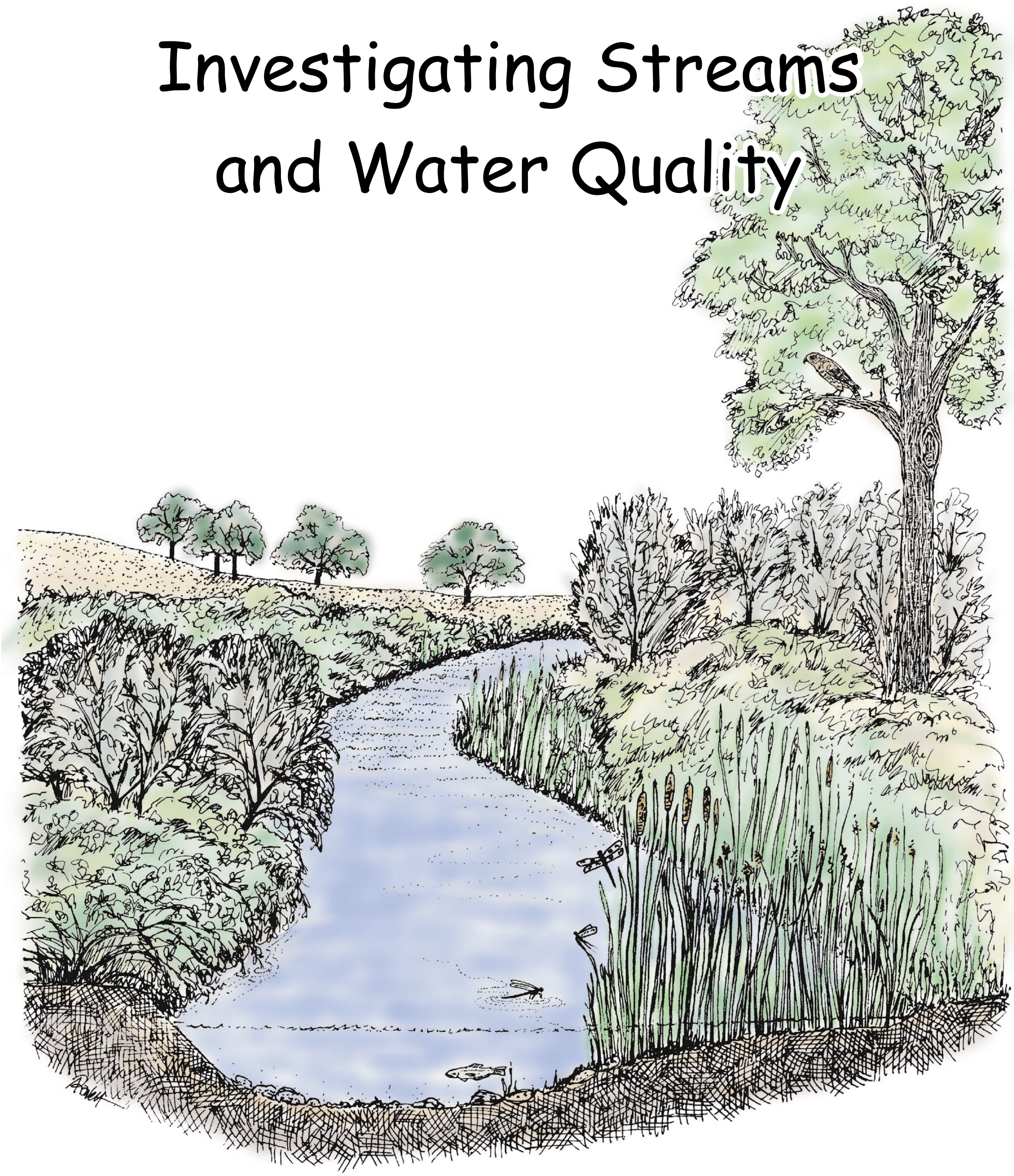
Life in Our Watershed

Investigating Streams and Water Quality



Student Handbook

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Lesson I: The Watershed

It's raining.

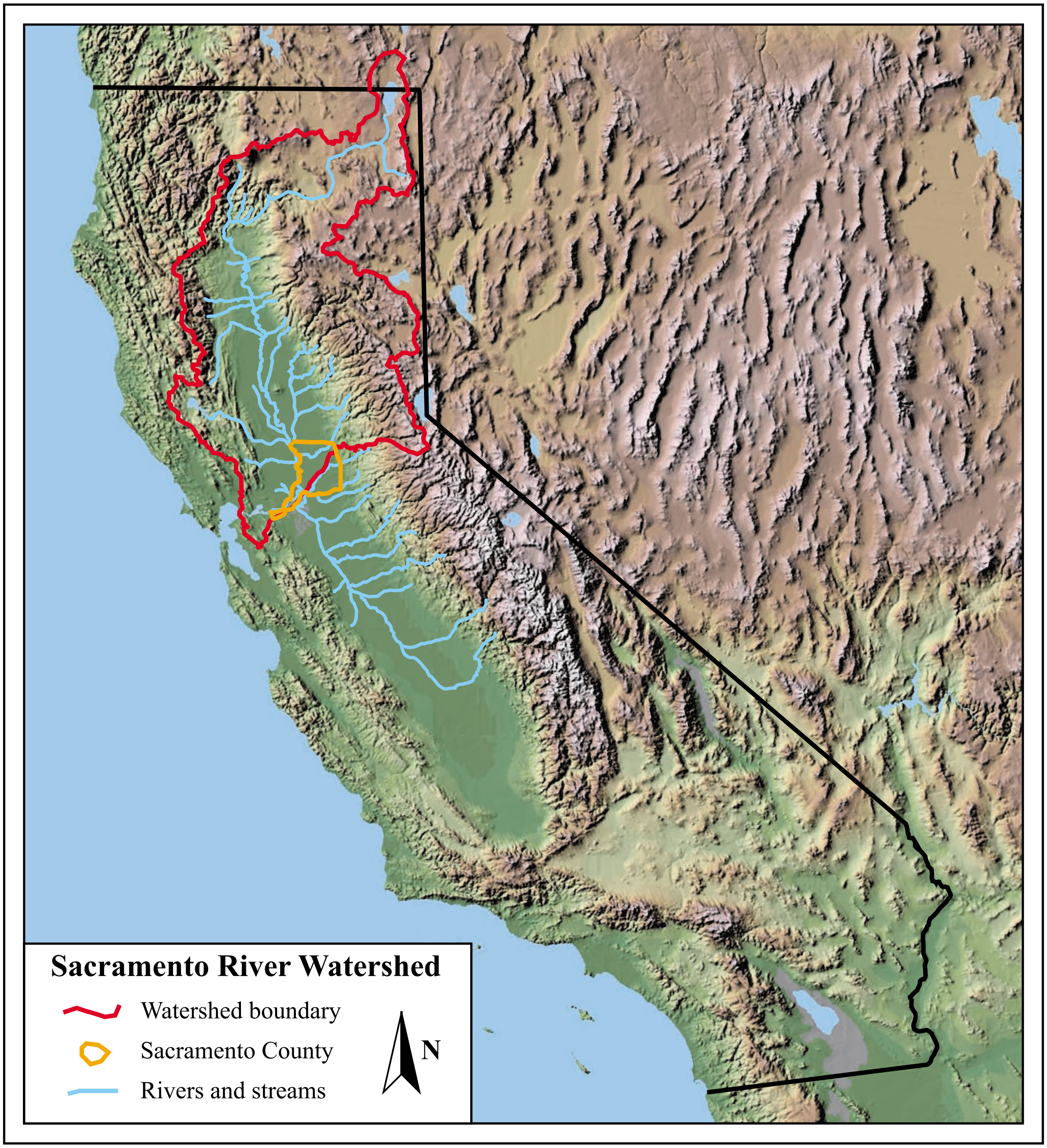
The rain soaks into the ground.

Once the ground becomes so wet that it can't hold any more water, the water runs off the land. Where does this **runoff** go?

Downhill of course…

The earth's gravity pulls runoff downhill into a branching network of streams. Streams come in all sizes, from small creeks to big rushing rivers. Each stream is a **tributary** of the bigger stream into which it flows. Each tributary moves the runoff closer to the largest stream in the **watershed**. You can think of a watershed as all the land that "sheds" water into the stream flowing through it. All the creeks in Sacramento County collect the runoff from our communities and transport it to the Sacramento River.

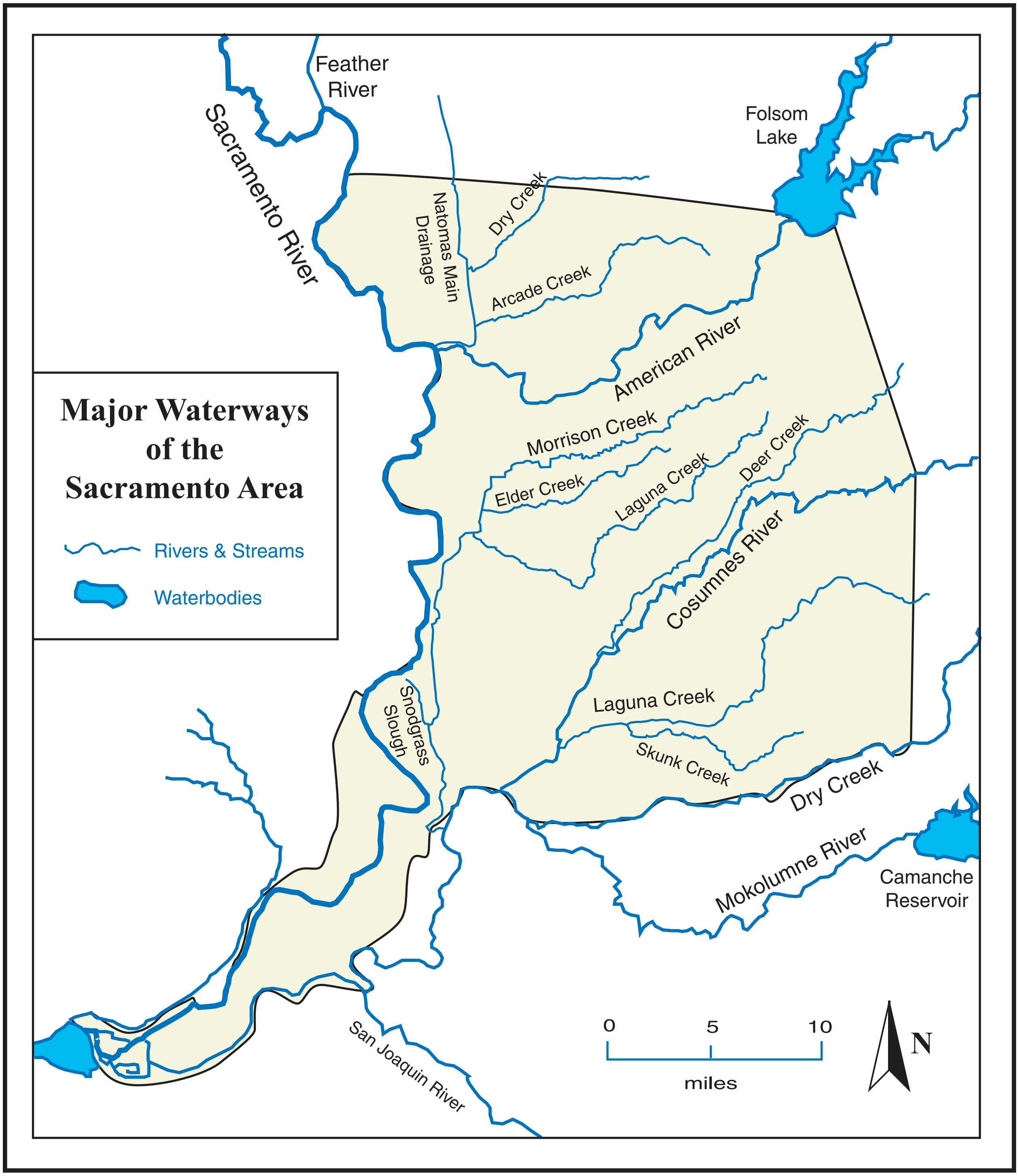
The Sacramento River Watershed



The Sacramento River is the largest stream in the Sacramento River Watershed. A total of 27,210 square miles of land contributes runoff to this river via its many tributaries, making the Sacramento River Watershed the biggest watershed in California. Sacramento is located within this watershed. The Sacramento River carries the runoff collected from all the watersheds of all of its tributaries and moves it toward the Pacific Ocean. Once it reaches sea level, its downhill run to the ocean is over.

Some of the tributaries of the Sacramento River are large rivers like the American River, which has its own big watershed. Hundreds of smaller tributaries, such as Arcade Creek, contribute water from their own watersheds to the American River Watershed. At Discovery Park in the City of Sacramento the American River finally reaches its final destination – the Sacramento River.

Look at the map and find where you live. Which tributary is nearest your home?

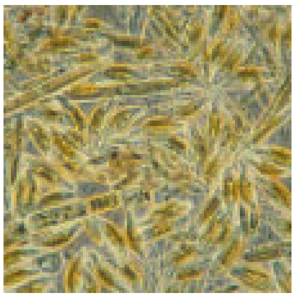


Life in the Watershed

fish

In the streams of our watershed, there is an underwater world of plants, animals, and microorganisms. How well they breathe, eat, grow, and reproduce is determined by the quality of the water and habitat in which they live. Clean water supports many species of aquatic life, the organisms that live in water. Polluted water supports far fewer species.

In this underwater community, everything is food for something else. That is how energy and materials get passed from one living thing to another. The sun provides energy for life on our planet. But how do fish eat sunlight?

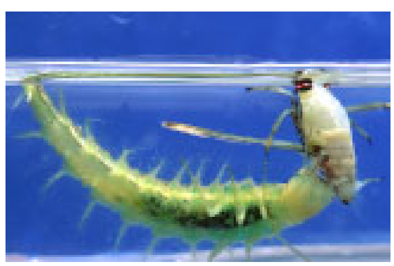


aquatic algae

They don't, at least not directly. Only plants can directly capture the energy in sunlight to make food for themselves. Plants do this through photosynthesis. By eating small organisms that eat plants, fish continue the distribution of the sun's energy throughout their underwater world. When a bird or a human eats the fish, the fish passes the sun's energy on to them. This movement of energy from one organism to another makes a **food web**.

macroinvertebrate

Many different species (kinds) of small animals live in streams. Most are called **aquatic macroinvertebrates** because they live in water (aquatic), are big enough to see without a microscope (macro), and have no backbone (invertebrate). They are the important energy link between plants and fish in an aquatic food web. Many aquatic macro-invertebrates collect, scrape, and shred plant material for their food. Some eat living plants, from microscopic algae to large, rooted macrophytes. Others prefer to eat detritus (dead or decaying plant material). Many macroinvertebrates skip the vegetables all together and simply eat other species of macroinvertebrates.



macroinvertebrates

Where in their watery world do they like to live? How do they breathe? What do they eat? Have you ever considered what it is like to live life as an aquatic macroinvertebrate? In Activity I you will look at them up close.

Lesson II: Life in Our Watershed

Land and water are connected by the circulatory system of streams that flow through our watershed. What we do on the land affects the quality of the water. Since most Californians depend on streams to bring them the clean water they need to live, the quality of water in our streams directly affects our quality of life. Water quality also affects the quality of life for the aquatic species that live in it. Simply put, the way we live in our world affects their world. Here's how.

Runoff Quality

All the land in a watershed and all the things on it get washed by rain. When rain washes human-developed environments like buildings, yards, streets, sidewalks, and parking lots, it picks up chemicals, soil, and other materials from the surfaces it touches. Irrigation water from sprinklers can also transport these contaminants.

Whether it's winter stormwater or summer irrigation, runoff from a city, town or neighborhood is called urban (city) runoff. The runoff from farms in rural (country) areas is agricultural runoff. Both urban runoff and agricultural runoff can carry toxic pollutants from the land into the water, where they can harm aquatic life.

Pollutants

A **pollutant** is any substance that contaminates soil, air, or water making it less fit to use or to live in. There are many sources and kinds of contaminants (pollutants) in the watershed. Some of the most common contaminants in urban runoff are from cars: motor oil, antifreeze, heavy metals from brake linings, and particles from auto exhaust. However, the fertilizers, pesticides and pet wastes from our yards also contaminate runoff. Agricultural runoff can contain high concentrations of nutrients and bacteria from animal manure and chemical fertilizers, as well as pesticides.

In both urban and rural areas soil erosion adds enormous volumes of soil to stream beds (bottoms) as **sediment**. The soil comes from many places, especially construction sites, farms, and roadsides. Although soil is a natural substance, too much sediment destroys the stream habitat for most aquatic macroinvertebrates and fish. It clogs their gills and fills in the spaces between rocks where macroinvertebrates live and fish lay eggs. In fact, sediment can be as deadly a pollutant as any chemical found in urban runoff.

Storm Drain Connections

Urban runoff flows into **storm drains** in city streets. Storm drains are the entrances to an underground network of pipes in urban areas called a storm drain system. The storm drain system collects urban runoff from everyone's neighborhood and carries it to our local streams. This water does not go to a treatment plant for cleaning. No treatment plant could handle the volume of runoff associated with a major rainstorm. Because contaminents are hard to remove from so much runoff, most of them end up in our streams.

This is a stormdrain. Do you know what's down there? Do you know where it goes?

The First Flush

The quality of runoff is worst during **first flush** storm events. First flush events occur each year when the first autumn rainstorms wash the accumulated pollutants off of surfaces where they have built up since the last rainfall. It all washes into our neighborhood storm drains and into the nearest stream. This is when the aquatic life in streams receives the highest concentrations of pollutants. Species of organisms that are sensitive to pollution can be killed by this high level of contamination. Their loss, in turn, can affect other species dependent on them for food. Soon the whole aquatic food web begins to crash. It can take several months for macroinvertebrate populations to recover from the contamination; just in time for another first flush event!

Nutrients, such as nitrogen and phosphorus, are elements necessary for plant growth. They are common ingredients in plant fertilizers. However, when used in excess, they wind up in the runoff from yards and gardens. When the runoff ends up in a stream, it allows algae to grow out of control causing algal blooms.

In an algal bloom, the number of algae grows rapidly. When the algae die, they are decomposed (broken down) by **bacteria**. With so much food available from masses of dead algae, the population of bacteria can increase dramatically. Bacteria need oxygen to live. Soon they use up all the oxygen that is dissolved in the water. This causes the other aquatic life, which also need oxygen, to die of suffocation.

Heavy metals, like copper, rub off of some types of automobile brake linings every time the brakes are applied. Particles from rubber tires and engine exhaust are also deposited on streets. All of these substances accumulate over the dry season and are washed into storm drains when it rains. Some of these chemicals can build up in the bodies of aquatic macroinvertebrates and fish (**bioaccumulate**), making them toxic to the organisms that eat them, including people.

Cleaning up urban and agricultural runoff is the latest in a long series of challenges to improving water quality. Over the second half of the last century, many major sources of water pollution have actually been eliminated. In fact, many streams are much cleaner now than they were 100 years ago. Most of this improvement has resulted from the elimination of **point sources** of pollution through treatment of the end-of-pipe discharges of sewage and industrial wastewater from factories such as paper mills. Overall, the history of wastewater treatment is a success story.

Wastewater Connections

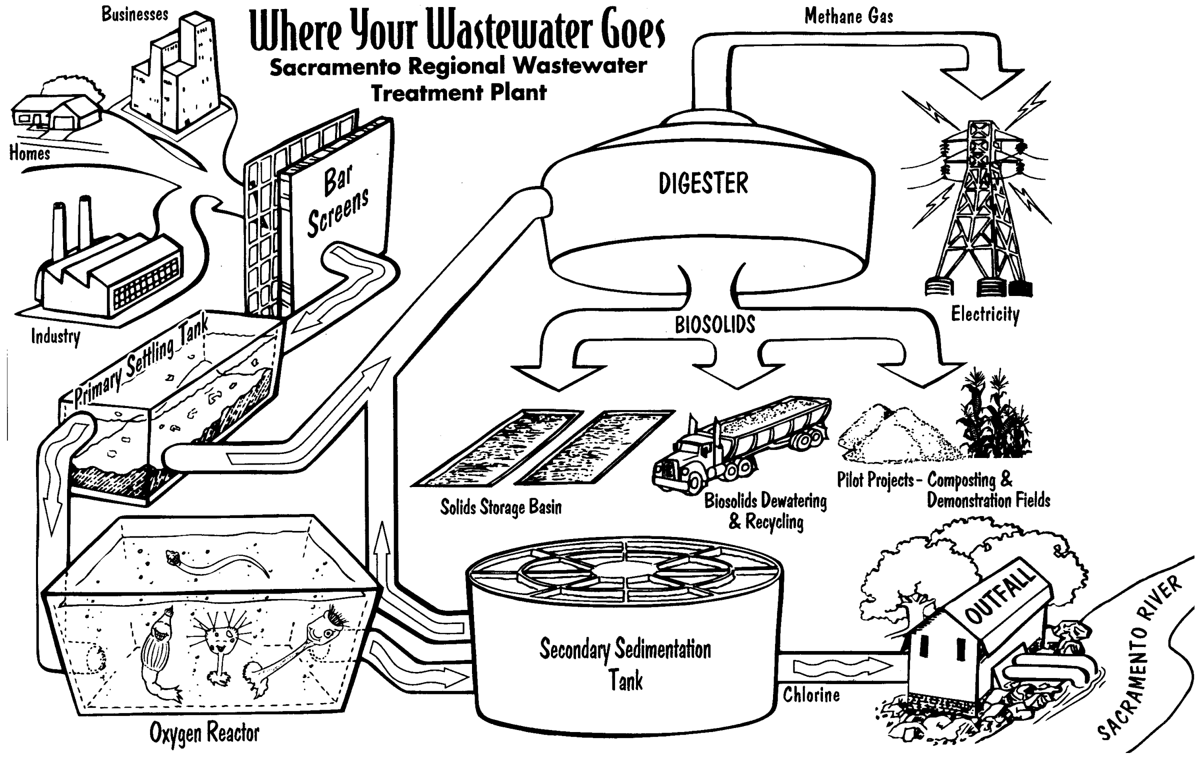
Wastewater, or **sewage**, is the water and wastes collected from inside our homes and businesses. Our used water drains down pipes from toilets, sinks, garbage disposals, bathtubs, showers, and washing machines into an underground network of larger pipes. Once it enters the **sanitary sewer** system, it officially becomes wastewater. Most of the wastewater from Sacramento County is transported through sewer pipes to the Sacramento Regional Wastewater Treatment Plant in Elk Grove. By the time they reach the plant, the pipes are 10 feet in diameter, big enough to drive through in a Volkswagen Bug! They have to be big considering that each of us sends an average of 130 gallons of wastewater to the plant every day!

Wastewater Treatment

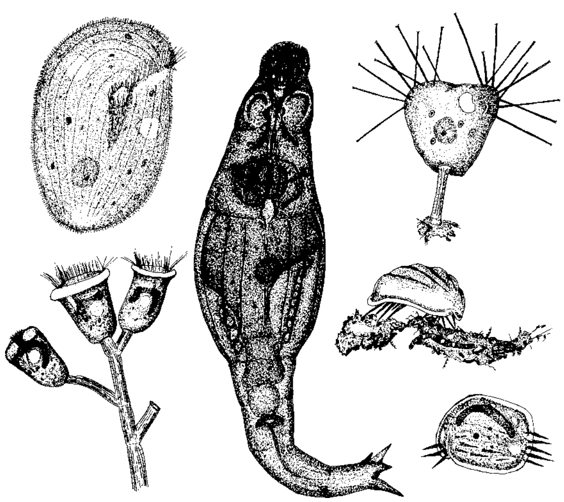
The **wastewater treatment plant** removes the wastes during two stages of treatment: primary treatment and secondary treatment. Lastly, disinfection kills any possible pathogens (disease organisms), so that the water can safely be discharged (released) into the Sacramento River and reused by people downstream of us. Everyone is someone's downstream neighbor, so we all have an interest in making sure the water is clean.

The Sacramento Regional Wastewater Treatment Plant.
Sewer pipes take wastewater to the wastewater treatment facility.

Prior to primary treatment, the water runs through huge screens that catch trash such as plastic, paper, and come uncommon items such as wedding rings, and even false teeth! This trash is collected and taken to a **landfill**. Primary treatment begins when this water is sent to large primary settling tanks where the solid matter is removed and sent to **digesters**. Inside the digesters, **anaerobic bacteria** break down the solids in an environment that lacks oxygen. The products of this anaerobic digestion are **biosolids** and methane gas.



At the treatment plant, wastewater is cleaned in two steps: primary treatment and secondary treatment.



Some helpful organisms used to digest waste.

Secondary treatment begins in an **oxygen reactor** that bubbles large amounts of oxygen into the wastewater. This oxygen speeds the growth of helpful bacteria that break down and consume organic matter in the wastewater. **Protozoa** then eat the massive number of bacteria. The treatment plant operators monitor the number and types of organisms eating the waste, changing conditions to maintain the optimal mix. Next, the wastewater flows through secondary sedimentation tanks where most of the organisms settle out. The disinfectant, chlorine, is then added to the wastewater to kill most of the disease-causing organisms before the **effluent** is discharged to the river.

A third step in the process is conducted only on a small part of the treated wastewater to make it available as "recycled water". Recycled water is treated wastewater that has undergone an additional filtration and disinfection process to make the water safe for non-drinking uses such as irrigating landscapes, parks and school sites. Benefits of recycling water are that it conserves groundwater that would otherwise be pumped for irrigation use; it provides a reliable, growing and drought-proof water supply source; and it provides an alternative to wastewater discharge into the Sacramento River.

Water Quality Monitoring

The agencies that manage our wastewater treatment plant and our storm drain system monitor (check) water quality to see if discharges to streams will harm aquatic life. They use three tests to measure water quality: chemical analysis, bioassays, and bioassessment. All help to investigate the question: Why are most species of aquatic life still absent from local streams, despite many improvements to water quality?

Chemical Analysis. The oldest tool for testing water quality is chemical analysis. Samples of water are collected and sent to laboratories to measure the concentrations of dozens of different chemicals. Chemical analyses can tell you exactly how much of each contaminant is present in each sample. However, these numbers cannot tell you if this same water is toxic to plants and animals living in it.

Bioassays. To determine whether the water is toxic to aquatic life, samples can be sent to a toxicity testing laboratory. Live test organisms are placed into each water sample for several days to see if they continue to survive and reproduce. This type of test is called a bioassay. Bioassays can tell you how the water affects a few organisms over a short time, but it cannot tell you how it would affect a real stream community over long periods of time.

Bioassessment. Bioassessment measures the long-term impacts of discharges on a stream ecosystem, that is, the entire plant and animal community and the physical habitat that supports it. Biologists count aquatic macroinvertebrates collected from the bottom of a stream. If a sample contains species that are tolerant of pollution, while it lacks the species known to require clean water, it indicates that something has destroyed the clean water habitat. Conversely, if the sample contains many different species (a high diversity) and some are known to live only in clean water, discharges probably have not impacted the stream. Bioassessment cannot tell you precisely which contaminants are causing the impacts but it can identify streams that need to be investigated further for sources of pollution.

Testing Runoff. Now that most point sources of pollution (like wastewater discharges) have been eliminated, Sacramento has turned its attention to our primary non-point source of pollution — urban runoff. As residents we have a major role in watching out for water quality where we live, work or go to school. Your class will assess water quality by conducting a real bioassay using live aquatic macroinvertebrates.

Lesson III: Improving Life in Our Watershed

Although much remains to be done, it is important to recognize how much we have accomplished in improving water quality. It is easy to take clean drinking water and clear streams and lakes for granted if you don't know about their dirty past. Likewise, it is easy to forget how much life should be in a stream, if you've never played in one that was clean. We have a long way to go to improve life for everyone in the watershed, but we have come a long way.

19th Century Sacramento
What do you suppose washed downhill when it rained in Old Sacramento?

Looking Back

One of the earliest problems faced by human civilization was keeping fecal material out of the water supply. It was very common for people to settle next to lakes, creeks, or rivers. As populations grew, human wastes from outhouses, cesspools, and animal stables seeped down into groundwater and flowed into rivers. The problem got so bad that filth and disease resulted. Cities became very dangerous places to live because the water carried **pathogens** that were the cause of waterborne diseases, such as **cholera** and **dysentery**.

18th Century Paris. Historians recount that in 1780, when the population of Paris was about 600,000 people, city street sweepers removed 270,000 cubic meters (714 million gallons) of horse and human waste. Cesspool collectors picked up an additional 60,000 cubic meters (159 million gallons) of human wastes and "house water" that was dumped from chamber pots out the doors of houses. The entire 330,000 cubic meters (873 million gallons) of waste was conveniently dumped into the Seine River.

19th Century Boston. Boston in the early 1800's was networked with collective sewers that drained kitchen sinks. Homeowners would dig trenches and lay pipes directly to the nearest waterways. The City of Boston banned human wastes from the sewers until 1833. The increasing popularity of the "flush toilet" changed the role of the central sewer and the scent of the city.

In 1860, Boston collected sewage in holding tanks and dumped it into the ocean when the tide was going out. At the time ocean disposal was thought to be a step forward in sewage management. Dump it and dilute it!

When people in cities and towns sent their wastes into the sea or into the nearest stream, their quality of life and health was improved. However, these benefits were at the expense of people living downstream, especially if they took their drinking water from these same rivers. People got sick and eventually learned a lesson: The watershed connects us all because everyone is someone's downstream neighbor.

Sacramento in the 1800's. By 1854, young Sacramento had completed the installation of a central water line that brought water to the city's central district (what is now Old Town and the Capitol Mall areas). While this created a system for bringing water into the town, there was no system for removing the wastewater. Sewage was taken care of on an individual basis. Most city bathrooms and outhouses emptied into cesspools. Liquid wastes were washed or carried from buildings to drainage ditches that ran through alleys and along the odd-numbered streets. These smaller drainage ditches emptied into a main drainage ditch (located at 6th and R Streets) that sent wastewater via a canal through a slough and directly into the Sacramento River. Solid waste material was collected in cesspools constructed of 2-inch thick redwood planks. Lots of **lime** was used to absorb odors, but this did nothing to control the spread of waterborne diseases.

Disastrous floods in December 1861 and January 1862 left stagnant pools of waste throughout the central district. This was followed by a smallpox epidemic in 1862-1863. The flooding and spread of disease led the Sacramento Board of Health to recommend the construction of a comprehensive sewer system for the city.

This plan called for raising the entire central district of the city (where most of the sewage came from) higher than the surrounding areas and sloping it towards the sewage collection ditch at 6th and R Streets. Residents could then more easily wash all liquid sewage into a central system of sewer ditches, downhill into the main collection ditch, and into the Sacramento River. Solid wastes were still supposed to be reserved for cesspools. However, the city dug 3-foot pits every 400 feet along the bottom of the sewer system, to catch any solid waste that accidentally or deliberately wound up in the system. The entire system was flushed every so often, and these pits were emptied and the solid material was carted away.

The Clean Water Act. Water quality continued to deteriorate in the United States until the effects of polluted water on communities and the environment became intolerable. In 1972, the United States Congress passed the Clean Water Act in response to a national crisis in water quality. Every city was required to build a wastewater treatment plant capable of primary and secondary treatment. Up to that time, many towns and cities discharged effluent from simple settling tanks or primary treatment ponds directly to our streams and oceans. Millions of dollars flowed from the federal government to communities throughout the United States to pay for these improvements. To reduce the impacts of factories on water quality, the Clean Water Act required industries to install the best available technology to reduce the flow of pollutants into America's waterways. In June 1992, Congress prohibited the dumping of sewage sludge into the ocean. All of these actions were taken in an effort to meet the Clean Water Act's goal to "restore and maintain the chemical, physical and biological integrity of the Nation's waters."

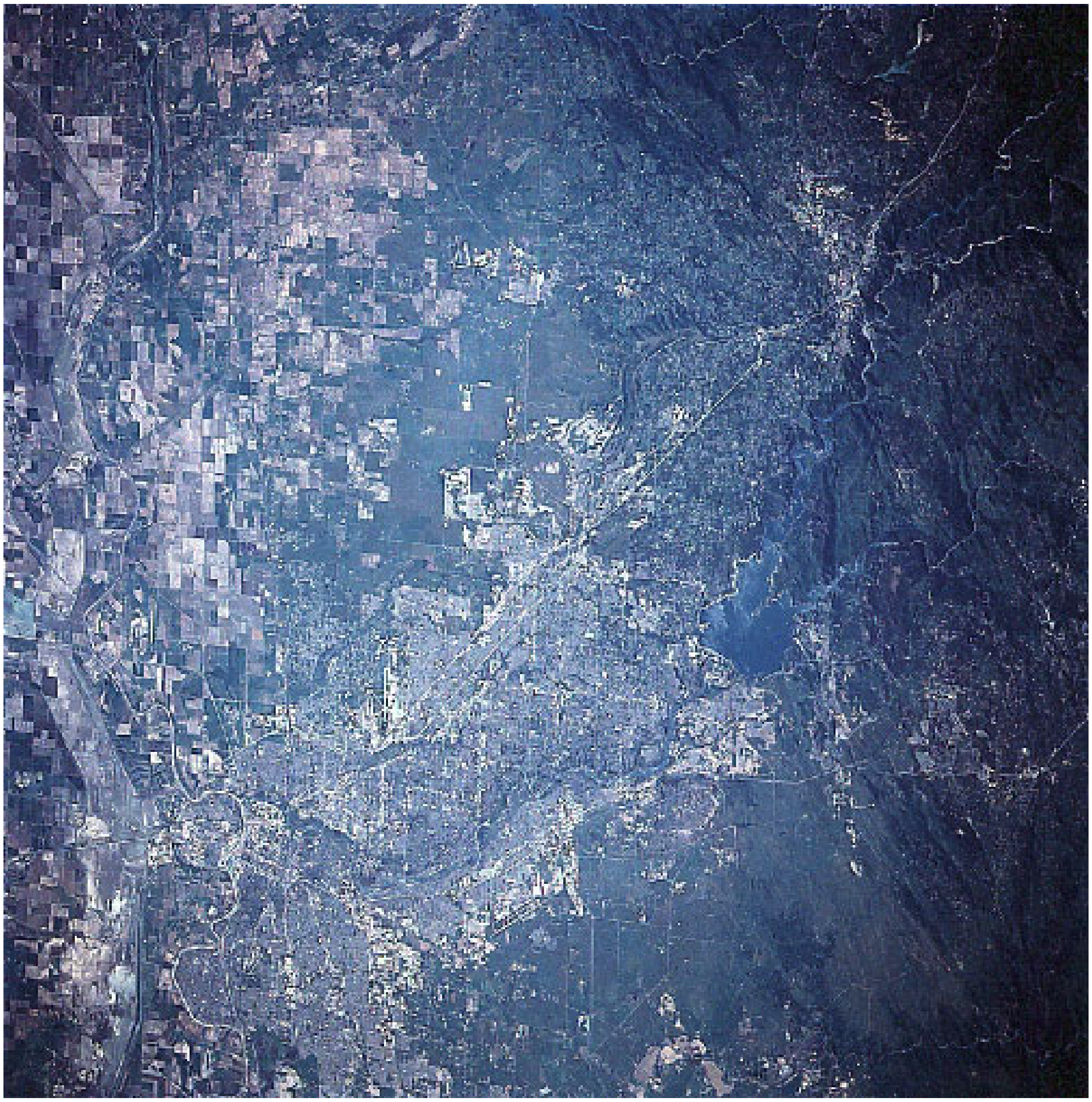
Looking Ahead

The Clean Water Act continues to press our communities toward achieving its elusive goals. Over the years, we have made many great strides toward improving water quality by cleaning up our wastewater. However, urban and agricultural runoff now pose an equal, if not greater, challenge, technically and socially. Non-point sources of pollution are more difficult to manage because they come from so many places in the watershed. Everyone contributes to the problem, so everyone must contribute to the solution. The solution to runoff pollution will require new ways of thinking, planning, and acting.

As we build our homes and cities, we cover patches of ground within our watershed with cement, asphalt, rooftops, and other surfaces that prevent rain from soaking into the earth. These types of water barriers are called **impervious surfaces**. Researchers tell us that when ten percent (10%) or more of the land within a watershed becomes covered by impervious surfaces, then streams in the watershed are impacted significantly. The velocity of urban runoff erodes stream banks, the temperature of urban runoff increases, and pollutants washed from the surfaces degrade the habitat of streams and poison aquatic life. All of these effects of impervious surfaces limit the types of aquatic macroinvertebrates and fishes that can survive in a watershed.

The image of the Sacramento area on the next page was taken from the Space Shuttle. Can you find patches of impervious surface?

Technical Solutions. Given the huge volume of runoff from a single storm, collecting and treating the county's stormwater runoff at a treatment plant would be technically impossible, as well as prohibitively expensive. Therefore, the problem calls for a different solution. Across the nation people are experimenting with various approaches to solving the problem. One approach used in new developments in Sacramento is to build runoff storage facilities called **detention basins**. The detention basins hold the water to allow time for some of the particles of soil and heavy metals to settle out of the water and sink to the bottom. Other approaches include preserving or restoring wetlands along stream corridors to naturally filter out sediment, nutrients and other pollutants.



A view of Sacramento from space. Folsom is center right.

Grassy swales can be installed in neighborhoods to allow runoff to collect and move more slowly toward streams, removing sediment and chemicals along the way. Some developments try to reduce the area covered by pavement and buildings, so more rain can go into the ground rather than into rapidly rising streams. Various methods have been developed to reduce sedimentation (the deposit of soil into streams), by minimizing erosion of soils at construction sites, along roadways, and from plowed fields.

People Solutions. Perhaps the best method for reducing runoff pollution is to keep contaminants from getting into runoff in the first place. By changing the way we live in the watershed, we can keep many chemicals out of the storm drains and out of our streams. But changes in behavior only come about with better understanding. We are all part of the problem of runoff pollution, so we all have to be part of the solution. Local public education programs are helping us to build that understanding and, with it, a growing awareness of our connection to the watershed.

Your understanding of life in our watershed creates opportunities for you to improve it. You can make personal choices that reduce your impact on water quality. Beyond that, you can actively work to improve conditions in local streams. Most importantly, by sharing your knowledge with others, you can help to create a community that is protective of its waters. Your challenge is to find ways to use your knowledge to improve life in our watershed.

Developing Understanding

Understanding what gets into urban runoff and how it gets there is the first step in figuring out how to stop it. The table below lists the pollutants of concern in Sacramento's urban runoff and their sources. As individuals, we can reduce toxic runoff by following the instructions when using household chemicals. We can decrease the amount of litter and pet wastes in runoff by putting trash and pet feces in trash cans. We can prevent oil and other engine fluids from contaminating streams by fixing leaks in our automobiles and by never dumping used oil or anything else into storm drains.

As a community, we can encourage our city leaders and planners to design and build developments that reduce the amount of impervious surface, reduce the amount of automobile use, and remove sediment and pollutants by filtering runoff through vegetation. A few ways to reduce urban runoff pollution are summarized in the table "Ways to Decrease Urban Runoff Pollution."

Pollutants of Concern in Sacramento Urban Runoff

Pollutant	Source
Sediment	Soil washed from construction sites and areas where vegetation has been removed
Insecticides (Diazinon, Chlorpyrifos)	Over-spraying in the yard, dumping leftover spray down storm drains
Polyaromatic Hydrocarbons (PAHs)	Engine exhaust and oil leaks
Oil and gasoline	Oil and gas leaking from cars, trucks, and gas stations; illegal dumping of used oil into storm drains
Heavy Metals copper, zinc, lead	Copper from brake linings Zinc from tire wear Lead from past uses in paints and gasoline
Fecal coliform bacteria	Cat and dog feces washing down storm drains

Ways to Decrease Urban Runoff Pollution

When we…	we reduce urban runoff pollution by…
follow fertilizer and pesticide manufacturers' instructions…	decreasing the amount of over-spraying and over-fertilizing in our neighborhoods.
keep our cars tuned-up and well maintained…	decreasing the amount of engine fluids leaking onto streets and the amount of smog in the air.
pick up after our pets…	decreasing the amount of nutrients and bacteria from pet waste that washes into creeks.
take left-over paints, oil, antifreeze, pesticides, etc. to official collection sites…	preventing people from dumping them directly onto the ground or down a storm drain.
plan and build homes and businesses closer together…	reducing the use of automobiles and their contaminants.
use permeable surfaces…	increasing the amount of rain that soaks into the ground.
include vegetated swales in city plans…	capturing sediment and pollutants in urban runoff before they enter our streams.
include detention basins in city plans…	settling some pollutants out of runoff before they flow into streams.
maintain a vegetated buffer zone between creeks and homes and buildings…	allowing plants and trees to filter incoming runoff, and preventing soil from streamside construction from washing into streams.
grow plants on rooftops and use light-colored roofing…	decrease urban temperatures and the amount of runoff from rooftops.

Developing Solutions

Today our community and many others face the challenge to improve the quality of urban runoff. Our local stormwater agencies are making progress in treating stormwater (in new developments) and in building community awareness of our watershed. People are learning that it takes everyone's help to keep contaminants out of runoff. When each of us reduces our own contribution to water pollution, together we protect water and habitat for all life in our watershed.

COUNTY OF SACRAMENTO
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