PROTECTING EARTH'S WATER

Protecting Earth's Water Lecture

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Protecting Earth's Water Objectives

1. Identify compounds that are considered pollutants in water systems and understand their impact on human health.
2. Differentiate between point source pollution and nonpoint source pollution.
3. Identify and describe key legislation, policies and actions related to the protection of water resources.
4. Identify characteristics and services of riparian areas and describe strategies for maintaining healthy riparian areas.

Objective 1: Identify compounds that are considered pollutants in water systems and understand their impact on human health.

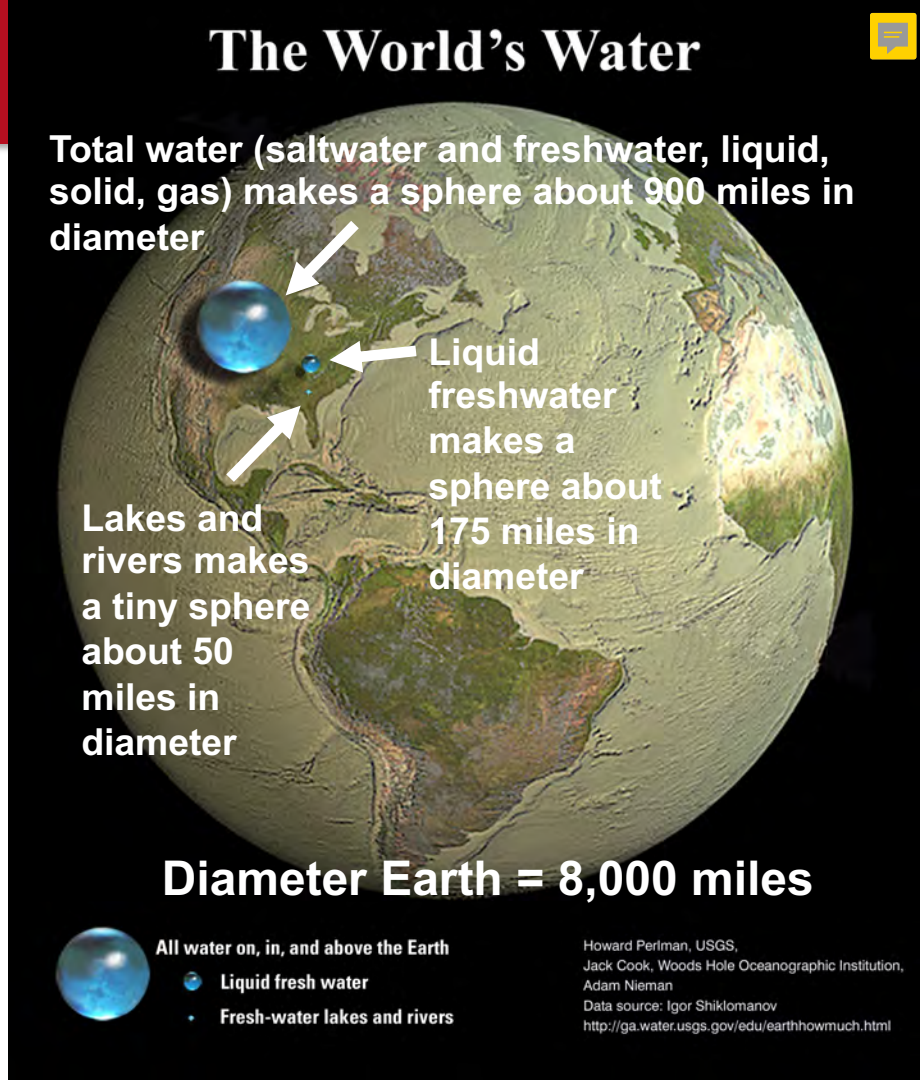
All of Earth's water as a sphere

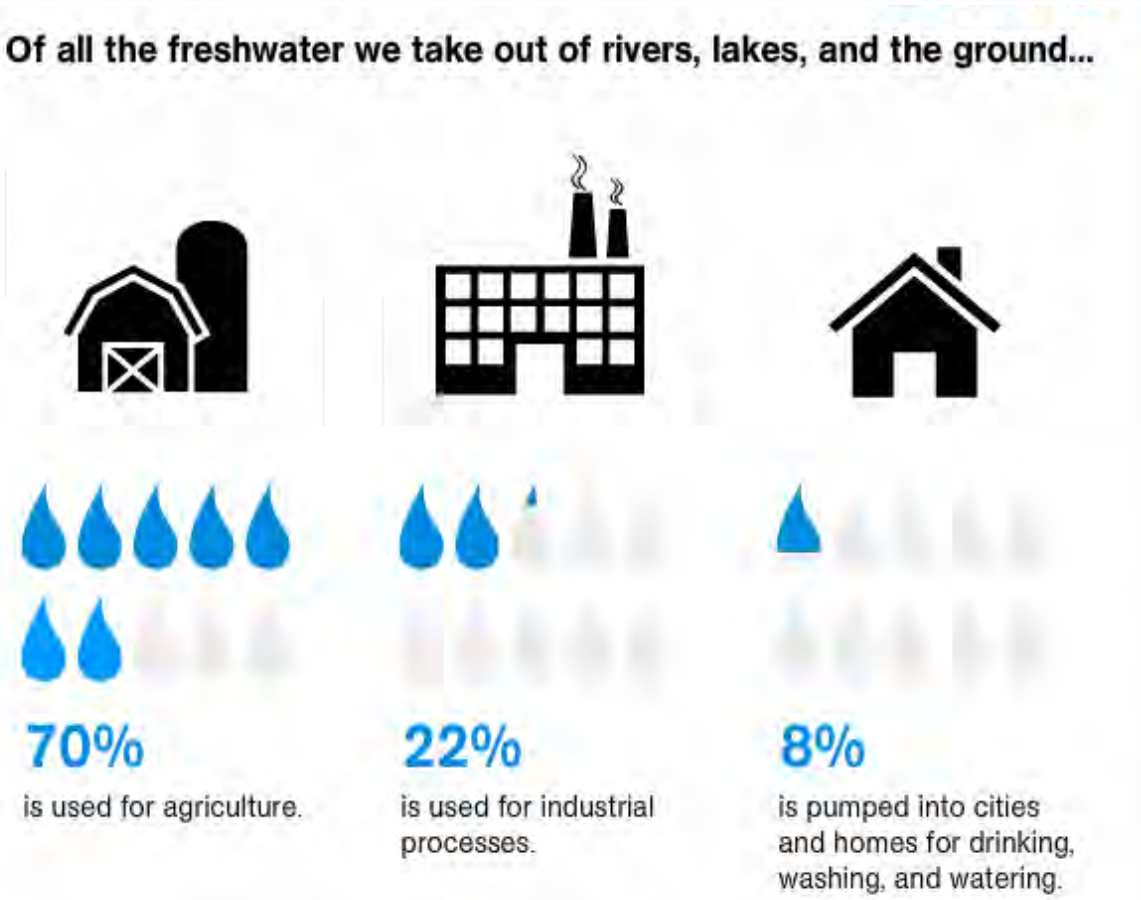
Earth's water is a finite resource, we aren't getting any more H_2O.

The water on Earth today is the same water that has been on our planet for 3-4 billion years. Life constantly recycles and reuses this H_2O.

Earth's water came from outer space riding on chondrite meteorites that fell to Earth 3-4 billion years ago.

[Where did Earth's Water come from?]





Most freshwater that humans use is used to grow the food we need to live.

National Geographic, A Freshwater Story

Water Pollution = the contamination of a body of water (e.g., stream, river, lake, ocean) with a substance that degrades its quality.

Water Pollution

Pollutants are contaminants that can be biological, chemical, physical, or radiological and at elevated levels, these substances cause increased risk of both acute and/or chronic diseases.

Pollution residence time = the time that a substance remains in the environment before it is removed

Some pollutants can be removed or cleaned from water quickly in hours or days. Other pollutants can take decades to remove. There are even some contaminants that scientists believe may never be totally removed from water sources.

EPA: Types of Drinking Water Contaminants

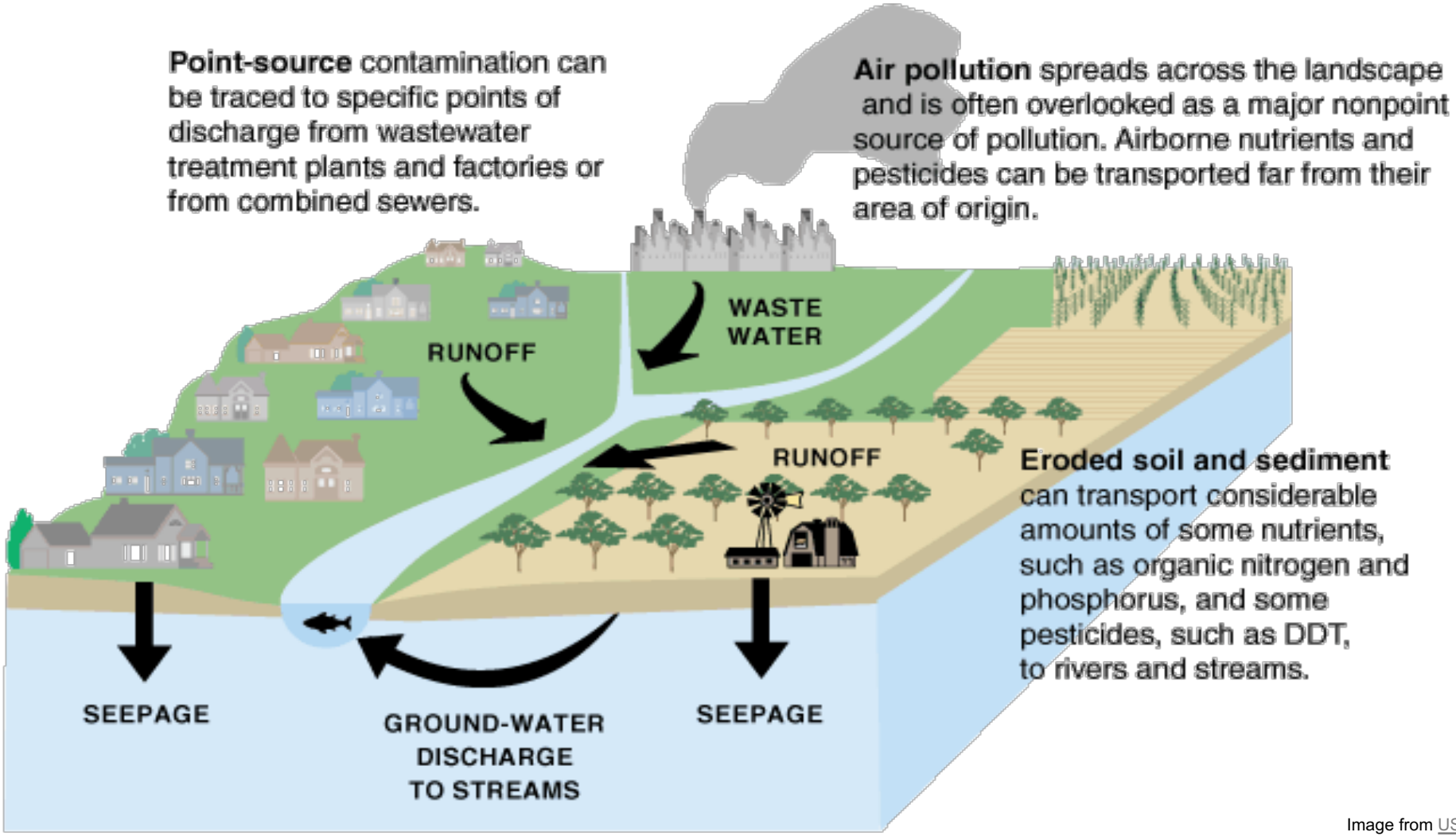
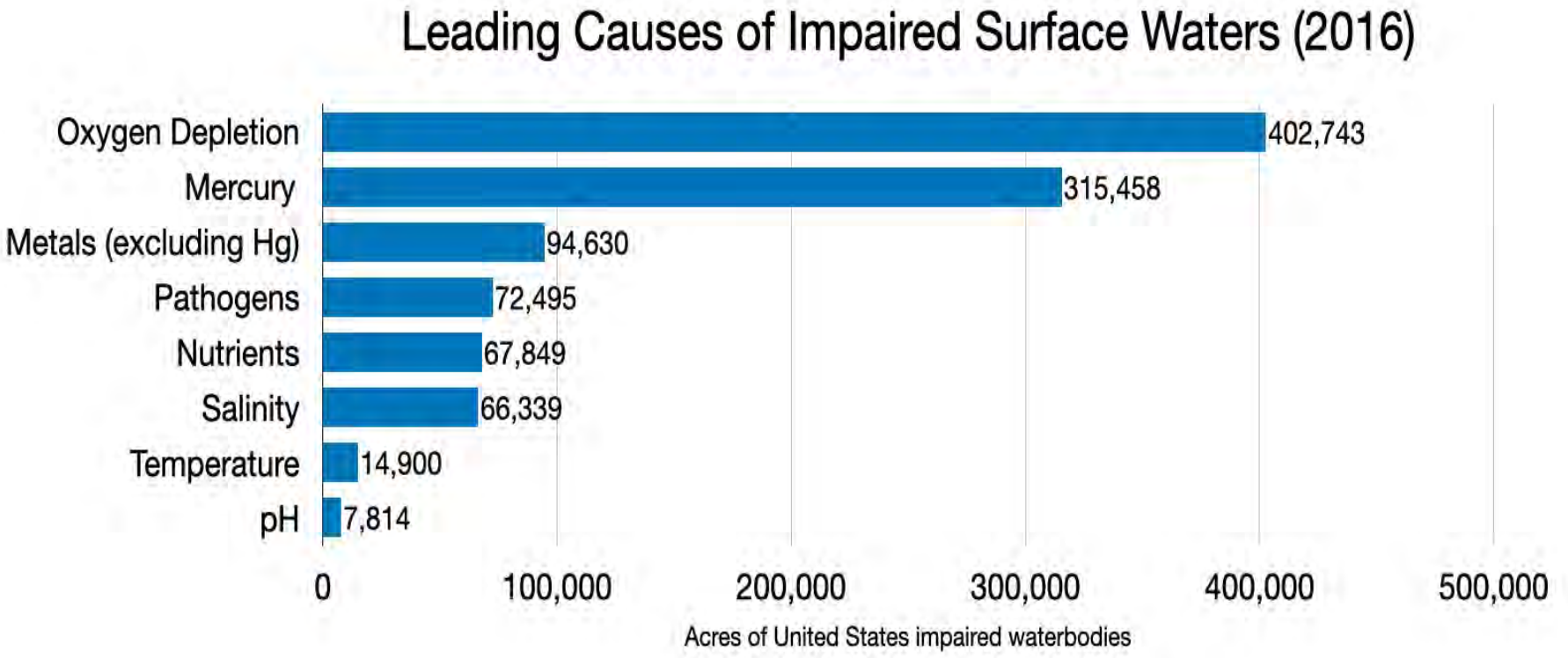


Image from USGS

Pollutants don’t remain at their source, they never stay in one place, they are constantly in motion.

Earth’s natural processes (e.g., ocean circulation, atmospheric circulation, gravity, energy flow and food webs) are constantly moving pollutants. Think about all the ways that pollutants can move on Earth (e.g., food webs, bioaccumulation, biomagnification, migration patterns, ocean currents, high- and low-pressure systems, weather patterns, winds, storms, underground aquifers, rivers, streams, lakes, hurricanes). Sometimes these natural processes act to concentrate pollutants in one area.

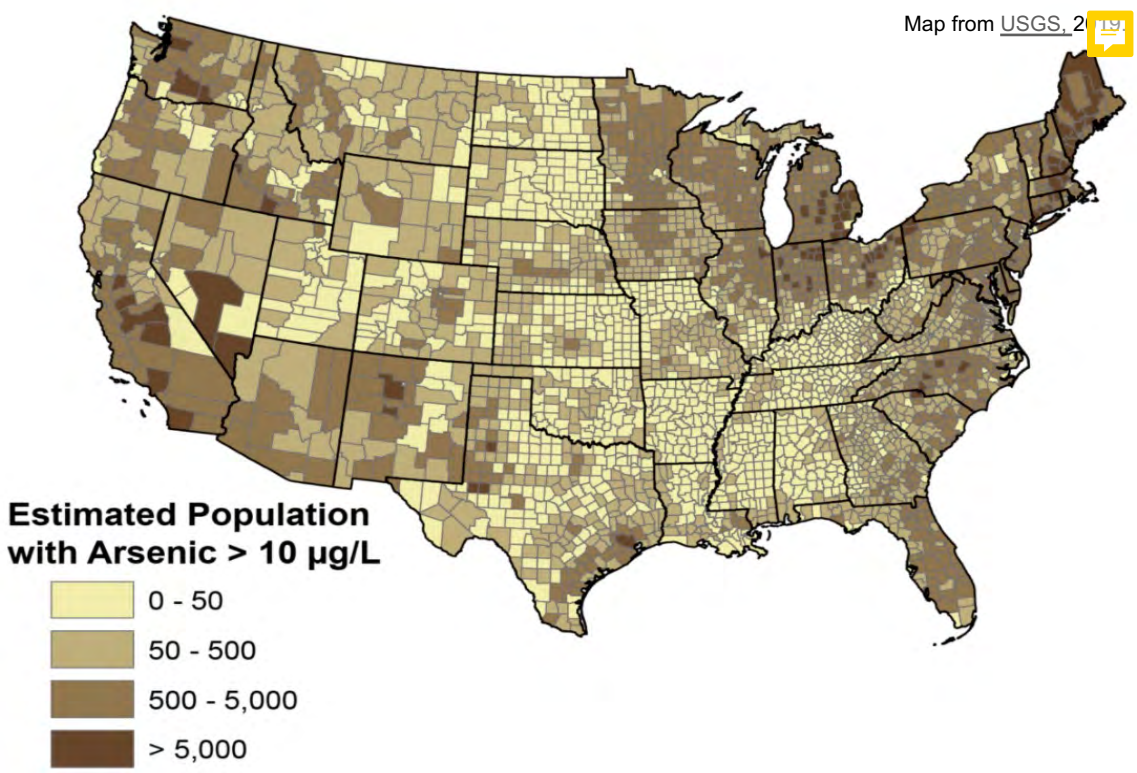
It is impossible for humans to stop water’s movement on Earth.



Data from Environmental Science for a Changing World

Heavy Metals

Heavy metals occur naturally, however can become concentrated due to human activities. When high levels of these metals build up in the water, they can reach concentrations that are toxic to all species of life.



Map from USGS, 2019

Examples:

- Arsenic
- Mercury
- Lead

Groundwater aquifers can become contaminated with heavy metals leading to contaminated well water.

https://www.epa.gov/dwlabcert

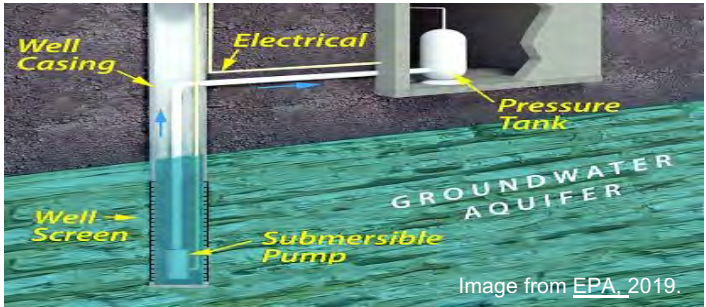


Image from EPA, 2019.

Pathogens

Waterborne pathogens include bacteria, parasites, viruses, and other microorganisms that can be transmitted to humans if we consume untreated or poorly treated water. This can lead to serious health problems such as nausea, vomiting, diarrhea and even hospitalization.

Examples of waterborne pathogens:

- *Norovirus*
- *Legionella*
- *Giardia*
- *Cholera*
- *E. coli*
- *Salmonella*

Excess Nutrients

Nutrient pollution is caused by excess nitrogen (N) and phosphorus (P) in water. These nutrients are naturally present in aquatic systems at very low concentrations. However, when an excess of N or P enters water from runoff pollution, it can result in toxic algae blooms. The algae produce toxic compounds, reduce the dissolved oxygen concentration in water, and ultimately kill aquatic organisms and make the water unsafe to drink.

Sources of excess N and P:

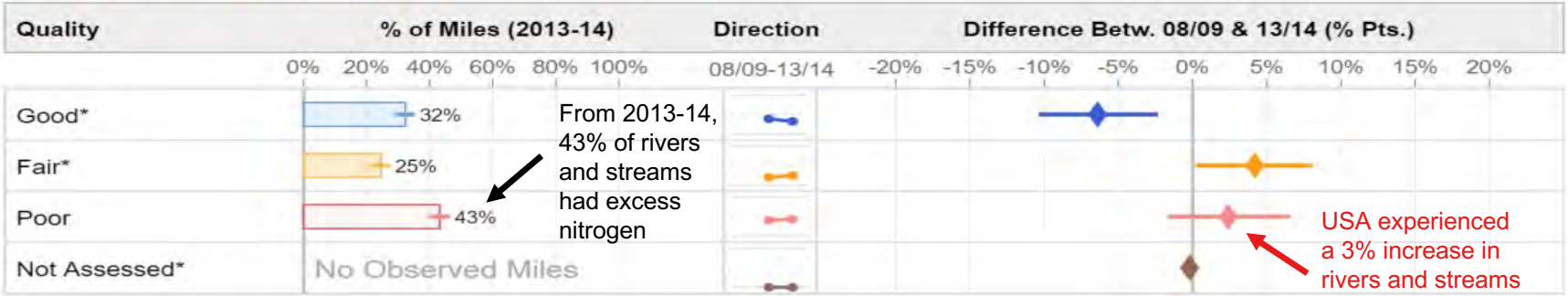
- Agriculture runoff
- Stormwater runoff
- Wastewater

Toxic algae blooms (green photo-synthetic organisms above) are a major problem each summer in Lake Erie for both Canada and the United States.

Lake Erie Harmful Algal Bloom Forecast

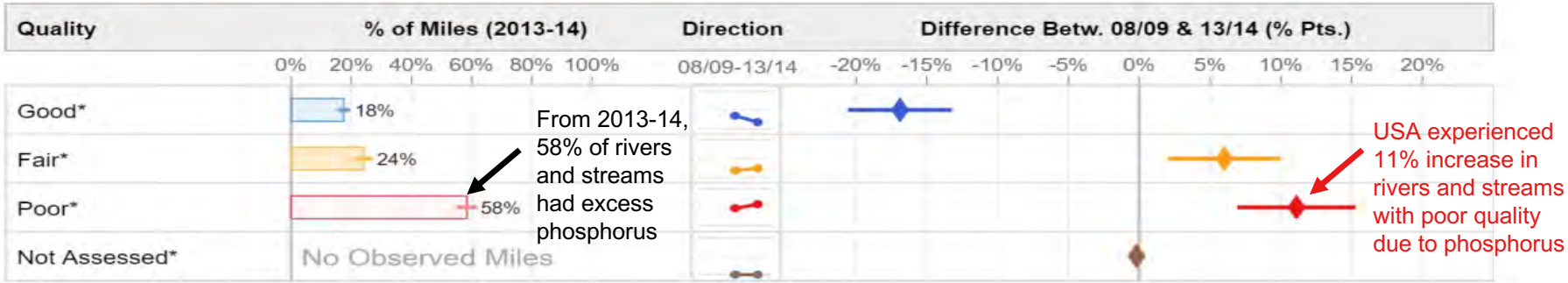
Excess Nutrients

Figure 3.5 Nitrogen: NRSA 2013–14 National Results — National Rivers and Streams Assessment (NRSA)



*Reflects a statistically significant change between 2008–09 and 2013–14 (95% confidence).

Figure 3.4 Phosphorus: NRSA 2013–14 National Results — National Rivers and Streams Assessment (NRSA)

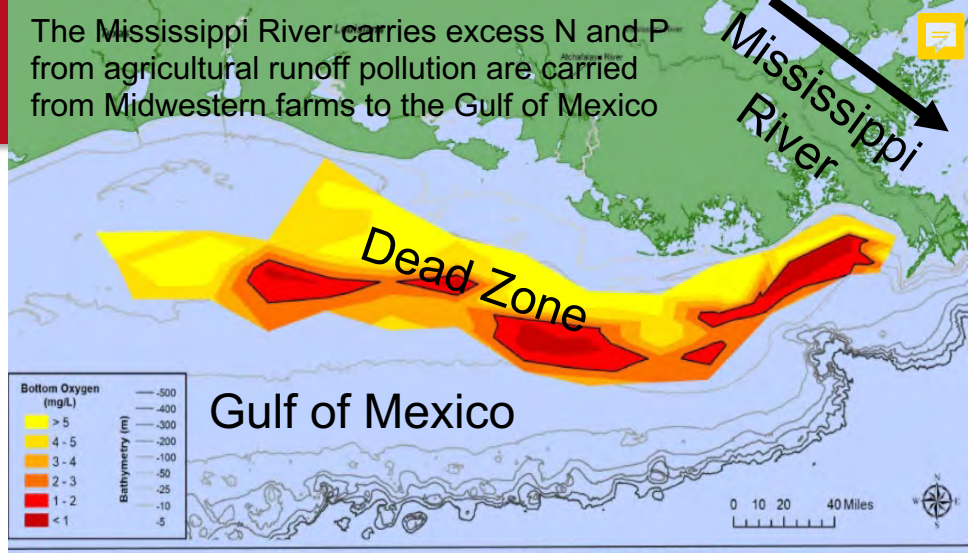


*Reflects a statistically significant change between 2008–09 and 2013–14 (95% confidence).

Hypoxia = low or depleted oxygen in a body of water

Oxygen levels within water bodies varies naturally. However, when excess nutrients flow into a waterway algae blooms can occur, which leads to a depletion of dissolved oxygen levels.

Hypoxia leads to dead zones. Dead zones are unable to support aerobic life (organisms that need oxygen to live) and can cause die-offs of fish, shrimp, crabs, clams and other organisms.



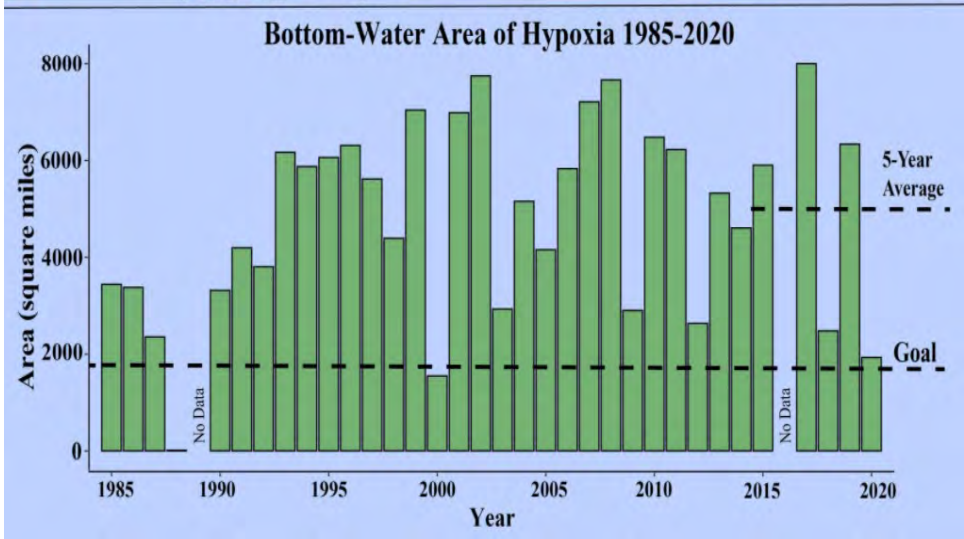
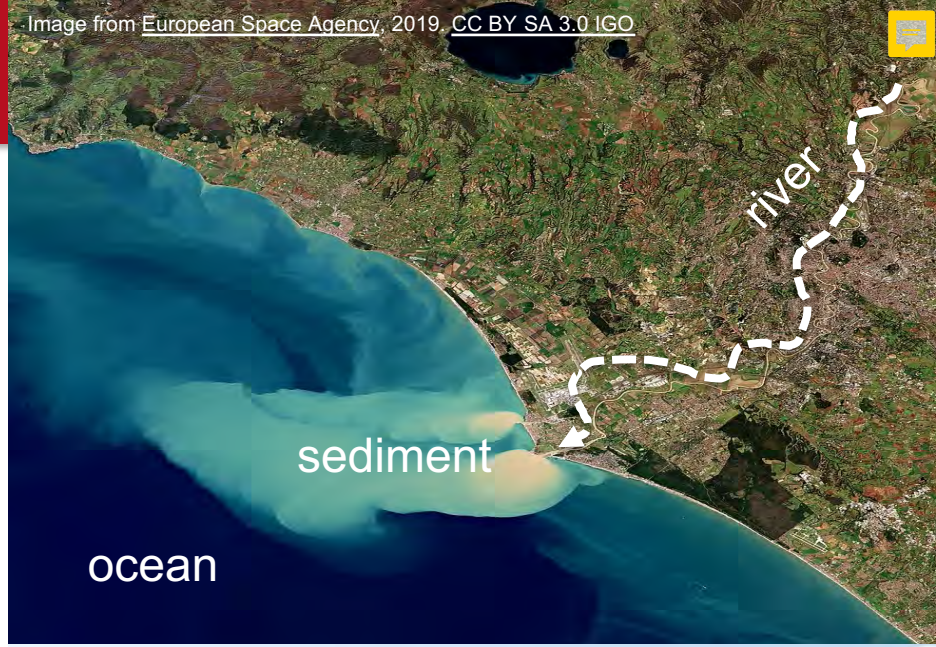


Image from Louisiana Universities Marine Consortium, NOAA

Sediments

Sediment pollution occurs when loose sand, clay, silt, and other soil particles enter a water system typically from soil erosion or the decomposition of animals and plants. These particles are carries to water systems by wind, water, and ice. Streams and rivers carry the sediment to lakes and oceans.

Sediment pollution is damaging to water systems in that it can decrease the water quality for drinking, prevent growth of natural vegetation, reduce water depth, destroy habitat, make it difficult for organisms to see and cause health risks.



Chemical Contaminants

1. Natural or manmade (synthetic)
2. Organic (carbon-hydrogen) or inorganic
3. Cleaning products
4. Personal care products and pharmaceuticals
5. Disinfectants and disinfectant byproducts

Persistent Organic Pollutants (POPs)

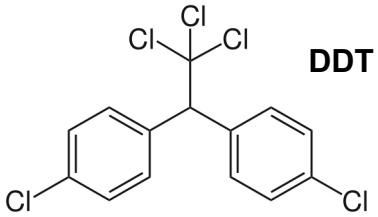
POPs are synthetic chemicals that were introduced into commercial use after World War II. They were used to manage pests and diseases, in industrial processes/manufacturing and in the agriculture. Scientists later discovered the toxic effects on the environment, wildlife and human health.

Examples of POPs:

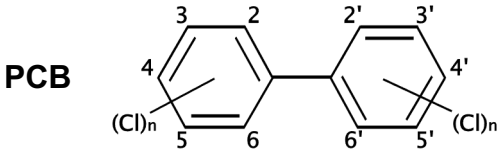
- DDT – used as insecticide
- Dioxin – used as herbicide
- PCBs – used as electrical coolant

Image by Forest Health Protection, 1955.

DDT application by aircraft in the USA during 1950s to kill mosquitoes



DDT



PCB

Image by D.328, 2006. CC BY-SA 3.0.

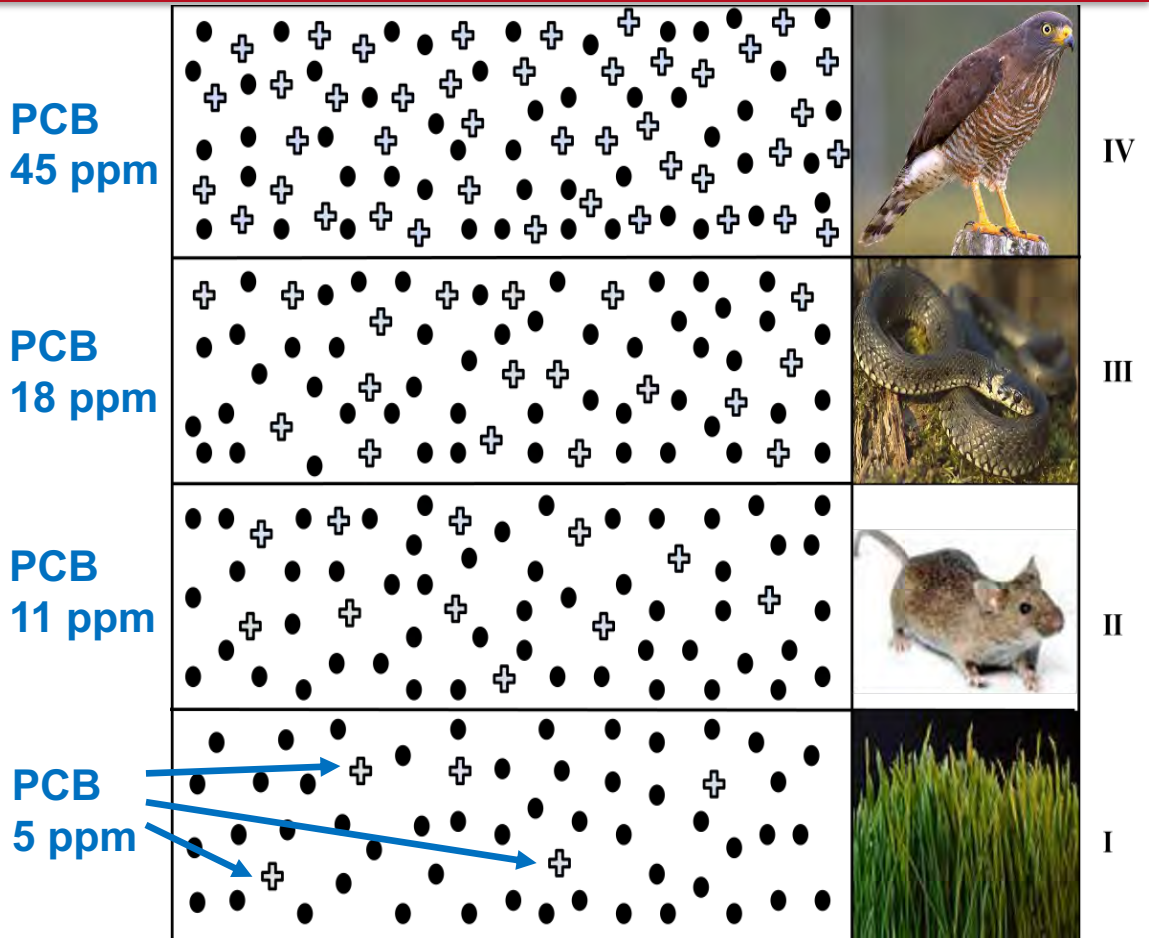
The "Dirty Dozen"

aldrin [1]
chlordane [1]
dichlorodiphenyl trichloroethane (DDT)[1]
dieldrin[1]
endrin[1]
heptachlor[1]
hexachlorobenzene [1],[2]
mirex[1]
toxaphene[1]
polychlorinated biphenyls (PCBs) [1],[2]
polychlorinated dibenzo-p-dioxins[2](dioxins)
polychlorinated dibenzofurans[2] (furans)

1-Intentionally Produced.
2-Unintentionally Produced - Result from some industrial processes and combustion.

Biomagnification = the process of toxic chemicals accumulating within organisms across a food chain

As organisms higher up in the food chain consume those below, more and more toxic chemicals enter their systems, and these concentrations magnify. Predators at the top of the food chain are most affected and the most at risk of serious health effects.



Plastics

It is difficult to gauge how much plastic is currently in our rivers, lakes and oceans, however, scientists estimate about 8 million metric tons entered the ocean in 2010. Plastic is an especially dangerous water pollutant because unlike other forms of waste, plastic does not readily decompose.

Microplastics = small microbeads and microfibers less than 5 mm in size

Plastic is found in personal care products, cosmetics, clothing (e.g., polyester, nylon), cars, computers, shoes, homes, etc. Over time sunlight, weather and waves break down plastics into smaller and smaller pieces. Plastics acts like sponges absorbing substances, including PCB, DDT and persistent pollutants, and toxic when consumed by aquatic organisms.

PLASTICS IN THE OCEAN

Plastics are the most common form of marine debris. They can come from a variety of land- and ocean-based **SOURCES**, **ENTER THE WATER** *in many ways, and* **IMPACT** *the ocean and Great Lakes. Once in the water, plastic debris never fully biodegrades.*

COMMONLY FOUND PLASTICS

HOW TO HELP?

MICROPLASTICS

Microplastics are small plastics less than 5mm. They can come from large plastics breaking down, or can be produced as small plastics such as microbeads, which can be found in products such as toothpaste and face wash.

ENTANGLEMENT

Marine life can get caught and killed in derelict fishing nets and other plastic debris.

BOATS/NETS

Fishing gear can become marine debris when it is lost or abandoned.

INGESTION

Animals can easily mistake plastic debris for food.

https://marinedebris.noaa.gov/

RAIN & WINDS

Rain and wind can sweep debris into nearby waterbodies.

LITTERING

Intentional littering or improper disposal of trash can cause marine debris.

STREAMS & STORM DRAINS

Streams and storm drains can carry debris directly into the ocean or Great Lakes.

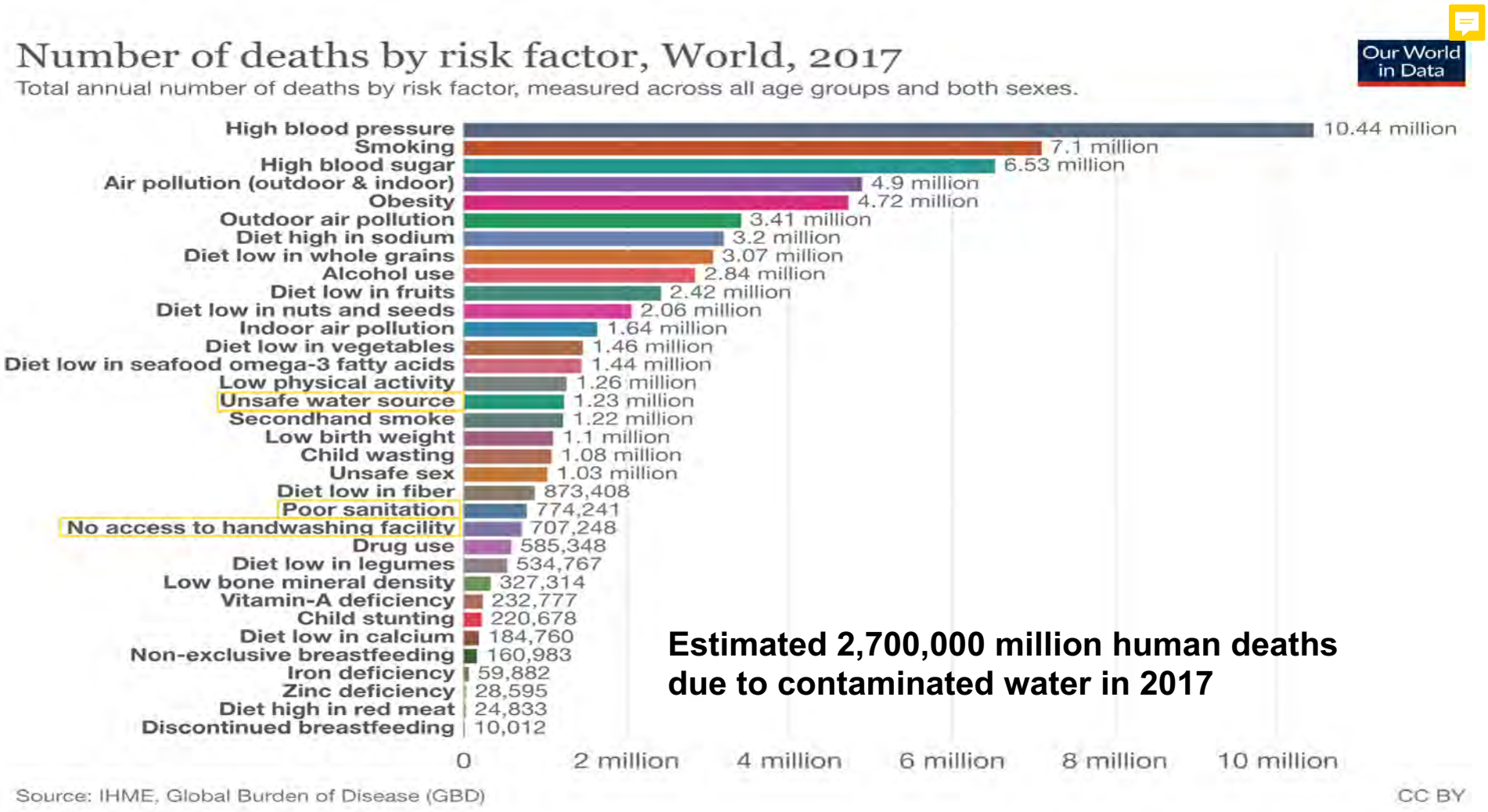
Human Health

Poor water quality is one of the world's largest public health problems and environmental problems. Humans can be affected by poor water quality by drinking, swimming, eating fish or bathing in contaminated water. This problem disproportionally affects the world's poorer and developing countries.

The United Nations estimates that 2 million human deaths occur each year as a result of unsafe drinking water, sanitation and hand hygiene.

Unsafe water sources:

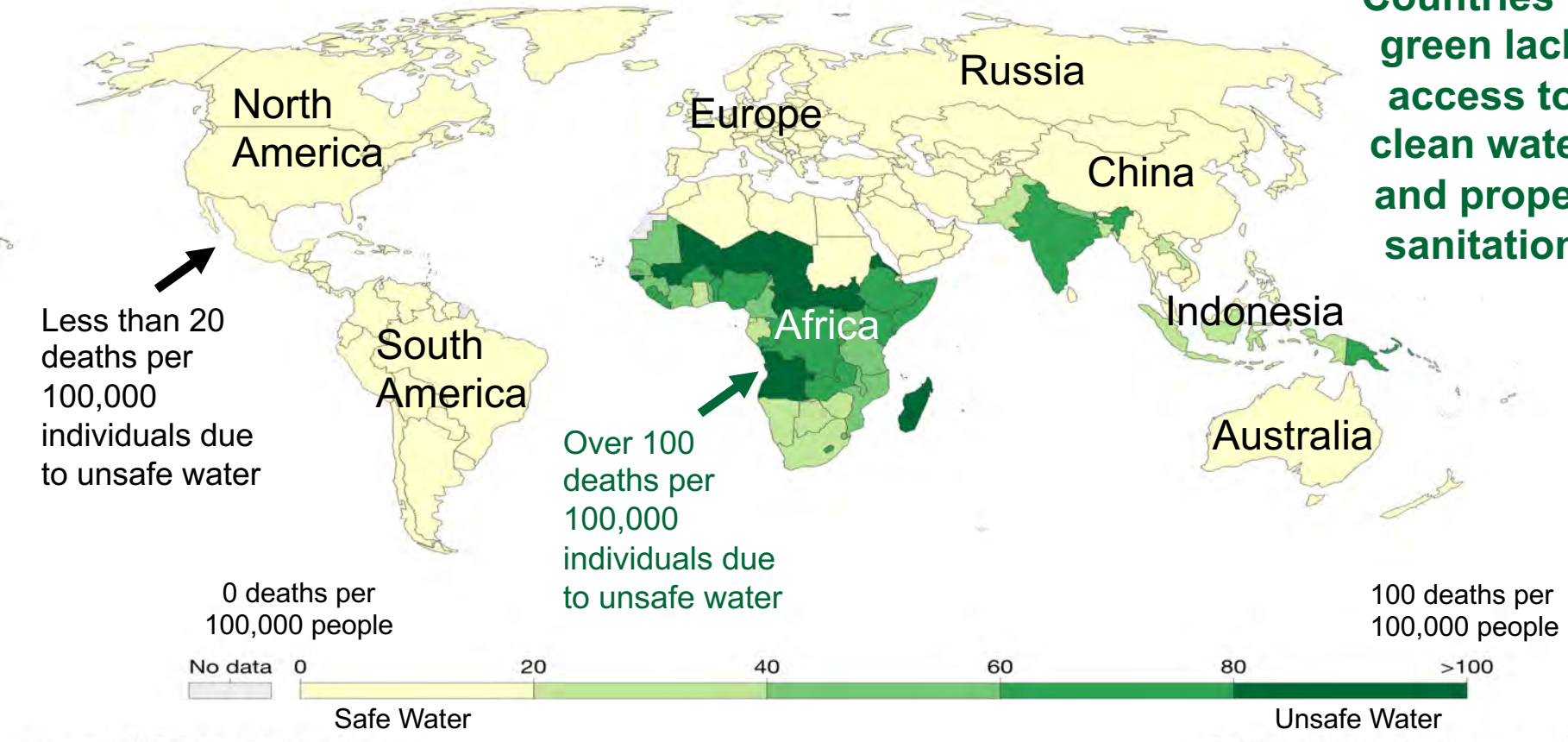
- Due to poor sanitation and inadequate sources of drinking water
- Causes diseases like cholera, dysentery
- Can result in childhood malnutrition and even death



Estimated 2,700,000 million human deaths due to contaminated water in 2017

Death rates from unsafe water sources, 2017

Death rates are measured as the number of deaths per 100,000 individuals.



Source: IHME, Global Burden of Disease

OurWorldInData.org/water-access • CC BY

Objective 2: Differentiate between point source pollution and nonpoint source pollution.

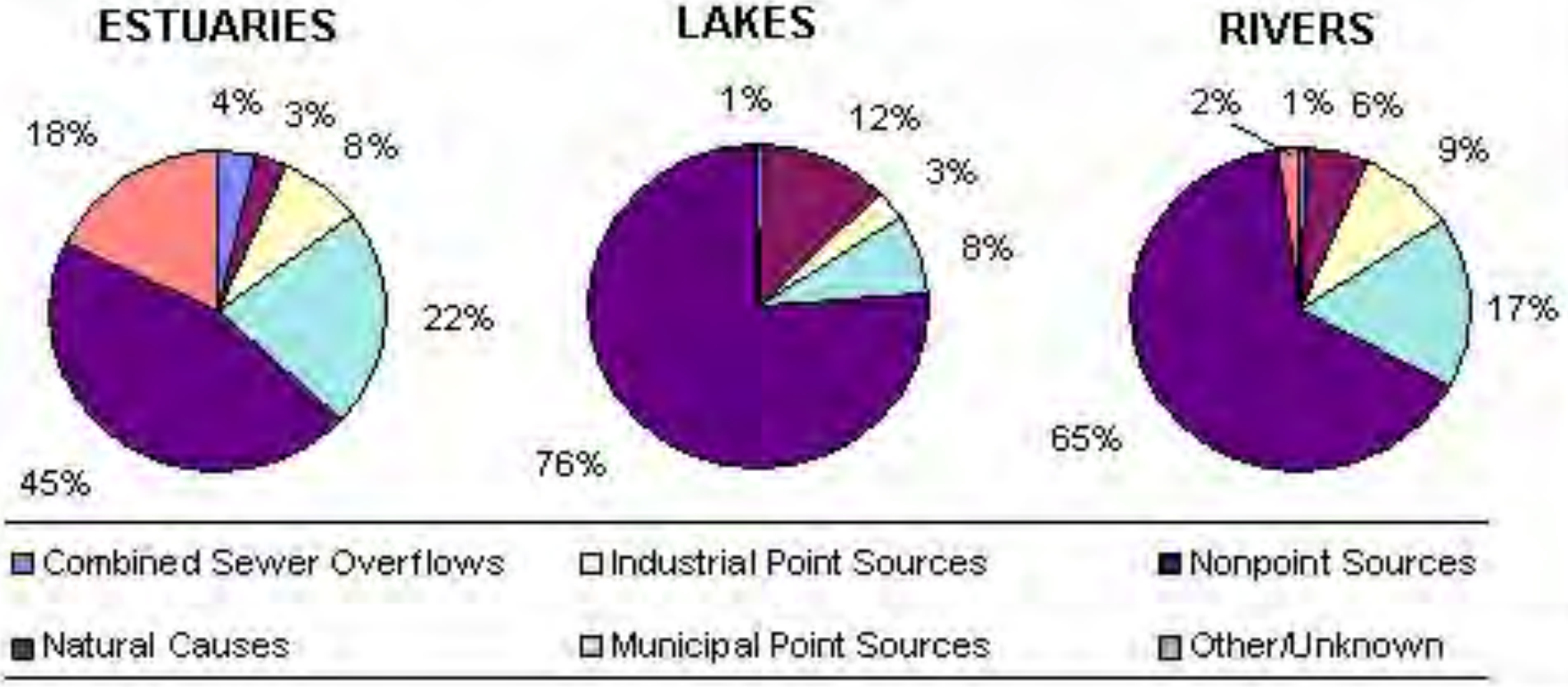
Nonpoint Source Pollution = originates from multiple diffuse sources that are often impossible to trace back

According to the EPA, nonpoint source pollution is the “leading remaining cause of water quality problems.”

Nonpoint source pollution exists in a variety of environments and is extremely difficult to fully assess.

Image from EPA.

RELATIVE IMPACT OF NONPOINT SOURCE POLLUTION PROBLEMS IN IMPAIRED WATERS



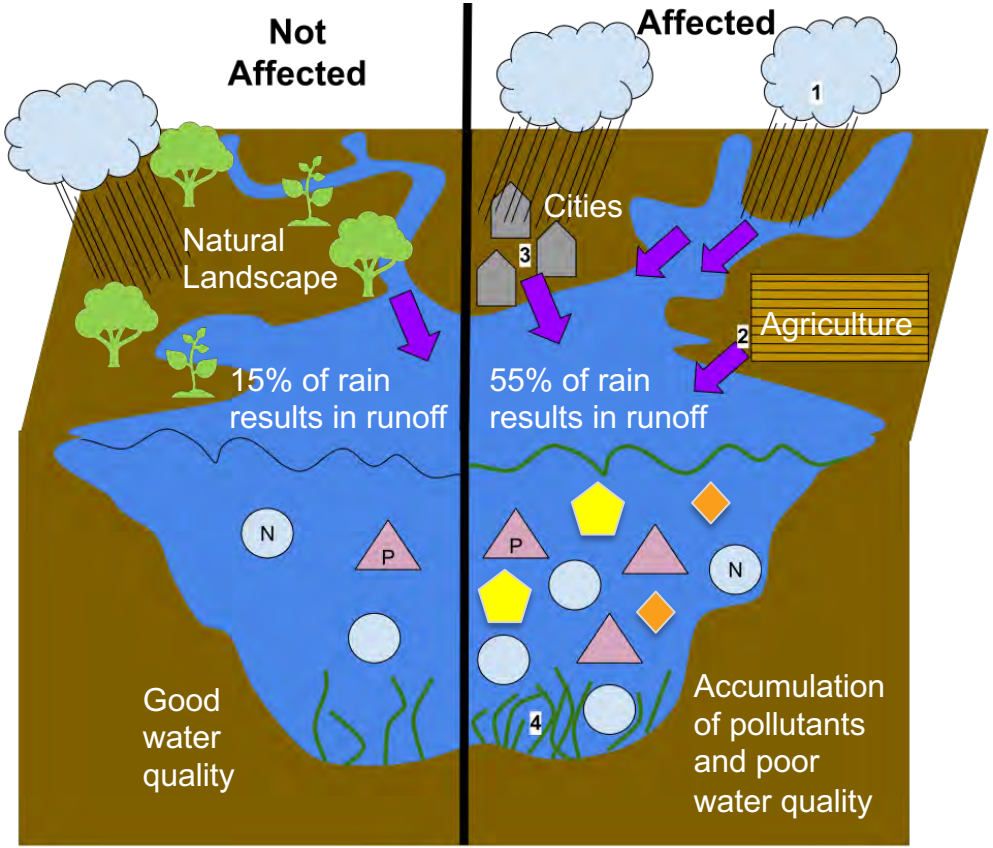


Image modified from Houellette, 2017. CC BY-SA 4.0.

Nonpoint source pollution comes from many sources such as urban landscapes, agricultural land and mining sites.

Rainfall or snowmelt moves over and through the ground picking up pollutants and carrying them away from the source, such as agricultural fields or suburban neighborhoods.

Gravity carries the water to larger bodies of water such as rivers, wetlands, lakes, and oceans where it is deposited and accumulates over time resulting in poor water quality.

Image from Lynn Betts, USDA.

Sources of Nonpoint Source Pollution

1. Urban and residential areas
2. Agricultural land
3. Roads, highways and bridges
4. Construction sites
5. Atmospheric inputs
6. Mining operations
7. Deforested lands
8. Boats and marinas

These human systems lack natural vegetation that slows the movement of water allowing plants, natural microorganisms and soil minerals to filter pollutants out of the water resulting in clean water.

Controlling Nonpoint Source Pollution in Agriculture

1. Add buffer strips of natural vegetation between farm fields and water bodies to absorb and filter runoff pollution
2. Reduce tillage or utilize conservation tillage practices to reduce soil erosion and loss
3. Properly manage crop nutrients and apply fertilizers sparingly and at the correct times (e.g., don't apply manure to fields during winter months when crops are not growing)
4. Manage insects and weeds responsibility and with minimal to no pesticides or herbicides

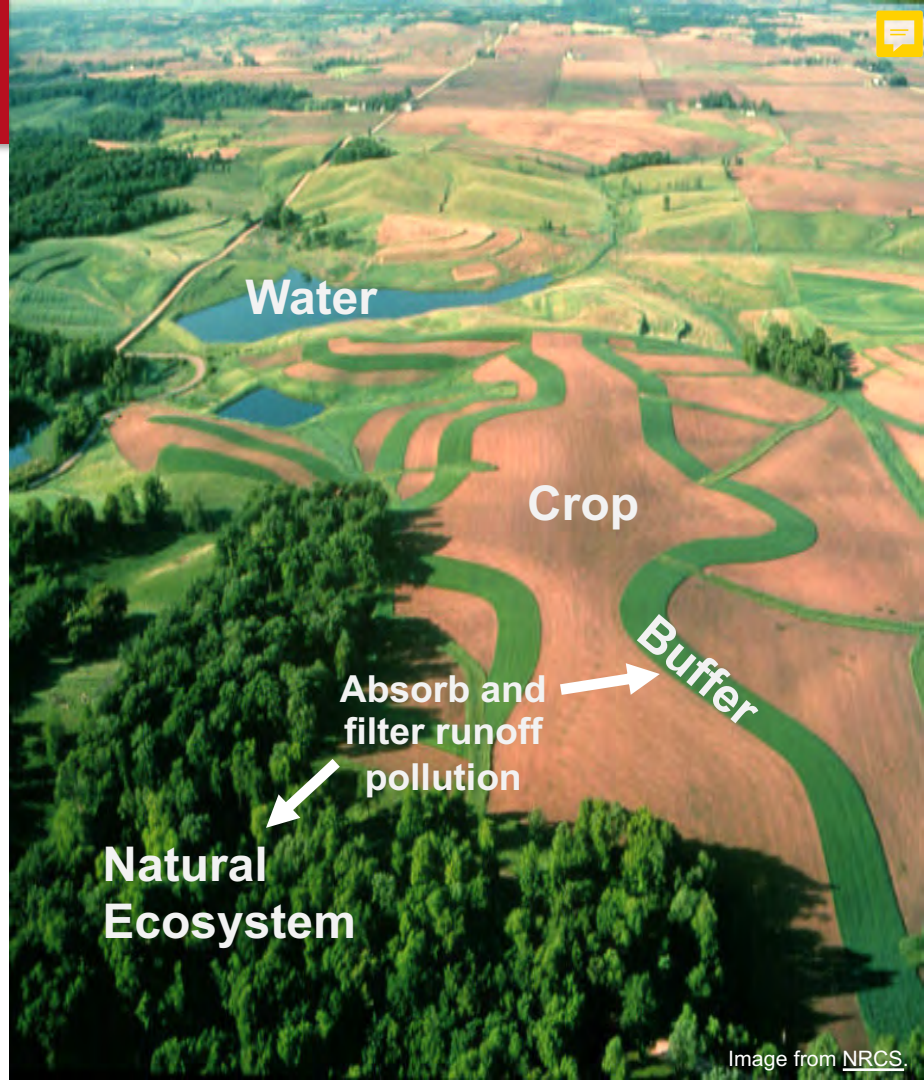


Image from NRCS.

Controlling Nonpoint Source Pollution in Urban Areas

1. Add buffer strips or natural vegetation around parking lots, sidewalks, or other areas with excess pavement
2. Add retention ponds to hold runoff and stormwater giving microorganisms and plants more time to breakdown pollutants
3. Construct sediment fences at construction sites to slow runoff
4. Establish wetlands, plant trees and other natural elements to hold soil in place and reduce runoff
5. Use porous materials for pavement and highways to allow rainwater and snowmelt to filter into soil

Point Source Pollution

According to the EPA, a point source is “any discernible, confided and discrete conveyance such as ditches, pipes, tunnels, wells, etc. from which pollutants are or may be discharged from.”

Effluent = wastewater discharged into the environment

While point source pollution originates from a specific source, it can greatly impact the overall environment.

Sources of Point Source Pollution

1. Industrial plants and factories (e.g., oil refineries, chemical manufacturers, food processors, pharmaceutical manufactures)
2. Sewage treatment plants
3. Concentrated animal feeding operations
4. Waste discharge from ships, boats, vessels or floating craft
5. Construction zones

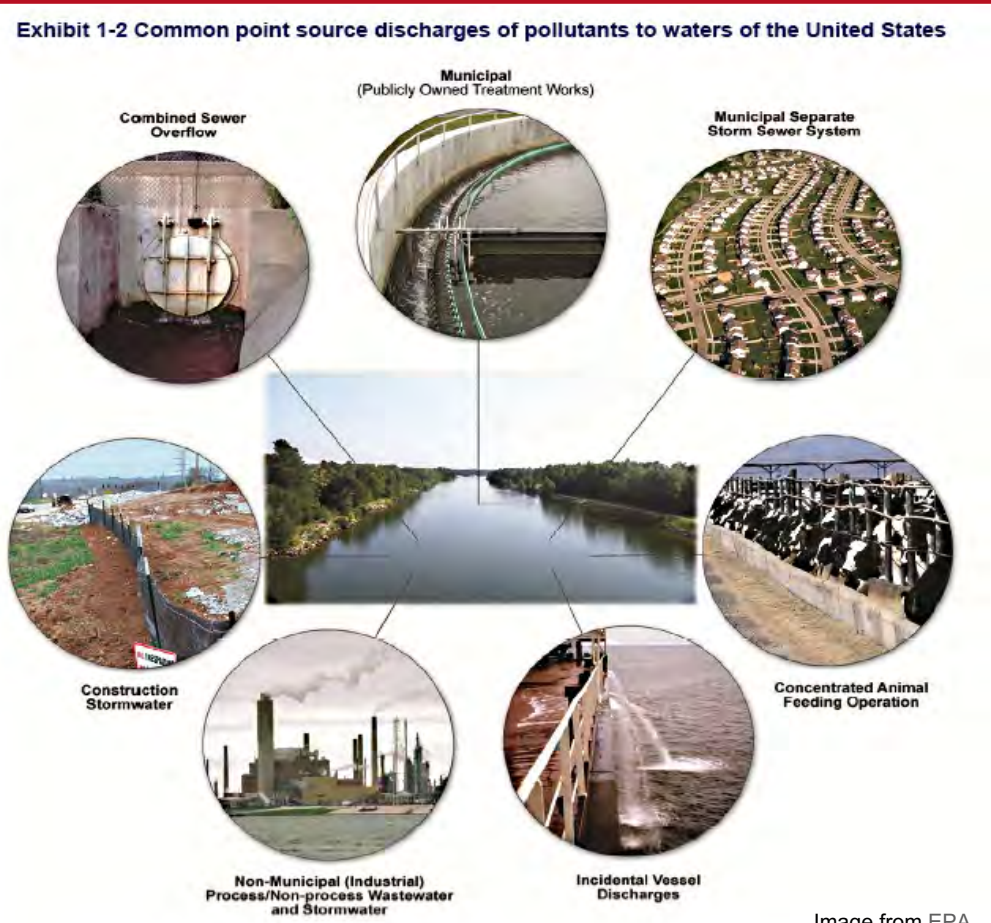


Image from EPA.

Municipal Wastewater

Image by ehpien, Flickr, CC BY-NC-ND 2.0.

Combined Sewer Overflows (CSOs)

Combined sewer systems collect both rainwater runoff and domestic sewage (e.g., wastewater from toilet, washing machine, dishwasher, sink). It transports this wastewater for treatment to a sewage treatment plan.

However, if large storm or rain events occur, the wastewater can overwhelm the system and discharge directly into nearby water bodies and polluting these areas.

National Pollutant Discharge Elimination System, Municipal Wastewater

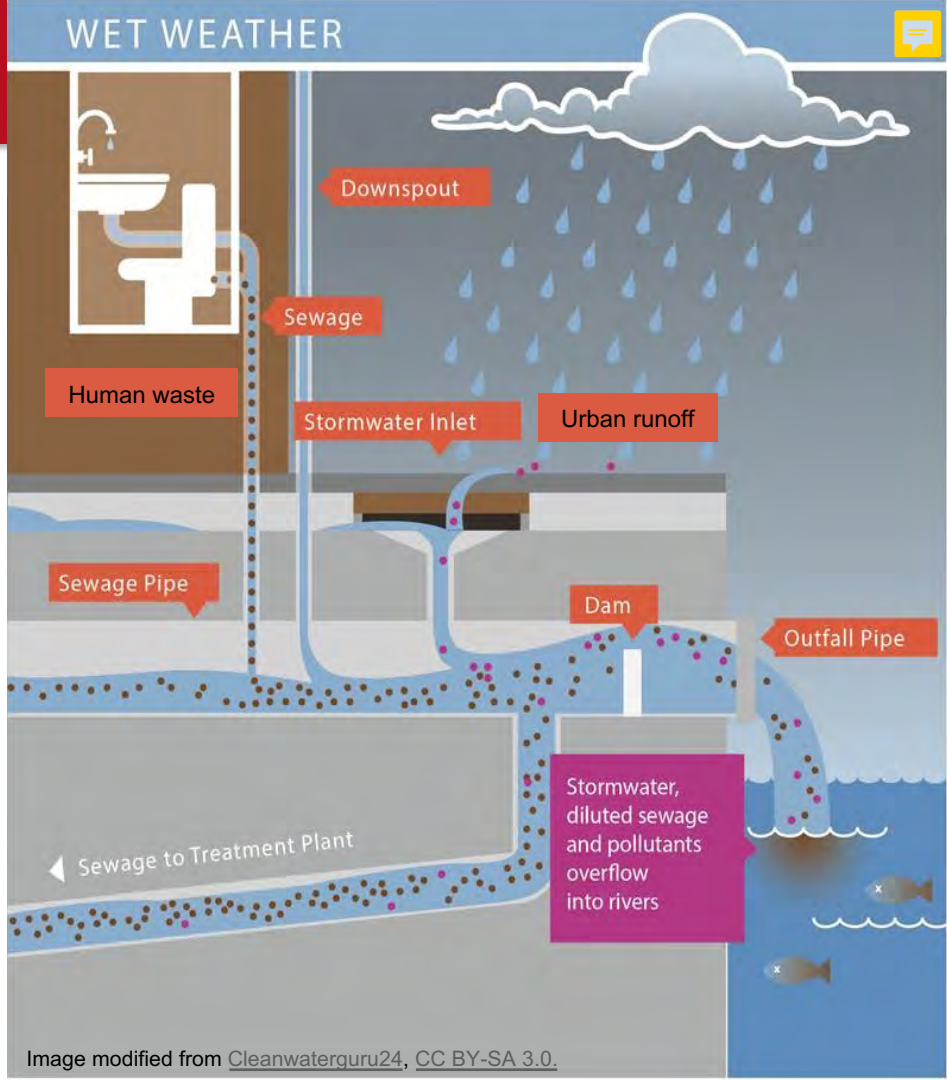


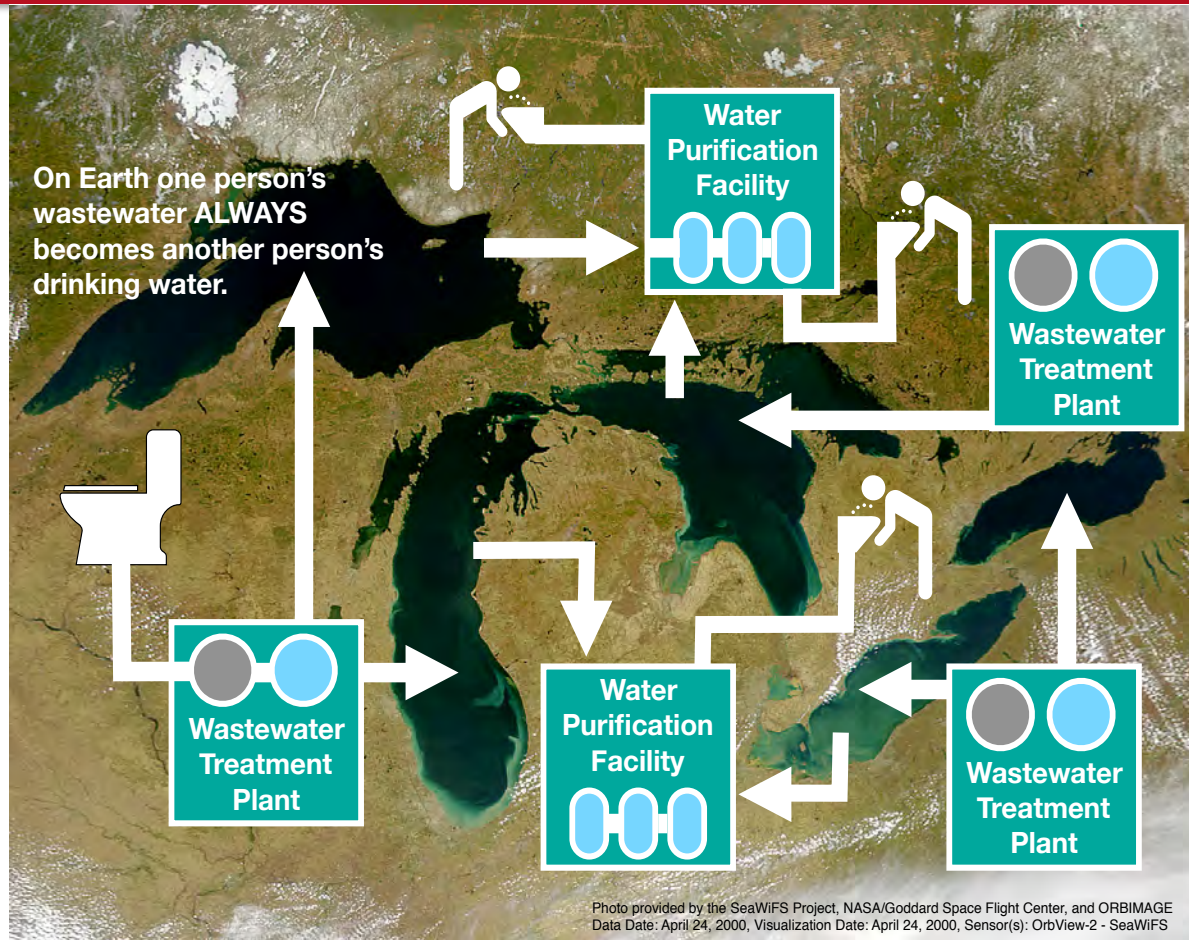
Image modified from Cleanwaterguru24, CC BY-SA 3.0.

Municipal Wastewater Plant

Cleans wastewater and then puts it into a river, lake or ocean

Water Purification Plant

Takes water out of a river or lake, purifies it with filters and distributes it to people as drinking water (i.e., tap water)



Objective 3: Identify and describe key legislation, policies and actions related to the protection of water resources.

Cuyahoga River

Between 1936 and 1969, the Cuyahoga River in Cleveland, Ohio caught fire at least 13 times. The river experienced heavy levels of industrial pollution that was highly flammable.

The large 1969 fire helped spur activism towards environmental awareness and preservation of our nation's water resources. This ultimately resulted in new legislation like the **U.S. Clean Water Act** that aimed to prevent water pollution.

Clean Water Act (CWA) of 1972

Originally passed as the Federal Water Pollution Control Act of 1948 it was amended, rewritten and renamed the Clean Water Act of 1972.

The Clean Water Act is the major federal law governing water pollution in the United States and was a milestone for environmental laws.

The CWA has 2 basic goals:

1. **Eliminate the discharge of toxic pollutants in U.S. waterways**
2. **Attain water quality levels that make U.S. waterways safe for swimming and fishing**

Unfortunately, the EPA estimates that 70% of nation's lakes, ponds and reservoirs and 90% of nation's ocean coastal areas still have not achieved these 2 basic goals today.

Image from EPA.

Clean Water Act of 1972

The Environmental Protection Agency enforces the Clean Water Act (CWA). The CWA of 1977 saw large numbers of amendments as the public became more concerned of water pollution issues.

The CWA introduced a permitting system in order to regulate point sources of pollution. It also establishes efforts to research water quality standards to improve impaired waters of the United States.

Treating and Cleaning Wastewater

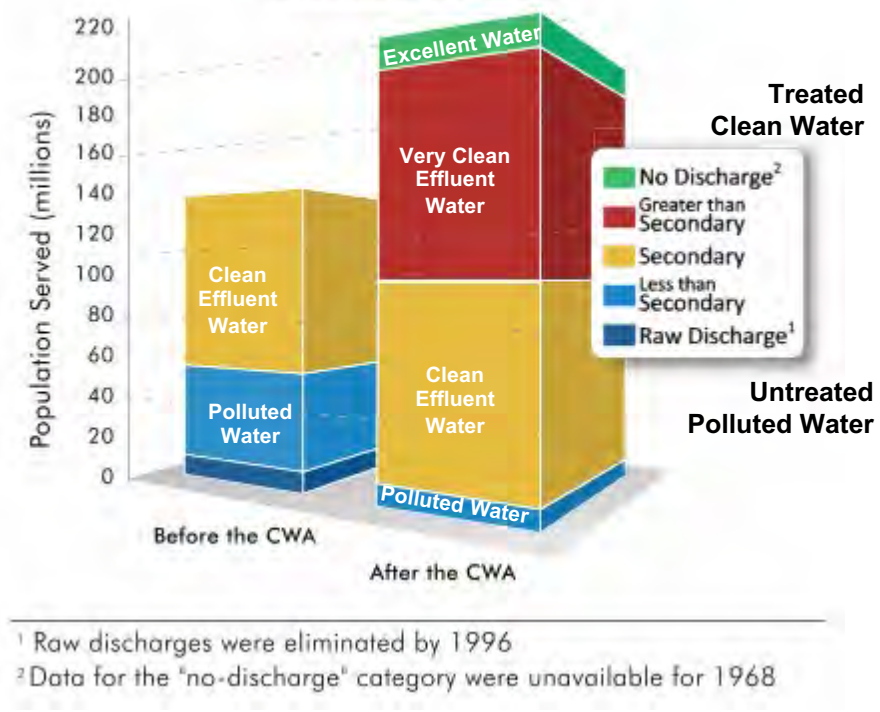


Image modified from EPA.

National Recommended Water Quality Standards

Under the CWA, water quality standards are established. The Water Quality Standards Program (WQS) designates intended uses of surface water in the United States (recreation, agriculture, aquatic life, etc.) and generates water quality criteria based on research data. Criteria includes numerous pollutant levels that affect both aquatic life and human health.

If a body of water does not meet the water quality criteria, a Total Maximum Daily Load (TMDL) will likely be developed.

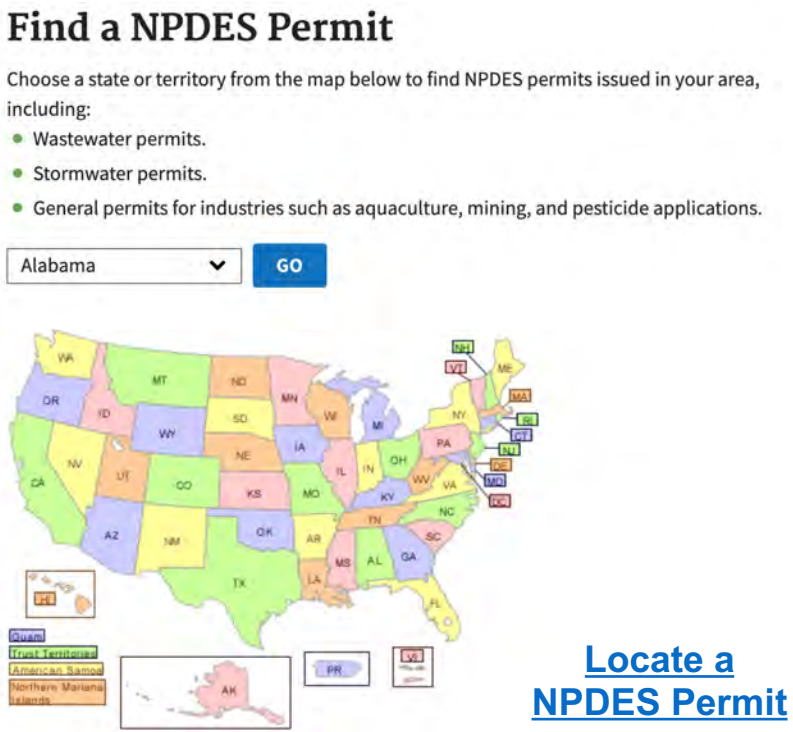
Total Maximum Daily Load (TMDL) = "a calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards" --EPA

National Pollution Discharge Elimination System

The NPDES permit program was established by the Clean Water Act and regulates point source pollution in the United States. Either state governments or the EPA issue permits within each state.

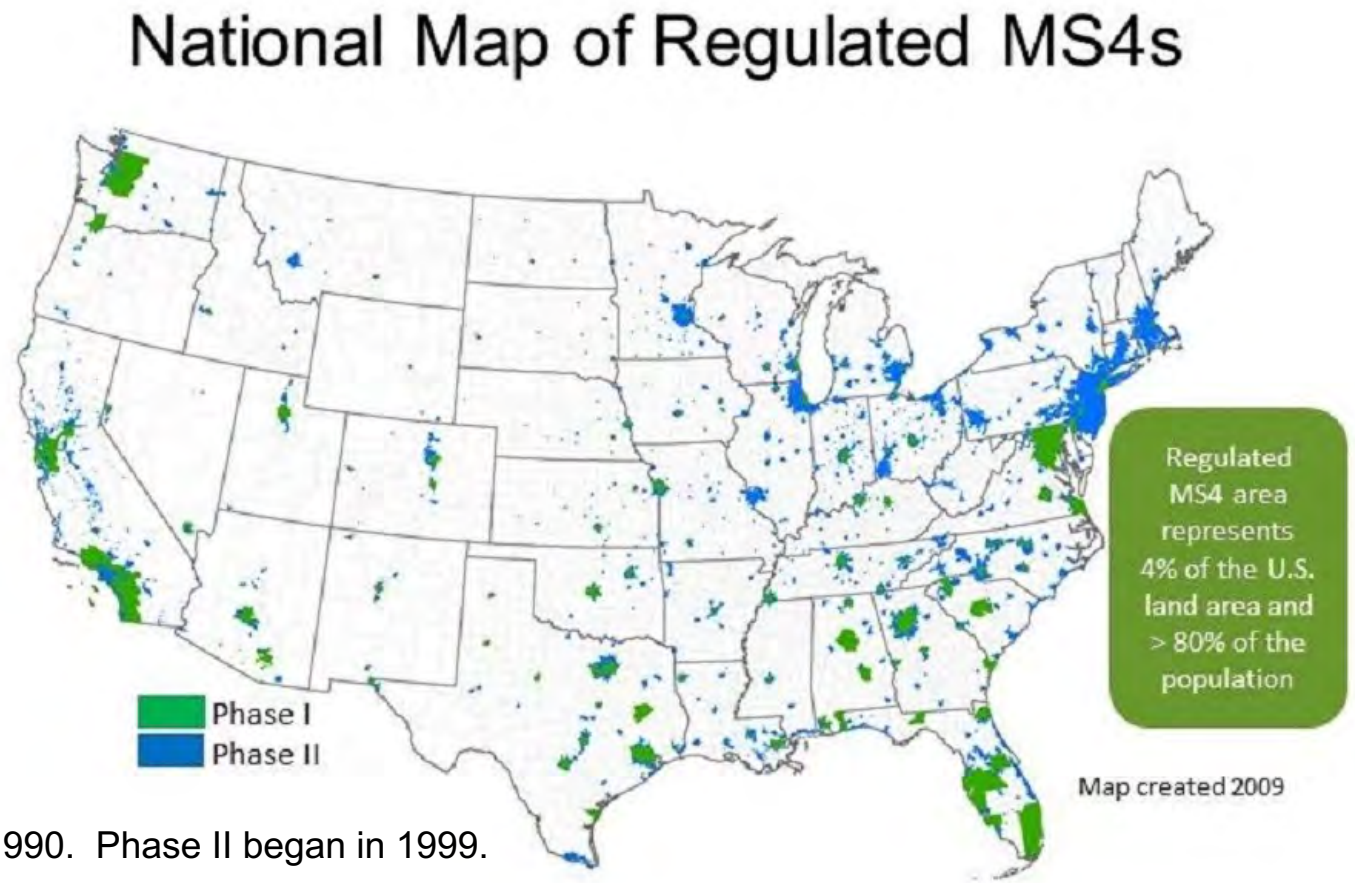
“The Clean Water Act prohibits anyone from discharging pollutants through a point source into a body of water of the United States unless that have an NPDES permit.”

Permits have limits on discharge and require constant monitoring and reporting.



Stormwater Discharges from Municipal Sources

Polluted stormwater runoff is commonly transported through municipal separate storm sewer systems (MS4s) and are often discharged, untreated to streams, rivers, lakes and oceans.



Phase I regulation began in 1990. Phase II began in 1999.

The Fight to Define Water

Water is a finite resource and our most valuable resource. Without it, life cannot exist. Water pollution can be difficult to control and regulate.

The Clean Water Act and rules within it have been amended many times since its creation in 1972 and will likely continue to change as research, policy, and public interest develops. These changes come in the form of new restrictions, technologies, standards, etc.

It is difficult for us to define which waters we want to regulate. Legislation in the past has included the term "**navigable waters" (those that are or have been used by boats and ships for interstate or foreign commerce)** to define what waters are federally regulated.

More amendments and provisions have been created in recent years with goals to even further clarify which waters fall under federal jurisdiction.

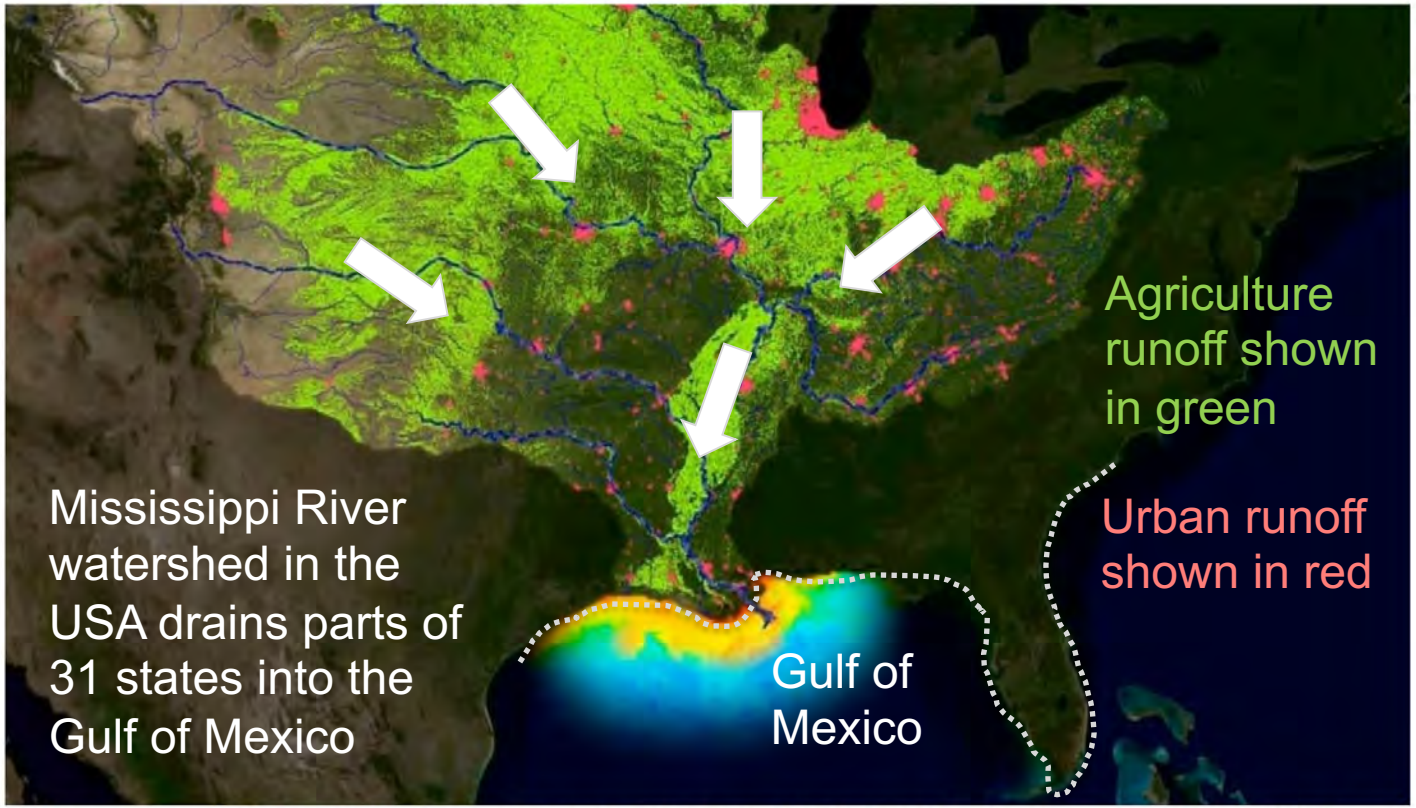
Marine Water Protection

There are several U.S. laws and policies in place that protect marine waters, coastal beaches and the Great Lakes.

- Marine Plastic Pollution Research and Control Act
  - Studies the effects of improper plastic disposal and methods for reduction
- Marine Debris Research, Prevention, and Reduction Act
  - Works to locate and reduce marine debris
- Shore Protection Act
  - Aims to eliminate improper waste management near shorelines
- Marine Protection, Research, and Sanctuaries Act
  - Prohibits ocean dumping from traveling vessels
- BEACH Act
  - Creates water quality standards for areas used as recreation

Objective 4: Identify characteristics and services of riparian areas and describe strategies for maintaining healthy riparian areas and water bodies.

Watershed = an area of land that by gravity, channels snowmelt and rainfall into rivers and streams that flow into an outflow point such as a lake or bay



The Mississippi River watershed drains 1.245 million square miles, including all or parts of 31 U.S. states and two Canadian provinces. This map generally illustrates how runoff from farms (green areas) and cities (red areas) drains into the Mississippi River, delivering nutrients into the Gulf of Mexico and fueling the annual hypoxic zone. Credit: NOAA.

Water from thousands of creeks and streams flows to larger bodies of water through each watershed in the United States. As this water flows, it can pick up pollutants or toxins in its path. These can have negative effects on water quality and aquatic life.

Contaminated water never stays in one place, it is transported by gravity to other freshwater systems, oceans, or into groundwater aquifers.

Riparian Area = areas adjacent to water bodies, such as flood plains or stream banks

Riparian areas may not be large in area, but they are key for healthy watersheds and their ecological function. Riparian areas are essential in providing ecosystem services to surrounding water bodies.

They are unique in that they properly cycle nutrients and water, control hydrologic function and water flow, and provide plant and animal habitat.

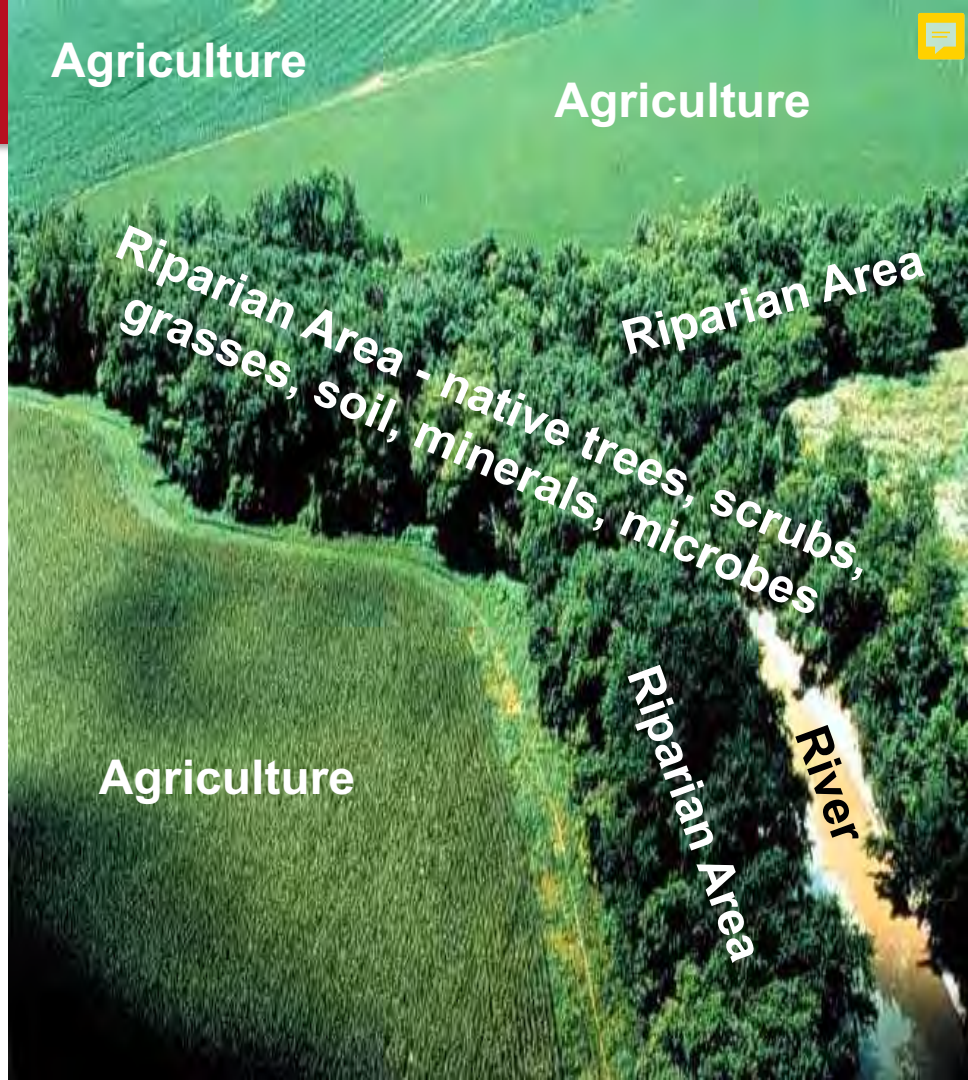
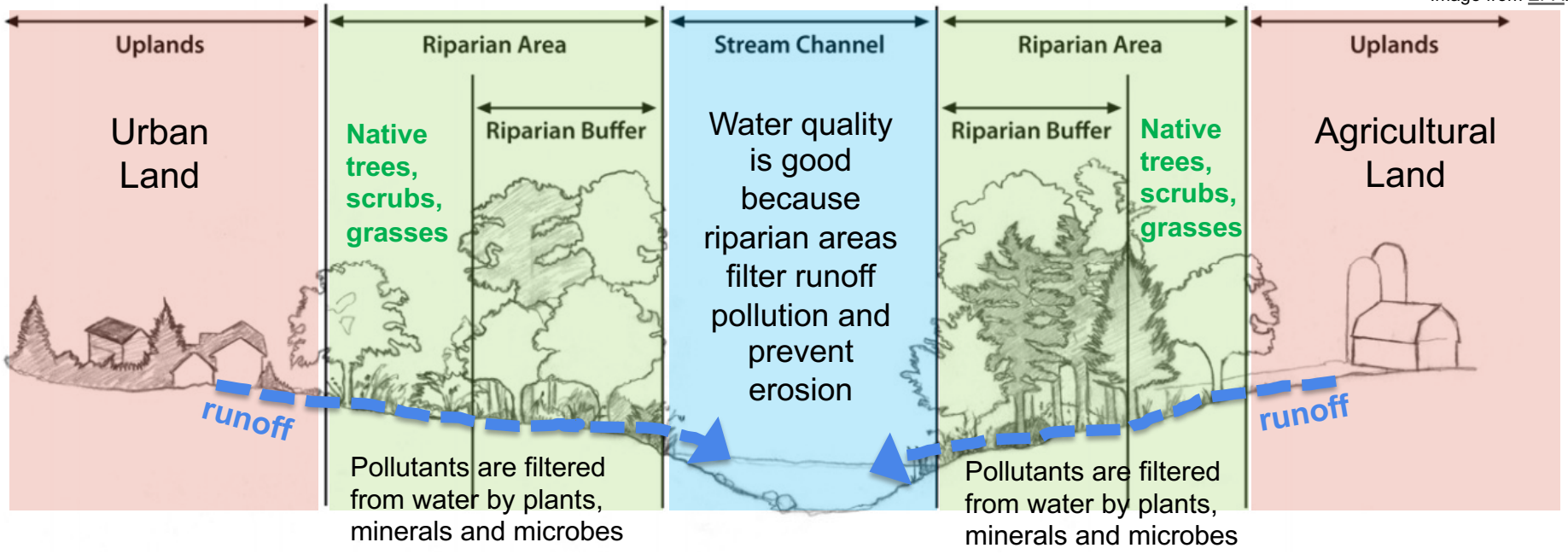


Image from EPA.



Riparian areas are characterized by their **soils** and **vegetation**. Soils that have larger particles (sandy/loamy) allow for more infiltration and transmission of water. A diversity of vegetation is important in riparian areas to provide habitat, nutrients, proper drainage, stability, etc. Trees are especially important for their root systems that hold banks in place and reduce erosion.

Benefits of Riparian Areas

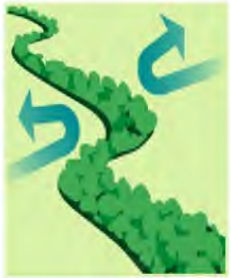
- Filter sediment pollution
- Filter nutrient pollution
- Plants and soil minerals absorb pollutants
- Soil microbes absorb, break down pollutants
- Reduce flooding and controls water flow
- Create and maintain aquatic habitat
- Maintain water quality levels for aquatic life
- Aesthetic value

Habitat—the spatial structure of the environment which allows species to live, reproduce, feed, and move.

Habitat

Filter–the selective penetration of materials, energy, and organisms.

Filter



Barrier—the stoppage of materials, energy, and organisms.

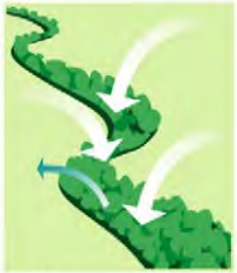
Barrier

Source—a setting where the output of materials, energy, and organisms exceeds input.

Source

Conduit-the ability of the system to transport materials, energy, and organisms.

Conduit



Sink—a setting where the input of water, energy, organisms and materials exceeds output.

Sink

Image from EPA.

Conducting Research

There are many federal and state agencies that conduct research on our nation's water resources. The U.S. Environmental Protection Agency (EPA) and the United States Geological Survey (USGS) are two prominent agencies in this research.

The USGS has water quality laboratories across the country where water samples are analyzed. Over 150 field offices conduct research and protect our water resources by:

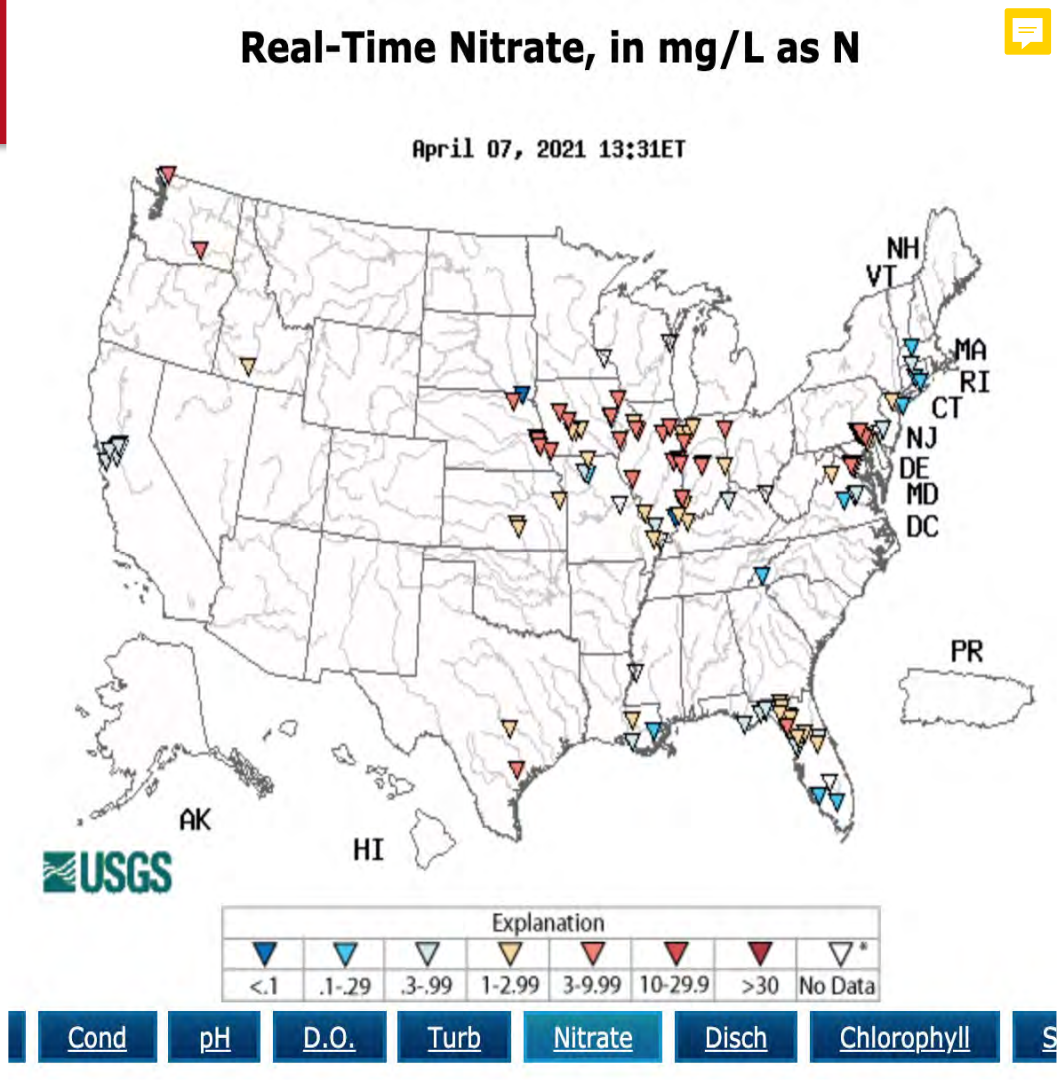
- Collecting water samples from groundwater and surface-water bodies
- Measuring water properties, such as pH or temperature
- Compiling data from many sources on water use
- Writing reports on water resources
- Creating water databases and computerized models
- Producing maps, reports and websites to educate the public
- Informing governmental leaders of water related issues

Monitoring and Assessment

Water research and monitoring allows scientists to develop long term programs, such as the USGS's National Water Quality Assessment (NAWQA) Project. Based on data collected over time, researchers can assess the conditions and propose new solutions or strategies.

This real-time nitrate tracker shows the concentration of nitrate at different USGS sample sites throughout the USA.

[WaterQualityWatch Continuous Real-Time Water Quality of Surface Water in the United States]

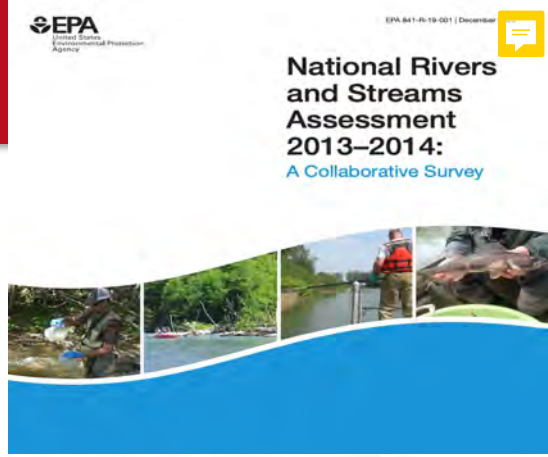


Freshwater Ecosystem Health Indicators

Scientists at the EPA, evaluate water quality based on health indicators. These surveys help form water policy and guide protection efforts. Researchers typically look at many indicators, specifically biological, chemical, physical and human health.

Indicator = "represents the state or trend of certain environmental conditions over a given area and a specified period of time" --EPA

The EPA National Rivers and Streams Assessment (NRSA) uses indicators to provide an overall evaluation of our nation's streams and rivers. Four types of indicators: (1) Biological, (2) Chemical, (2) Physical and (4) Human Health

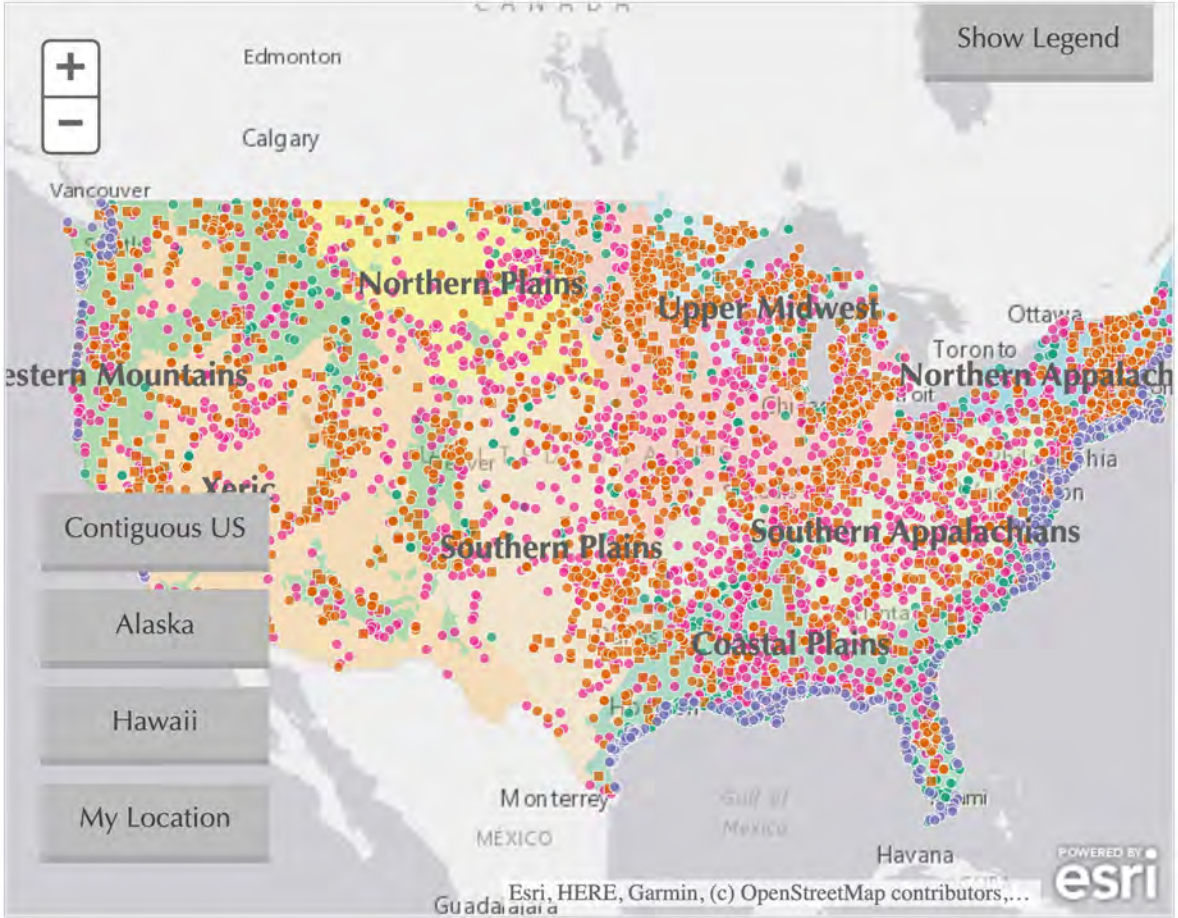


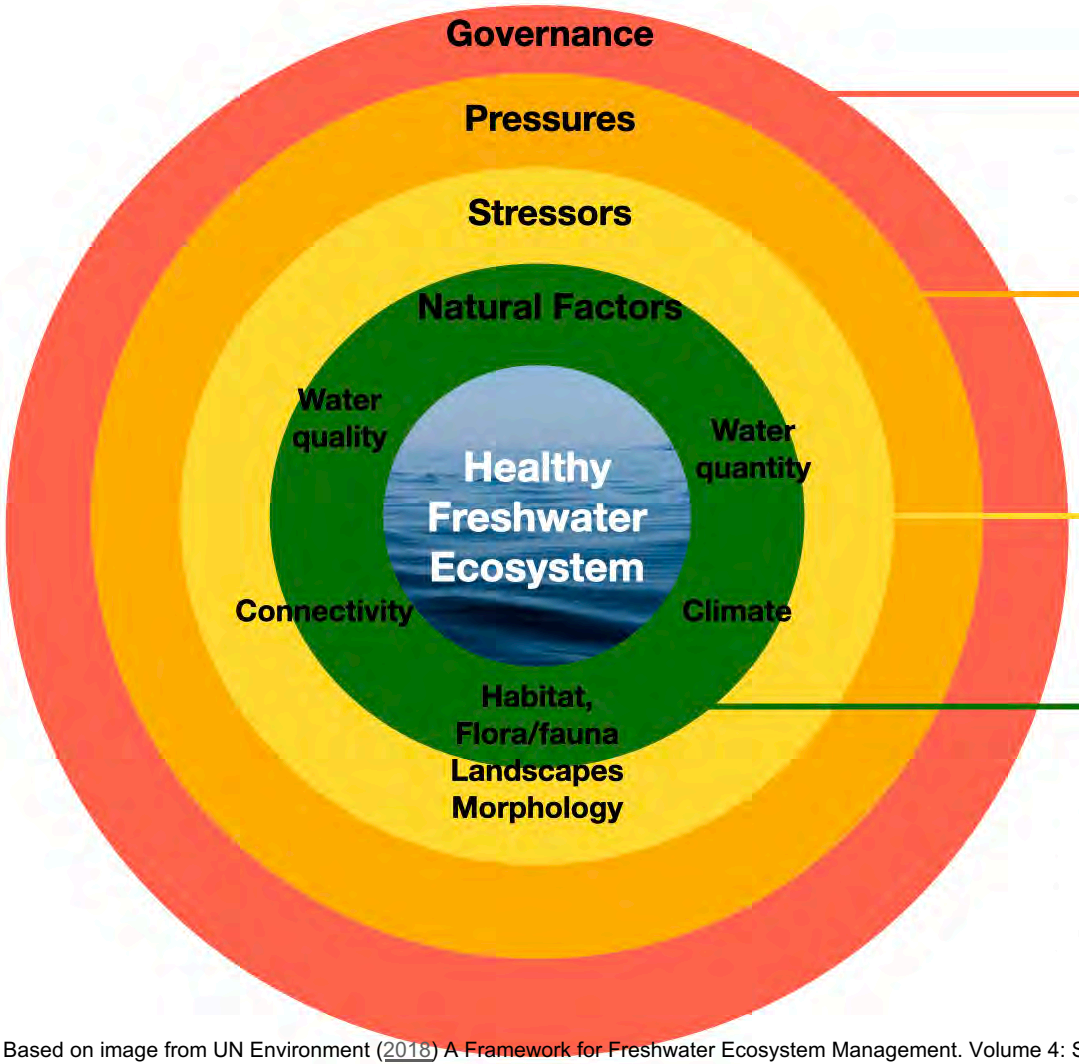
Biological Indicators	• Macroinvertebrates • Fish
Chemical Indicators	• Phosphorus • Nitrogen • Salinity • Acidification
Physical Indicators	• In-stream Fish Habitat • Riparian Disturbance • Riparian Vegetative Cover • Streambed Sediments
Human Health Indicators	• Enterococci • Microcystins • Contaminants in Fish Tissue

U.S. EPA, National Rivers and Streams Assessment (NRSA) Sampling Sites

The goals of the NRSA are to determine the extent to which rivers and streams support a healthy biological condition and the extent of major stressors that affect them. The survey supports a longer-term goal: to determine whether our rivers and streams are getting cleaner and how we might best invest in protecting and restoring them.

[National Rivers and Streams Assessment (NRSA)]





Governance

Institutions, ethics, value systems, population dynamics, multi-stakeholders, financial mechanisms

Pressures

Recreation, human settlements, hazard security, terrestrial biomass production, transport — infrastructure and traffic, hydropower generation, biomass extraction, water withdrawal

Stressors

Water infrastructure, flow alteration, modification of aquatic habitat, overexploitation, biological water pollution, chemical water pollution, thermal water pollution

Natural Factors

Water quality: geo hydrochemistry, geological/geophysical factors, nutrient cycling, sediments
Connectivity: lateral/longitudinal surface/ground-water lakes, wetlands, rivers/floodplains, waterfalls, watersheds
Habitat, flora&fauna, landscapes, morphology: mountain to coasts continuum
Climate: precipitation, winds, ice regime, temperature, evapotranspiration

Based on image from UN Environment (2018) A Framework for Freshwater Ecosystem Management. Volume 4: Scientific Background

What can YOU do to protect water?

1. Be aware of what you are dumping down your drain.
2. Practice water conservation in your home.
3. Reduce your use of plastic and recycle.
4. Clean up your pet waste.
5. Clean up litter and properly dispose of outdoor waste.
6. Check your vehicles for leaks and repair if needed.
7. Minimize use of pesticides, herbicides and fertilizers.
8. Reduce erosion in your yard with proper landscaping.
9. Purchase and use environmentally friendly household cleaning agents.
10. Research the companies that you support and be a well-informed consumer.