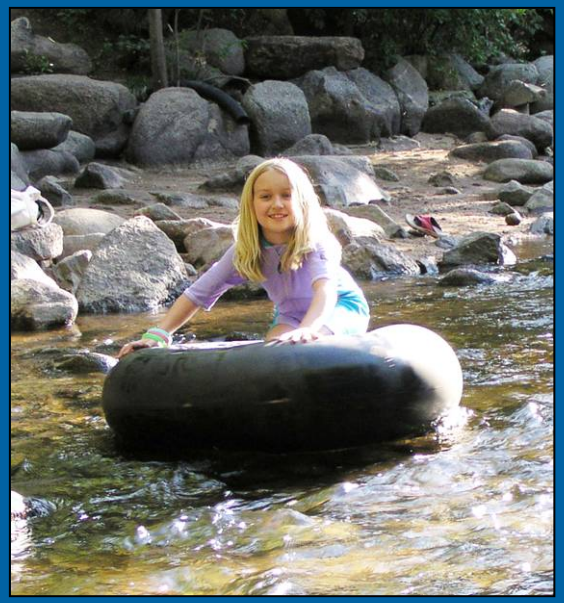
Basics of Water Quality
Sheila Murphy

Water quality:

The chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose



“Water quality” can include:

- Basic water quality variables (such as pH, dissolved oxygen, nitrate)
- Bacteria (such as giardia, *E coli*)
- Metals (such as lead, mercury)
- Pesticides
- Wastewater-derived organic compounds (hormones, prescription drugs)
- Fish and macroinvertebrate populations

Some basic water quality variables:

- Temperature
- Dissolved oxygen
- pH
- Nitrate
- Phosphate

Temperature

Affects:

- Fish species present
- Metabolism and reproduction of fish, macroinvertebrates, and bacteria
- Dissolved oxygen

Measured with:

- thermometer
- probe

Measurement units:

- degrees Celsius (°C)
- degrees Fahrenheit (°F)

Dissolved Oxygen (DO)

- Important indicator of a water body's ability to support aquatic life
- Fish absorb dissolved oxygen through their gills

- Measured with:
- probe and meter
- titration

- Measurement units:
- milligrams per liter (mg/L)
  AKA parts per million (ppm)
- percent saturation

Dissolved Oxygen (DO)

$$\text{Percent (\%) saturation} = \frac{\text{measured DO (mg/L)}}{\text{maximum DO (mg/L)}}$$

Maximum DO: maximum amount of oxygen a particular water can hold at equilibrium (depends on elevation and temperature)

pH

$pH = -\log [H^+]$

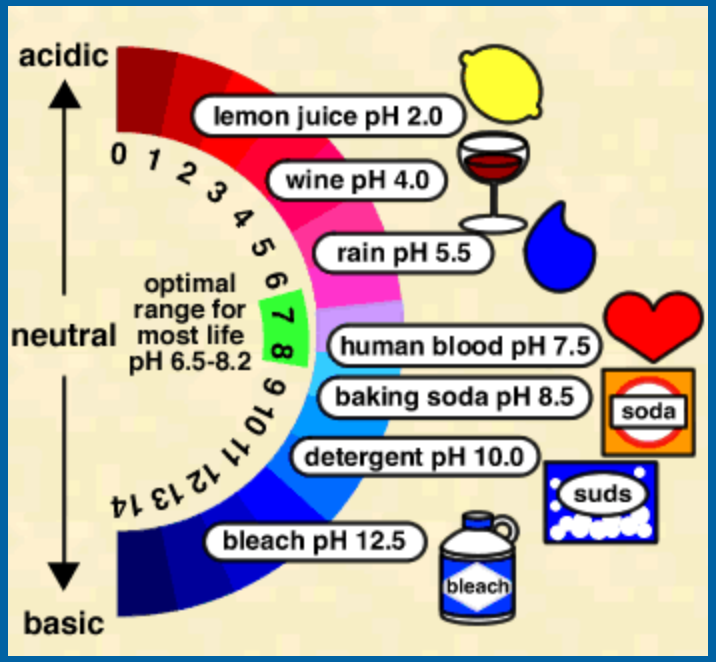
$[H^+]$= concentration of hydrogen ions (in moles per liter)

In pure water,

$[H^+] = 1.0 \times 10^{-7}$ moles per liter;

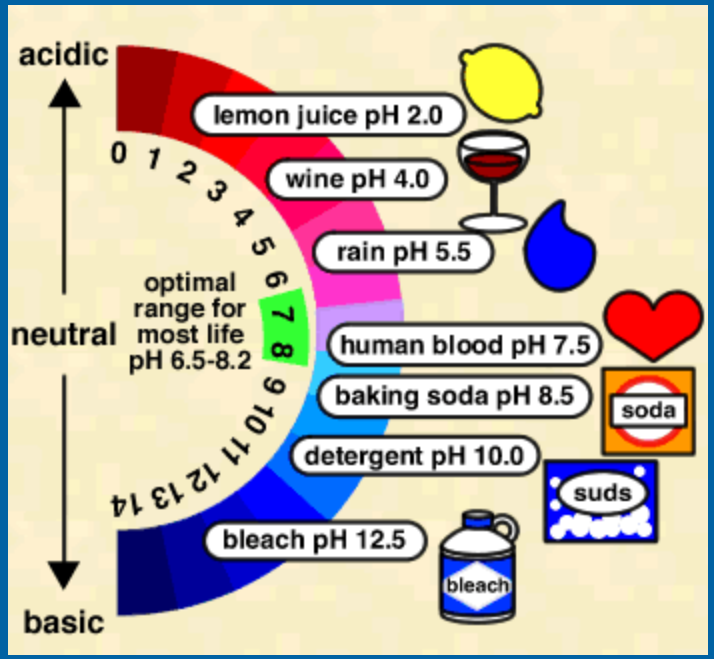
so $-\log(1.0 \times 10^{-7}) = 7.00$,

and the pH is neutral



pH

- Below pH 5, immature fish and macroinvertebrates may die
- Above pH 9, fish cellular membranes can be damaged
- Low pH levels accelerate release of metals from rocks or sediments



Measured with:

- probe
- pH paper

Measurement units:

- none, or “standard units”

Nitrogen (N)

Inorganic forms:

- **Nitrate – NO_3**
- **Nitrite – NO_2**
- **Ammonia – NH_3 and NH_4^+**
- **Nitrogen gas – N_2**

Organic (carbon-containing) forms:

- **Component of proteins, peptides, and amino acids**

Nitrogen

- Required by all organisms to live
- High nitrate & nitrite can cause methemoglobinemia in humans (“blue baby” syndrome) and fish (“brown blood disease”)
- High levels can increase algae growth, leading to low DO and death of fish (“eutrophication”)

Measured with:

- Colorimetry

Measurement units:

- Milligrams per liter (mg/L) as N, NO_2, NO_3, NH_3

Phosphorus (P)

- Required by all organisms to live
- Usually in the form of phosphate, PO_4^{3-}, in natural waters
- High levels can lead to eutrophication

Measured with:

- Colorimetry

Measurement units:

- Milligrams per liter (mg/L) as P or PO_4^{3-}

Nutrients

Nitrogen (N)
Phosphorus (P)

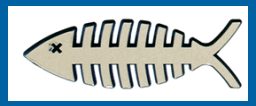
Act as fertilizers

Increased algae growth → Algae die → Bacteria eat them

Bacteria use up oxygen

Oxygen levels get so low that fish can't breathe

Fish kills

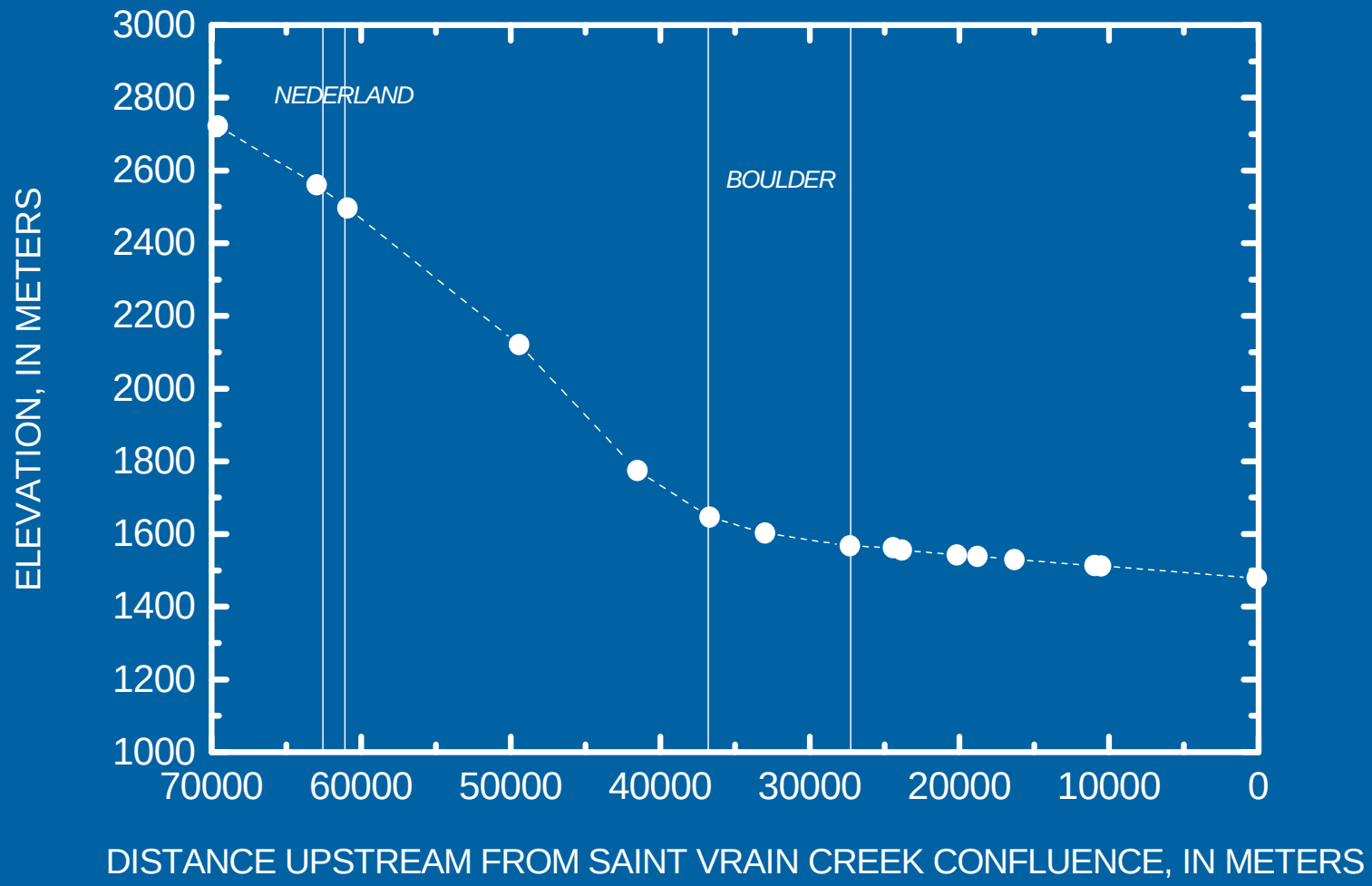


"Eutrophication"

What affects water quality?

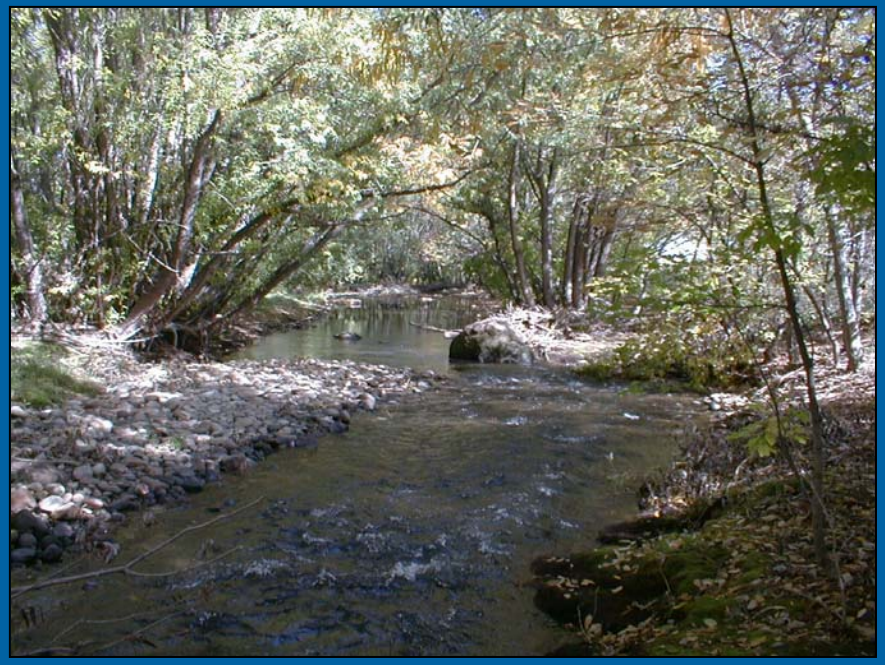
Climate/Season

Elevation



Lower-elevation waters hold more oxygen because of higher atmospheric pressure

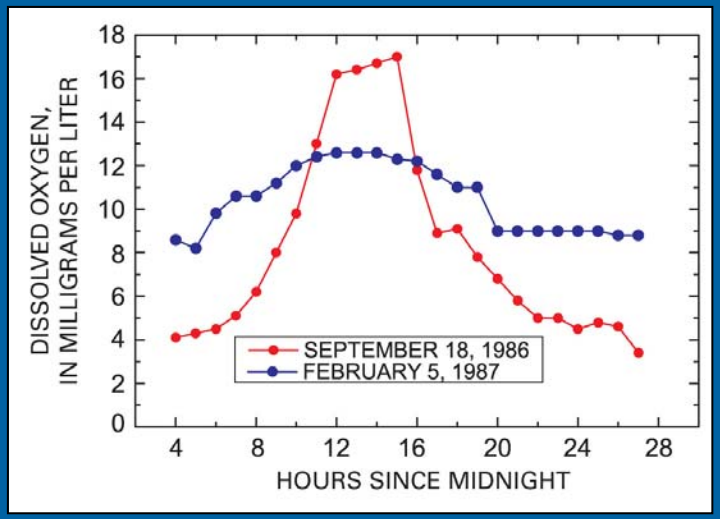
Riparian (streamside) vegetation

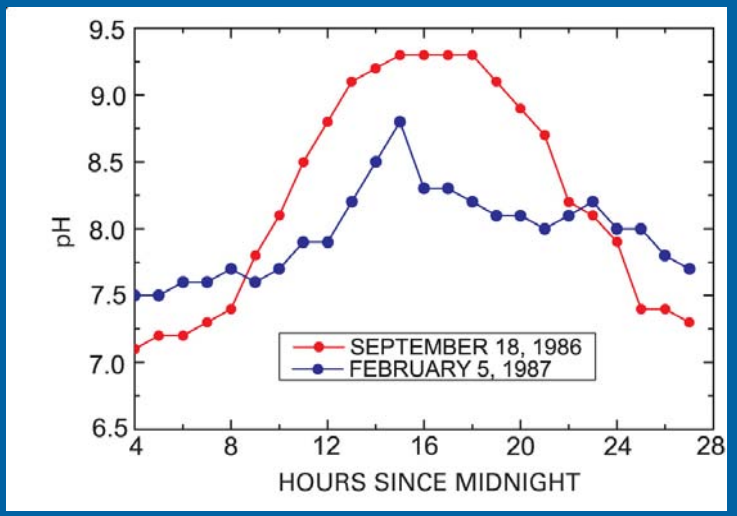


Instream vegetation

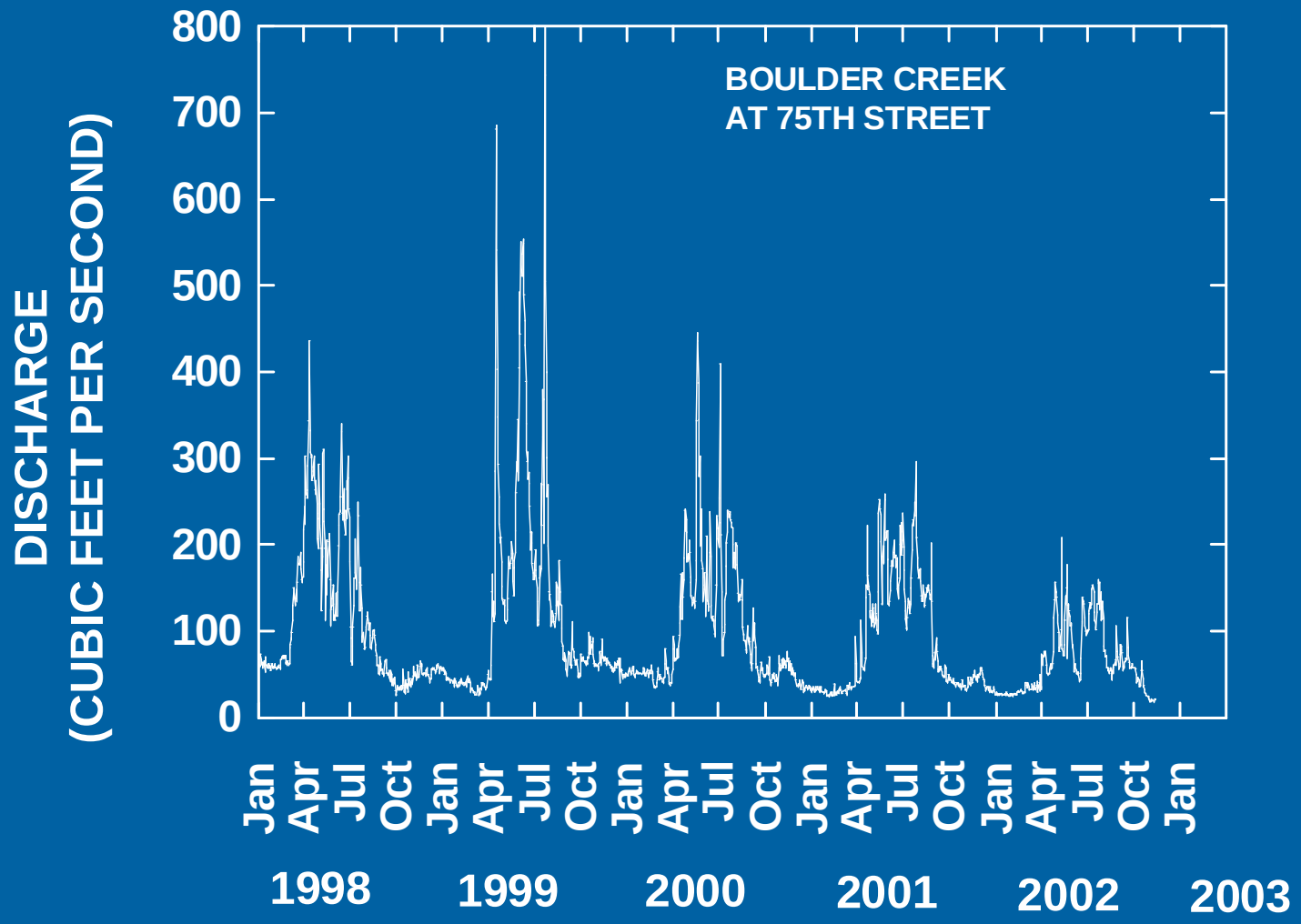
Photosynthesis

$$106CO_2 + 16\,NO_3^- + HPO_4^{2-} + 122H_2O + 18H^+ \rightarrow C_{106}H_{263}O_{110}N_{16}P + 138O_2$$





Discharge


BOULDER CREEK
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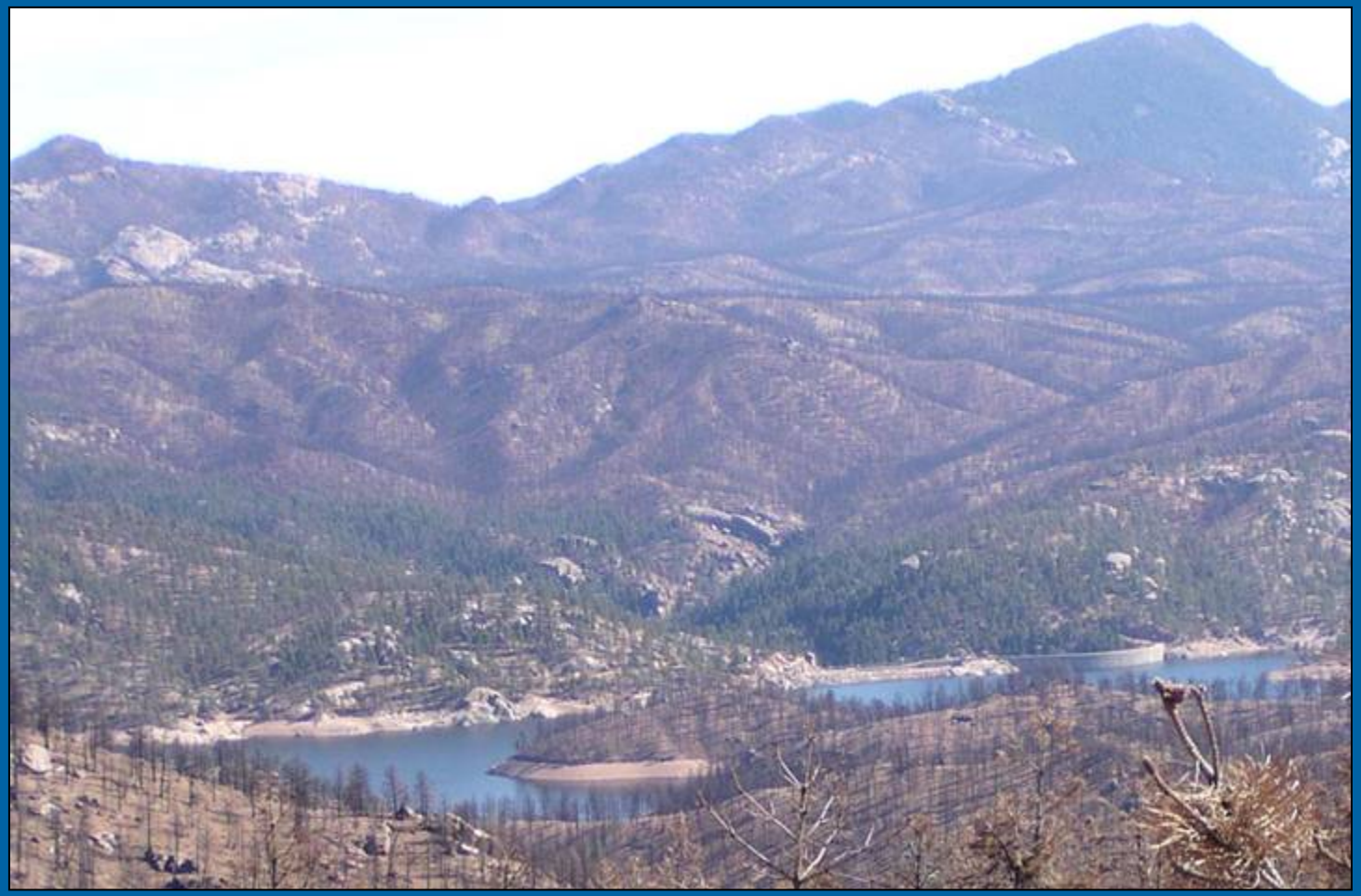
Geology

Igneous Rock

Sedimentary Rock

Forest fires



Cheeseman Reservoir after Hayman Fire, 2002

Mining

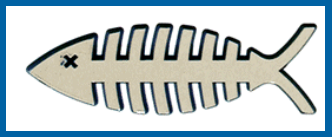
Pyrite
Iron sulfide, or FeS_2
AKA "fool's gold"

$$FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{+2} + 2SO_4^{-2} + 2H^+$$

Acid!

Acid dissolves metals in the rock, and they get into water

Like Hg, Fe, Zn, Cu, Pb



Can kill fish & make water undrinkable

Wastewater

Our waste

Sewer pipes

Wastewater
Treatment Plant

Solids settled out
Bugs eat carbon
Chlorine kills pathogens

Treated wastewater
discharged to rivers

Agriculture

- Greatest nonpoint source pollution problem in the U.S.
- Fertilizers and pesticides sprayed on crops can get washed into streams and lakes
- Fertilizer contains nitrate and phosphorus

Recreation- instream

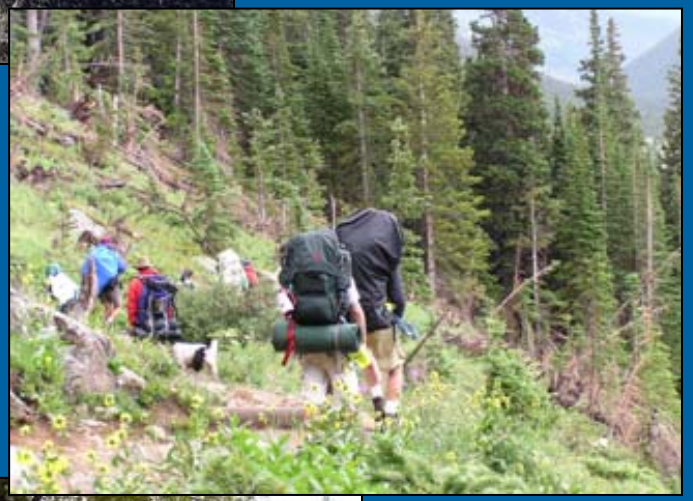
- Swimming
- Tubing
- Boating

Potential impacts:

- Bacteria (*E coli*)
- Nutrients
- Pharmaceuticals and personal care products

Recreation

- Off-road vehicles
- Hiking & camping
- Dog walking
- Golf courses



Potential impacts:

- Sediment
- Bacteria
- Nutrients
- Pesticides
- Pharmaceuticals and personal care products

Road runoff

Can contribute:

- Leaked automobile fluids
- Breakdown of brake pads (metals)
- Road salt and gravel
- Spills
- Trash

Industry

- Before 1972 Clean Water Act, few rules about release of chemicals to water bodies
- In developing world, industry is often the greatest pollution source

Photo from Cleveland Public Library

Cuyahoga River, Ohio, in 1952

Thermal pollution:
Power plants, chemical factories, and refineries use water for cooling and release warm water back to the environment

Valmont Power Plant

Burning of Fossil Fuels

NO_2

NO_3

SO_2

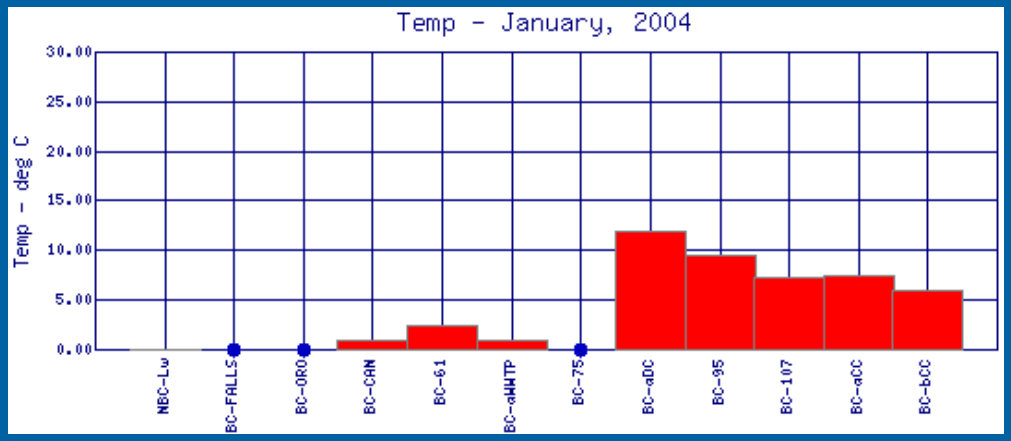
HNO_3

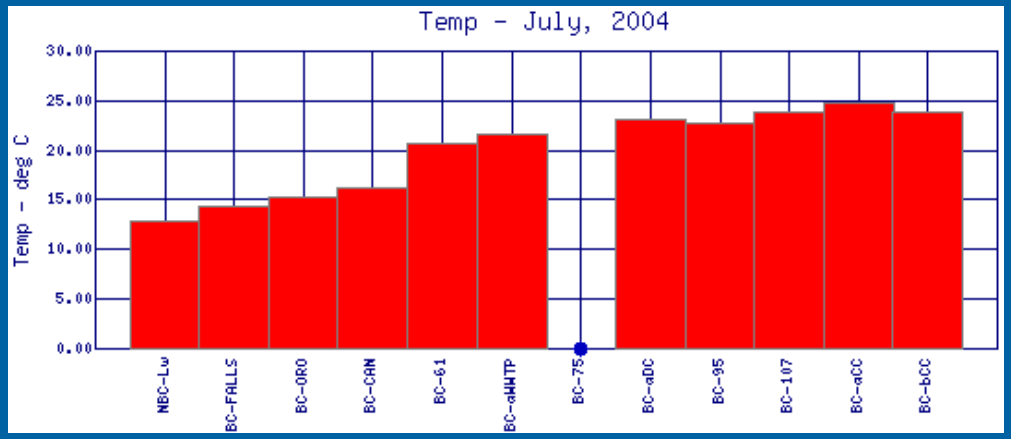
H_2SO_4

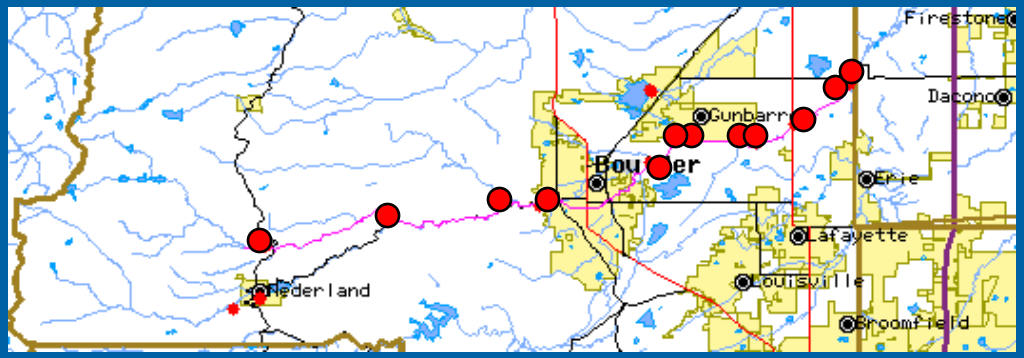
Acids!

Let’s look at some data!

Temperature along North Boulder Creek-Boulder Creek







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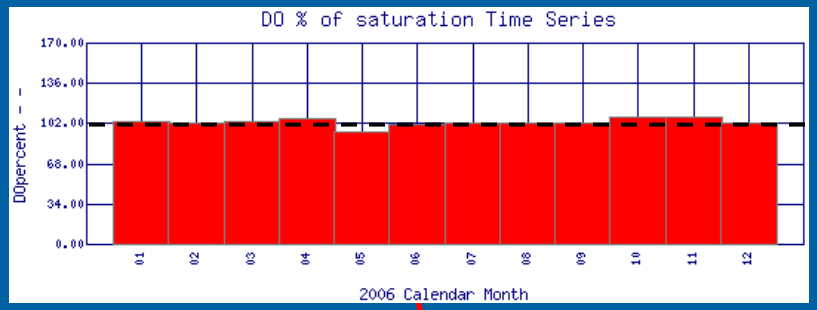
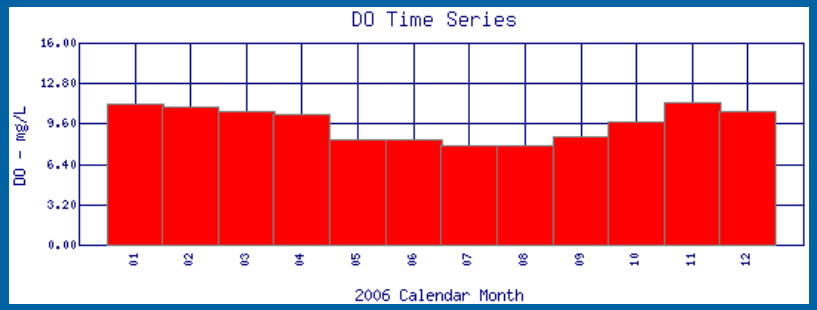
From www.basin.org

Dissolved oxygen



North Boulder Creek
at Lakewood Res.



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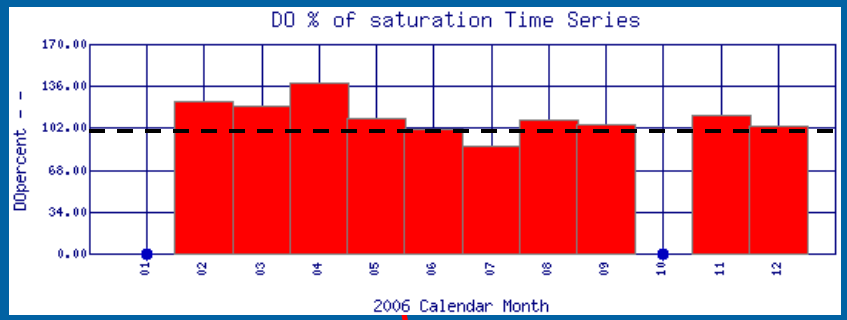

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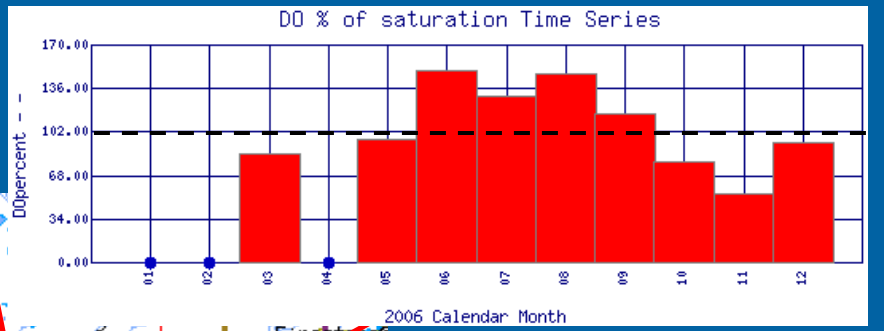
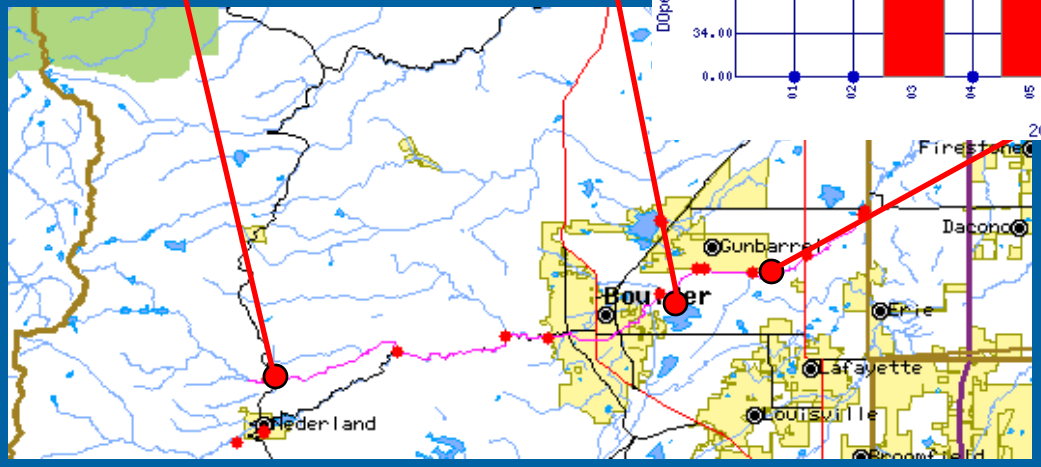
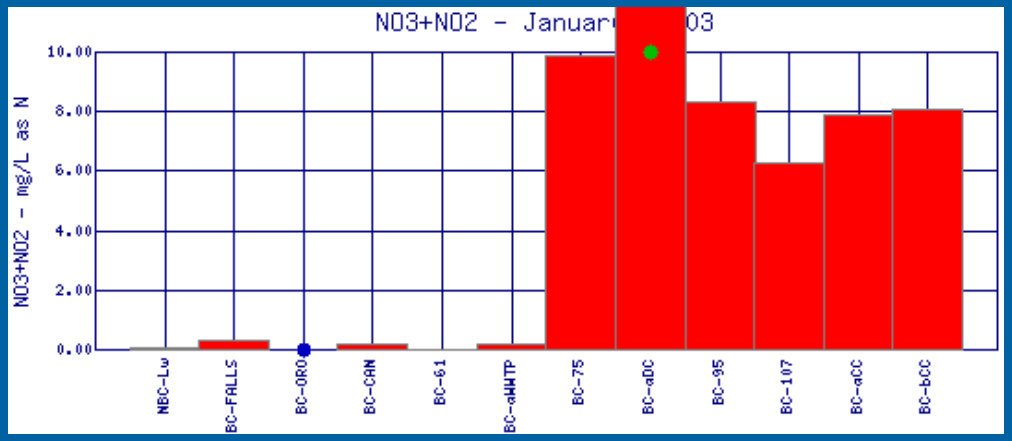
Boulder Creek
at 61st St.

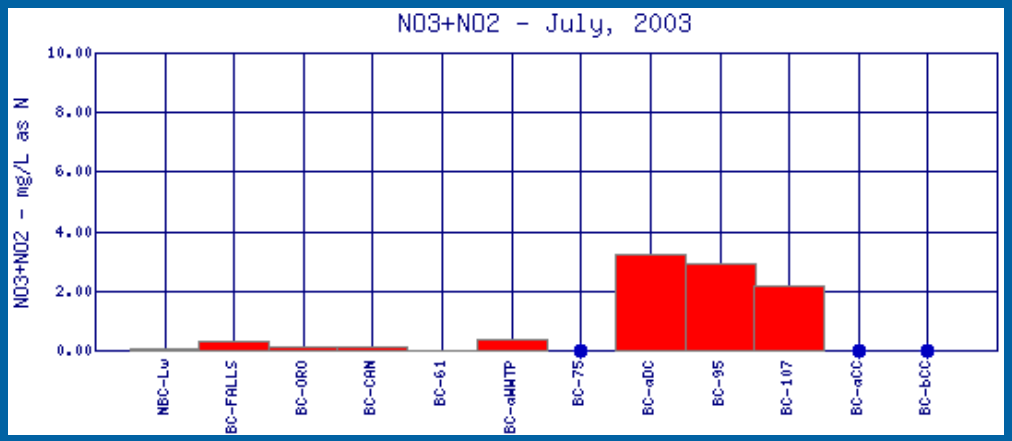




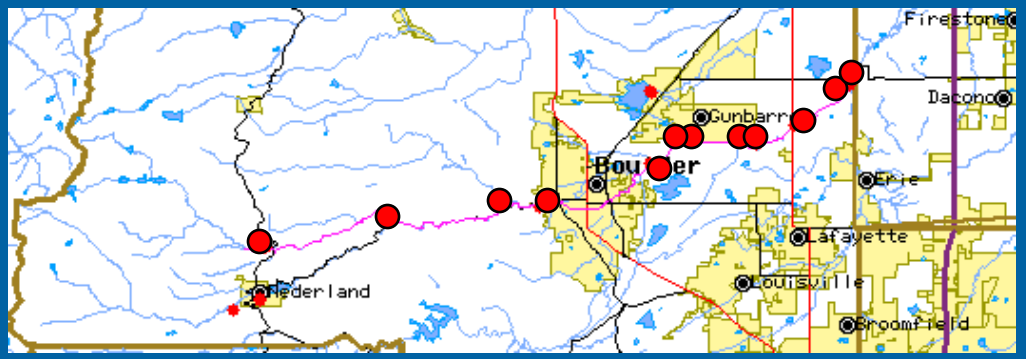
Boulder Creek
At Highway 287

Nitrate + nitrite along North Boulder Creek-Boulder Creek





- No data available
- Value exceeds plot scale



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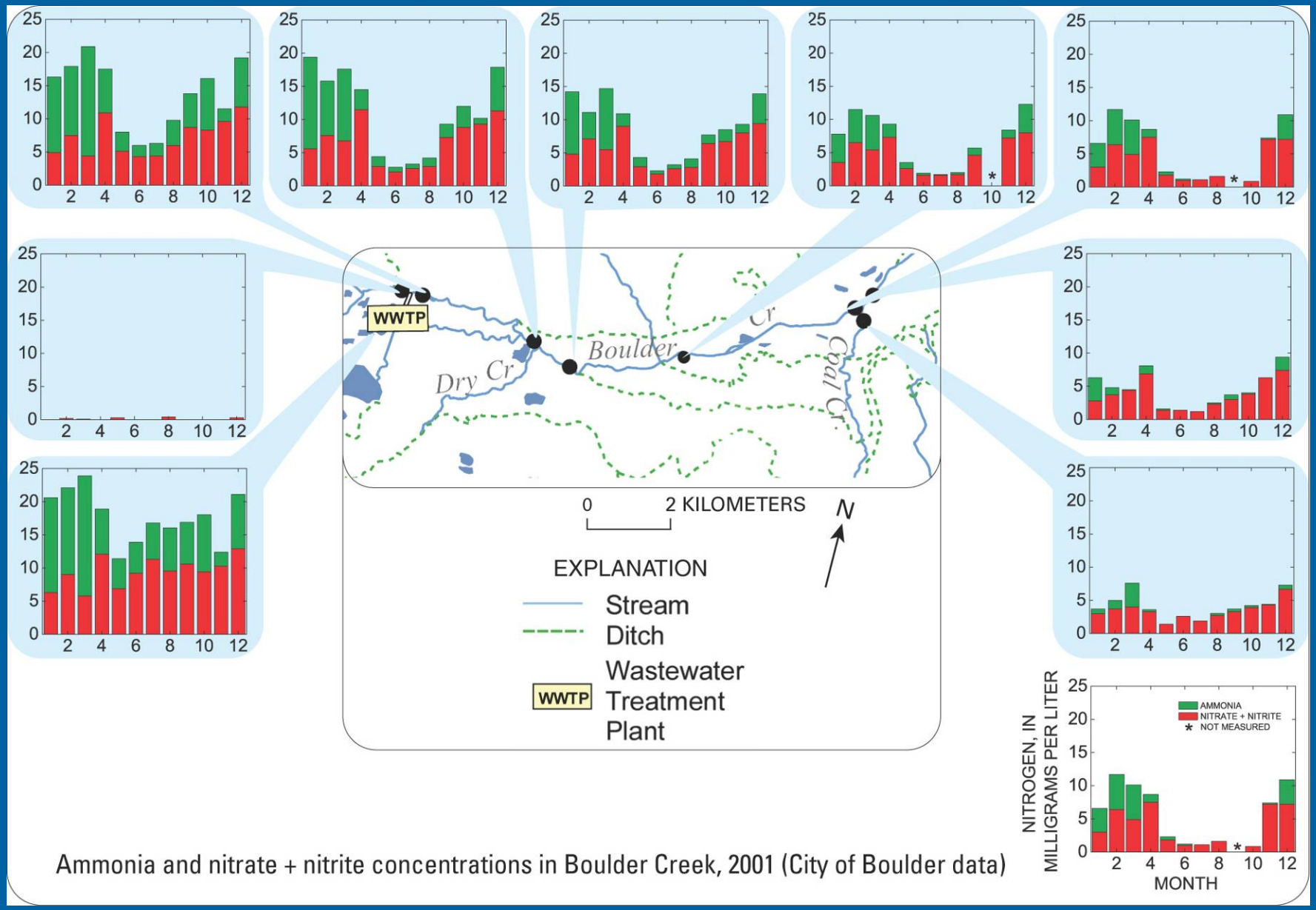
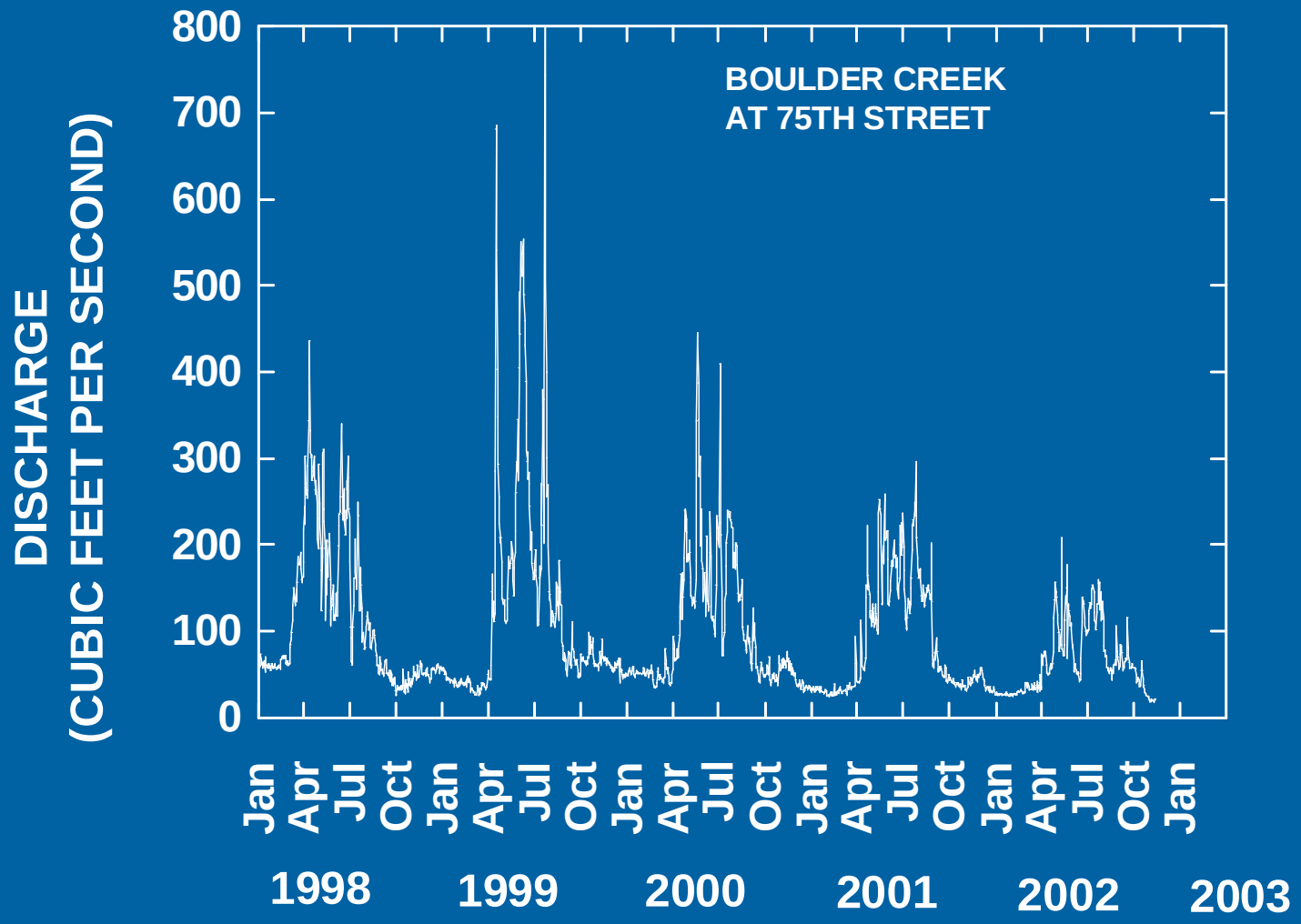


Ammonia and nitrate + nitrite concentrations in Boulder Creek, 2001 (City of Boulder data)

Discharge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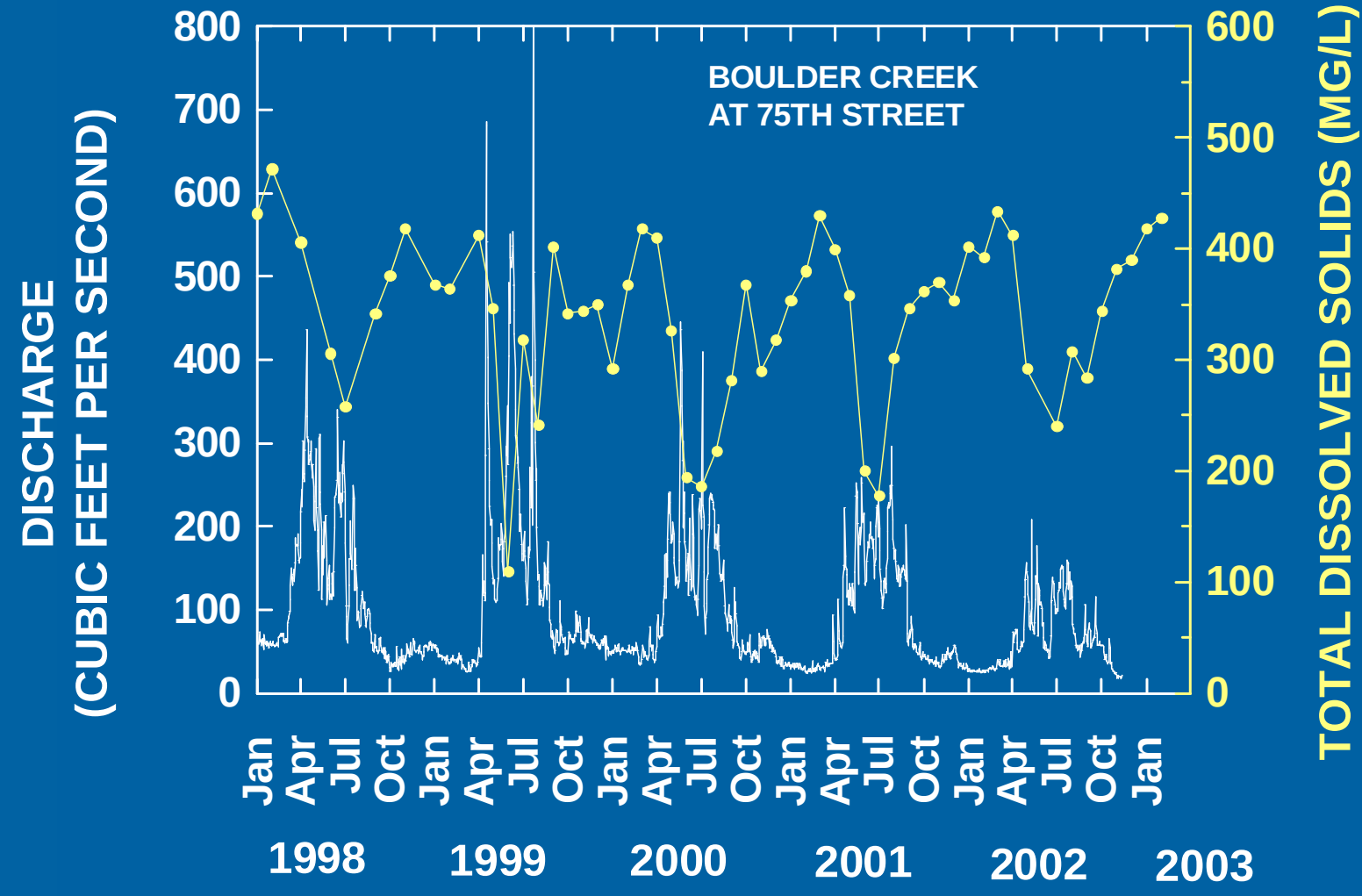
2003

Effect of discharge on water chemistry



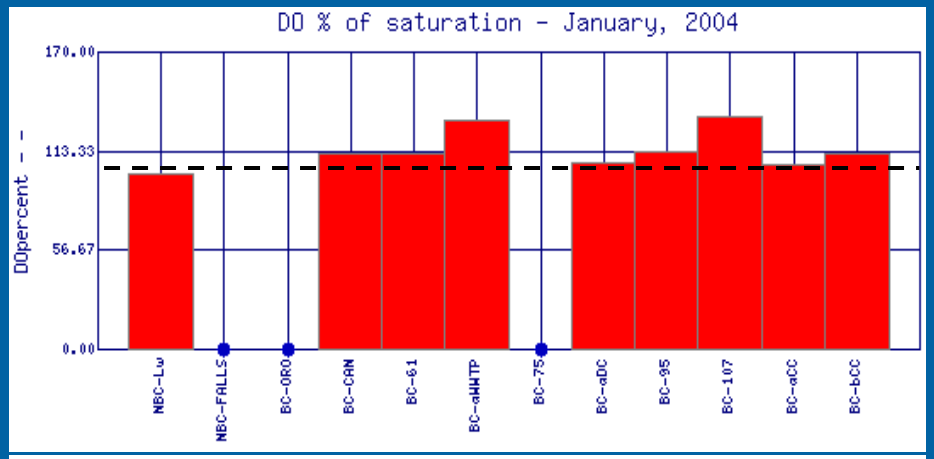
For more information…

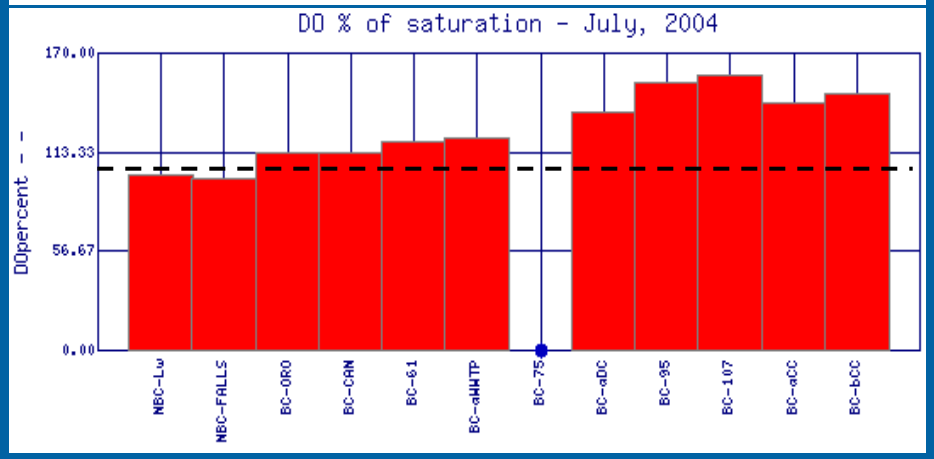
Boulder Area Sustainability Information Network:
www.BASIN.org

U.S. Geological Survey, Water Resources Discipline: http://water.usgs.gov

sfmurphy@usgs.gov

Dissolved oxygen along North Boulder Creek-Boulder Creek





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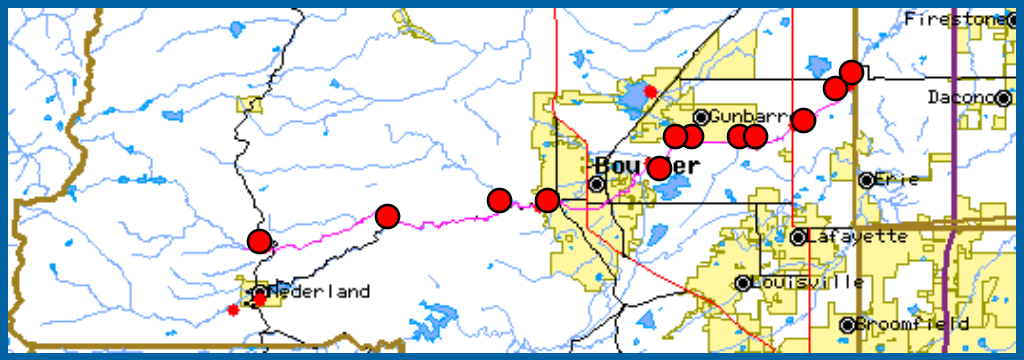

What affects water quality?

Natural things… like:

- **Climate/season**
- **Streamside vegetation**
- **Geology**
- **Forest fires**
- **Discharge (flow rate)**

What affects water quality?

Natural things… like: