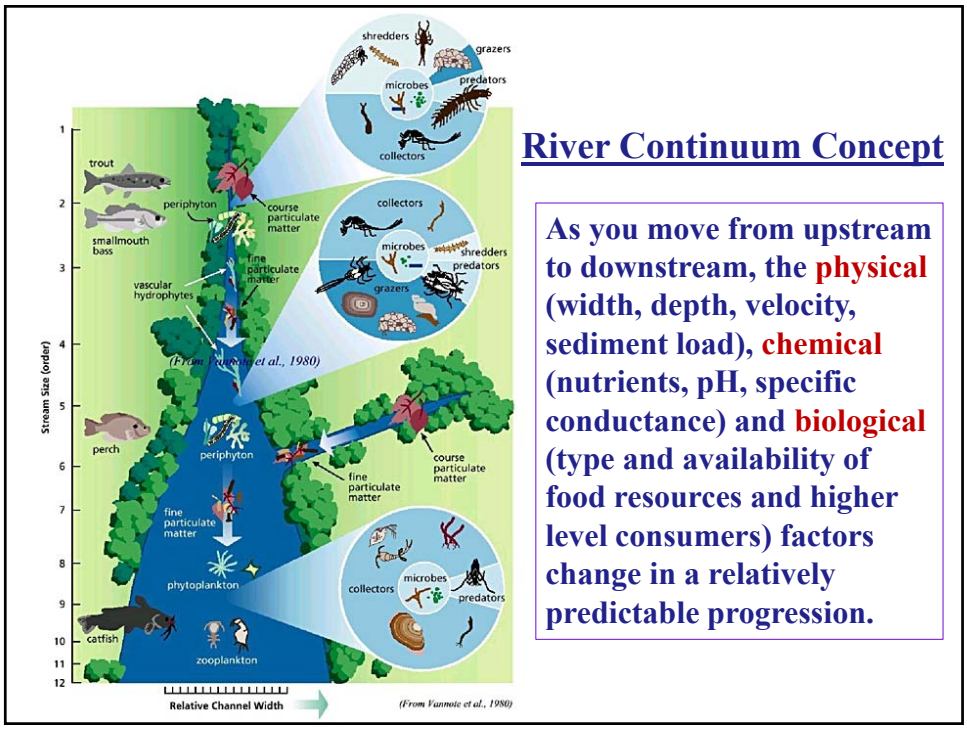
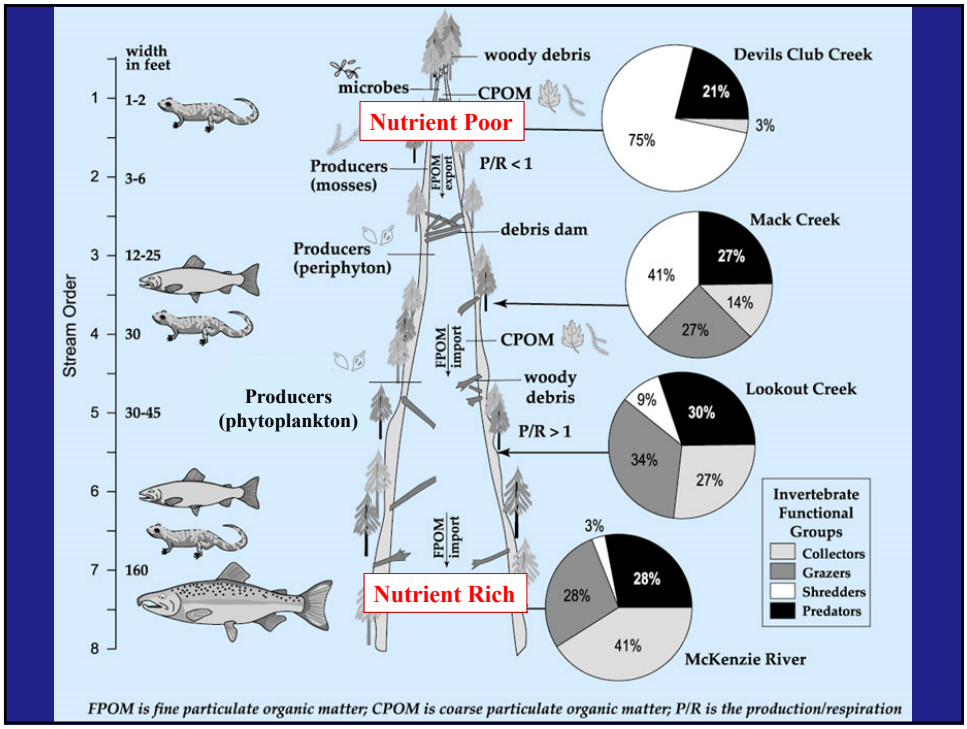


River Continuum Concept

As you move from upstream to downstream, the **physical** (width, depth, velocity, sediment load), **chemical** (nutrients, pH, specific conductance) and **biological** (type and availability of food resources and higher level consumers) factors change in a relatively predictable progression.



Nutrient

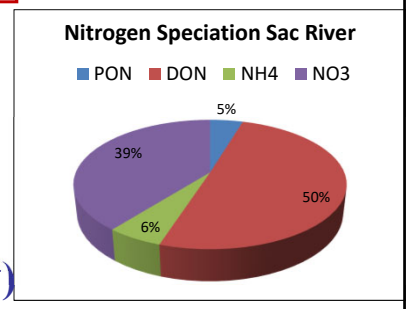
Nitrogen & Phosphorus

Nitrogen

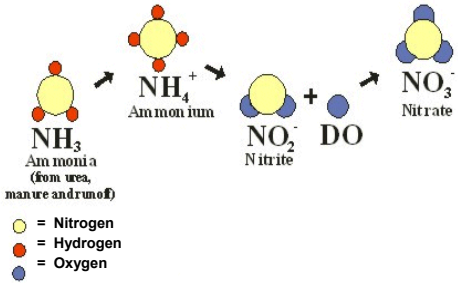
Organic forms
- **particulate (PON)**
- **dissolved (DON)**

Ammonium (NH_3/NH_4^+)

Nitrate (NO_3^-)/Nitrite (NO_2^-)



Organic N



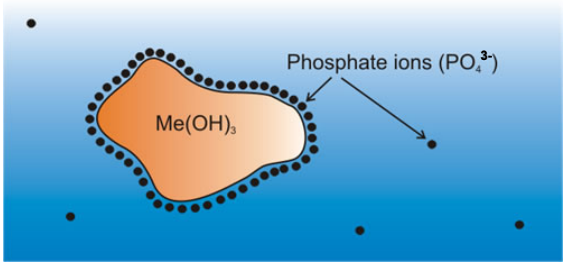
Phosphorus

Organic forms

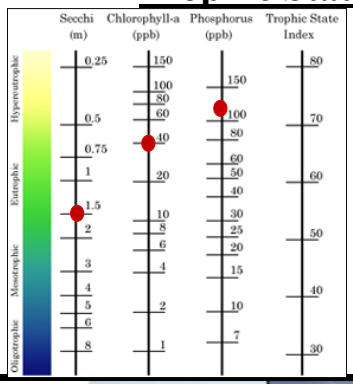
Adsorbed to particles

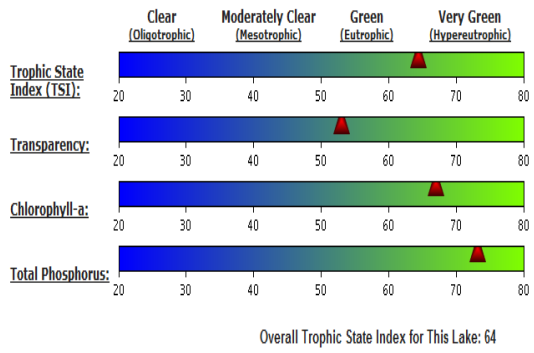
Dissolved phosphate (PO_4^{3-})

Organic P

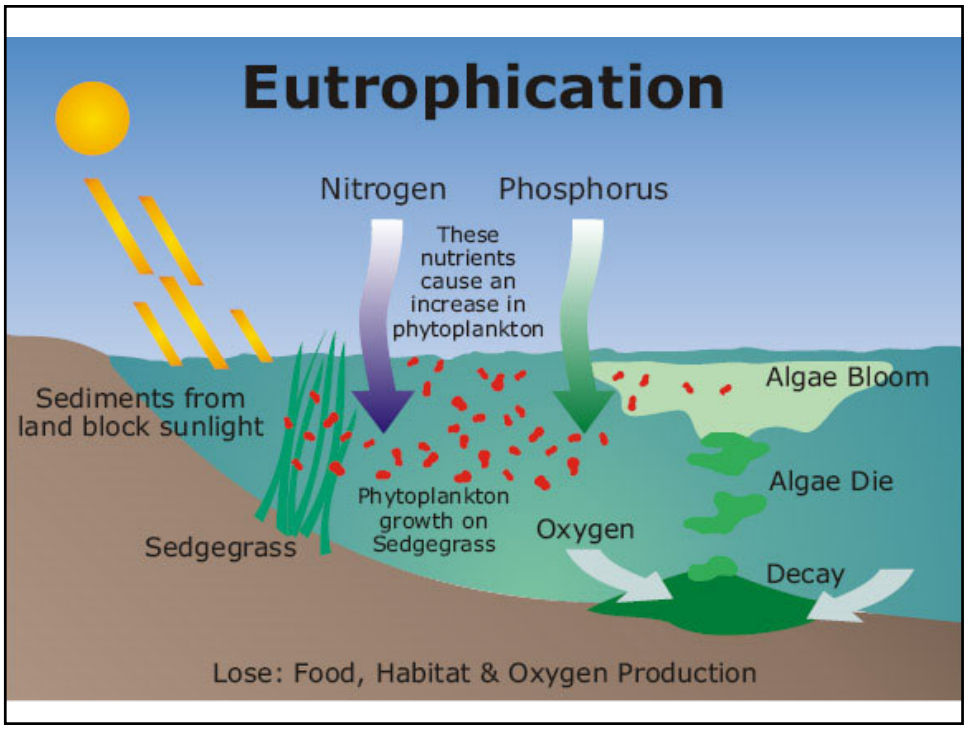


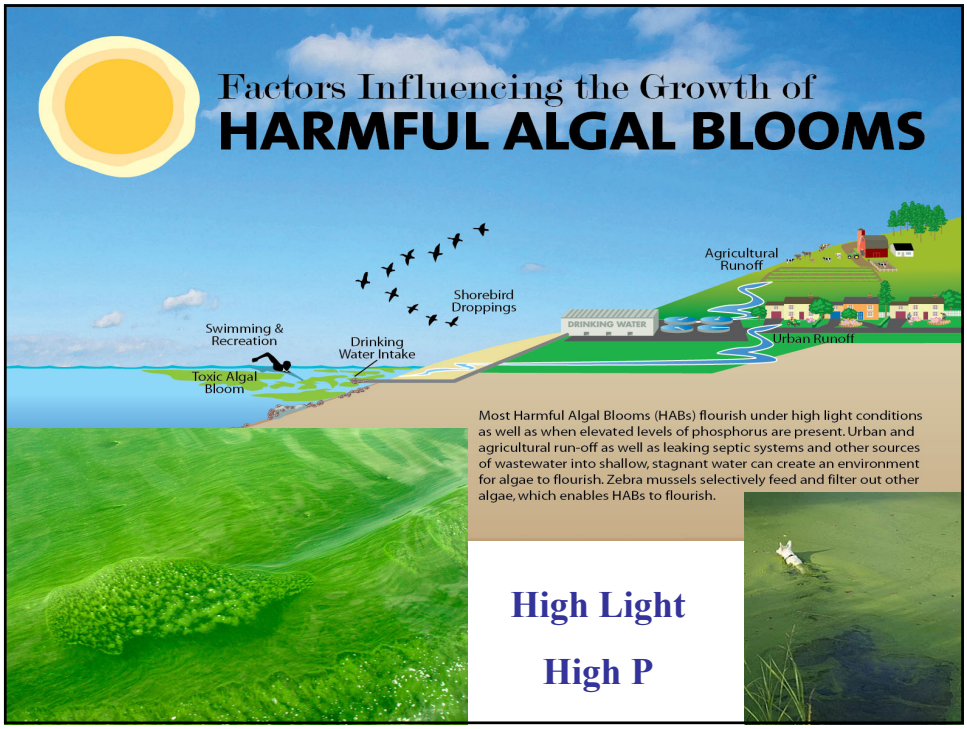
Trophic State Index for Lakes/Rivers





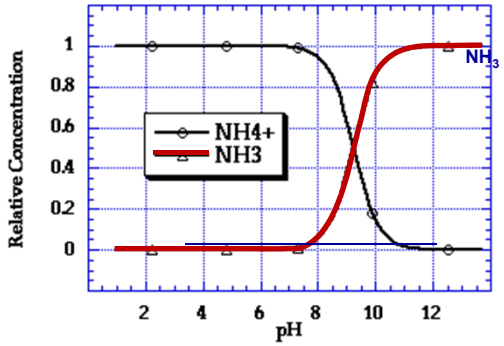
Low Oligotrophic | Medium Mesotrophic | High Eutrophic | Very High Hypereutrophic





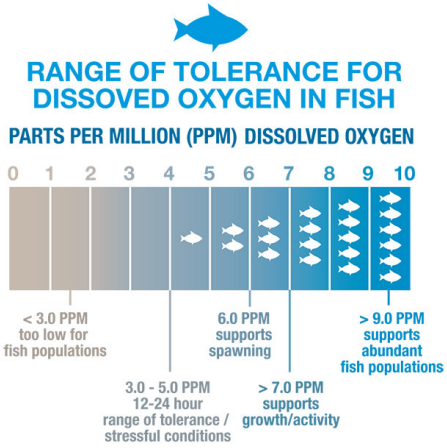
Ammonia (NH_3) Toxicity – Aquatic Ecosystems

Criterion Duration	2013 Final Criteria TAN at pH = 7 & 20 °C
Acute (1-hr average)	17 mg N/L
Chronic (30-d rolling average)	1.9 mg N/L
TAN = NH_3 + NH_4^+	



Dissolved Oxygen (DO) is the amount of oxygen that is present in the water. It is measured in milligrams per liter (mg/L), or the number of milligrams of oxygen dissolved in a liter of water.

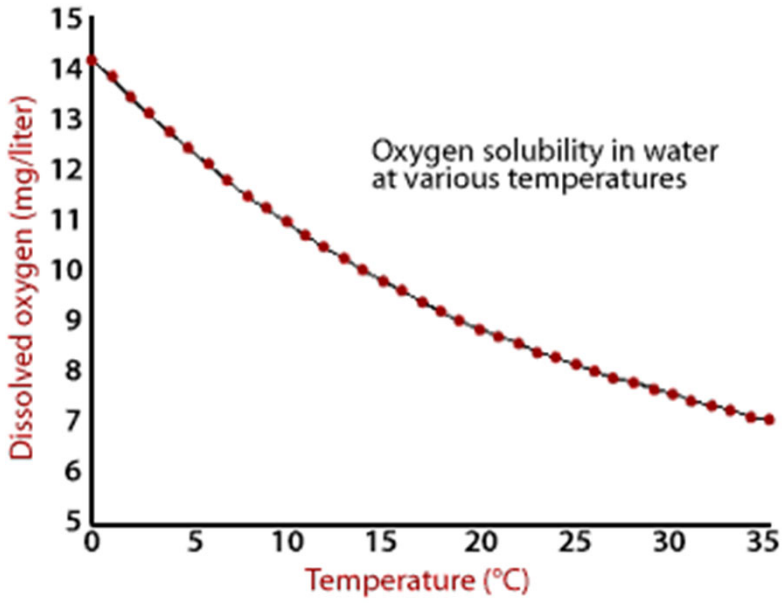
Dissolved Oxygen Stress to Aquatic Organisms



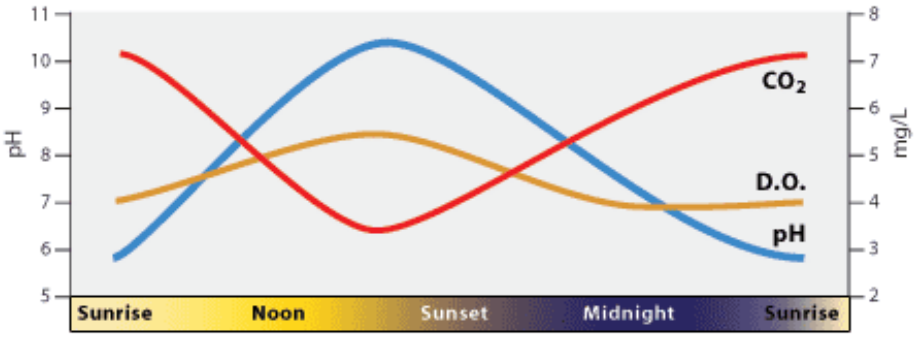
DO Concentration is a function of:

1. **Elevation**
2. **Temperature**
3. **Salinity**
4. **Barometric Pressure**
5. **Time of Day**

Oxygen Solubility in Water vs Temperature



Diel Dissolved Oxygen Dynamics



Algae Photosynthesis

$$HCO_3^- + H_2O \rightarrow (CH_2O) + O_2 + {+} + OH^-$$

Bicarbonate ion | Water | Carbohydrate | Oxygen | Hydroxyl ion

Organic Matter Respiration

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O + \text{energy}$$

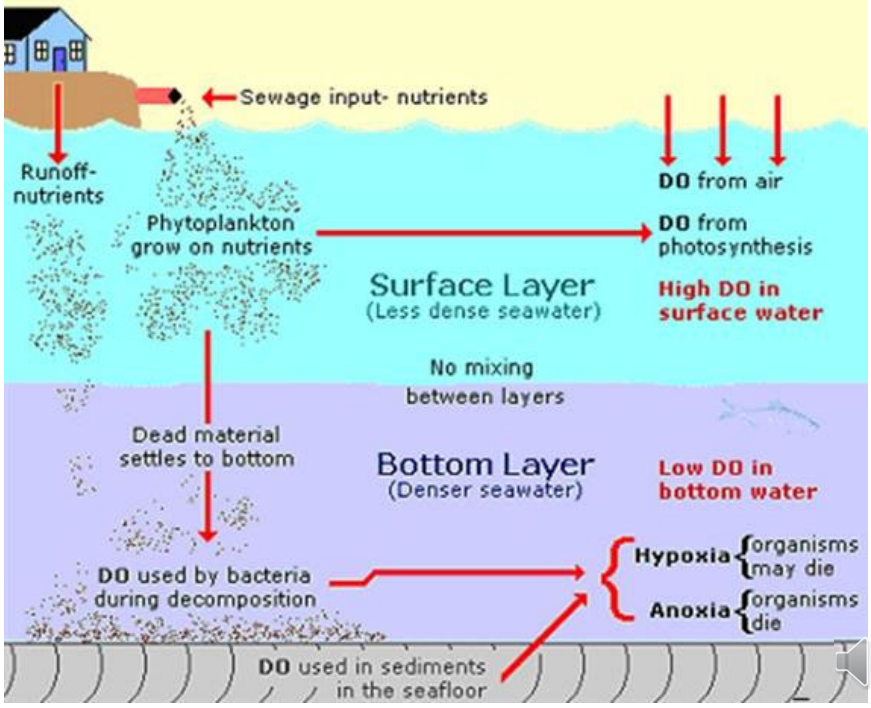
Respiration →

← Photosynthesis

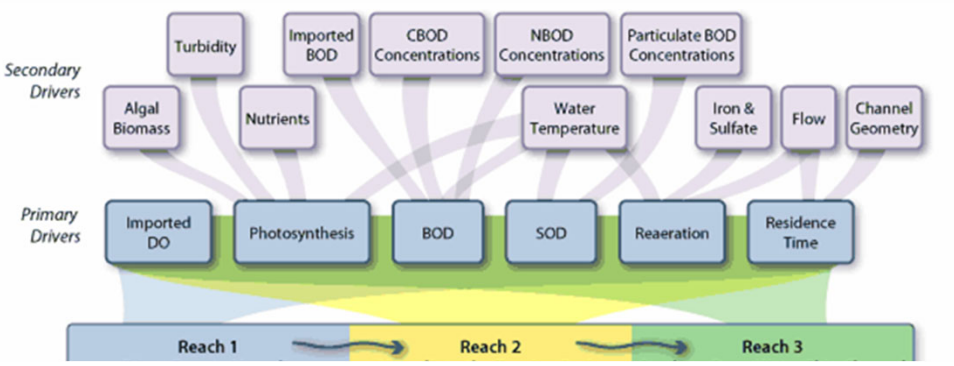
Nitrification

$$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 2H_2O + 4H$$

$$2NO_2^- + O_2 \rightarrow 2NO_3^-$$

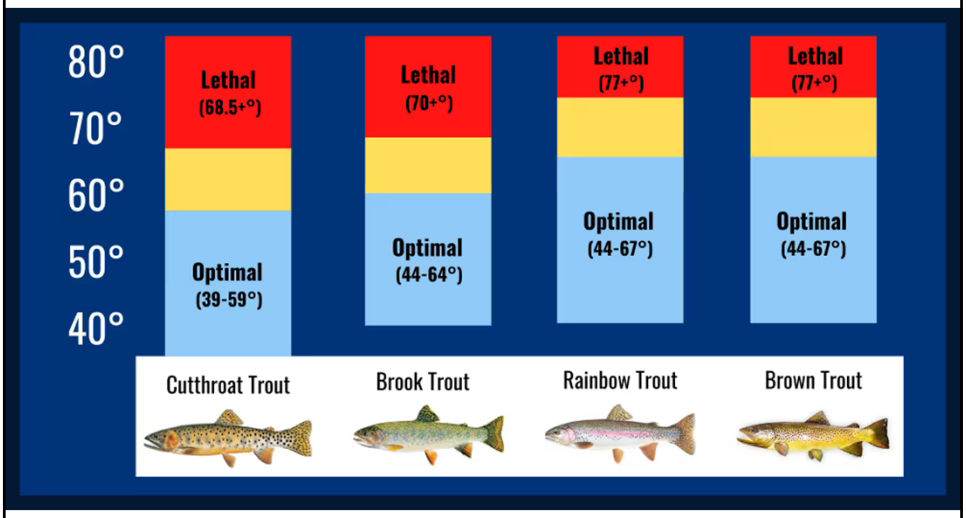


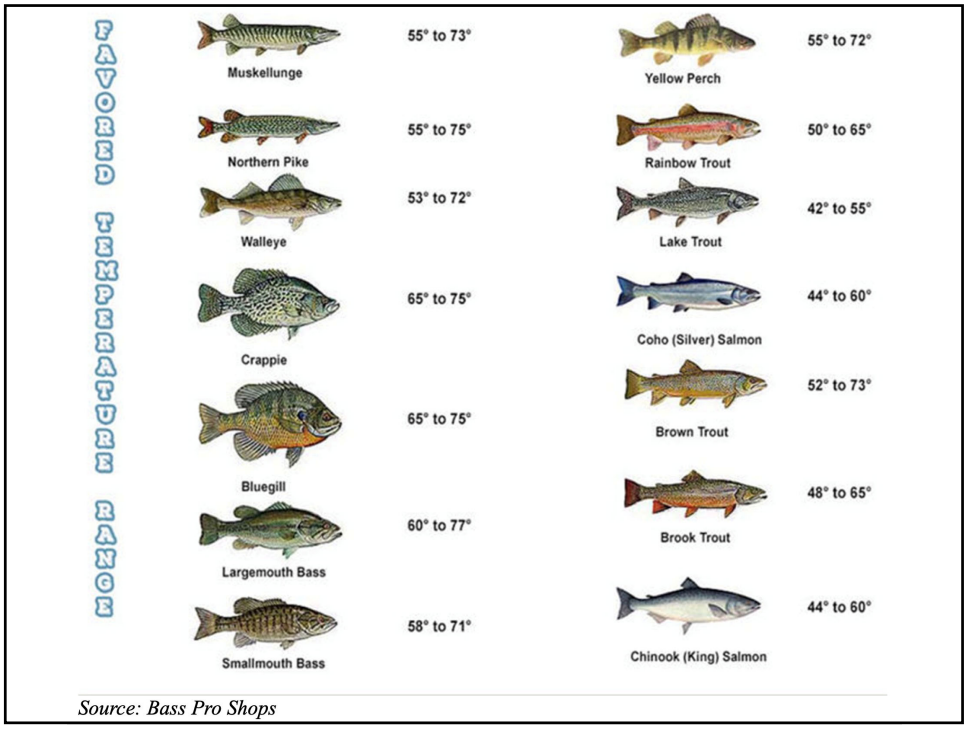
Dissolved Oxygen Conceptual Model for River Systems



Dissolved Oxygen

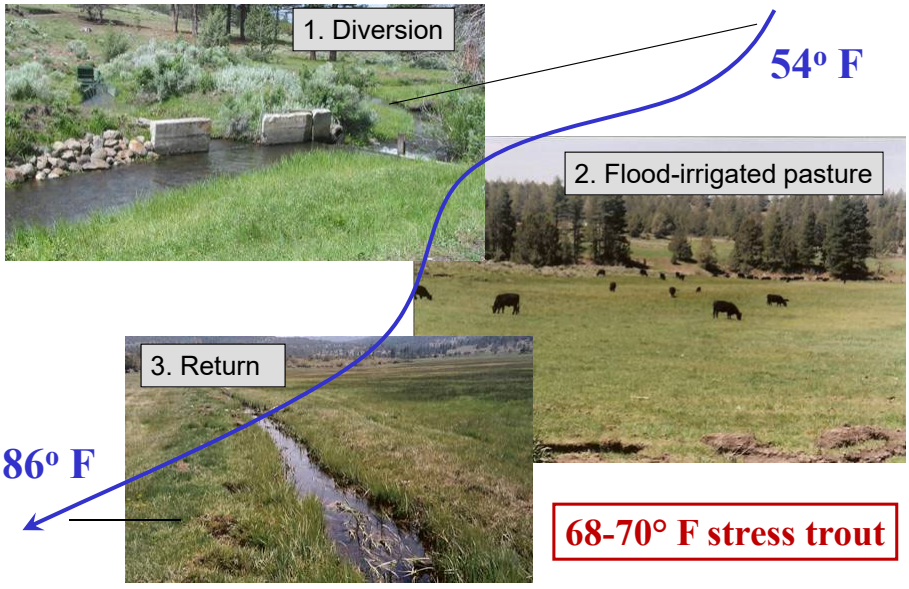
Stream Temperature – Heat Pollution





Source: Bass Pro Shops

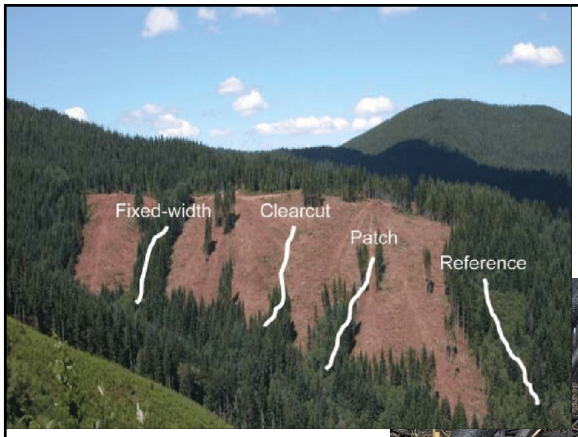
Stream Temperature – Heat Pollution



68-70° F stress trout

Grazing and Stream Temperature

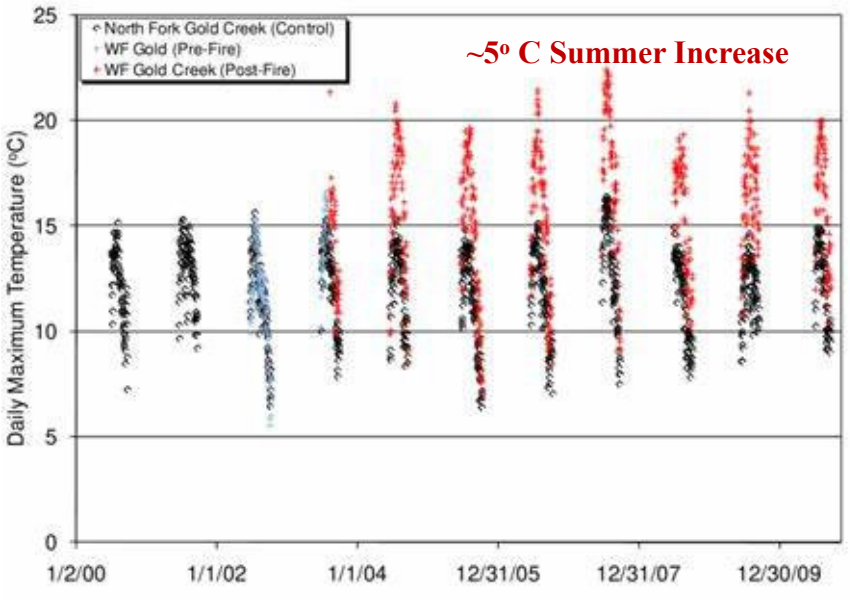
Excessive Grazing ⟶ Reduced Shade



Clearcut Harvesting

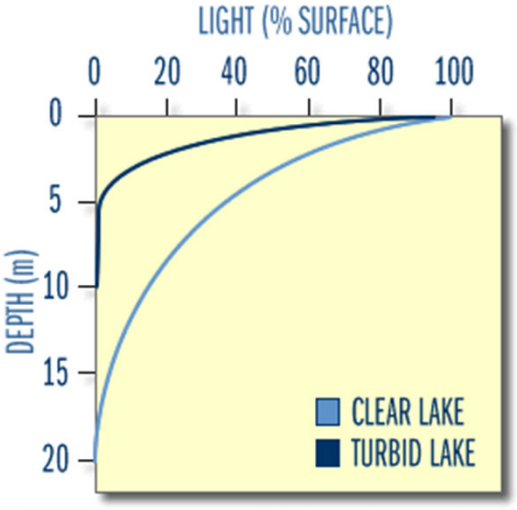
Wildfire Disturbance

Post-Fire Stream Maximum Stream Temperature – Western Montana

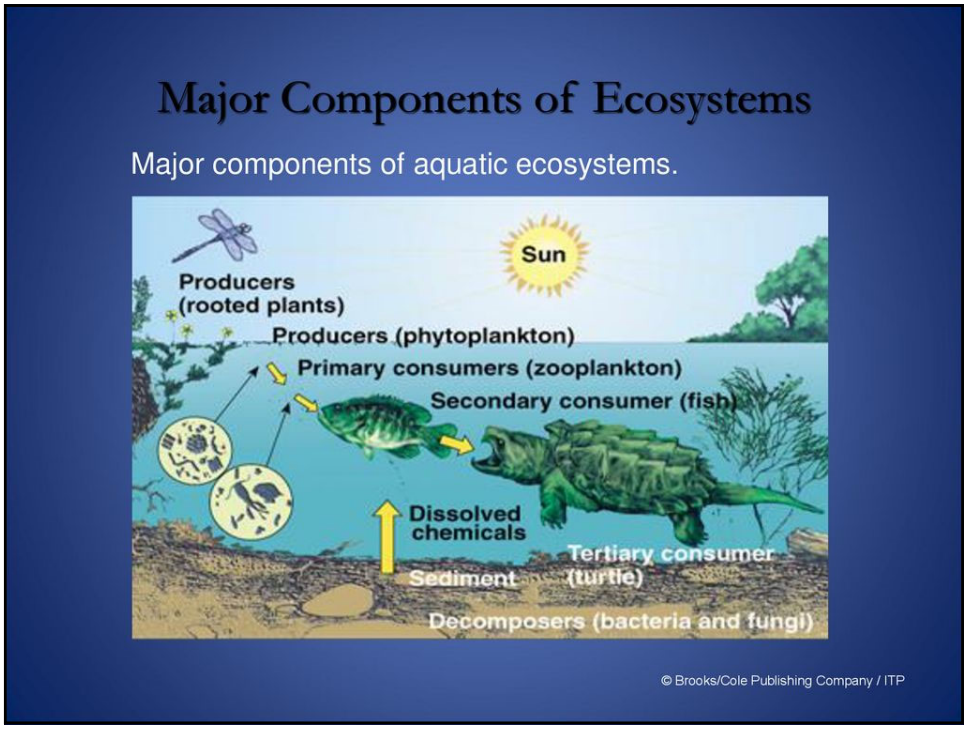


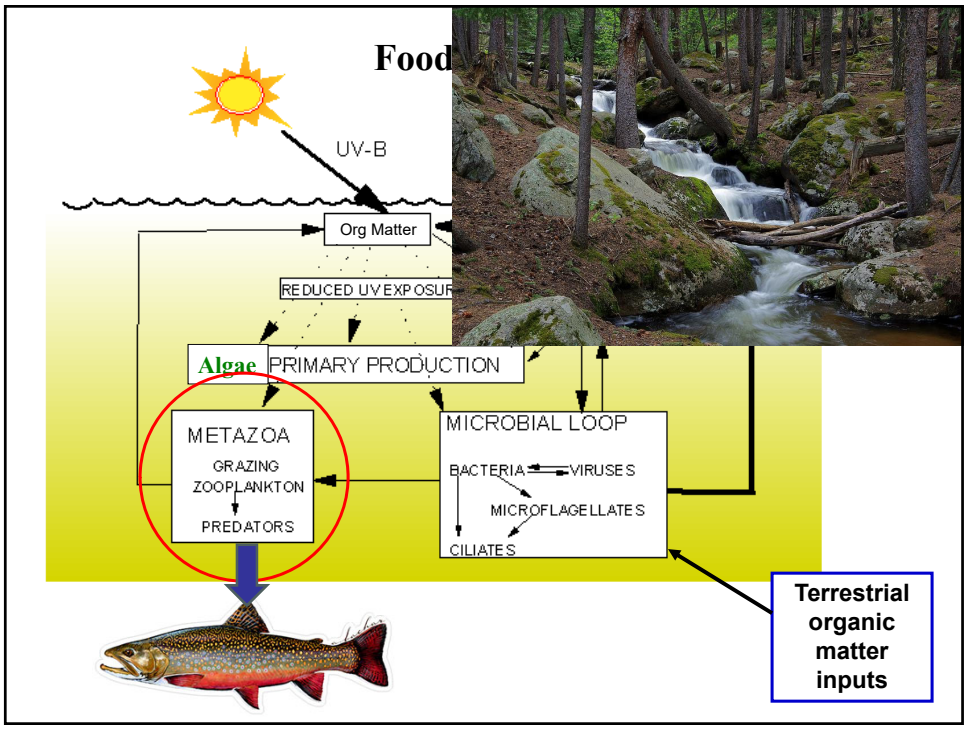
Photic Zone

Depth to 1% light extinction



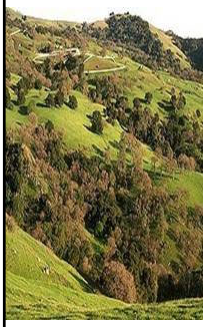
LIGHT VERSUS DEPTH PROFILES FOR A CLEAR LAKE ($k=0.2\ M^{-1}$) AND A TURBID LAKE ($k=0.9\ M^{-1}$).

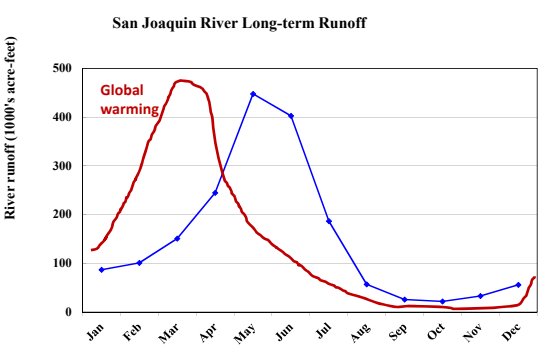

Major Components of Ecosystems
Major components of aquatic ecosystems.
Sun
Producers (rooted plants)
Producers (phytoplankton)
Primary consumers (zooplankton)
Secondary consumer (fish)
Dissolved chemicals
Sediment
Tertiary consumer (turtle)
Decomposers (bacteria and fungi)
© Brooks/Cole Publishing Company / ITP

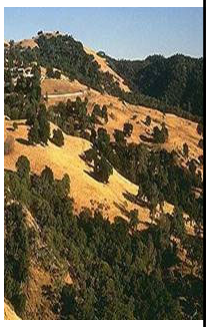

Food
UV-B
Org Matter
REDUCED UV EXPOSUR
Algae
PRIMARY PRODUCTION
METAZOA
GRAZING ZOOPLANKTON
PREDATORS
MICROBIAL LOOP
BACTERIA
VIRUSES
MICROFLAGELLATES
CILIATES
Terrestrial organic matter inputs

California's Mediterranean Climate

Winter Feast **Summer Famine**

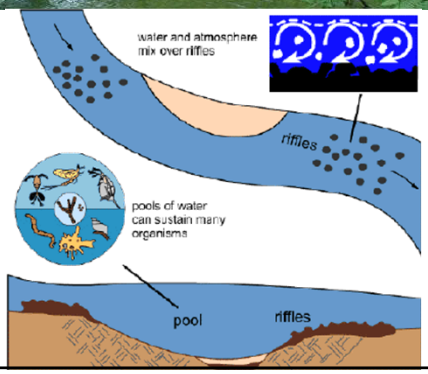






Winter **arm-dry**

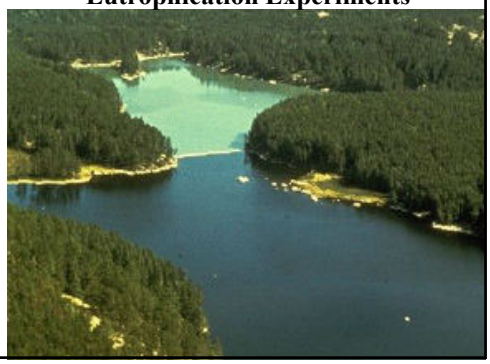
Stream Habitat



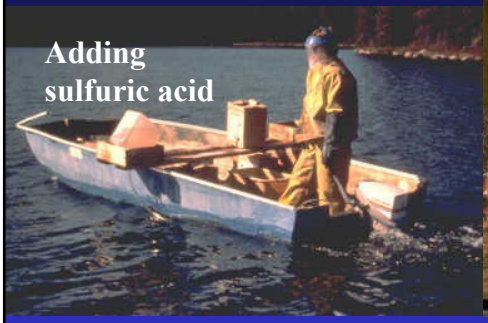
Experimental Lakes Area
Ontario, Canada

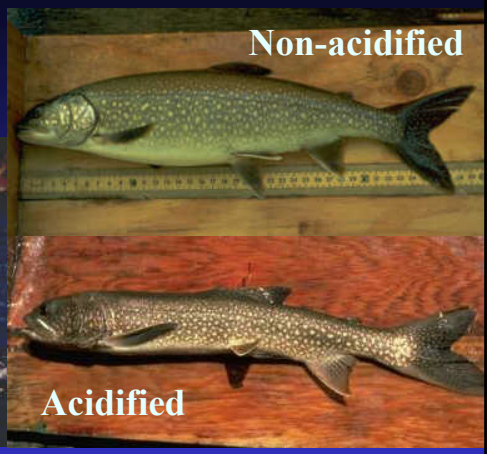
David Schindler

Eutrophication Experiments

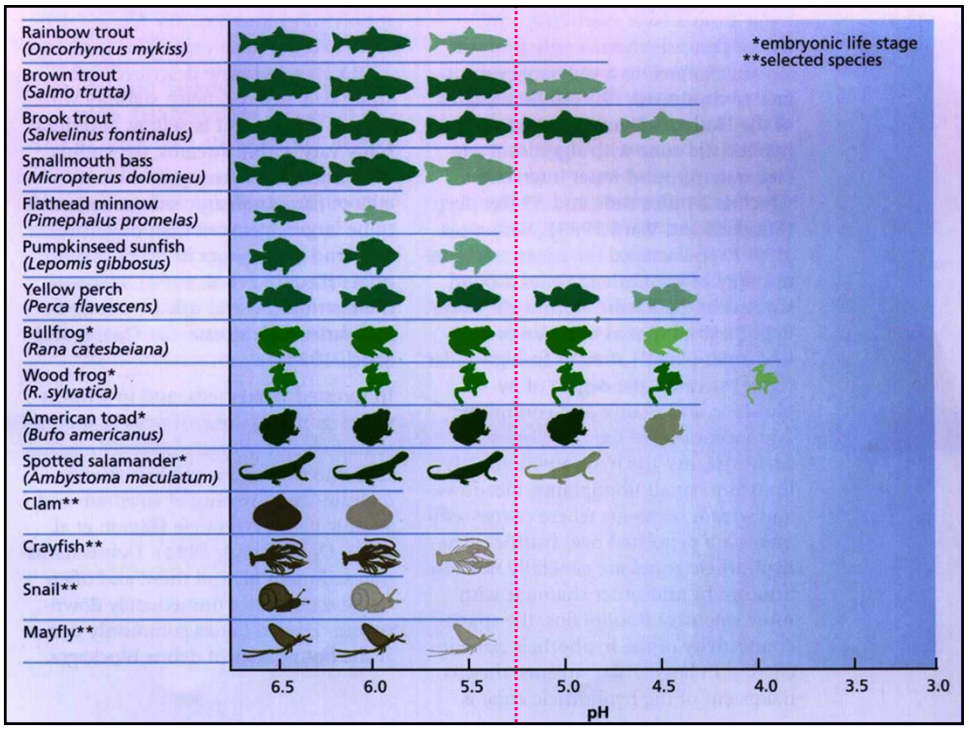


Lake Acidification in Canada





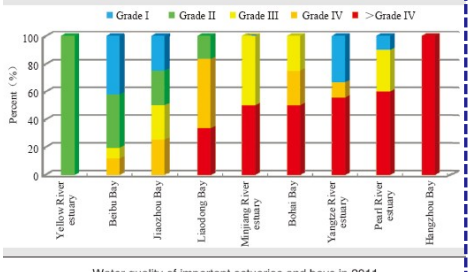
A starving lake trout captured in acidified Lake 223 when the pH was 5.1. Most of the trout's food supply had been killed off by the acid.



Adding lime to increase the pH of lakes in northern USA

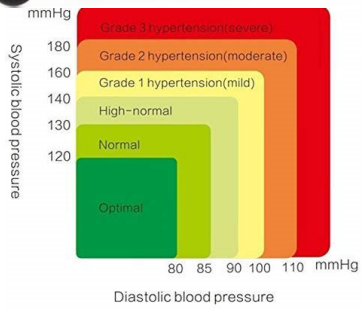
$CaCO_3$ (lime) + H_2O = Ca^{2+} + HCO_3^- + OH^- base

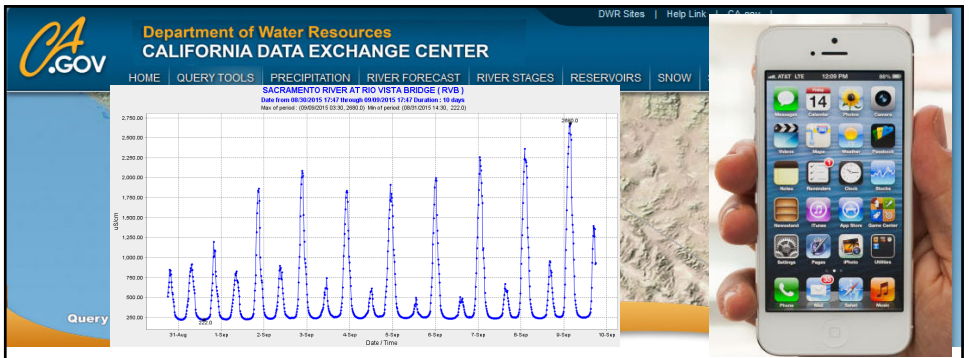
Water Quality Monitoring



Water quality of important estuaries and bays in 2011

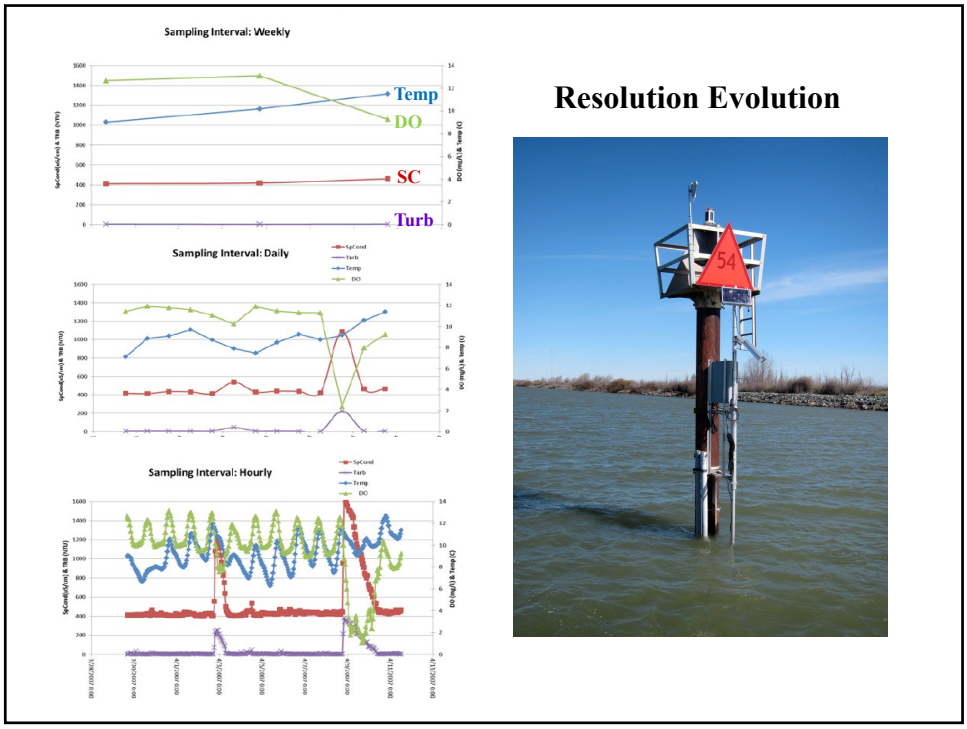
Blood Pressure Monitoring





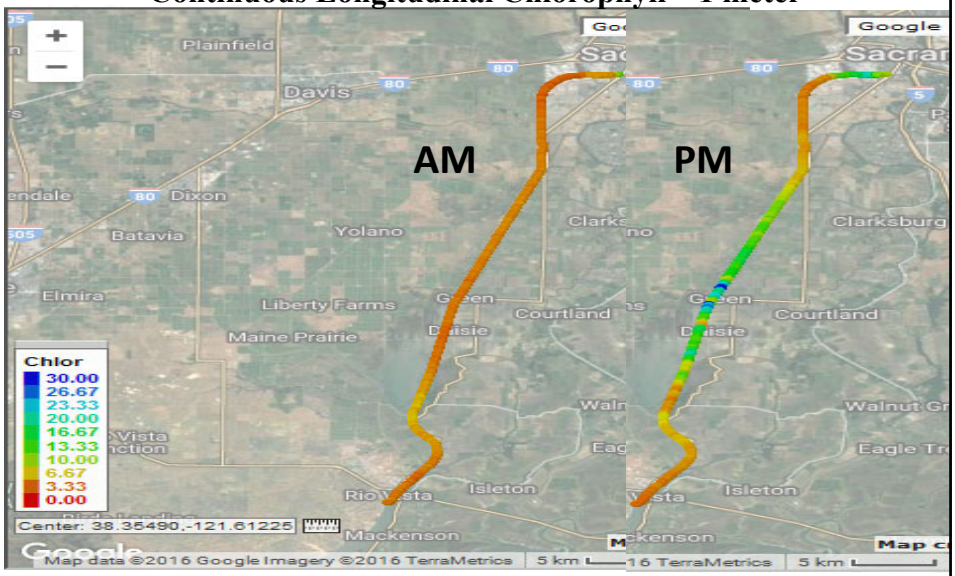
SACRAMENTO RIVER AT RIO VISTA BRIDGE *(RVB)*

Date / Time	*RIV STG*	*TEMP*	*WIND SP*	*WIND DR*	*EL COND*	*CHLORPH*	*PH VAL*	*TEMP W*	*TURB W*	*DIS OXY*	*SOLAR R*
(PST)	FEET	DEG F	MPH	DEG	uS/cm	ug/L	PH	DEG F	NTU	MG/L	W/M^2
03/10/2016 07:00	5.70	56	3	169	171	4.90	7.4	54.2	38.60	8.9	21.00
03/10/2016 08:00	5.11	56	4	151	143	4.90	7.3	53.2	46.50	9.1	77.10
03/10/2016 09:00	4.56	56	9	152	138	6.30	7.4	53.4	41.20	9.1	115.10
03/10/2016 10:00	4.08	58	4	107	140	5.80	7.4	53.5	39.20	8.9	111.80
03/10/2016 11:00	3.68	59	8	129	140	4.40	7.4	53.6	44.00	9.0	250.40
03/10/2016 12:00	3.71	60	5	163	149	4.60	7.5	53.9	41.80	9.1	148.20
03/10/2016 13:00	4.66	61	6	165	167	5.40	7.5	54.0	40.50	9.1	161.60
03/10/2016 14:00	5.57	61	4	179	168	5.30	7.5	54.1	39.30	9.2	131.20
03/10/2016 15:00	6.34	60	5	186	166	4.30	7.5	54.0	40.10	9.1	30.30
03/10/2016 16:00	6.79	59	4	182	163	5.10	7.5	53.9	40.30	9.2	40.40
03/10/2016 17:00	6.90	59	2	166	161	5.40	7.5	53.9	39.20	9.0	6.30
03/10/2016 18:00	6.45	57	4	182	160	4.70	7.5	53.9	38.60	9.0	1.00

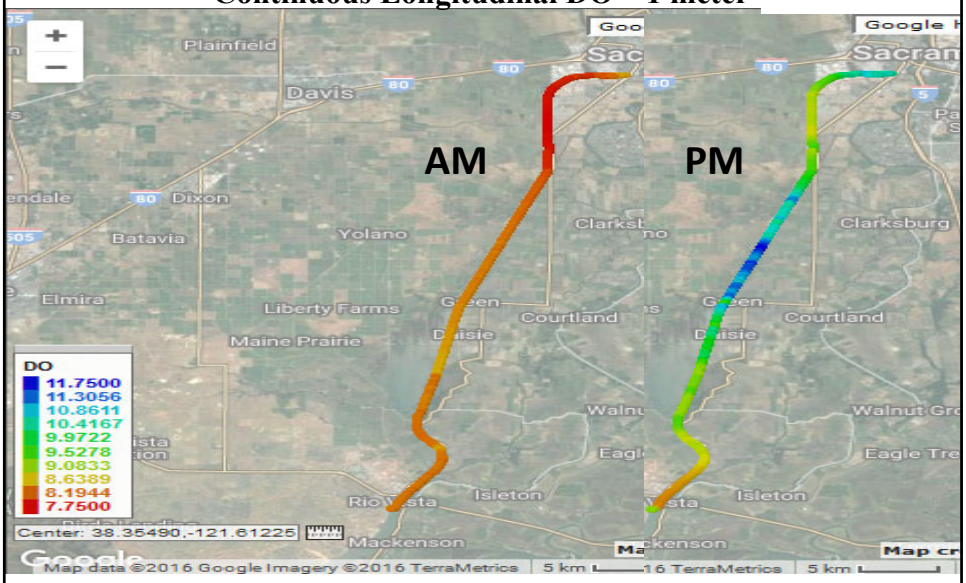

Sampling Interval: Weekly
Temp
DO
SC
Turb
Sampling Interval: Daily
Sampling Interval: Hourly
Resolution Evolution
54

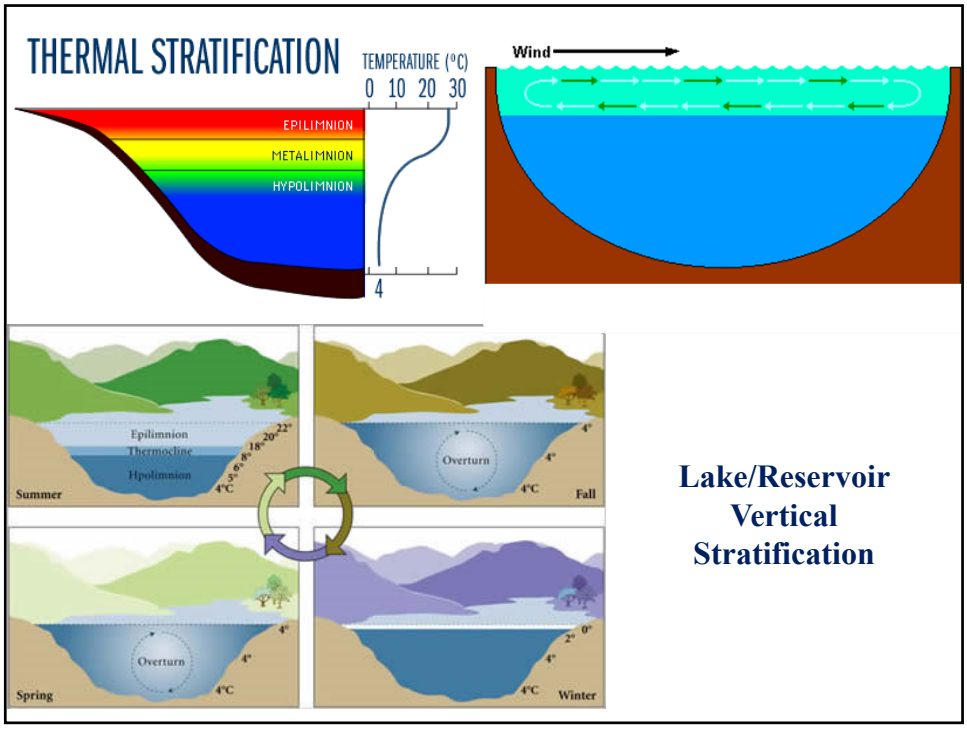

BUREAU OF RECLAMATION

Continuous Longitudinal Chlorophyll – 1 meter



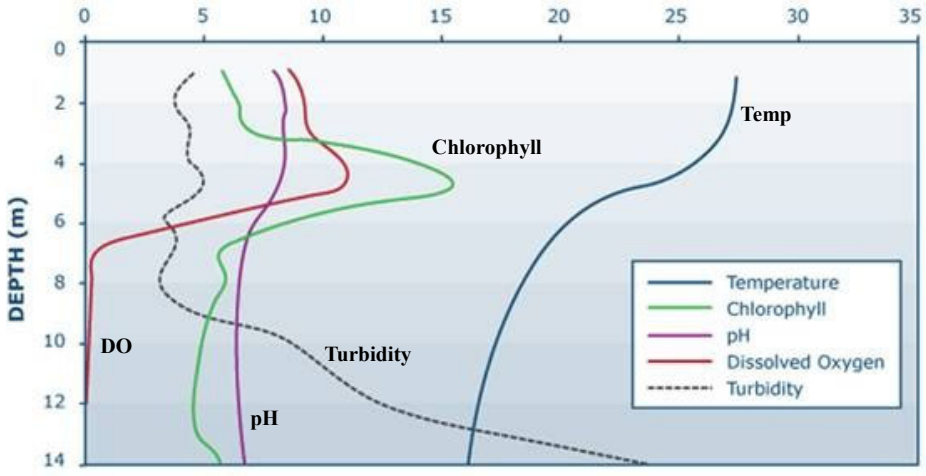
Continuous Longitudinal DO – 1 meter





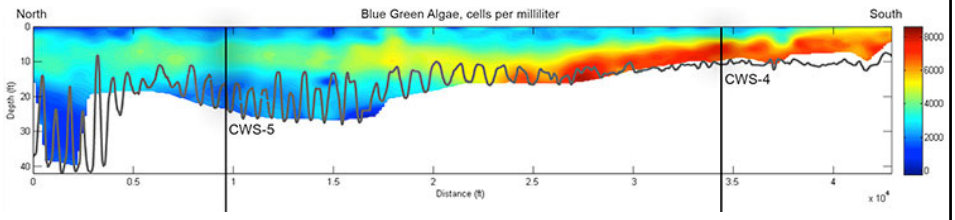
Lake/Reservoir Vertical Stratification

Water Quality Patterns with Depth During Stratification



Three-dimensional mapping of reservoirs using an AUV to identify location and conditions for elevated chlorophyll and blue-green algae concentrations

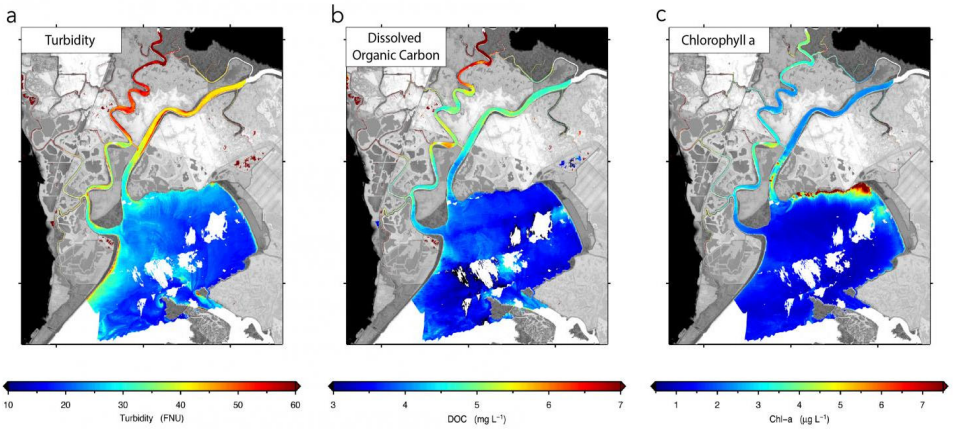
Downstream ← → **Upstream**



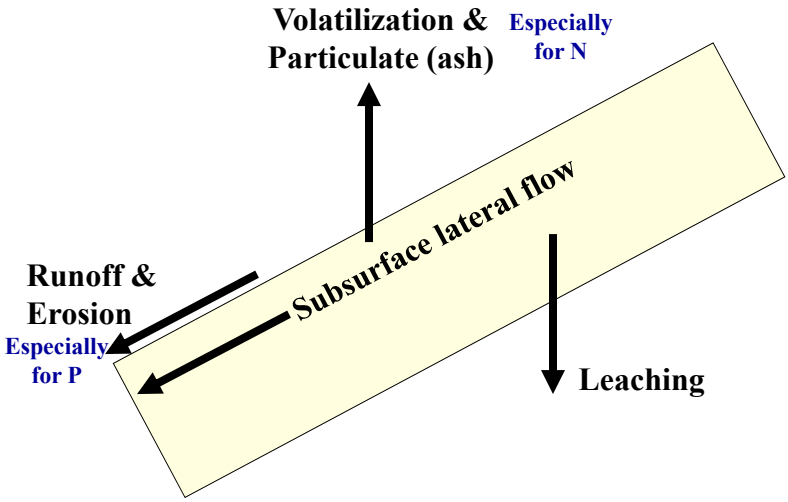
Autonomous Underwater Vehicle (AUV)

http://sc.water.usgs.gov

High-resolution Remote Sensing of water quality

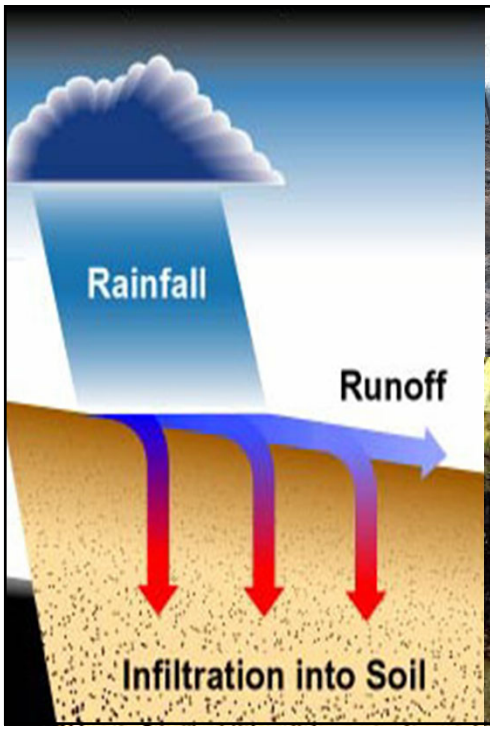


Loss of Nutrients

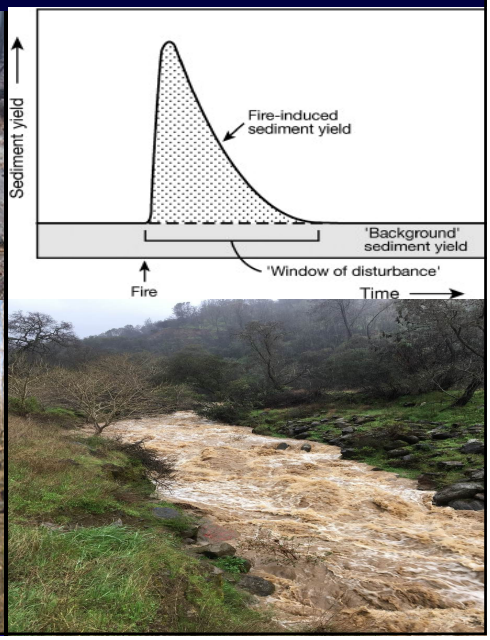


Importance of Soil Cover

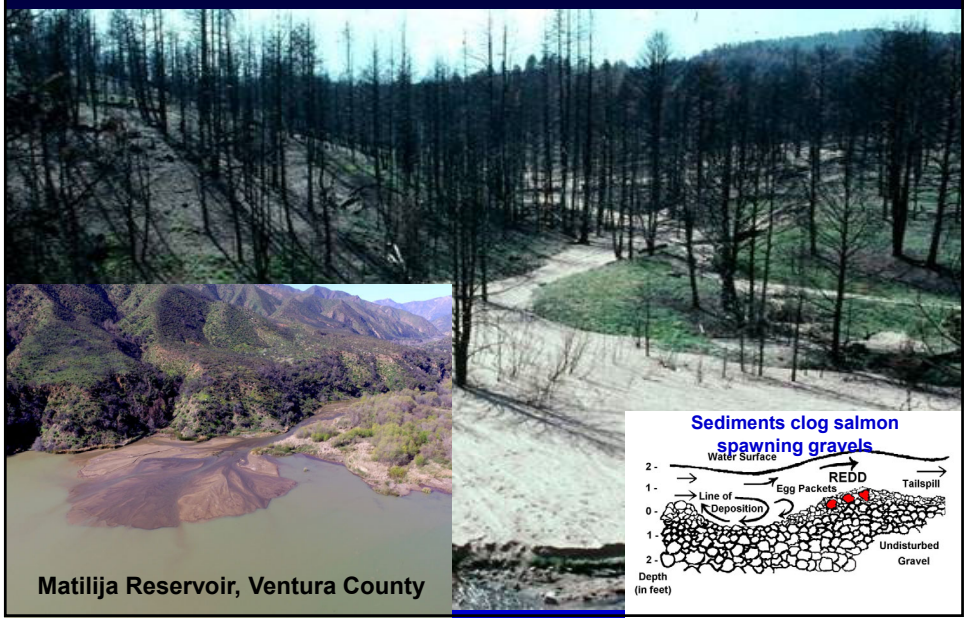
Good ground cover	Fair ground cover	Poor ground cover
60 -75% of ground covered with plants and litter	37 % of ground covered with plants and litter	10 % of ground covered with plants and litter
		
Surface runoff 2 % of rainfall Soil Loss 0.05 tons/ acre	Surface runoff 14 % of rainfall Soil Loss 0.5 tons/ acre	Surface runoff 73 % of rainfall Soil Loss 5.55 tons/ acre



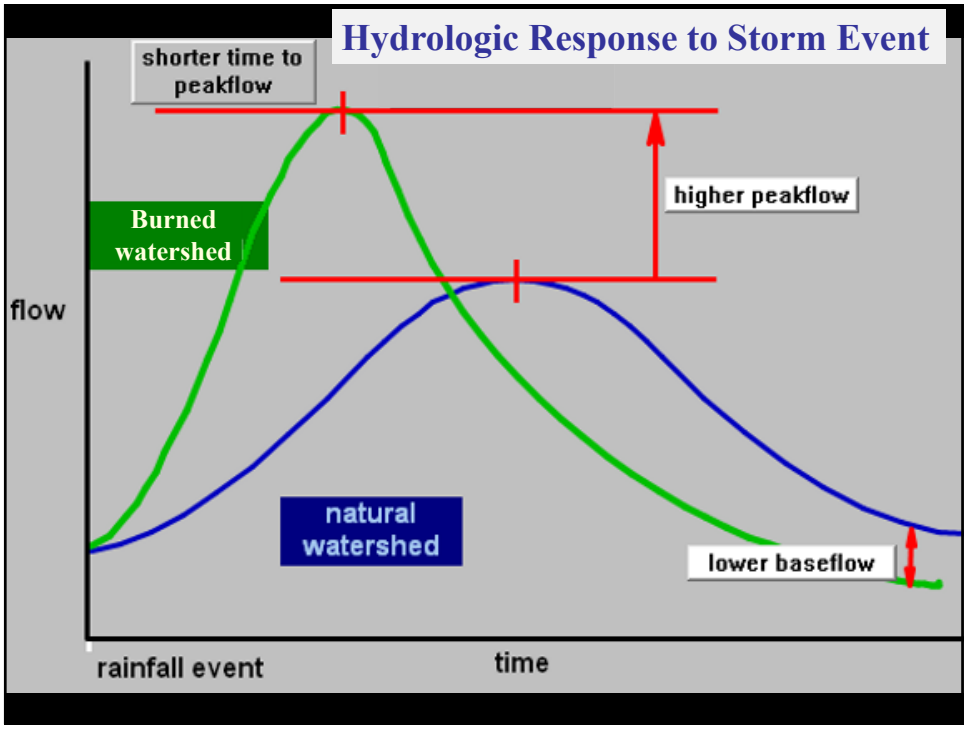
Soil Erosion

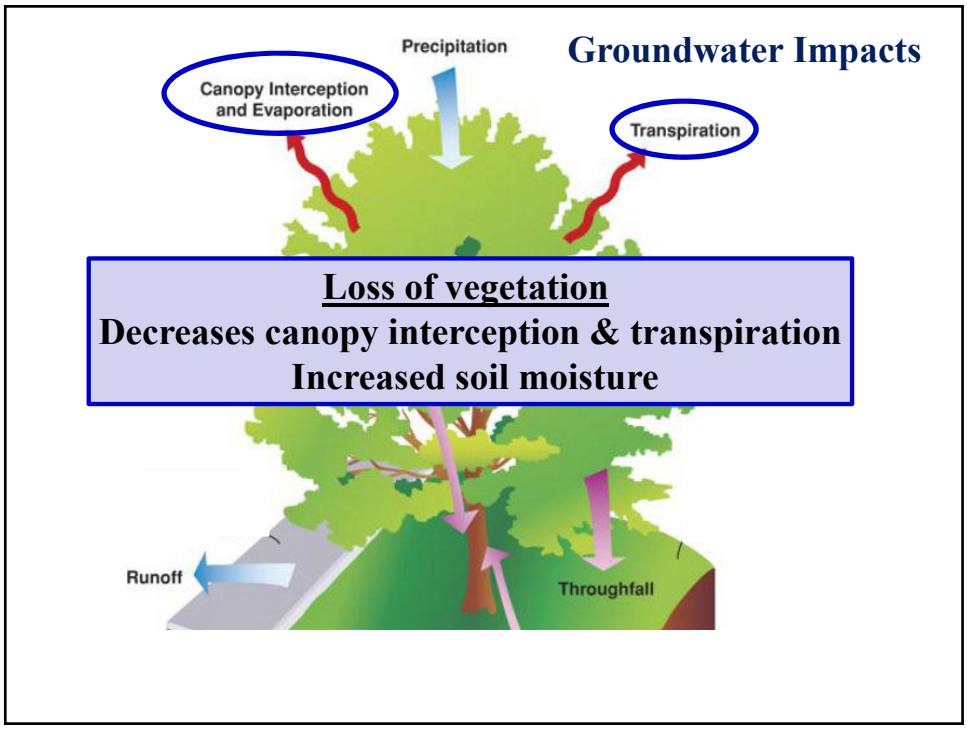


Sediment Deposition in Streams

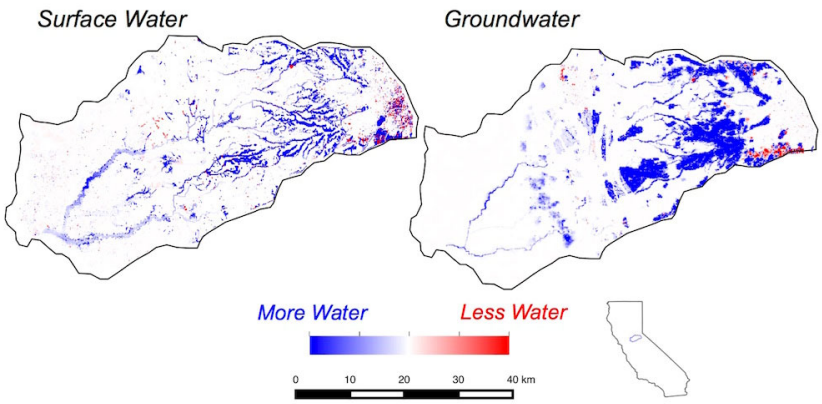


Sediments clog salmon spawning gravels


Hydrologic Response to Storm Event
shorter time to peakflow
higher peakflow
Burned watershed
flow
natural watershed
lower baseflow
rainfall event
time


Groundwater Impacts
Precipitation
Canopy Interception and Evaporation
Transpiration
Loss of vegetation
Decreases canopy interception & transpiration
Increased soil moisture
Runoff
Throughfall

Post-fire Changes in Surface and Ground Water



Maina, F.Z. and Siirila-Woodburn, E.R. 2019. Watersheds dynamics following wildfires: Nonlinear feedbacks and implications on hydrologic responses. Hydrological Processes. https://doi.org/10.1002/hyp.13568

Wildfire Impacts on Water Quality

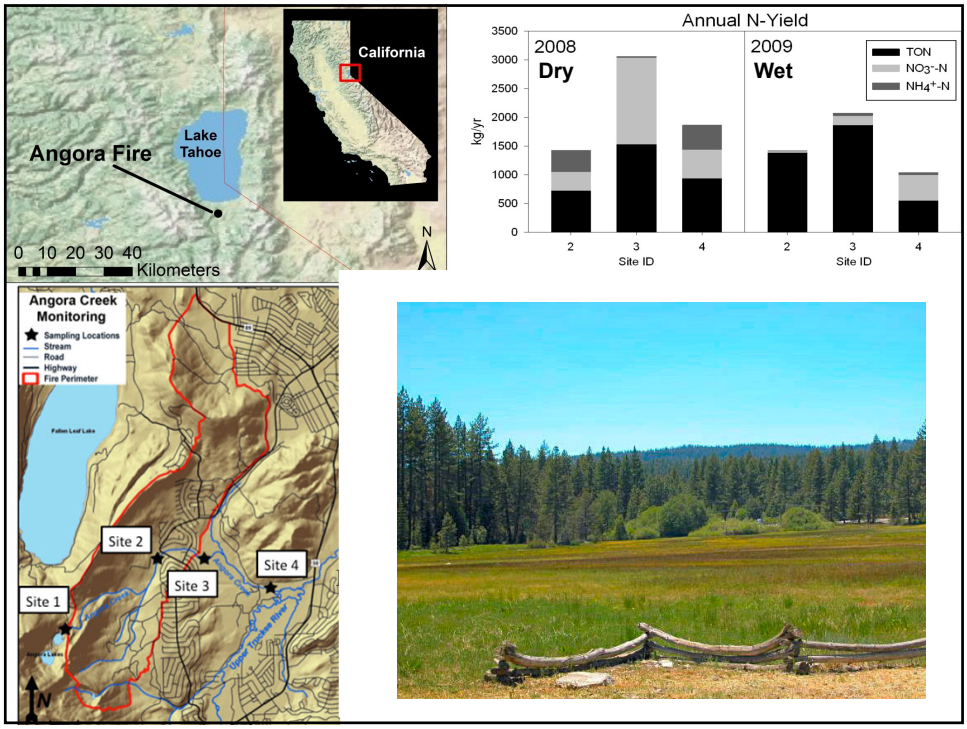
Wildfire Impacts on Water Quality

<u>Potential</u> for adverse water quality effects depends on:

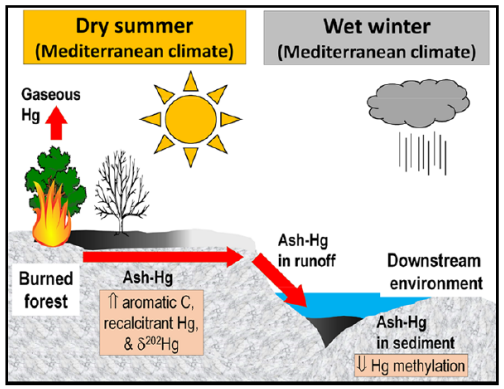
- **Fire Size – percentage of watershed area burned**
- **Fire Intensity – vegetation death & soil cover**
- **Urban Area – impervious surface & pollutant source**
- **Vegetation Recovery – fire adaptive vs conifers**

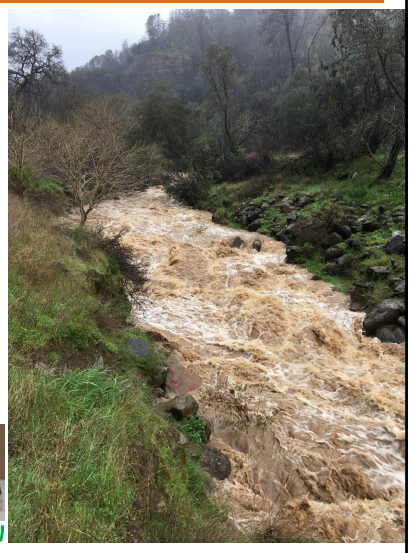
Realized WQ impacts are modulated by post-fire weather

- **Amount of precipitation**
- **Timing of precipitation**
- **Snow vs rain**



Mercury (Hg) Transport with Sediment





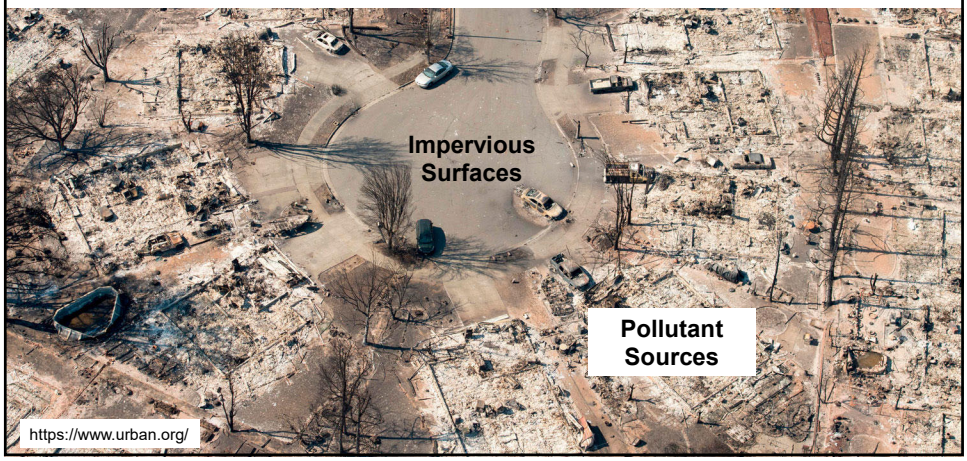
100% Wragg Fire (2016)

20% Rocky Fire (2016)

0% Reference (2016)

Urban Wildfire Impacts

- Sediments
- Heavy metals
- Mercury
- Nutrients
- Toxic organics – PAHs, benzene
- Electronic & Plastic pollutants
- Oil & grease
- Pesticides & pharmaceuticals



Storm Flow

Base Flow

Stream Habitat Quality

Nutrients

Sediments

Summer Water Temp

Primary Production vs Microbial Food Web