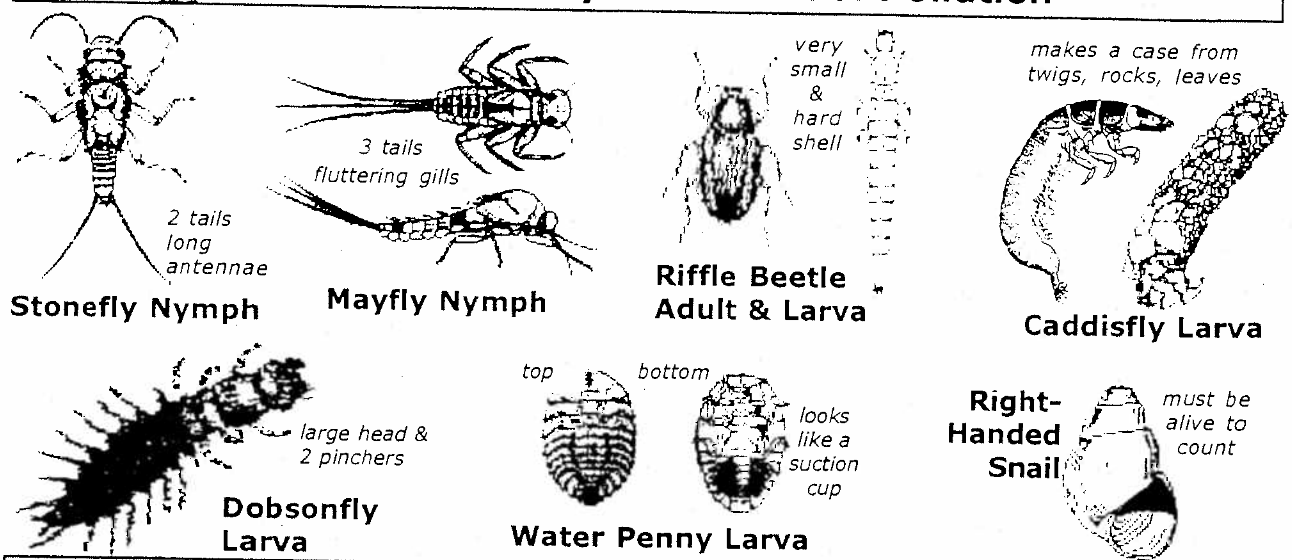
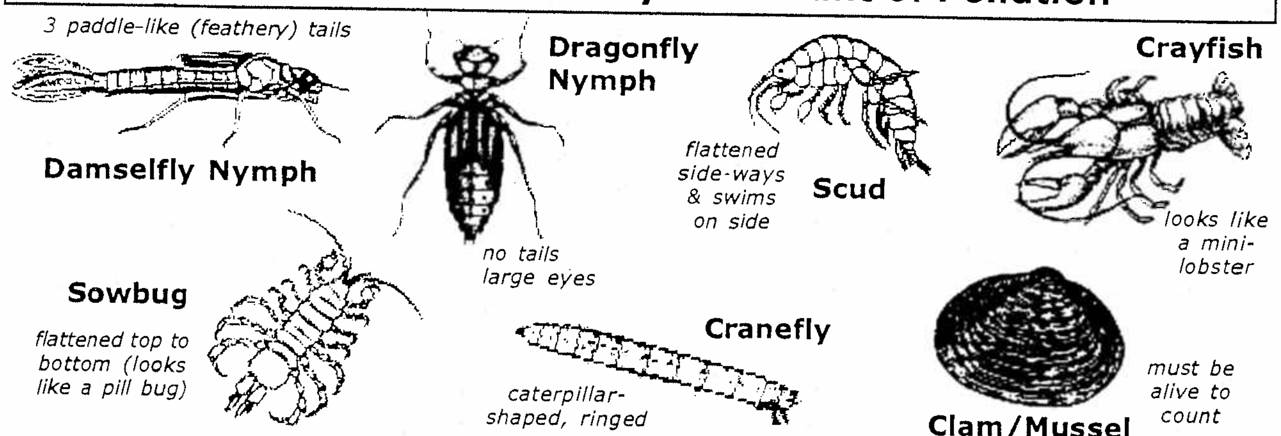
Macroinvertebrate Identification Key

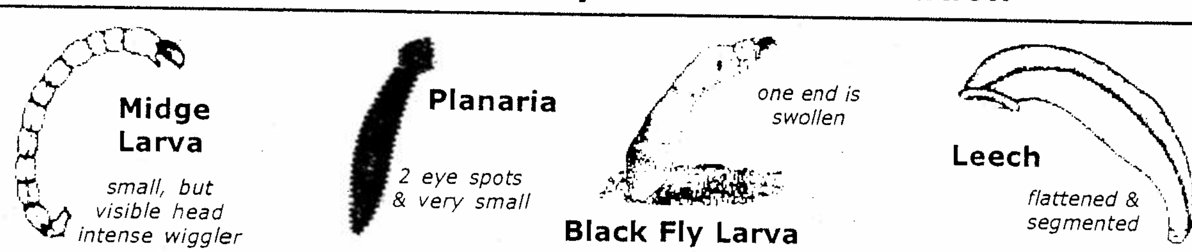
GROUP 1 – Very Intolerant of Pollution



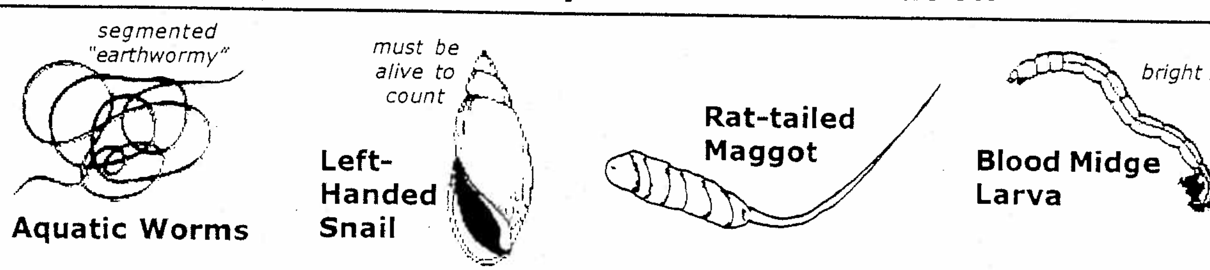
GROUP 2 – Moderately Intolerant of Pollution



GROUP 3 – Fairly Tolerant of Pollution



GROUP 4 – Very Tolerant of Pollution



CENTER FOR WATERSHED PROTECTION

What's a Watershed?

A watershed is all the land area that drains to a given body of water. We all live in a watershed!

Depending on where we live, we cross quite a few brooks, creeks, runs, branches, gulches, arroyos, bayous, ditches, or channels as we drive to work each day. Each stream we cross is part of a massive network of perhaps three million streams that drain to the rivers and, ultimately, to the sea. Each stream has its own watershed that circumscribes all of the land that drains to the point where we cross it. Collectively, these small watersheds provide critical natural services that sustain or enrich our daily lives: they supply our drinking water, critical habitat for plants and animals, areas of natural beauty, and water bodies for recreation and relaxation. Small streams are an important element of our local geography, and confer a strong sense of place to a community. View our ***Why Watersheds?*** presentation.

Communities across the nation are turning to watershed protection to sustain the watershed services that they stand to lose as they grow. Regardless of region, the underlying cause of threats to watershed quality and health is usually the same: watershed development. Current or future watershed development has been implicated as a prime threat to salmon runs in the streams of the Pacific Northwest, coral reefs in the Florida Keys, freshwater mussel diversity in Midwestern streams, endangered salamanders found in Texas springs, shellfish harvesting along our coastlines, sea grass beds in Long Island Sound, and trout streams across the country.

Communities across the nation have discovered that they must work at the watershed level to solve their diverse water resource problems. They have also found that no matter what watershed they are working in, the same eight basic management tools are needed to mitigate the impacts of development: watershed planning, land conservation, aquatic buffers, better site design, erosion control, stormwater treatment practices, control of non-stormwater discharges, and watershed stewardship. To be sure, these basic tools may need to be applied in different ways or in different combinations, but together they form the backbone of all Center projects.

Types of Aquifers

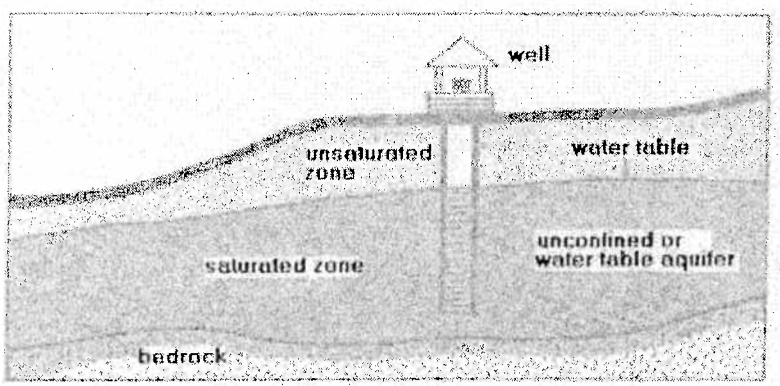
Michigan Environmental Education Curricul
Groundwater Contaminat

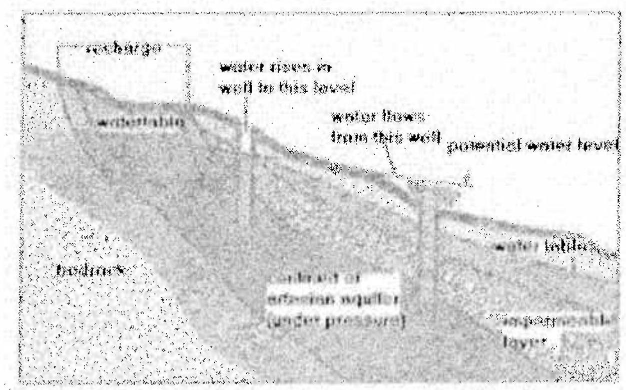
Aquifers come in two types which are shown below: unconfined and confined.

Unconfined aquifers are those into which water seeps from the ground surface directly above th aquifer.

Confined aquifers are those in which an <u>impermeable</u> dirt/rock layer exists that prevents water fro seeping into the aquifer from the ground surface located directly above. Instead, water seeps int confined aquifers from farther away where the impermeable layer doesn't exist.

Which type do think is in more danger of contamination? Which aquifer would you want to drill into for drinking water well? Answers below.





Click for Answer

Last revision: 11/21/2000 - js
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Aquifer Types and Terminology

R. W. Buddemeier, P. A. Macfarlane, G. Misgna

Boldface items are linked to other sections; *italic* items are linked to glossary definitions

Groundwater terminology can be confusing, in part because there are often many different terms describing the same phenomenon, and the same term can be used with different meanings. This section provides a brief summary of the general issues and an indication of the way the terms are used in this atlas, with sections on terminology, internal structure, and aquifer type.

Terminology:

What is an *aquifer*? The word literally means 'water bearer' and refers to a layer of rock or sediment that contains enough accessible water (see appendix on **groundwater storage and flow**) to be of interest to humans. Water in an aquifer is stored between the grains of rock. Aquifers can be either consolidated rock (such as sandstone) or unconsolidated (such as the sands and gravels that make up the High Plains aquifer. The variety of reasons for human interest create some of the differences in definition: a person seeking a municipal or irrigation well that can pump a thousand gallons per minute has a different perspective from a domestic well user who can be content with ten gallons per minute, and both have a very different perspective than a scientist interested in the migration of fluids over geologic time. Yet, all can and do call the objects of their attention 'aquifers.' In keeping with the major uses of the Kansas High Plains aquifer, we use the term to mean a body that can supply pumped groundwater at rates at least adequate for domestic water supplies, and that contains primarily potable water.

And what is not an aquifer? Two other common terms used are *aquitard* (which retards groundwater flow) and *aquiclude* (which excludes groundwater flow). These terms are also relative for the same reasons used as examples in the case of 'aquifer.' A number of similar or synonymous terms exist for these features; aquicludes are also known as *confining* or impermeable layers, and aquitards as semi-confining or leaky impermeable layers.

Aquifer names: Aquifers are often named for the geologic formation in which they occur -- Kansas examples include the Ogallala and the Dakota aquifers. However, the geologic formation may not be uniformly water-bearing -- the Dakota is a good example, having a greater volume of relatively impermeable units than of actual aquifer units (see http://www.kgs.ku.edu/Dakota). Aquifers (especially smaller units) are often identified by the way they were formed (e.g., *alluvial aquifers* are water-deposited, and *glacial drift* aquifers are deposited by glacial action). Because aquifer function is defined by continuity and characteristics rather than by the origin of the materials, large aquifer systems may be composed of several geologic formations. The High Plains aquifer is such a composite; in western Kansas it consists of the Ogallala formation, which in eastern Ford County grades into the more recent but very similar deposits of the Great Bend Prairie and Equus Beds aquifers. The alluvial stream and river channel deposits on the surface of the High Plains units (which are also alluvial in origin) are usually also considered part of the High Plains aquifer system when there is a good hydraulic connection between them. See also aquifer type below.

Internal structure:

Alluvial material is deposited from water (usually flowing water) -- rapidly moving water transports and deposits coarse material (gravel and sand), which turns into permeable aquifer deposits when buried, while flood plains and lake bottoms may have thick layers of relatively impermeable silts and clays. The dimensions of alluvial features may range from a few feet to many miles in lateral extent, and from vanishingly thin to hundreds of feet in thickness. This accounts for the spatial variability of properties within an alluvial aquifer unit, and for the common complaint that "we do not have enough data." When the zone of influence of a single well is on the order of a mile (see appendix on **drawdown and pumping**) and the aquifer properties can vary significantly at both smaller and larger scales, precise and accurate prediction of behavior is not possible without intensive -- and expensive -- field studies.

The aquifer cross-section figure illustrates some of the features common in alluvial deposits. Laterally extensive clay layers can lead to 'confined aquifer' or 'perched aquifer' characteristics.

One of the ways to deal with the problem of spatial variability is being pursued by the High Plains Aquifer Evaluation Project -- this is to use intensively studied or well characterized areas as case study sites to see how detailed information can be related to or predicted from the more general information usually available. Understanding these relationships does not provide the same level of knowledge as real measurements would, but it does improve the odds of making a valid estimate when faced with questions where the data base is sparse.

Aquifer types:

The High Plains, like most Kansas aquifers, is an unconsolidated, unconfined aquifer. Other terms similar to 'unconfined' are 'water table,' or 'phreatic,' aquifer. Some deeper water bearing units like the Dakota aquifer contain consolidated (e.g., sandstone) layers, and may be separated from the surface by confining layers impermeable enough so that the deep water can be under pressure. Breaches in the confining layer may result in a spring or *artesian well* flowing at the surface.

The cross section figure illustrates the occurrence of a rather extensive clay layer within the the water table aquifer below the Arkansas River. If such layers are large enough and impermeable enough, the water beneath them is said to be 'locally confined' or 'semi-confined,' and the water on top of them is said to be 'perched.' Effectively, the layer divides the aquifer into two unconnected regions which are not in flow or pressure equilibrium. Such regions occur in the High Plains; for example, areas in south-central Kansas (southwestern GMD5 and northwestern GMD2) and along the Upper Arkansas River Corridor (see Kansas aquifer section) display confined behavior. In such areas the usual relationships between water table elevation and change and the underlying water resource are not valid, so it is important to recognize the differences for effective management and monitoring.

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Funded (in part) by the Kansas Water Plan Fund

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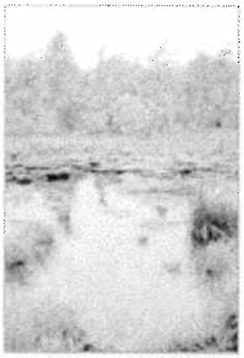
Office of Water
Office of Wetlands,
Oceans and Watersheds (4502T)

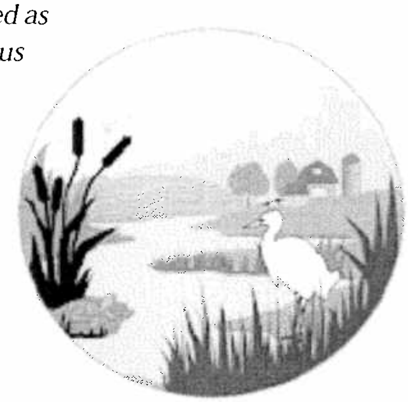
EPA 843-F-01-002c
September 2001

Functions and Values of Wetlands



Dave Davis

Long regarded as wastelands, wetlands are now recognized as important features in the landscape that provide numerous beneficial services for people and for fish and wildlife. Some of these services, or functions, include protecting and improving water quality, providing fish and wildlife habitats, storing floodwaters, and maintaining surface water flow during dry periods. These beneficial services, considered valuable to societies worldwide, are the result of the inherent and unique natural characteristics of wetlands.



Wetlands are considered valuable because they clean the water, recharge water supplies, reduce flood risks, and provide fish and wildlife habitat. In addition, wetlands provide recreational opportunities, aesthetic benefits, sites for research and education, and commercial fishery benefits.

Functions Versus Values

Wetland functions include water quality improvement, floodwater storage, fish and wildlife habitat, aesthetics, and biological productivity. The value of a wetland is an estimate of the importance or worth of one or more of its functions to society. For example, a value can be determined by the revenue generated from the sale of fish that depend on the wetland, by the tourist dollars associated with the wetland, or by public support for protecting fish and wildlife.

Although large-scale benefits of functions can be valued, determining the value of individual wetlands is difficult because they differ widely and do not all perform the same functions or perform functions equally well. Decision-makers must understand that impacts on wetland functions can eliminate or diminish the values of wetlands.

Water storage. Wetlands function like natural tubs or sponges, storing water and slowly releasing it. This process slows the water's momentum and erosive potential, reduces flood heights, and allows for ground water recharge, which contributes to base flow to surface water systems during dry periods. Although a small wetland might not store much water, a network of many small wetlands can store an enormous amount of water. The ability of wetlands to store floodwaters reduces the risk of costly property damage and loss of life—benefits that have economic value to us. For example, the U.S. Army Corps of Engineers found that protecting wetlands along the Charles River in Boston, Massachusetts, saved $17 million in potential flood damage.

Water filtration. After being slowed by a wetland, water moves around plants, allowing the suspended sediment to drop out and settle to the wetland floor. Nutrients from fertilizer application, manure, leaking septic tanks, and municipal sewage that are dissolved in the water are often absorbed by plant roots and microorganisms in the soil. Other pollutants stick to soil particles. In many cases, this filtration process removes much of the water's nutrient and pollutant load by the time it leaves a wetland. Some types of wetlands are so good at this filtration function that environmental managers construct similar artificial wetlands to treat storm water and wastewater.

Red osier dogwood

Biological productivity. Wetlands are some of the most biologically productive natural ecosystems in the world, comparable to tropical rain forests and coral reefs in their productivity and the diversity of species they support. Abundant vegetation and shallow water provide diverse habitats for fish and wildlife. Aquatic plant life flourishes in the nutrient-rich environment, and energy converted by the plants is passed up the food chain to fish, waterfowl, and other wildlife and to us as well. This function supports valuable commercial fish and shellfish industries.

The Great Flood of 1993 in the upper Mississippi River Basin caused billions of dollars in property damage and resulted in 38 deaths. Historically, 20 million acres of wetlands in this area had been drained or filled, mostly for agricultural purposes. If the wetlands had been preserved rather than drained, much property damage and crop loss could have been avoided.

DID YOU KNOW

- In 1991 wetland-related ecotourism activities such as hunting, fishing, bird-watching, and photography added approximately $59 billion to the national economy.
- According to the Pacific Coast Federation of Fishermen's Associations, almost $79 billion per year is generated from wetland-dependent species, or about 71 percent of the nation's entire $111 billion commercial and recreational fishing industry in 1997.
- An acre of wetland can store 1–1.5 million gallons of floodwater.
- Up to one-half of North American bird species nest or feed in wetlands.
- Although wetlands keep only about 5 percent of the land surface in the conterminous United States, they are home to 31 percent of our plant species.

Steve Delaney

Seventy-five percent of commercially harvested fish are wetland-dependent. Add shellfish species and that number jumps to 95 percent.

The Wetland Fact Sheet Series

Wetlands Overview	Funding Wetland Projects
Types of Wetlands	Wetland Monitoring & Assessment
Functions & Values of Wetlands	Sustainable Communities
Threats to Wetlands	Volunteering for Wetlands
Wetland Restoration	Teaching about Wetlands

For more information, visit www.epa.gov/owow/wetlands.

Wetland Resources

On the Internet

Ecosystem Valuation .... www.ecosystemvaluation.org

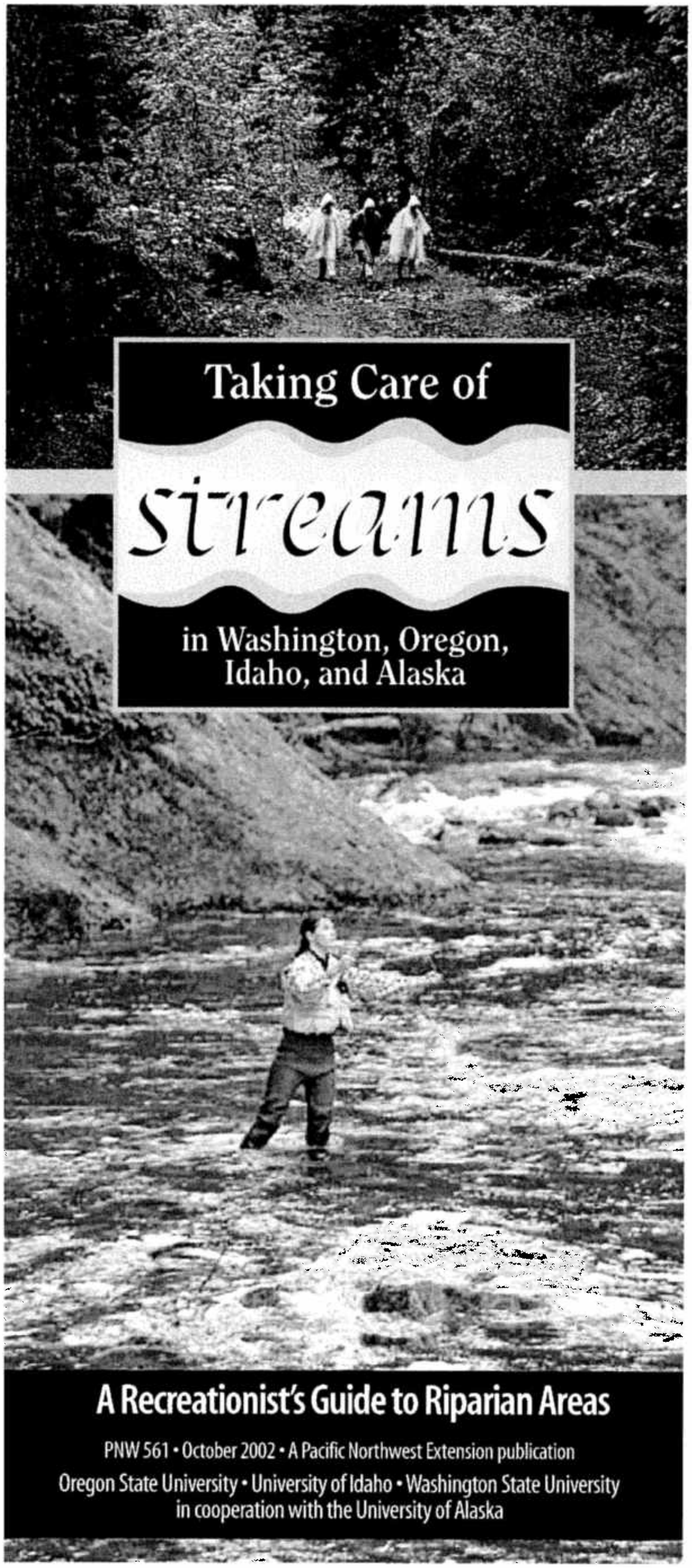
Economic Valuation of Wetlands .... www.ramsar.org/lib_val_e_index.htm

In Print

Restoration, Creation, and Recovery of Wetlands: Wetland Functions, Values, and Assessment, R.P. Novitzki, R.D. Smith, and J.D. Fretwell. United States Geological Survey Water Supply Paper 2425. Available on-line at http://water.usgs.gov/nwsum/WSP2425/functions.html.

Technical Aspects of Wetlands: Wetland Hydrology, Water Quality, and Associated Functions, Virginia Carter. United States Geological Survey Water Supply Paper 2425. Available on-line at http://water.usgs.gov/nwsum/WSP2425/hydrology.html.

Wetlands Functions and Values. Visit the North Carolina State University Water Quality Group's on-line informational database, WATERSHEDSS, at http://h2osparc.wq.ncsu.edu/info/wetlands/funval.html.



As a recreationist, you have a unique opportunity to help maintain or improve the health of streams and riparian areas. A riparian area is the land adjacent to a stream, lake, or wetland. Healthy riparian areas often have moist, fertile soils that support many types of plants. These plants provide food and shelter to numerous fish and wildlife.

The Pacific Northwest's growing population adds to the numbers of people accessing our waterways. Recreational uses include fishing, kayaking, bird watching, camping, biking, hunting, jet skiing, and more. Although designated access points are provided throughout the Northwest, many people access the water from public or private properties that lack proper access facilities. In these places, proper care of the riparian area will ensure a more pleasant experience for all users, as well as better conditions for fish and wildlife.

Healthy riparian areas:

- Reduce the chance of damaging floods
- Improve water quality
- Store and release water, moderating stream flow
- Provide habitat for fish and wildlife

Why do riparian areas matter?

Plants in healthy riparian areas:

- Provide wood to streams, creating fish habitat and slowing the stream current after storms.
- Shade streams in summer. Cool water is healthier for many native fish species.
- Help prevent erosion by holding soil in place with roots.
- Filter sediment out of muddy runoff, keeping sediment from smothering fish habitat.
- Allow rain to soak into the soil instead of running directly into the stream. This allows water to be released slowly to the stream during the dry season.
- Filter out pollutants, such as fertilizers, pesticides, sediment, and animal wastes.
- Provide food sources, homes, shelter, and travel corridors for wildlife, fish, and other aquatic organisms.

The bottom line is:

- A more appealing natural setting
- Cleaner water
- More water in the stream during summer
- Homes and food for fish and wildlife

It's all about plants

Healthy riparian areas include a variety of types and ages of plants, including trees, shrubs, grasses, and groundcovers.

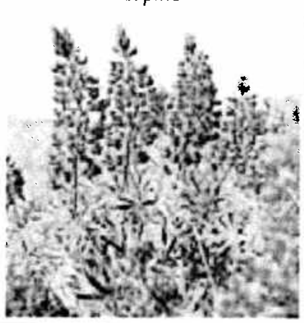
Most native plants are well adapted to their region. In the Pacific Northwest, a few of the common native riparian plants are:

- Alder
- Black cottonwood
- Devils club
- Douglas-fir
- Elderberry
- Oceanspray
- Oregon ash
- Pacific ninebark
- Red-osier dogwood
- Salmonberry
- Sitka spruce
- Snowberry
- Swamp rose
- Western hemlock
- Western redcedar
- Willow

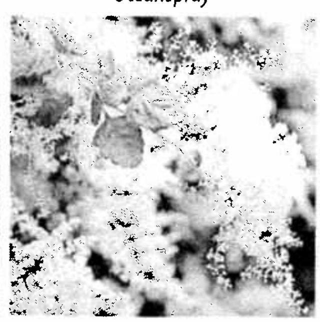
Enjoy and respect our streams.

Snowberry

Lupine



Oceanspray



Fishermen. (Photo courtesy of USDA NRCS)

How do people change riparian areas?

When we recreate in and along riparian areas, we may damage the plants that are vital to the area. Riparian plants can be damaged and eliminated through trampling, soil compaction, and other recreational practices. Nonnative noxious weeds, which compete with native plants, can be spread via the soles of boots, tire treads, and boat propellers and trailers.

Plants, particularly trees and shrubs, catch rainfall and allow it to soak slowly into the ground instead of running quickly into streams. When riparian plants are absent or sparse, runoff from storms reaches streams too fast, causing erosion as well as downstream flooding. In areas without riparian plants to slow and filter water, pesticides, animal waste, fertilizers, and sediment can reach the stream more easily.

When streams and riparian areas are not healthy, people feel the consequences.

- We lose recreational areas.
- Fish and wildlife decline, reducing opportunities for hunting, fishing, and wildlife viewing.
- Increased flooding may cause erosion and property damage.
- The region may lose economic opportunities because people avoid unattractive and unhealthy areas.

What Can You Do?

Campers

- Set your camp away from the water's edge to prevent trampling of riparian vegetation and to protect yourself from varying stream flows.
- Avoid creating numerous trails through riparian areas.
- Use biodegradable detergents for washing, and wash away from streams and lakes.
- Reduce garbage by minimizing the amount of disposable items and prepackaged foods you use. Pack out and properly dispose of all garbage.
- Bring in your own firewood. Forest woody debris are an important part of the ecosystem, building soils when they decay, holding soil during floods, and providing habitat for wildlife, fish, and insects.
- Discourage dogs and people from walking in rivers or streams to protect salmon eggs and fry that may be hiding in bottom gravels.
- Bury human and dog fecal matter at least 6 inches deep and well away from riparian areas. Better yet, use a bucket for later disposal in a campground toilet.

Hikers and bikers

- Stay out of streams as much as possible and use designated stream crossings to prevent bank and stream degradation.
- Stay on designated trails to prevent off-trail damage to natural vegetation.
- Avoid hiking in restricted salmon areas to prevent stress to spawning fish.
- Check shoe soles and tire treads for weed seeds before and after using trails.
- Be aware of and respect private property boundaries.

Pets and pack animals

- Keep all animals out of streams.
- Tether riding animals away from streams, wetlands, and lakes to prevent fecal matter from entering the water and to protect riparian plants from damage.
- Minimize the number of stock you use by packing less.

Fishers and floaters

- Use officially established access points.
- Avoid driving to the water's edge, as this damages plants and habitat.
- Be careful not to damage habitat or litter.
- If you catch a hook in a tree, remove it and properly dispose of any tangled line.
- Do not release leftover live bait into streams.

Motorized craft users

- Maintain your boat in proper working condition.
- Do repairs and painting in dry dock, using tarps to contain spilled pollutants.
- Be sure your equipment is not leaking fuel or oils.
- Add fuel in a parking lot to minimize the chance of spills. Clean up any spills that do occur.
- Fill fuel tanks only 90 percent full; gas expands when warm.
- Check propellers and jets for exotic plant or animal species before launching boats and immediately after removing them from the water.
- Empty bilge and bait buckets away from the waterway to prevent introduction of nonnative species.
- Empty sewage only in approved dumping stations to prevent pollution of waterways.
- Identify and avoid nesting and spawning habitats before using watercraft in nearshore areas.
- Watch your wake to prevent shoreline erosion.

All campground and waterway users

- Pack out all cans, bottles, and garbage to protect humans and wildlife. Trash endangers wildlife and jeopardizes water quality and safety.
- Dispose of coolers or bait containers properly to prevent breakdown and distribution of Styrofoam beads.
- Keep pet wastes away from streams, riparian areas, and paved areas.

Taking Care of Streams in Washington, Oregon, Idaho, and Alaska

A Recreationist's Guide to Riparian Areas

For more information

Life on the Edge: Improving Riparian Function (D. Godwin, 2000, Oregon State University Extension Service, EM 8738). http://eesc.oregonstate.edu/agcomwebfile/edmat/EM8738.pdf

Principles of Leave No Trace (Leave No Trace, Inc.). http://www.LNT.org/

Stream Corridor Restoration—Principles, Processes, and Practices (The Federal Interagency Stream Restoration Working Group, 1998, revised August 2000). http://www.usda.gov/stream_restoration

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State Fish and Wildlife offices
Alaska—907-465-4100
http://www.state.ak.us/adfg/adfghome.htm

Idaho—208-334-3700
http://www2.state.id.us/fishgame/fishgame.html

Oregon—503-872-5268
http://www.dfw.state.or.us/

Washington—360-902-2200
http://www.wa.gov/wdfw/

U.S. Forest Service
http://www.fs.fed.us

Bureau of Land Management
http://www.blm.gov/nhp/

Funded in part by USEPA Region 10 and the USDA Cooperative State Research, Education, and Extension System. Regional Water Quality Coordination Team: Marilyn Freeman, EPA liaison; Robert L. Mahler, University of Idaho; J. Ronald Miner, Oregon State University; Robert Simmons, Washington State University; Fred Sorensen, University of Alaska; and Sylvia Kantor, Washington State University (editor). Cover photo (bottom) courtesy of USDA NRCS. Canoe photo courtesy of John H. McShane.

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Published October 2002.

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How to Read a Topographic Map and Delineate a Watershed

This fact sheet is an excerpt from Appendix E of the *Method for the Comparative Evaluation of Nontidal Wetlands in New Hampshire*, 1991. Alan Ammann, PhD and Amanda Lindley Stone. This document and method is commonly called "The New Hampshire Method."

Interpreting Topographic Maps

In order to successfully delineate a watershed boundary, the evaluator will need to visualize the landscape as represented by a topographic map. This is not difficult once the following basic concepts of the topographic maps are understood.

Each contour line on a topographic map represents a ground elevation or vertical distance above a reference point such as sea level. A contour line is level with respect to the earth's surface just like the top of a building foundation. All points along any one contour line are at the same elevation.

The difference in elevation between two adjacent contours is called the contour interval. This is typically given in the map legend. It represents the vertical distance you would need to climb or descend from one contour elevation to the next.

The horizontal distance between contours, on the other hand, is determined by the steepness of the landscape and can vary greatly on a given map. On relatively flat ground, two 20 foot contours can be far apart horizontally.

On a steep cliff face two 20 foot contours might be directly above and below each other. In each case the vertical distance between the contour lines would still be twenty feet.

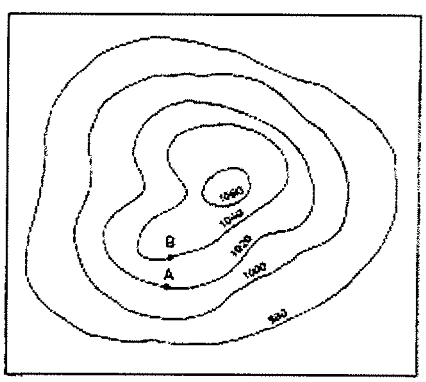

Figure E-1: Isolated Hill

One of the easiest landscapes to visualize on a topographic map is an isolated hill. If this hill is more or less circular the map will show it as a series of more or less concentric circles (Figure E-1). Imagine that a surveyor actually marks these contour lines onto the ground. If two people start walking in opposite directions on the same contour line, beginning at point A, they will eventually meet face to face.

If these same two people start out in opposite directions on different contours, beginning at points A and B respectively, they will pass each other somewhere on the hill and their vertical distance apart would remain 20 feet. Their horizontal distance apart could be great or small depending on the steepness of the hillside where they pass.

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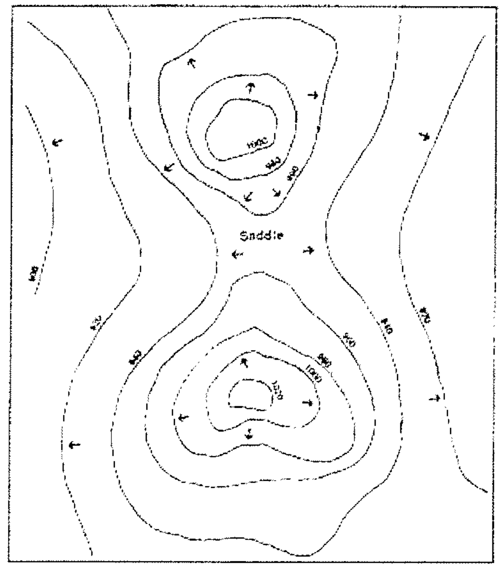
A rather more complicated situation is one where two hills are connected by a saddle (Figure E-2). Here each hill is circled by contours but at some point toward the base of the hills, contours begin to circle both hills.

How do contours relate to water flow? A general rule of thumb is that water flow is perpendicular to contour lines. In the case of the isolated hill, water flows down on all sides of the hill. Water flows from the top of the saddle or ridge, down each side in the same way water flows down each side of a garden wall (See arrow on Figure E-2).

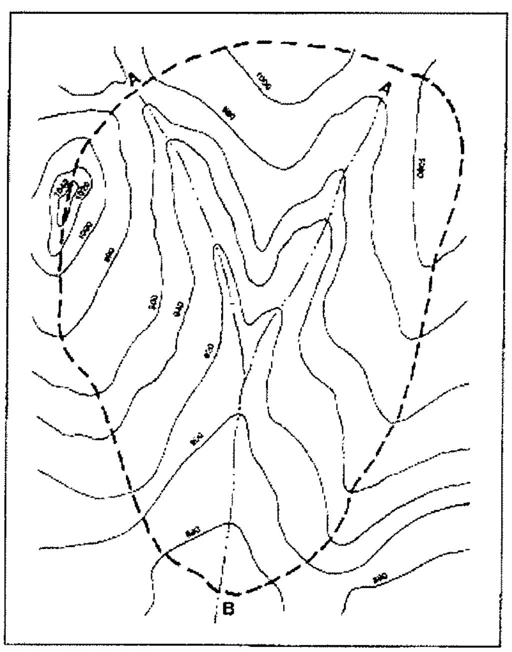


KEY: → = Surface Water Flow

Figure E-2: Saddle

As the water continues downhill it flows into progressively larger watercourses and ultimately into the ocean. Any point on a watercourse can be used to define a watershed. That is, the entire drainage area of a major river like the Merrimack can be considered a watershed, but the drainage areas of each of its tributaries are also watersheds.

Each tributary in turn has tributaries, and each one of these tributaries has a watershed. This process of subdivision can continue until very small, local watersheds are defined which might only drain a few acres, and might not contain a defined watercourse.



KEY:

Stream — • • —

Watershed Boundary — — —

Figure E-3: Idealized Watershed Boundary

Figure E-3 shows an idealized watershed of a small stream. Water always flows downhill perpendicular to the contour lines. As one proceeds upstream, successively higher and higher contour lines first parallel then cross the stream. This is because the floor of a river valley rises as you go upstream. Likewise the valley slopes upward on each side of the stream. A general rule of thumb is that topographic lines always point upstream. With that in mind, it is not difficult to make out drainage patterns and the direction of flow on the landscape even when there is no stream depicted on the map. In Figure E-3, for example, the direction of streamflow is from point A to point B.

Ultimately, you must reach the highest point upstream. This is the head of the watershed, beyond which the land slopes away into another watershed. At each point on the stream the land slopes up on each side to some high point then down into another watershed. If you were to join all of these high points around the stream you would have the watershed boundary. (High points are generally hill tops, ridge lines, or saddles).

Delineating a Watershed

The following procedure and example will help you locate and connect all of the high points around a watershed on a topographic map shown in Figure F-4 below. Visualizing the landscape represented by the topographic map will make the process much easier than simply trying to follow a method by rote.

1. Draw a circle at the outlet or downstream point of the wetland in question (the wetland is the hatched area shown in Figure E-4 to the right)
2. Put small "X's" at the high points along both sides of the watercourse, working your way upstream towards the headwaters of the watershed.
3. Starting at the circle that was made in step one, draw a line connecting the "X's" along one side of the watercourse (Figure E-5, below left). This line should always cross the contours at right angles (i.e. it should be perpendicular to each contour line it crosses).
4. Continue the line until it passes around the head of the watershed and down the opposite side of the watercourse. Eventually it will connect with the circle from which you started.

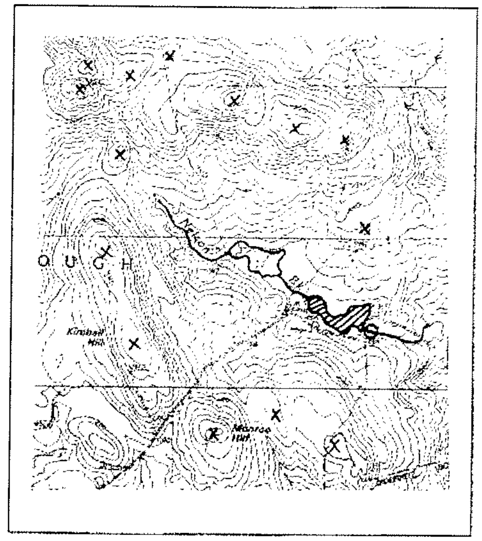


Figure E-4: Delineating a Watershed Boundary - Step 1

At this point you have delineated the watershed of the wetland being evaluated.

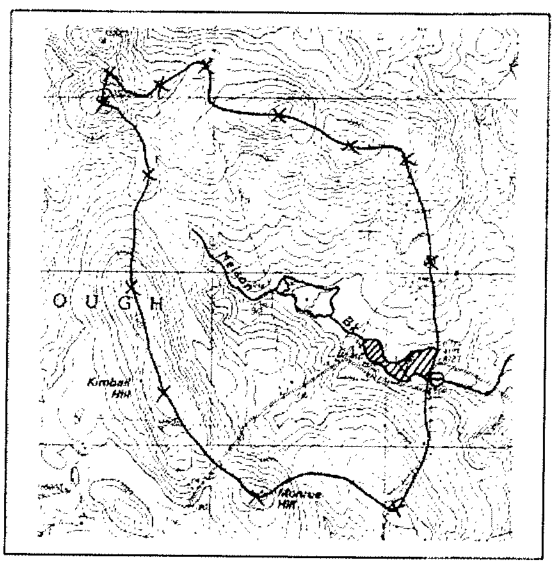


Figure E-5: Delineating a Watershed Boundary - Step 2

The delineation appears as a solid line around the watercourse. Generally, surface water runoff from rain falling anywhere in this area flows into and out of the wetland being evaluated. This means that the wetland has the potential to modify and attenuate sediment and nutrient loads from this watershed as well as to store runoff which might otherwise result in downstream flooding.

Measuring Watershed Areas

There are two widely available methods for measuring the area of a watershed: a) Dot Grid Method, and b) Planimeter. These methods can also be used to measure the area of the wetland itself as required by The New Hampshire Method.

a) The dot grid method is a simple technique which does not require any expensive equipment. In this method the user places a sheet of acetate or mylar, which has a series of dots about the size of the period at the end of this sentence printed on it, over the map area to be measured. The user counts the dots which fall within the area to be measured and multiplies by a factor to determine the area. A hand held, mechanical counting device is available to speed up this procedure.

b) The second of these methods involves using a planimeter, which is a small device having a hinged mechanical arm. One end of the arm is fixed to a weighted base while the other end has an attached magnifying lens with a cross hair or other pointer. The user spreads the map with the delineated area on a flat surface. After placing the base of the planimeter in a convenient location the user traces around the area to be measured with the pointer. A dial or other readout registers the area being measured.

Planimeters can be costly depending on the degree sophistication. For the purposes of The New Hampshire Method, a basic model would be sufficient. Dot counting grids are significantly more affordable. Both planimeters and dot grids are available from engineering and forestry supply companies. Users of either of these methods should refer to the instructions packaged with the equipment they purchase.

For more information on The New Hampshire Method, wetlands restoration programs, conservation planning, ecosystem restoration, and other technical references, visit www.nh.nrcs.usda.gov or call (603) 868-7581.

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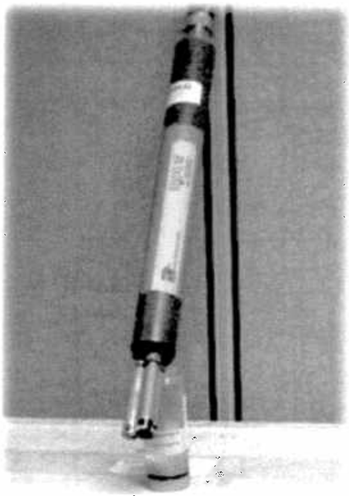
Water Science for Schools

Common water measurements



Water-quality meter to measure multiple parameters in the field.

The U.S. Geological Survey has been measuring water for decades. Millions of measurements and analyses have been made. Some measurements are taken almost every time water is sampled and investigated, no matter where in the U.S. the water is being studied. Even these simple measurements can sometimes reveal something important about the water and the environment around it.

The results of a single measurement of a water's properties are actually less important than looking at how the properties vary over time. For example, if you take the pH of the creek behind your school and find that it is 5.5, you might say "Wow, this water is acidic!" But, a pH of 5.5 might be "normal" for that creek. It is similar to how my normal body temperature (when I'm not sick) is about 97.5 degrees, but my third-grader's normal temperature is "really normal" -- right on the 98.6 mark. As with our temperatures, if the pH of your creek begins to change, then you might suspect that something is going on somewhere that is affecting the water, and possibly, the water quality. So, often, the ***changes*** in water measurements are more important than the actual measured values.

pH is only one measurement of a water body's health; there are others, too. Choose from this list to find out what they are and how they can reveal something about water.

Temperature ◆ pH ◆ Specific conductance ◆ Turbidity
Dissolved oxygen ◆ Hardness ◆ Suspended sediment

Water temperature

Water temperature is not only important to swimmers and fisherman, but also to industries and even fish and algae. A lot of water is used for cooling purposes in power plants that generate electricity. They need cool water to start with, and they generally release warmer water back to the environment. The temperature of the released water can affect downstream habitats. Temperature also can affect the ability of water to hold oxygen as well as the ability of organisms to resist certain pollutants.

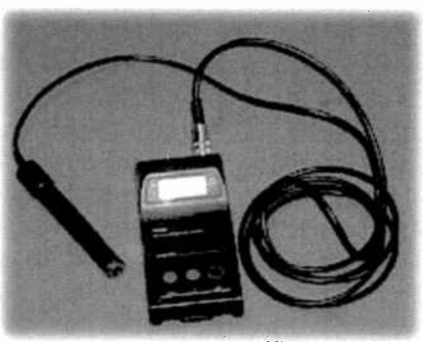
pH

pH is a measure of how acidic/basic water is. The range goes from 0 - 14, with 7 being neutral. pHs of less than 7 indicate acidity, whereas a pH of greater than 7 indicates a base. pH is really a measure of the relative amount of free hydrogen and hydroxyl ions in the water. Water that has more free hydrogen ions is acidic, whereas water that has more free hydroxyl ions is basic. Since pH can be affected by chemicals in the water, pH is an important indicator of water that is changing chemically. pH is reported in "logarithmic units," like the Richter scale, which measures earthquakes. Each number represents a 10-fold change in the acidity/basicness of the water. Water with a pH of 5 is ten times more acidic than water having a pH of six.

Pollution can change a water's pH, which in turn can harm animals and plants living in the water. For instance, water coming out of an abandoned coal mine can have a pH of 2, which is very acidic and would definitely affect any fish crazy enough to try to live in it! By using the logarithm scale, this mine-drainage water would be 100,000 times more acidic than neutral water -- so stay out of abandoned mines.

Diagram about pH Picture of a pH meter

Specific conductance


Meter to measure specific conductance in the field and lab

Specific conductance is a measure of the ability of water to conduct an electrical current. It is highly dependent on the amount of dissolved solids (such as salt) in the water. Pure water, such as distilled water, will have a very low specific conductance, and sea water will have a high specific conductance. Rainwater often dissolves airborne gasses and airborne dust while it is in the air, and thus often has a higher specific conductance than distilled water. Specific conductance is an important water-quality measurement because it gives a good idea of the amount of dissolved material in the water.

Probably in school you've done the experiment where you hook up a battery to a light bulb and run two wires from the battery into a beaker of water. When the wires are put into a beaker of distilled water, the light will not light. But, the bulb does light up when the beaker contains salt water (saline). In the saline water, the salt has dissolved, releasing free electrons, and the water will conduct an electrical current.

Turbidity

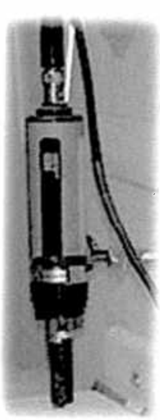
Turbidity is the amount of particulate matter that is suspended in water. Turbidity measures the scattering effect

that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid include:

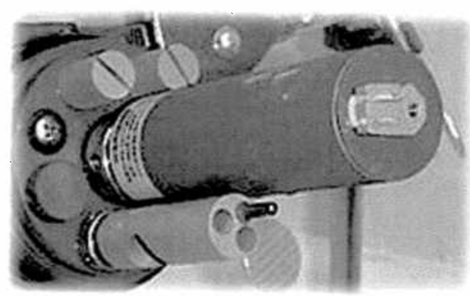
- clay
- silt
- finely divided organic and inorganic matter
- soluble colored organic compounds
- plankton
- microscopic organisms

Turbidity makes the water cloudy or opaque. The picture to the left shows highly turbid water from a tributary (where construction was probably taking place) flowing into the less turbid water of the Chattahoochee River in Georgia. Turbidity is measured by shining a light through the water and is reported in nephelometric turbidity units (NTU). During periods of low flow (base flow), many rivers are a clear green color, and turbidities are low, usually less than 10 NTU. During a rainstorm, particles from the surrounding land are washed into the river making the water a muddy brown color, indicating water that has higher turbidity values. Also, during high flows, water velocities are faster and water volumes are higher, which can more easily stir up and suspend material from the stream bed, causing higher turbidities.

Turbidity can be measured in the laboratory and also on-site in the river. A handheld turbidity meter (left-side picture) measures turbidity of a water sample. The meter is calibrated using standard samples from the meter manufacturer. The picture with the three glass vials shows turbidity standards of 5, 50, and 500 NTUs. Once the meter is calibrated to correctly read these standards, the turbidity of a water sample can be taken.



State-of-the-art turbidity meters (left-side picture) are beginning to be installed in rivers to provide an instantaneous turbidity reading. The right-side picture shows a closeup of the meter. The large tube is the turbidity sensor; it reads turbidity in the river by shining a light into the water and reading how much light is reflected back to the sensor. The smaller tube contains a conductivity sensor to measure electrical conductance of the water, which is strongly influenced by dissolved solids (the two holes) and a temperature gauge (the metal rod).



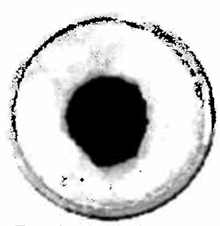
Dissolved oxygen

Eutrophic conditions, Hartbees River, South Africa
Credit: National Eutrophication Monitoring Programme

Although water molecules contain an oxygen atom, this oxygen is not what is needed by aquatic organisms living in our natural waters. A small amount of oxygen, up to about ten molecules of oxygen per million of water, is actually dissolved in water. This dissolved oxygen is breathed by fish and zooplankton and is needed by them to survive.

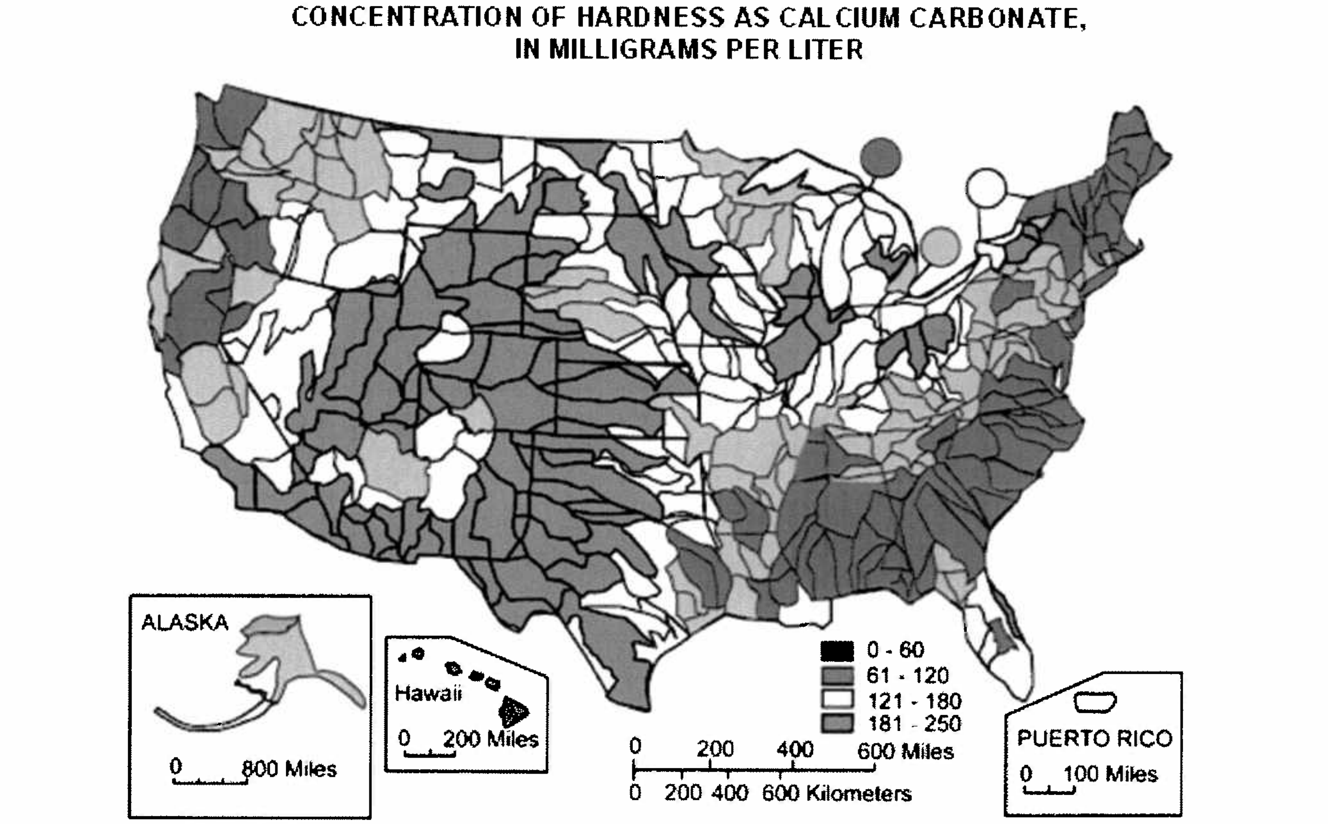
Rapidly moving water, such as in a mountain stream or large river, tends to contain a lot of dissolved oxygen, while stagnant water contains little. Bacteria in water can consume oxygen as organic matter decays. Thus, excess organic material in our lakes and rivers can cause an oxygen-deficient situation to occur. Aquatic life can have a hard time in stagnant water that has a lot of rotting, organic material in it, especially in summer, when dissolved-oxygen levels are at a seasonal low.

Hardness



Scale buildup in a a pipe, caused by hard water.

The amount of dissolved calcium and magnesium in water determines its "hardness." Water hardness varies throughout the United States. If you live in an area where the water is "soft," then you may never have even heard of water hardness. But, if you live in Florida, New Mexico, Arizona, Utah, Wyoming, Nebraska, South Dakota, Iowa, Wisconsin, or Indiana, where the water is relatively hard, you may notice that it is difficult to get a lather up when washing your hands or clothes. And, industries in your area might have to spend money to soften their water, as hard water can damage equipment. Hard water can even shorten the life of fabrics and clothes! Does this mean that students who live in areas with hard water keep up with the latest fashions since their clothes wear out faster?



Mean hardness as calcium carbonate at NASQAN water-monitoring sites during 1975 water year.
Colors represent site data representing streamflow from the hydrologic-unit rea.
(Map edited by USEPA, 2005)

More information: Hard water and water softening - Stephen Lower

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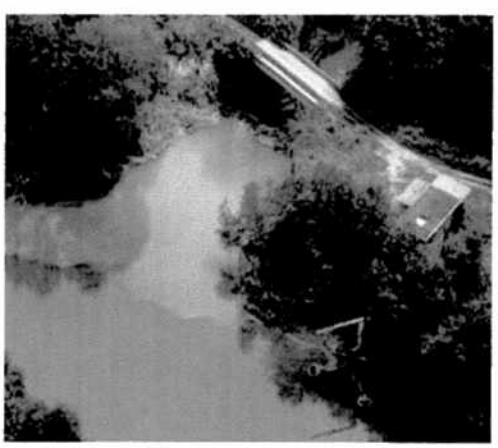
Suspended sediment



Suspended sediment is the amount of soil moving along in a stream. It is highly dependent on the speed of the water flow, as fast-flowing water can pick up and suspend more soil than calm water. During storms, soil is washed from the stream banks into the stream. The amount that washes into a stream depends on the type of land in the river's watershed and the vegetation surrounding the river.

If land is disturbed along a stream and protection measures are not taken, then excess sediment can harm the water quality of a stream. You've probably seen those short, plastic fences that builders put up on the edges of the property they are developing. These silt fences are supposed to trap sediment during a rainstorm and keep it from washing into a stream, as excess sediment can harm the creeks, rivers, lakes, and reservoirs.

Sediment coming into a reservoir is always a concern; once it enters it cannot get out - most of it will settle to the bottom. Reservoirs can "silt in" if too much sediment enters them. The volume of the reservoir is reduced, resulting in less area for boating, fishing, and recreation, as well as reducing the power-generation capability of the power plant in the dam.

Information on this page is from *A Primer on Water Quality, by Swanson, H.A., and Baldwin, H.L., U.S. Geological Survey, 1965*

Related Topics

Capillary action ◆ Water properties ◆ pH Diagram ◆ Sediment in rivers
Water basics ◆ Water Science home page

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Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen

SUMMARY

Runoff from our farms and cities is a major source of phosphorus (P) and nitrogen (N) entering rivers, lakes, and coastal waters. Acid rain and airborne pollutants generated by human activities also supply N to surface waters. These nutrient sources are called "nonpoint" because they involve widely dispersed activities. Nonpoint inputs are difficult to measure and regulate because of their dispersed origins and because they vary with the seasons and the weather. Yet nonpoint inputs are the major source of water pollution in the United States today, and their impacts are profound. In aquatic ecosystems, over-enrichment with P and N causes a wide range of problems, including toxic algal blooms, loss of oxygen, fish kills, loss of seagrass beds and other aquatic vegetation, degradation of coral reefs, and loss of biodiversity — including species important to commercial and sport fisheries and shellfish industries. Thus, nutrient fouling seriously degrades our marine and freshwater resources and impairs their use for industry, agriculture, recreation, drinking water, and other purposes.

Based on our review of the scientific literature, we are certain that:

- Eutrophication caused by over-enrichment with P and N is a widespread problem in rivers, lakes, estuaries, and coastal oceans.
- Nonpoint pollution is a major source of P and N to surface waters of the United States. The major sources of nonpoint pollution are agriculture and urban activity, including industry and transportation.
- In the U.S. and many other nations, inputs of P and N to agriculture in the form of fertilizers exceed outputs of those nutrients in the form of crops.
- High densities of livestock have created situations in which manure production exceeds the needs of crops to which the manure is applied. The density of animals on the land is directly related to nutrient flows to aquatic ecosystems.
- Excess fertilization and manure production cause a P surplus, which accumulates in soil. Some of this surplus is transported in soil runoff to aquatic ecosystems.
- Excess fertilization and manure production create a N surplus on agricultural lands. Surplus N is mobile in many soils, and much leaches into surface waters or percolates into groundwater. Surplus N can also volatilize to the atmosphere and be redeposited far downwind as acid rain or dry pollutants that may eventually reach distant aquatic ecosystems.

If current practices continue, nonpoint pollution of surface waters is virtually certain to increase in the future. Such an outcome is not inevitable, however, because a number of technologies, land use practices, and conservation measures are available that can decrease the flow of nonpoint P and N into surface waters.

From our review of the available scientific information, we are confident that:

- Nonpoint pollution of surface waters with P and N could be decreased by reducing excess nutrient flows in agricultural systems, reducing farm and urban runoff, and reducing N emissions from fossil fuel burning.
- Eutrophication of aquatic ecosystems can be reversed by decreasing input rates of P and N. However, rates of recovery are highly variable, and recovery is often slow.

The panel finds that the roots of the problem of nonpoint pollution and eutrophication are well understood scientifically. There is a critical need for creative efforts to translate this understanding into effective policies and practices that will lead to protection and recovery of our aquatic resources.

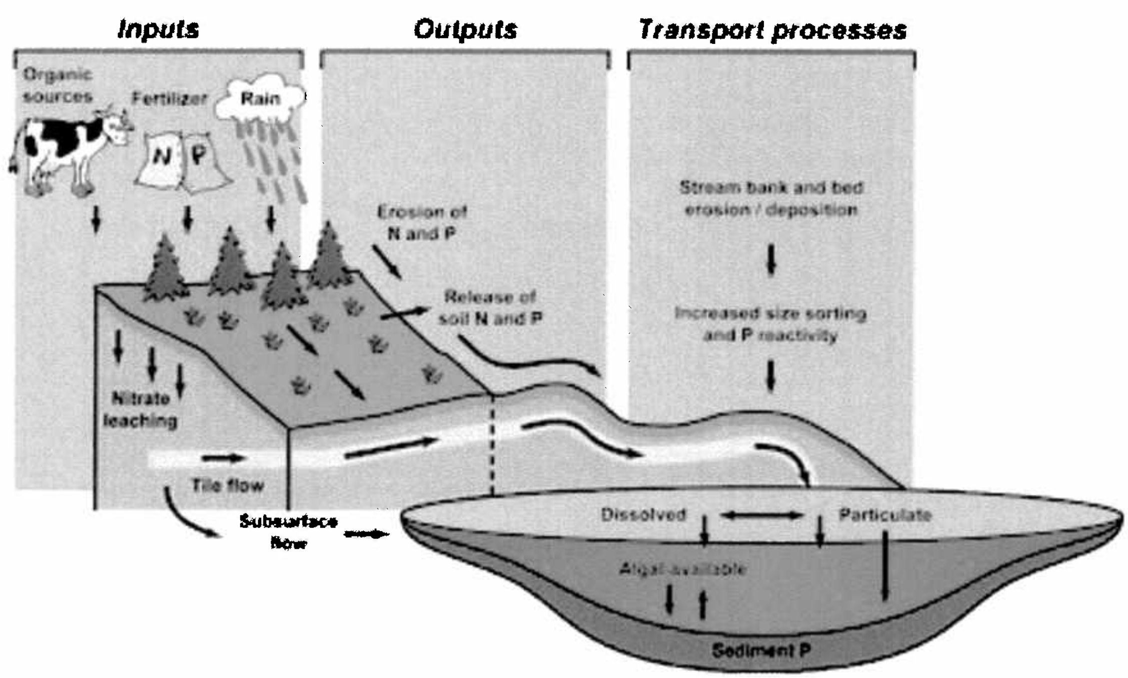
Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen

by
Stephen Carpenter, Chair, Nina F. Caraco,
David L. Correll, Robert W. Howarth,
Andrew N. Sharpley, and Val H. Smith

INTRODUCTION

From ancient times, people have chosen to live near water, settling in river valleys, beside lakes, or along coastlines. The attractions of water are as diverse as human needs and aspirations. Clean water is a crucial resource for drinking, irrigation, industry, transportation, recreation, fishing, hunting, support of biodiversity, and sheer esthetic enjoyment. For as long as humans have lived near waterways, they have also used them to wash away and dilute society's wastes and pollutants. But with growing populations and increased production and consumption, this long tradition of flushing wastes downstream has begun to overwhelm the cleansing capacities of the Earth's waters. Pollutant inputs have increased in recent decades, and the result has been degradation of water quality in many rivers, lakes and coastal oceans. This degradation shows up in the disruption of natural aquatic ecosystems, and the consequent loss of their component species as well as the amenities that these ecosystems once provided to society. Water shortages, for instance, are increasingly common and likely to become more severe in the future. Water shortages and poor water quality are linked, because contamination reduces the supply of water and increases the costs of treating water to make it safe for human use. Thus, preventing pollution is among the most cost-effective means of increasing water supplies.

The most common impairment of surface waters in the U.S. is eutrophication caused by excessive inputs of phosphorus (P) and nitrogen (N). Impaired waters are defined as those that are not suitable for designated uses such as drinking, irrigation, industry, recreation, or fishing. Eutrophication accounts for about half of the impaired lake area and 60% of the impaired river reaches in the U.S. and is also the most widespread pollution prob-



Artwork by W. Feeny

Figure 1 - Nutrients in manure and fertilizers are transported to lakes, rivers, and oceans. Excessive nutrient inputs result in degradation of water quality, causing the disruption of aquatic ecosystems.

POINT SOURCES	NONPOINT SOURCES
• Wastewater effluent, both municipal and industrial • Runoff and leachate from waste disposal sites • Runoff and infiltration from animal feed lots • Runoff from mines, oil fields, and unsewered industrial sites • Storm sewer outfalls from cities with a population of greater than 100,000 • Runoff from construction sites larger than two hectares • Overflows of combined storm and sanitary sewers	• Runoff from agriculture (including return flow from irrigated agriculture) • Runoff from pasture and range • Urban runoff from unsewered areas and sewered areas with a population of less than 100,000 • Septic leachate and runoff from failed septic systems • Runoff from construction sites smaller than two hectares • Runoff from abandoned mines • Atmospheric deposition over a water surface • Activities on land that generate contaminants, such as logging, wetland conversion, construction and development of land or waterways

Sources of Point and Nonpoint Pollution

Figure 2 - Sources of point and nonpoint chemical inputs to lakes, rivers, and oceans recognized by statutes. Pollutant discharges from point sources tend to be continous and therefore relatively simple to identify and monitor. Nonpoint sources, however, arise from a suite of activities across large areas and are much more difficult to control.

lem of U.S. estuaries. Other important causes of surface water degradation are siltation caused by erosion from agricultural, logging, and construction activities (silt also carries nutrients, contributing to eutrophication); acidification from atmospheric sources and mine drainage; contamination by toxins; introduction of exotic species such as zebra mussels and sea lampreys; and hydrologic changes created by dams, channelization, draining of wetlands, and other waterworks.

Chemical inputs to rivers, lakes, and oceans originate either from point or nonpoint sources. Point sources include effluent pipes from municipal sewage treatment plants and factories. Pollutant discharges from such sources tend to be continuous, with little variability over time, and often they can be monitored by measuring discharge and chemical concentrations periodically at a single place. Consequently, point sources are relatively simple to monitor and regulate, and can often be controlled by treatment at the source. Nonpoint inputs can also be continuous, but are more often intermittent and linked to seasonal agricultural activity such as planting and plowing or irregular events such as heavy rains or major construction. Nonpoint inputs often arise from a varied suite of activities across extensive stretches of the landscape, and materials enter receiving waters as overland flow, underground seepage, or through the atmosphere. Consequently, nonpoint sources are difficult to measure and regulate. Control of nonpoint pollution centers on land management practices and regulation of the release of pollutants to the atmosphere. Such controls may affect the daily activities of millions of people.

In many cases over recent decades, point sources of water pollution have been reduced, owing to their relative ease of identification and control. However, point sources are still substantial in some parts of the world and may increase with future expansion of urban areas, aquaculture, and factory "farms," such as hog factories. This report focuses on nonpoint sources, not because point sources are unimportant, but because nonpoint inputs are often overlooked and pose a significant environmental challenge.

Nonpoint inputs are the major source of water pollution in the U.S. today. The National Water Quality Inventory stated in 1988 that "the more we look, the more we find." For example, 72% to 82% of eutrophic lakes would require control of nonpoint P inputs to meet water quality standards, even if point inputs were reduced to zero.

This report primarily addresses nonpoint pollution of water by P and N because:

- Eutrophication is currently the most widespread water quality problem in the U.S. and many other nations.
- Restoration of most eutrophic waters requires the reduction of nonpoint inputs of P and N.
- A sound scientific understanding of the causes of nonpoint nutrient pollution exists. In many cases, we have the technical knowledge needed to decrease nonpoint pollution to levels compatible with water quality standards.
- The most important barriers to control of nonpoint nutrient pollution appear to be social, political, and institutional. We hope that our summary of the scientific basis of the problem will inform and support debate about solutions.

WHY IS NONPOINT P AND N POLLUTION A CONCERN?

Eutrophication: Scope and Causes

Eutrophication means the fertilization of surface waters by nutrients that were previously scarce. Over geologic time, eutrophication through nutrient and sediment inflow is a natural aging process by which warm shallow lakes evolve to dry land. Today human activities are greatly accelerating the process. Freshwater eutrophication has been a growing problem for decades. Both P and N supplies contribute to it, although for many lakes excessive P inputs are the primary cause.

Eutrophication is also widespread and rapidly expanding in estuaries and coastal seas of the developed world. For most temperate estuaries and coastal ecosystems, N is the element most limiting to production of plant material such as algae (primary productivity), and so N inputs are the most problematic. Although N is the major factor in eutrophication of most estuaries and coastal seas, P is also an essential element that contributes to coastal eutrophication. It is, in fact, the dominant control on primary production in some coastal ecosystems.

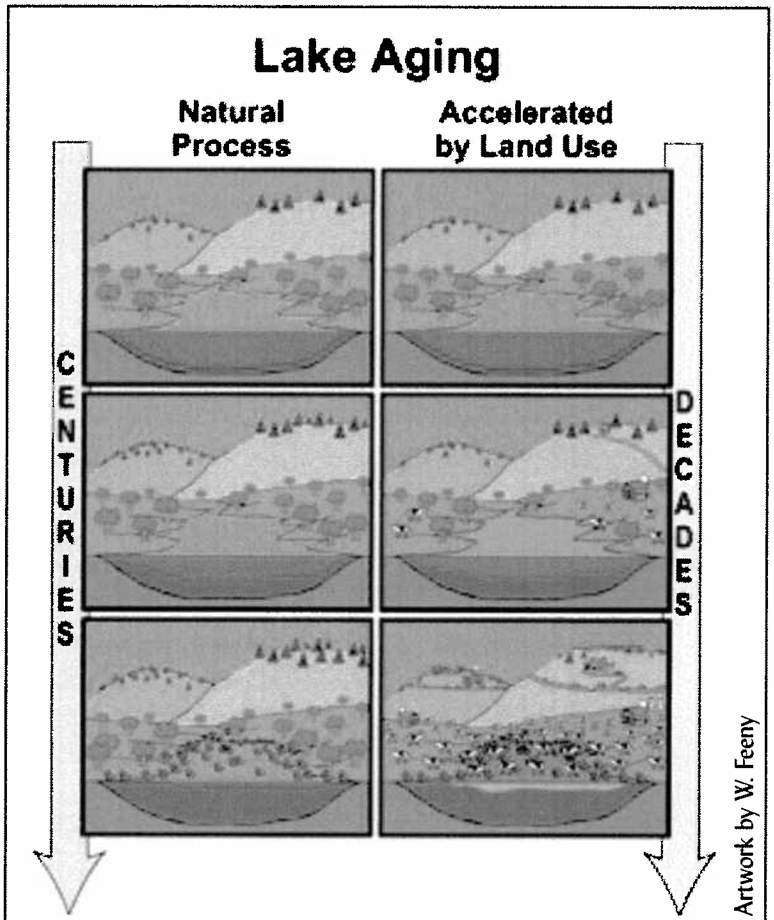


Figure 3 - Over extended periods of time, lakes tend to fill with sediment through natural processes (left). Currently, changes in land use and nutrient inputs are accelerating this process, filling lakes with sediments and algal blooms in just a few years (right).

Consequences

Eutrophication has many negative effects on aquatic ecosystems. Perhaps the most visible consequence is the proliferation of algae, which can turn water a turbid green and coat shallower surfaces with "pond scum." This increased growth of algae and also aquatic weeds can degrade water quality and interfere with use of the water for fisheries, recreation, industry, agriculture, and drinking. As overabundant nuisance plants die, bacterial decomposers proliferate; as they work to break down this plant matter, the bacteria consume more dissolved oxygen from the water. The result can be oxygen shortages that cause fish kills. Eutrophication can lead to loss of habitats such as aquatic plant beds in fresh and marine waters and coral reefs along tropical coasts. Thus, eutrophication plays a role in the loss of aquatic biodiversity.

Explosive growths of nuisance algae are among the most pernicious effects of eutrophication. These algae produce structures or chemicals that are harmful to other organisms, including livestock or humans. In marine ecosystems, algal blooms known as red or brown tides cause widespread problems by releasing toxins and by spurring oxygen depletion as they die and decompose. The incidence of harmful algal blooms in coastal oceans has increased in recent years. This increase is linked to coastal eutrophication and other factors, such as changes in marine food webs that may increase decomposition and nutrient recycling or reduce populations of algae-grazing fish. Algal blooms have severe negative impacts on aquaculture and shellfisheries. They cause shellfish poisoning in humans, and have caused significant mortality in marine mammals. A toxic dinoflagellate known as Pfiesteria has been associated with mortality of finfish on the U.S. Atlantic coast. The highly toxic, volatile chemical produced by this dinoflagellate can also cause neurological damage to people who come in contact with it.

In freshwater, blooms of cyanobacteria (formerly called blue-green algae) are a prominent symptom of

Adverse Effects of Eutrophication

- Increased biomass of phytoplankton
- Shifts in phytoplankton to bloom-forming species which may be toxic or inedible
- Increases in blooms of gelatinous zooplankton (marine environments)
- Increased biomass of benthic and epiphytic algae
- Changes in macrophyte species composition and biomass
- Death of coral reefs and loss of coral reef communities
- Decreases in water transparency
- Taste, odor, and water treatment problems
- Oxygen depletion
- Increased incidence of fish kills
- Loss of desirable fish species
- Reductions in harvestable fish and shellfish
- Decreases in perceived esthetic value of the water body

Figure 4 - Eutrophication, caused by excessive inputs of phosphorus (P) and nitrogen (N), has many adverse effects on lakes, reservoirs, rivers, and coastal oceans (modified from Smith 1998).

eutrophication. These blooms contribute to a wide range of water-related problems including summer fish kills, foul odors, and unpalatable tastes in drinking water. Furthermore, when such water is processed in water treatment plants, the high load of organic detritus reacts with chlorine to form carcinogens known as trihalomethanes. Water-soluble compounds toxic to the nervous system and liver are released when cyanobacterial blooms die or are ingested. These can kill livestock and may pose a serious health hazard to humans.

Contribution of Nonpoint Pollution

Nonpoint sources are now the dominant inputs of P and N to most U.S. surface waters. Nonpoint inputs of P cause eutrophication across a large area of lakes and reservoirs in the U.S. Nonpoint sources are also the dominant contributors of P and N to most rivers in the U.S., although point sources still generate more than half of the P and N flowing into rivers from urbanized areas. In one study of 86 rivers, nonpoint N sources were responsible for more than 90% of N inputs to more than half these rivers. Nonpoint P sources contributed over 90% of the P in a third of these rivers.

For many estuaries and coastal seas, nonpoint sources are the dominant N inputs. Along the entire coastline of the North Atlantic Ocean, for instance, nonpoint sources of N are some 9-fold greater than inputs from wastewater treatment plants. In some coastal areas, however, wastewater treatment plants remain the primary source of N inputs. And although nonpoint inputs of P are often significant, point sources supply the highest inputs of P in many marine environments.

Remediation

Reversal of eutrophication requires the reduction of P and N inputs, but recovery can sometimes be accelerated by combining input controls with other management methods. In fact, active human intervention may be necessary in some cases because the eutrophic state is relatively stable in lakes. Some internal mechanisms that may hamper recovery from this degraded state include continuing release of P from accumulations in lake-bottom sediments, loss of submerged plants whose roots served to stabilize sediments, and complex changes in the food web such as decreases in grazing fish or zooplankton that helped to control growth of nuisance algae. Less is known about the stability of eutrophication in estuaries and coastal oceans, but the eutrophic state may be more easily disrupted and remedied there because in open, well-mixed coastal oceans nutrients may be diluted and flushed away rapidly. However, in relatively confined, shallow marine waters such as the Baltic Sea, nutrients may be trapped and eutrophication may be as persistent as it is in lakes.

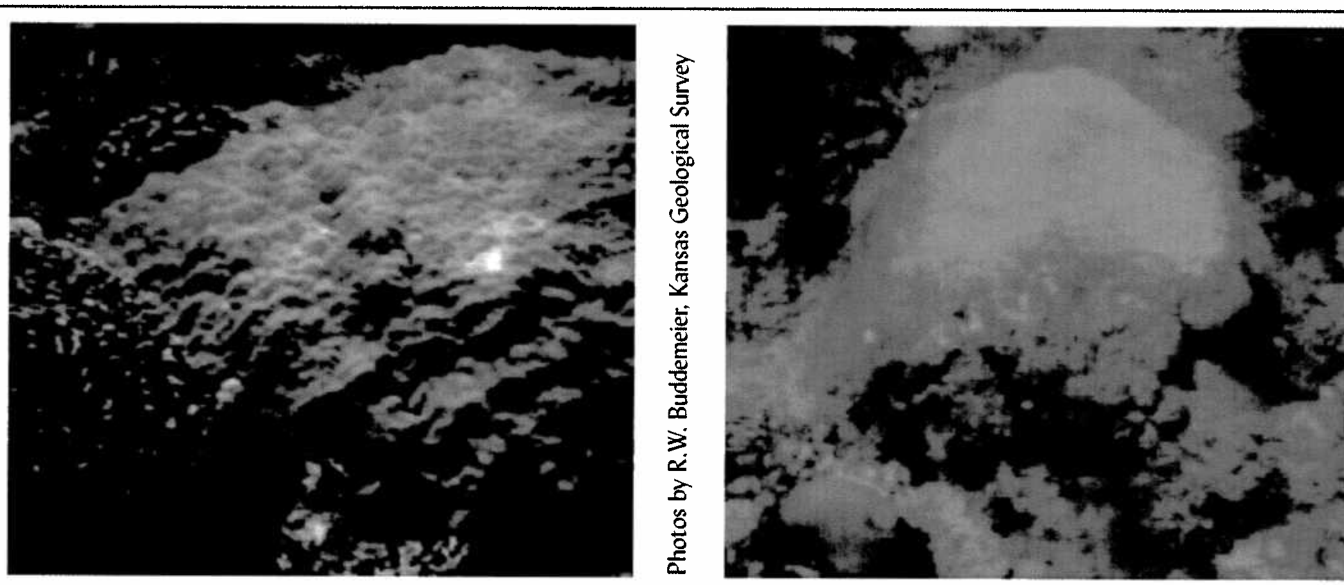
Direct Health Effects

Phosphorus in water is not considered directly toxic to humans and animals, and because of this, no

Figure 5 - Nitrogen and phosphorus pollution causes increased incidents of fish kills. Fish die because of toxic algal blooms or the removal of oxygen from the water as algal blooms decay.

drinking water standards have been established for P. Any toxicity caused by P pollution in fresh waters is indirect, through stimulation of toxic algal blooms or resulting oxygen depletion.

In contrast, nitrate pollution poses a direct health threat to humans and other mammals. Nitrate in water is toxic at high concentrations and has been linked to toxic effects on livestock and also to "blue baby disease" (methemoglobinemia) in infants. The Environmental Protection Agency has established a Maximum Contaminant Level for nitrate-N in drinking water of 10 milligrams per liter to protect babies under 3 to 6 months of age. This age group is most sensitive because bacteria that live in an infant's digestive tract can reduce nitrate to nitrite, which oxidizes hemoglobin and interferes with the oxygen-carrying ability of blood. In cattle, nitrate reduced to nitrite can also be toxic and causes a similar type of anemia as well as abortions. Levels of 40-100 milligrams of nitrate-N per liter in livestock drinking water are considered risky unless the animals' feed is low in nitrates and fortified with vitamin A.



Figures 6 and 7 - Eutrophication can lead to the loss of habitats such as coral reefs, therefore contributing to the loss of aquatic biodiversity. Note the healthy growth and coverage of hard corals in the figure on the left, versus the less diverse soft corals resulting from human disturbance, including increased turbidity, in the area of the reef shown on the right.

WHAT ARE THE SOURCES OF NONPOINT POLLUTION?

Nonpoint P and N pollution is caused primarily by agricultural and urban activities. In the U.S., agriculture is the predominant source of nonpoint pollution. Wind or rain-borne deposits from a variety of sources, including agriculture and fossil fuel burning, can add significant amounts of N to surface waters.

Agriculture

On the world's croplands, human additions and removals of nutrients have overwhelmed natural nutrient cycles. Globally, more nutrients are added as fertilizers than are removed as produce. Fertilizers are moved from areas of manufacture to areas of crop production. The nutrients in the fertilizer are only partly incorporated into crops, which are then harvested and transported to other areas for consumption by people or livestock. Thus on balance, there is a net transport of P and N from sites of fertilizer manufacture to sites of fertilizer deposition and manure production. This flux creates a nutrient surplus on croplands, and this surplus is the underlying cause of nonpoint pollution from agriculture.

Photo by Stephen R. Carpenter

Figure 8 - Intensive animal production, where large numbers of animals are concentrated in small feedlots, creates enormous amounts of waste, causing excess nutrients to build up in the soil, run off, or infiltrate water supplies.

Fertilizer

Phosphorus is accumulating in the world's agricultural soils. Between 1950 and 1995, about 600 million metric tons of fertilizer P were applied to Earth's surface, primarily on croplands. During the same time period, roughly 250 million metric tons of P were removed from croplands in the form of harvested crops. Some of this produce was fed to livestock and a portion of the manure from these animals was reapplied to croplands, returning some of the harvested P (about 50 million metric tons) to the soil. Thus the net addition of P to cropland soils over this period was about 400 million metric tons. This excess P may either remain in soils or be exported to surface waters by erosion or leaching. The majority of applied P remains on croplands, with only 3 to 20% leaving by export to surface waters. It is likely, therefore, that about 350 million metric tons of P has accumulated in the world's croplands. The standing stock of P in the upper 10 centimeters of soil in the world's croplands is roughly 1,300 million metric tons. That means that a net addition of 350 million metric tons between 1950 and 1995 would have increased the P content of agricultural soils by about 25%. In the U.S. and Europe, only about 30% of the P input in fertilizers ends up being incorporated into crop plants, resulting in an average accumulation rate of 22 kilograms of surplus P per hectare each year. Across whole watersheds, the amount of P applied to agricultural soils in excess of what plants can use is closely linked to eutrophication of surface waters.

Global industrial production of N fertilizers has increased steeply from nearly zero in the 1940s to roughly 80 million metric tons per year. In the U.S. and Europe, only 18% of the N input in fertilizer leaves farms in produce, meaning that on average, 174 kilograms per hectare of surplus N is left behind on croplands each year. This surplus may accumulate in soils, erode or leach to surface and ground waters, or enter the atmosphere. N is added to the atmosphere through volatilization of ammonia and microbial generation of nitrous oxide gas from soils. Nitrous oxide contributes to global warming and can also catalyze the destruction of stratospheric ozone. Much of the N volatilized to the atmosphere in these forms is rained out or redeposited in dry forms on land or water and eventually enters rivers, lakes, and other aquatic ecosystems.

Manure

Intensive animal production generally involves feeding large numbers of animals in small areas. For example, 4% of the cattle feedlots in the U. S. produce 84% of the cattle. Such large concentrations of animals

Figure 9 - Runoff from urban activities, such as lawn fertilizers and pet wastes, is a significant source of nonpoint pollution that we can all help to control.

Photo by S.C. Delaney/EPA

create enormous amounts of waste. The disposal problems are comparable to those for raw human sewage, and yet the regulatory standards for disposing of animal wastes are generally far less stringent than the standards cities and towns must meet for treating human sewage.

Nutrients in manure can be recycled by applying the manure to cropland. However, the amount of manure generated by concentrated livestock operations often far exceeds the capacity of nearby croplands to use and retain the nutrients. At typical stocking rates for feedlots, for instance, an area of cropland roughly 1,000 times greater than the feedlot area itself is required to distribute manure nutrients at levels equal to what the crops on that land can use. This much accessible cropland may not be available, so excess quantities of manure are applied to smaller land areas. The excess nutrients then build up in soil, run off, or infiltrate to water supplies. Or, in the case of N, they may enter the atmosphere.

Transport to Aquatic Ecosystems

Increased fluxes of P and N to surface waters have been measured after application of fertilizer or manure to farm land. Fertilizer P and N losses in runoff are generally less than 5% of the amount applied. Losses from manure can be slightly higher (up to 20% if rain falls immediately after application). However, these percentages underestimate total N flux to aquatic ecosystems because they do not include infiltration and leaching which ultimately carry N to ground and surface waters. N export from agricultural ecosystems to water, as a percentage of fertilizer inputs, ranges from 10% to 40% for loam and clay soils to 25% to 80% for sandy soils. In general, the rates of nutrient loss to water from fertilizer and manure are influenced by the rate, season, chemical form, and method of nutrient application; amount and timing of rainfall after application; and the plant cover. The greater proportional losses of P and N from manure than from industrially produced fertilizers may result from higher P and N concentrations in manure and less flexibility in the timing of applications, since manure must be worked into soils before or after the growing season rather than at the time growing crops require P and N.

The amount of P lost to surface waters increases with the P content of the soil. The loss can come in the form of dissolved P, but even more P is transported as particles. In the long term, this particulate P can be converted to phosphate and made available to aquatic organisms.

N transport to the oceans has increased in recent decades and the increase can be correlated to a number of human activities that increase N inputs into watersheds. Similarly, the amount of P carried in rivers to the oceans is positively correlated with human population density in watersheds. Globally, the movement of P to coastal oceans has increased from an estimated pristine flux rate of 8 million metric tons per year to the current rate of 22 million metric tons per year. About 30% of this increase is attributed to P enrichment of agricultural soils, and the remainder to increasing rates of erosion.

Urban Runoff

A significant amount of P and N enters lakes, rivers, and coastal waters from urban nonpoint sources such as construction sites, runoff of lawn fertilizers and pet wastes, septic systems and developed areas that lack sewers. Urban runoff is the third most important cause of lake deterioration in the U. S., affecting about 28% of the lake area that does not meet water quality standards.

Urban point sources of water pollution, such as sewage and industrial discharges, are also significant, but unlike nonpoint sources, they are often managed intensively.

Construction sites are a critical concern as sources of nonpoint pollution. Although construction sites may occupy a relatively small percentage of the land area, their erosion rates can be extremely high and the total nonpoint pollution yield quite large. Erosion rates from watersheds under development approach 50,000 metric tons per square kilometer a year, compared to 1,000 to 4,000 metric tons per square kilometer for agricultural lands and less than 100 metric tons for lands with undisturbed plant cover. Eroded material from construction sites contributes to siltation of water bodies as well as eutrophication.

Atmospheric Deposition of N

N deposited to surface waters from the atmosphere arises from several sources, including trace gases released from farm soils and the burning of fossil fuels. Combustion of fuels such as coal and oil releases significant quantities of nitrogen-based trace gases into the atmosphere, both by oxidizing organic N stored in the fuels themselves and by directly "fixing" molecular N from the air during high temperature, high pressure combustion. (Fixing N involves pulling it from the air and bonding it to hydrogen or oxygen to form compounds that plants and other organisms can use.) Currently, some 20 million metric tons of fixed N per year are released globally from fossil fuel combustion by automobiles, factories, and power plants. However, this represents only one-fourth of the amount of N used in inorganic N fertilizer and perhaps one-seventh of the total amount of N fixed globally through human activity, including the manufacture of inorganic fertilizers and the planting of N-fixing crops such as soybeans and other legumes. Nonetheless, N from fossil fuel combustion may contribute substantially to the nonpoint-source pollution of surface waters.

A comparative study of N fluxes from 33 rivers in the northeastern U.S. found that the amounts of both nitrate and total N in the rivers were correlated with the atmospheric deposition of oxidized N — which comes largely from fossil fuel combustion — onto the watersheds of these rivers. For a small subset of these rivers, historical data showed an increase in nitrate concentrations from the early 1900's to the present. The increase in nitrate concentrations correlates with estimates for increased fossil fuel emissions of N during the same period.

We still have much to learn about the transport of atmospherically-derived N from land to water. Clearly the atmosphere can be a significant source of N to lakes and rivers and make potentially large contributions to coastal eutrophication. And we know that volatilization of nitrogen-based gases from agricultural land supplies a significant fraction of this N.

WHAT CAN BE DONE ABOUT IT?

Unless current practices are changed, nonpoint pollution of surface waters will increase in the future. Some factors that drive this expectation are the substantial and growing buildup of P and N in agricultural soils; an increasing human population; people's preference for meat-rich diets, which mandates increasing livestock production; growth of urban areas with associated development and erosion; and increased fixation of N by human activities such as fertilizer production and fossil fuel burn-

Photo by S.C. Delaney/EPA

Figure 10 - The high erosion rate of construction sites is a major source of runoff from developing areas. Eroded materials contribute to siltation and eutrophication of lakes, rivers, and coastal oceans.

ing. (Ironically, the increasing use of more efficient engines and turbines for burning fossil fuels has had the inadvertent effect of increasing the fixation of N.)

However, this pessimistic forecast could prove to be incorrect, because there are a number of ways that nonpoint pollution can be reduced. Here we offer a brief catalog.

Landscape Management

Forests and other vegetation along riverbanks and shorelines can significantly reduce the flow of nonpoint nutrients into surface waters. This vegetation also makes important contributions to fish and wildlife habitat and regional biodiversity. Interest in the use of riparian vegetation for controlling nonpoint pollution has grown rapidly in recent years, and the number of scientific studies and articles on the subject has burgeoned.

Wetlands, lakes, and rivers are sites of denitrification — a bacterial process that breaks down organic N and releases it to the atmosphere, decreasing the flow of N to downstream ecosystems. Restoration of wetlands and floodplains is likely to increase denitrification at a landscape scale and to some extent reduce N pollution of lakes and rivers. Thus, wetland restoration may be the most cost-effective method of decreasing nonpoint N pollution.

Figure 11 - There are a number of ways that nonpoint source pollution can be reduced. For example, restoration of wetlands and increasing riparian vegetation intercepts nonpoint pollution and also provides wildlife habitat.

Agricultural P and N Management

The ultimate causes of nonpoint pollution from agricultural lands are excessive fertilizer use and development of high-density livestock operations. There are direct solutions. Fertilizer applications can be reduced to match crop needs. Wastes from high-density livestock operations can be managed as a point source of pollution just like human wastes. Nutrients in manure can be used as fertilizer, or nutrients can be removed (as in human sewage treatment) before wastes are discharged to surface waters. Work to implement these solutions now focuses on establishing the threshold levels at which soil nutrients threaten water quality, identifying intensive sources of pollutants, and developing mechanisms for controlling both nutrient sources and transport.

Thresholds

Threshold levels of soil nutrients that create unacceptable threats to water quality must be established in order to provide a firm basis for regulations that protect aquatic resources. Defining thresholds has been controversial, in part because data are insufficient. Unfortunately, the data base relating soil nutrient concentrations to runoff is limited to a few types of soils and crops, making it difficult to extrapolate these data to all regions. Because costs of nutrient management are significant, the agricultural industries most likely to be affected by thresholds have vigorously challenged their scientific basis. A stronger scientific foundation can and should be developed for soil nutrient thresholds so that scientifically based standards can be promulgated and defended.

Source Area Delineation

Typically, more than 90% of the P export from watersheds originates from less than 10% of the land area during a few large storms. Thus, remedial measures will be most effective if they are targeted to source areas of P export. These are lands that combine high soil P concentrations with characteristics that enhance erosion and surface runoff.

Source Management

N and P runoff can be greatly reduced if fertilizers are applied at rates that match the N and P uptake by crops, and if fertilizers are applied when crops are growing rapidly. Also, dietary P inputs to livestock can be matched to the animals' requirements, which would decrease the amounts of P excreted in manure. Source management can significantly reduce concentrations of P in runoff entering streams and lakes. For example, aggressive treatment of dairy wastes in Florida reduced total P concentrations in surface water by 62% to 87%.

Transport Management

Transport of P and N from croplands to surface waters by erosion and runoff may be reduced by maintaining vegetated riparian zones or buffer strips, creating retention ponds, or adopting farming practices such as conservation tillage, terracing, contour tillage, and cover crops. Vegetated buffer strips in riparian zones, for example, reduce P transport to streams by 50% to 85%. However, such solutions must be combined with reductions in nutrient sources to soils or soil nutrients will continue to accumulate.

Control of Urban Runoff

Control of urban nonpoint pollution is a well-developed branch of civil engineering with an extensive and sophisticated literature. One key goal is optimization of sewer systems. Other approaches include creation of retention ponds, wetlands, and greenways as integrated components in stormwater management systems; litter control and street sweeping; reduction of impervious areas such as concrete and asphalt pavement that enhance runoff; and reduction of erosion, especially from construction sites.

Atmospheric Deposition

Atmospheric deposition of N can be reduced by more efficient use of fertilizers and improved handling of animal wastes. Thus, steps needed to reduce surface movement of agricultural N will also reduce atmospheric transport. Reductions in fossil fuel combustion, and improved interception of nitrogen trace gases generated during fossil fuel combustion, will also reduce airborne N deposition.

CONCLUSIONS

We already have a sound fundamental understanding of the processes that cause nonpoint pollution and eutrophication. The causes and consequences are clear at both regional and global scales. Our capacity for site-specific analyses of nonpoint sources and their impacts is well-developed and improving. While science alone cannot solve the problem, the panel believes the necessary science is available and could be readily mobilized in the search for solutions. The most critical need now is for the development of creative policy and regulatory mechanisms that mesh the science with social realities and chart a course for reducing nonpoint pollution and mitigating eutrophication of our waterways.

FOR FURTHER INFORMATION

This report summarizes the findings of our panel. Our full report, which is being published in the journal *Ecological Applications* (Volume 8, Number 3, August 1998) discusses and cites more than 70 references to the primary scientific literature on this subject. From that list we have chosen those below as illustrative of the scientific publications and summaries upon which our report is based.

Naiman, R. J., J. J. Magnuson, D. M. McKnight, and J. A. Stanford. 1995. The Freshwater Imperative. Island Press, Washington D. C.

National Research Council. 1992. Restoration of Aquatic Ecosystems: Science, Technology and Public Policy. National Academy Press, Washington D.C.

Novotny, V. and H. Olem. 1994. Water Quality: Prevention, Identification and Management of Diffuse Pollution. Van Nostrand Reinhold, NY.

Postel, S.L. and S.R. Carpenter. 1997. Freshwater ecosystem services. Pages 195-214 in G.C. Daily, editor, Nature's Services. Island Press, Washington D.C.

Vitousek, P. M., J. Aber, R. W. Howarth, G. E. Likens, P. A. Matson, D. W. Schindler, W. H. Schlesinger, and G. D. Tilman. 1997. Human alteration of the global nitrogen cycle: Causes and consequences. Ecological Applications 7: 737-750.

About the Panel of Scientists

This report presents a consensus reached by a panel of six scientists chosen to include a broad array of expertise in this area. This report underwent peer review and was approved by the Board of Editors of *Issues in Ecology*. The affiliations of the members of the panel of scientists are:

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U.S. ENVIRONMENTAL PROTECTION AGENCY

Safe Drinking Water Act (SDWA)

Basic Information

The Safe Drinking Water Act (SDWA) was originally passed by Congress in 1974 to protect public health by regulating the nation's public drinking water supply. The law was amended in 1986 and 1996 and requires many actions to protect drinking water and its sources: rivers, lakes, reservoirs, springs, and ground water wells. (SDWA does not regulate private wells which serve fewer than 25 individuals.) For more information see:

- Laws and Statutes
- 30th Anniversary Celebration

SDWA authorizes the United States Environmental Protection Agency (US EPA) to set national health-based standards for drinking water to protect against both naturally-occurring and man-made contaminants that may be found in drinking water. US EPA, states, and water systems then work together to make sure that these standards are met.

- Find out more about how EPA sets national health-based standards for drinking water.

Millions of Americans receive high quality drinking water every day from their public water systems, (which may be publicly or privately owned). Nonetheless, drinking water safety cannot be taken for granted. There are a number of threats to drinking water: improperly disposed of chemicals; animal wastes; pesticides; human wastes; wastes injected deep underground; and naturally-occurring substances can all contaminate drinking water. Likewise, drinking water that is not properly treated or disinfected, or which travels through an improperly maintained distribution system, may also pose a health risk.

Originally, SDWA focused primarily on treatment as the means of providing safe drinking water at the tap. The 1996 amendments greatly enhanced the existing law by recognizing source water protection, operator training, funding for water system improvements, and public information as important components of safe drinking water. This approach ensures the quality of drinking water by protecting it from source to tap.

- Find out more about the 1996 amendments

SDWA applies to every public water system in the United States. There are currently more than 160,000 public water systems providing water to almost all Americans at some time in their lives.

For a better understanding of the basics of the Safe Drinking Water Act read the factsheet: Understanding the Safe Drinking Water Act

History of the Clean Water Act

The Federal Water Pollution Control Act of 1948 was the first major U.S. law to address water pollution. Growing public awareness and concern for controlling water pollution led to sweeping amendments in 1972. As amended in 1977, the law became commonly known as the Clean Water Act (CWA).

The 1977 amendments:

- Established the basic structure for regulating pollutants discharges into the waters of the United States.
- Gave EPA the authority to implement pollution control programs such as setting wastewater standards for industry.
- Maintained existing requirements to set water quality standards for all contaminants in surface waters.
- Made it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions.
- Funded the construction of sewage treatment plants under the construction grants program.
- Recognized the need for planning to address the critical problems posed by nonpoint source pollution.

Subsequent amendments modified some of the earlier CWA provisions. Revisions in 1981 streamlined the municipal construction grants process, improving the capabilities of treatment plants built under the program. Changes in 1987 phased out the construction grants program, replacing it with the State Water Pollution Control Revolving Fund, more commonly known as the Clean Water State Revolving Fund. This new funding strategy addressed water quality needs by building on EPA-state partnerships.

Over the years, many other laws have changed parts of the Clean Water Act. Title I of the Great Lakes Critical Programs Act of 1990, for example, put into place parts of the Great Lakes Water Quality Agreement of 1978, signed by the U.S. and Canada, where the two nations agreed to reduce certain toxic pollutants in the Great Lakes. That law required EPA to establish water quality criteria for the Great Lakes addressing 29 toxic pollutants with maximum levels that are safe for humans, wildlife, and aquatic life. It also required EPA to help the States implement the criteria on a specific schedule.

For a thorough understanding of the Clean Water Act students should go on-line and review this training module: http://www.epa.gov/watertrain/cwa/

Reading should concentrate on the answers to the attached test. Test answers are on Page 70.

Self Test for Clean Water Act Module

After you've completed the quiz, check your answers with the ones provided on page 63 of this document. A passing grade is 14 of 20 correct, or 70%.

1. The objectives of the Clean Water Act are to:

☐ A. Restore and maintain the integrity of the nation's waters
☐ B. Finance wastewater treatment plans and facilities
☐ C. Address polluted runoff
☐ D. Support research and demonstration projects
☐ E. All of the above

2. Currently, EPA, states, and tribes are focused solely on the portions of the Clean Water Act, dealing with discharge of pollutants from industrial sources.

☐ A. True
☐ B. False

3. Water Quality Standards are parameter-specific based on which of these factors?

☐ A. Recurrence interval/ frequency
☐ B. Duration
☐ C. Level/concentration/magnitude
☐ D. All of the above

4. A key element of the Water Quality-based approach under the CWA is the development of a Total Maximum Daily Load (TMDL).

☐ A. True
☐ B. False

5. TMDLs determine what level of ____________ would be consistent with meeting Water Quality Standards.

☐ A. stream flows
☐ B. pollutant load
☐ C. best management practice
☐ D. treatment
☐ E. None of the above

6. The CWA requires states to establish Water Quality Standards only for surface waters.

☐ A. True

☐ B. False

7. Key Clean Water Act Tools include:

☐ A. National Pollutant Discharge Elimination System (NPDES)

☐ B. Section 401 Water Quality Certification

☐ C. Section 319 Nonpoint Source Programs

☐ D. Clean Water State Revolving Fund

☐ E. Section 404 Regulation of discharge of dredged and fill materials

☐ F. All of the above

8. The three major components of the Water Quality Standards Program are:

☐ A. Designated use, existing use, and TMDLs

☐ B. Water quality criteria, antidegradation, and existing uses

☐ C. Antidegradation, designated use, and water quality criteria

☐ D. TMDLs, water quality criteria, and designated use

9. "Existing use" refers to any use to which the waterbody has been put since this date:

☐ A. January 10, 1978

☐ B. November 28, 1975

☐ C. October 15, 1976

☐ D. July 31, 1977

☐ E. None of the above

10. If a waterbody is no longer able to support a documented existing use, that use is no longer listed as one of the designated uses.

☐ A. True

☐ B. False

11. When a waterbody needs cleaner water to support a particular use, that use is a _________ use, and the opposite is a ___________ use.

☐ A. Lower, higher

☐ B. Higher, lower

12. _________ use is a term that answers the public's question, "To what uses do we want to be able to put this waterbody?"

☐ A. Preferred

☐ B. Wishful

☐ C. Designated

☐ D. Priority

13. Water quality criteria specify the conditions that a waterbody needs to meet a particular designated use.

☐ A. True

☐ B. False

14. ___________ criteria, like human health/fish consumption criteria, deal with the effects of pollutants with high bioaccumulation factors.

☐ A. Technical

☐ B. Wildlife

☐ C Zoological

☐ D. Human health

15. Generally, EPA scientists have indicated that most kinds of aquatic ecosystems can endure being significantly impacted once every 3 years and still remain healthy overall.

☐ A. True

☐ B. False

16. States, tribes, and territories are required to adopt in their WQS the exact numbers that EPA has published as water quality criteria.

☐ A. True

☐ B. False

17. Water quality criteria aimed at providing protection from short term exposure to __________ levels of pollutants are called __________ criteria, whereas WQC addressing long-term exposure to __________ concentrations are called __________ criteria.

☐ A. low, acute, higher, chronic

☐ B. high, acute, lower, chronic

☐ C. steady, acute, intermittent, chronic

18. A waterbody shows symptoms of impairment when it has:

☐ A. A higher percentage of tolerant species

☐ B. A lower proportion of predators

☐ C. A higher number of generalists

☐ D. A greater proportion of exotics

☐ E. More disease, malformations, and lesions

☐ F. All of the above

☐ G. None of the above

19. A _____ allows certain portions of a waterbody below a point source discharge to not meet applicable designated uses and water quality criteria.

☐ A. Designated use

☐ B. Low flow exemption

☐ C. Mixing zone

☐ D. None of the above

20. If a waterbody is attaining water quality standards, __________ policies apply.

☐ A. Antidegradation

☐ B. Designated use

☐ C. TMDL

☐ D. Degradation

☐ E. None of the above

21. The three tiers for antidegradation include:

☐ A. Preventing degradation that would result in loss of an existing/ attained use.

☐ B. Virtually no lowering of water quality, on specially designated waters

☐ C. Preventing "freefall" from considerably better than WQS down to just barely meeting them

☐ D. Bringing a waterbody to a zero level of pollution.

☐ E. A, B, C

☐ F. A, C, D

22. EPA must approve Water Quality Standards adopted by states, authorized tribes, and territories.

☐ A. True

☐ B. False

23. The CWA sets specific requirements on the amount (location, frequency) and type of ambient monitoring to be done by states.

☐ A. True

☐ B. False

24. The two biennial reports that states, tribes, and territories are required to submit providing the results of their monitoring efforts are:

☐ A. Section 319(a) and 301(c) reports

☐ B. Section 303(b) and 303(d) reports

☐ C. Section 401(d) and 305 Reports

☐ D. None of the above

25. The biennial report that includes all information that the state, tribe, or territory knows about its waters (healthy, threatened, and impaired) is the___________ Report.

☐ A. 319 (a)

☐ B. 303 (d)

☐ C. 303 (b)

☐ D. 305 (b)

26. The biennial report that should include only a list of waters that are threatened or impaired is the __________ List.

- ☐ A. 319(a)
- ☐ B. 303(d)
- ☐ C. 303(b)
- ☐ D. 305

27. If monitoring and assessment indicate that a waterbody is impaired by nonpoint sources, and the waterbody is put on the 303 (d) list, the state, tribe, or territory must develop a regulatory strategy leading to attainment of Water Quality Standards.

- ☐ A. True
- ☐ B. False

28. TMDL strategies are required only for pollutants, not for all forms of pollution.

- ☐ A. True
- ☐ B. False

29. EPA regulations require that WQS be met within ________ years after a TMDL is approved for a waterbody.

- ☐ A. 5
- ☐ B. 10
- ☐ C. 15
- ☐ D. None of the above – there is no time limit

30. TMDLs must be reviewed and approved by EPA.

- ☐ A. True
- ☐ B. False

31. A TMDL includes an overall "budget" for a particular pollutant in a particular body of water, also known as its ______________.

- ☐ A. Pollutant "cap"
- ☐ B. Margin of safety
- ☐ C. Load allocation
- ☐ D. Wasteload allocation

32. Once the pollutant budget has been met, the next step is "slicing the pie" or allocating the pollutant load among various sources of the pollutant for which the TMDL has been developed.

☐ A. True

☐ B. False

33. TMDLs may be expressed as daily, weekly, monthly, or even yearly loads.

☐ A. True

☐ B. False

34. Wasteload Allocations apply to _________ sources.

☐ A. Nonpoint

☐ B. Point

☐ C. Critical

☐ D. None of the above

35. Load Allocations apply to _______ sources.

☐ A. Nonpoint

☐ B. Point

☐ C. Critical

☐ D. None of the above

36. Generally, point sources required to have individual NPDES permits are also required to be assigned individual Wasteload Allocations.

☐ A. True

☐ B. False

37. EPA issues regulations identifying exactly how the pollutant budget in a TMDL should be allocated among sources.

☐ A. True

☐ B. False

38. In most cases, the National Pollutant Discharge Elimination System (NPDES) permitting program applies only to direct discharges to _________.

☐ A. Ground water

☐ B. Surface water

☐ C. A and B

39. Examples of sources covered by NPDES permits include _____________:

☐ A. Abandoned mines on nonfederal lands

☐ B. Industrial and municipal discharges

☐ C. Abandoned mines on federal land

☐ D. Return flows from irrigated agriculture

☐ E. A and B

☐ F. B and C

40. NPDES permits must eliminate any discharge of pollutants from the permittee's operations.

☐ A. True

☐ B. False

Answers for Clean Water Act Module Self Test

Q1: E	Q2: B	Q3: D	Q4: A	Q5: B	Q6: A	Q7: F	Q8: C
Q9: B	Q10: B	Q11: B	Q12: C	Q13: A	Q14: B	Q15: A	Q16: B
Q17: B	Q18: F	Q19: C	Q20: A	Q21: E	Q22: A	Q23: B	Q24: B
Q25: D	Q26: B	Q27: B	Q28: A	Q29: D	Q30: A	Q31: A	Q32: A
Q33: A	Q34: B	Q35: A	Q36: A	Q37: B	Q38: B	Q39: F	Q40: B

Water in a Changing World

SUMMARY

Life on land and in the lakes, rivers, and other freshwater habitats of the earth is vitally dependent on renewable fresh water, a resource that comprises only a tiny fraction of the global water pool. Humans rely on renewable fresh water for drinking, irrigation of crops, and industrial uses as well as production of fish and waterfowl, transportation, recreation, and waste disposal.

In many regions of the world, the amount and quality of water available to meet human needs are already limited. The gap between freshwater supply and demand will widen during the coming century as a result of climate change and increasing consumption of water by a growing human population. In the next 30 years, for example, accessible runoff of fresh water is unlikely to increase more than 10 percent, yet the earth's population is expected to grow by one third. Unless humans use water more efficiently, the impacts of this imbalance in supply and demand will diminish the services that freshwater ecosystems provide, increase the number of aquatic species facing extinction, and further fragment wetlands, rivers, deltas, and estuaries.

Based on the scientific evidence currently available, we conclude that:

- More than half of the world's accessible freshwater runoff is already appropriated for human use.
- More than a billion people currently lack access to clean drinking water, and almost three billion lack basic sanitation services.
- Because human population will grow faster than any increase in accessible supplies of fresh water, the amount of fresh water available per person will decrease in the coming century.
- Climate change will intensify the earth's water cycle in the next century, generally increasing rainfall, evaporation rates, and the occurrence of storms, and significantly altering the nutrient cycles in land-based ecosystems that influence water quality.
- At least 90 percent of river flows in the United States are strongly affected by dams, reservoirs, interbasin diversions, and irrigation withdrawals that fragment natural channels.
- Globally, 20 percent of freshwater fish species are threatened or extinct, and freshwater species make up 47 percent of all federally listed endangered animals in the United States.

Growing demands on freshwater resources are creating an urgent need to link research with improved water management, a need that has already resulted in a number of water-policy successes.

Better monitoring, assessment, and forecasting of water resources would help government agencies allocate water more efficiently among competing needs. Currently in the United States, at least six federal departments and twenty agencies share responsibilities for various aspects of the water cycle. We believe either creation of a single panel with members drawn from each department or else oversight by a central agency is needed in order to develop a well-coordinated national plan that acknowledges the diverse and competing pressures on freshwater systems and assures efficient use and equitable distribution of these resources.

Cover (clockwise from top): Homestead, Kalahari Desert of South Africa (R. Jackson); Coastal zone of Serra da Arrábida, Portugal (R. Jackson); "The Water Seller" (H. Bechard, Egypt ca. 1870); Monteverde Cloud Forest, Costa Rica (R. Jackson); Little Colorado River, Grand Canyon National Park, USA (R. Jackson); Elk and riparian zone, Gardner River of Yellowstone National Park, USA (R. Jackson); and the town of Flores, Guatemala (R. Jackson).