**Chapter 3**
Water and hydrology
The Water Molecule
The Water Cycle
Stream Processes
The Path of a River
River Derivatives
California's Lakes
Aquatic Ecosystem Management
Challenges for the Future

**Water and hydrology**

a. driven by gravity
   - falls from sky as precipitation
   - flows from high to low elevation

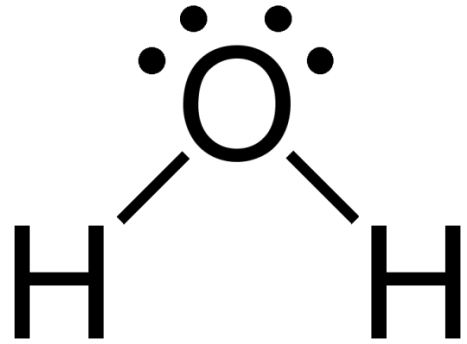

b. shapes and alters the landscape
   - spills over banks
   - moves sand, pebbles, rocks, boulders, trees
   - periodically floods houses built too close to the river

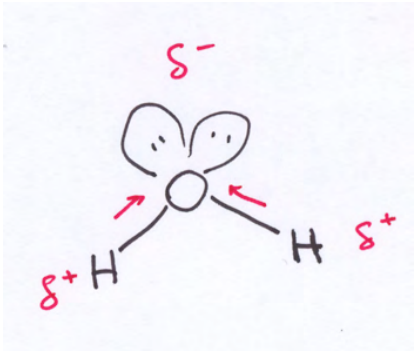
c. factors determining influence of water on landscape
   - water volume
   - shape of the channel through which it flows

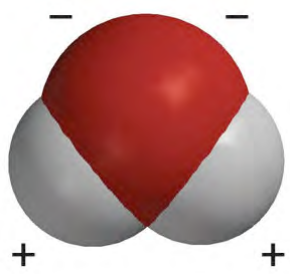
## The Water Molecule

a. basics

- molecular weight: 18 grams/mole
- boiling point: 100 °C
- freezing point: 0 °C
- density: 1.000 g/mL



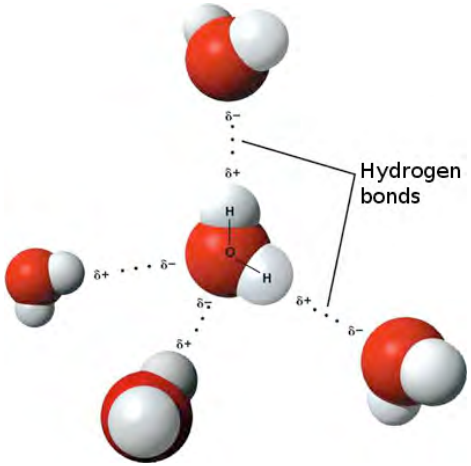




b. water is polar

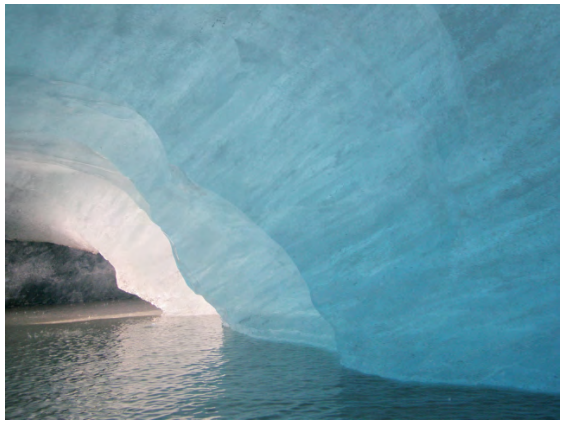
- electric dipole caused by oxygen's higher electronegativity
- reason why oil and water don't mix

c. hydrogen bonding

- the electrical attraction between a partially + charged H atom of one polar molecule to a partially - charged oxygen atom on a second polar molecule
- dynamic, constantly breaking and reforming



d. hydrogen bonding gives water its unique properties
   - liquid phase (water)
     - more dense than solid phase
     - hydrogen bonds form and break apart quickly and locally



- solid phase (ice)
  - less dense than liquid phase
  - crystalline structure
  - hydrogen bonds cannot break and reform as readily because the water molecules are moving too slowly

- gaseous phase (water vapor)

- cohesion
  - the attraction of like molecules to like molecules
  - surface tension of water
    - ➢ quasi-crystalline structure in liquid water makes it difficult to break or stretch

- adhesion
  - attraction of unlike molecules
  - adhesion keeps these water droplets in place

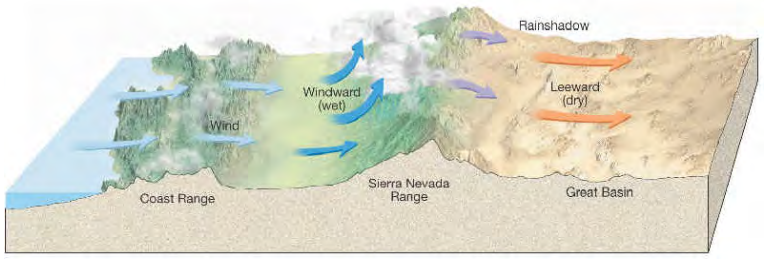
- transpiration
  - evaporating water from leaf pores pulls up water from the roots
    - ➢ cohesion between water molecules
    - ➢ adhesion along internal plant vessel wall

**The Water Cycle**

a. wind and solar radiation over an incredibly large surface area results in the evaporation of ocean water

b. cloud formation

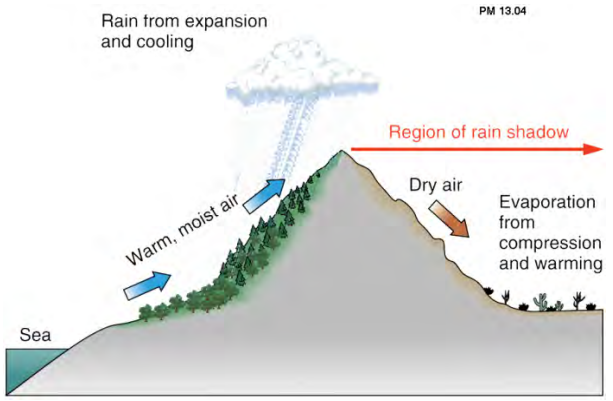
c. winds begin blowing these clouds across the continent



d. orographic effect
   - clouds cool as they rise up mountain
   - eventually results in release of precipitation (rain, snow)

- precipitation trends
  - increases along coast
  - increases northwards
  - increases with increasing mountain elevation

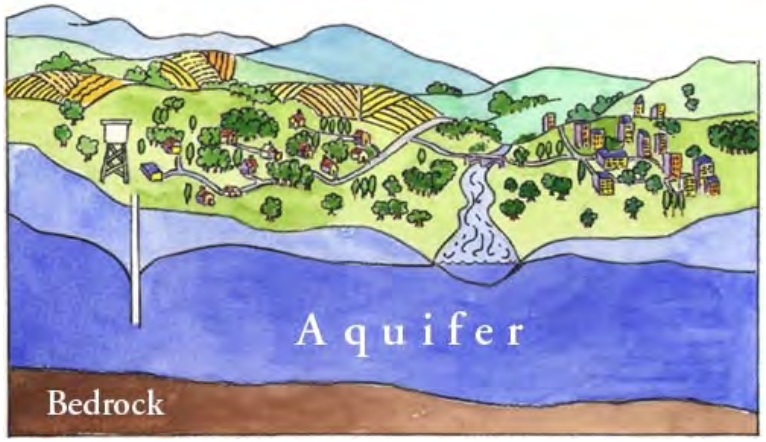
- rain shadow
  - areas on leeward side experience less rainfall due to drier clouds



e. destinations for precipitation
   - 60% ends up in streams
     - usually flows back to the ocean

- soil
  - causes stream levels to rise

- ground-water holding areas
  - variable permeability, but overall less permeable than soil
  - often becomes saturated and no longer able to absorb
  - ex. bedrock



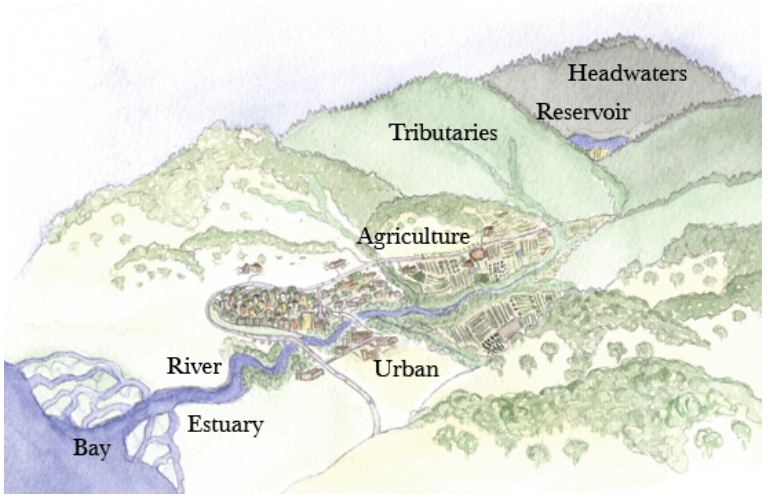
- Large lakes
  - CA topography and geology is not conducive to formation of large lakes, but we still have a few

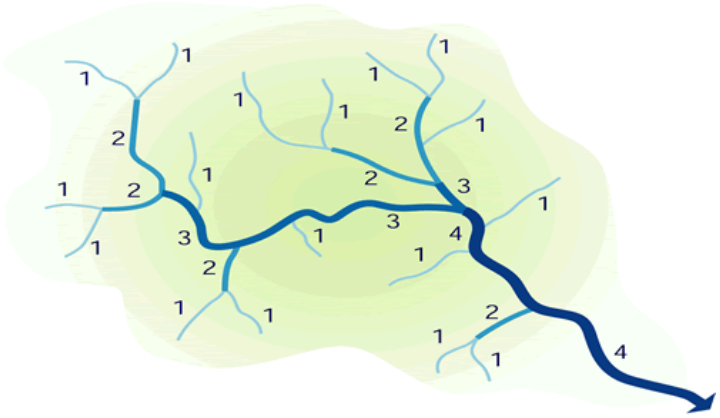

- small lakes nestled in glacier carved depressions up in the mountains

- absorbed by plants
- ingested by animals
- evaporated

## Stream Processes

a. stream classification by watershed type
   - watershed is portion of land for which all rainfall drains through a common stream point
   - provides water and anything else that can be transported downstream by water



b. stream classification by stream order
   - number streams beginning with small headwater streams
     - two streams of equal order combine to form a stream of the next highest order
       - ex. two first order streams combine to form second order stream

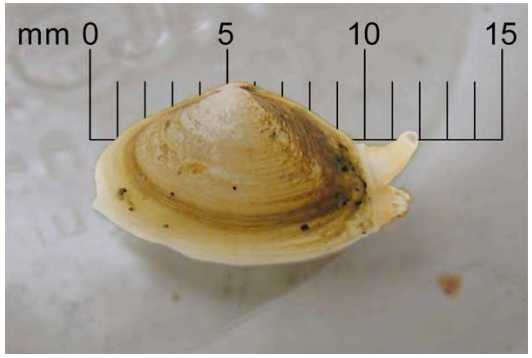
c. bio inputs from nearby terrestrial ecosystems
   - food and nutrients from immediate riparian zone
   - leaf litter
   - trees and branches, large woody debris provides source of nutrients and shapes stream channel


d. transport of aquatic invasive species
   - disrupts agriculture, shipping, water delivery, recreational and commercial fishing
   - undermines levees, docks and environmental restoration activities
   - impedes navigation and enjoyment of the state's waterways
   - damages native habitats and the species that depend on them

- ex. water hyacinth
  - introduced as ornamental plant for water gardens
  - in hot weather, can double the area it covers in ten days
  - blankets over 4,000 acres of Sacramento-San Joaquin Delta in summer

- arundo
  - originally planted for erosion control
  - displaces native vegetation
  - increases flooding
  - increases siltation (deposition of silt in waterways)
  - degrades wildlife habitat

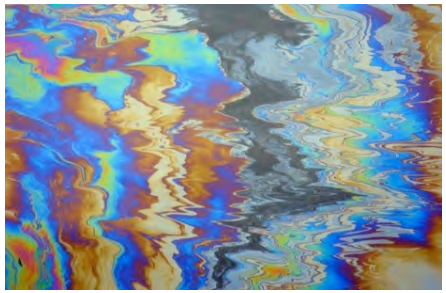
- Asian overbite clam
  - hermaphroditic, reproduces rapidly
  - outcompetes native clams
  - clogs power plants
  - can lead to declines in fish and shrimp populations



e. chemical inputs
    - transportation of ionic compounds
        - dissolves ionic compounds on rock surfaces and carries them downstream from higher headwaters to lower reaches
        - supplies the salt that makes desert lakes salty

•transportation of autochthonous nutrients
    - nutrients weathered from bedrock
        - Phosphorous
        - Nitrogen
        - Carbon
    - these nutrients promote algal and biofilm (periphyton) growth along the stream bed
        - foundation for many aquatic food webs

- transportation of pollutants
  - point source



  - non-point source
    - derives from many scattered point sources
    - rainfall or snowmelt picks up and sweeps pollutants into lakes, rivers, coastal waters, wetlands, underground sources of drinking water


f. physical inputs
   - dictate shape of stream channel

- provide substrate and suspensions to the stream
  - fine sediment
  - coarse cobble
  - fine gravel
  - sand
  - coarse boulders that roll along channel bed during very high-flow conditions

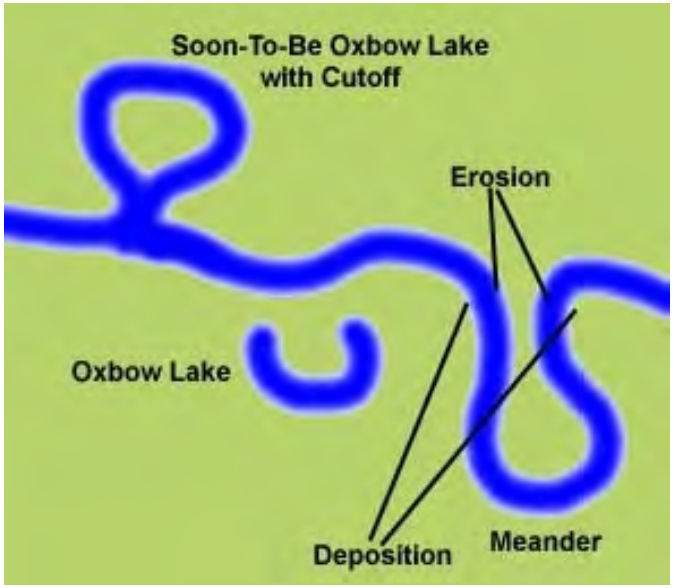
- alluvium is sediment that moves due to the force of water in the stream
  - hillslope failures often coincide with alluvial forces
  - high-flow events eroding stream channels may undermine and destabilize hillslopes
  - hillslopes become much heavier when saturated with water and lose their stability

- colluvium is material that can collect at the foot of a slope as a results of gravity

- problems arise when land use activities lead to higher rates of erosion, which produce more sediment than can possibly be moved downstream by alluvial processes

**The Path of a River**

a. most rivers around the globe have headwaters in mountains and downstream portions in valleys
   - begin as first-order stream in mountain and then branch out to higher stream orders
   - drainage network occurs in its upper headwaters




b. oxbow lakes

c.floodplains

- •caused by inundation of river during and after flood season
- •vegetation within a river's floodplain is adapted to the frequency of inundation it may experience

- water spilling over onto the floodplains moves much slower than that occurring in the river channel
  - silt material in water has opportunity to settle on the floodplain
  - silt contains an abundance of nutrients that supports aquatic plants and animals

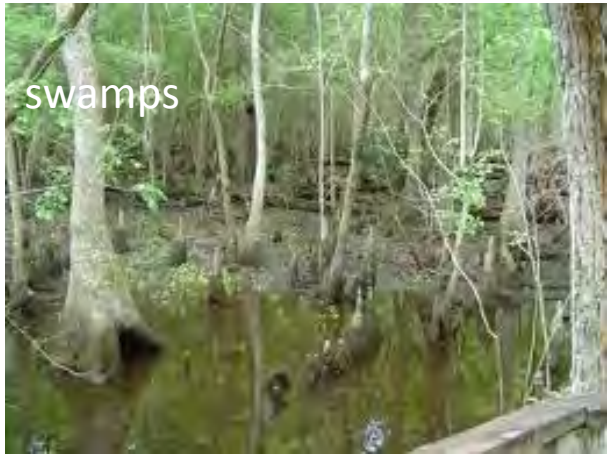
d. estuary
   - transition zone where river meets ocean
   - intermediate salinity
     - varies depending on season and tide
     - supports both marine and freshwater organisms, as well as specialists adapted to intermediate salinity

- nutrient inputs and constant mixing by tides make estuaries among the most biologically productive zones of the ocean

e. wetlands


salt marsh


vernal pools


swamps


riparian area


bogs


baylands

- values and functions of wetlands
  - home to 50% of federally listed threatened or endangered species
  - waterfowl habitat
  - fish habitat
  - flood control
  - absorbs and filters pollutants
  - recharges ground water
  - recreation

- historically viewed as dumping grounds or pest-ridden bogs to be drained, filled and developed
  - 97% of the San Francisco Bay-Delta Estuary has been lost

**Rivers Today**

a. levee
   - prevents water from spilling out of the channel
   - disrupts natural processes of flooding & sediment/nutrient deposition onto the floodplain
   - threatens survival of organisms dependent on periodic inundation

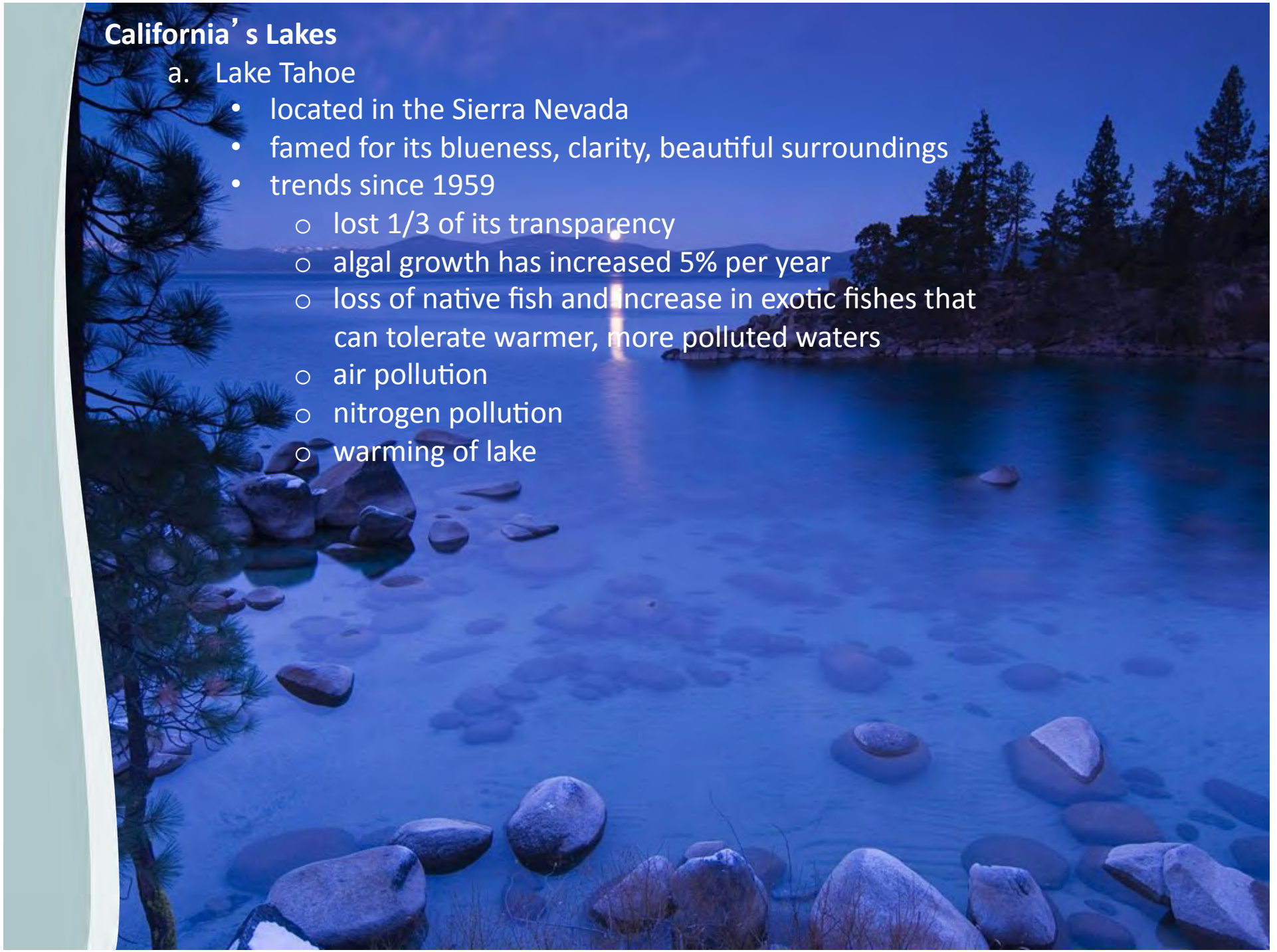
b. dam
   - permanent, reliable, and protective against flooding
   - changes type and size of sediment accumulating in river
   - changes the species composition of the stream ecosystem

c. small reservoirs
   - located on small streams
   - lack capacity to release water until they are filled
   - a single reservoir usually does not pose adverse effects downstream

d. conflicting water needs
   - ex. San Joaquin River
   - at 300 miles, San Joaquin River is the second longest river in California
   - ordinarily has ample seasonal flows and abundant salmon runs

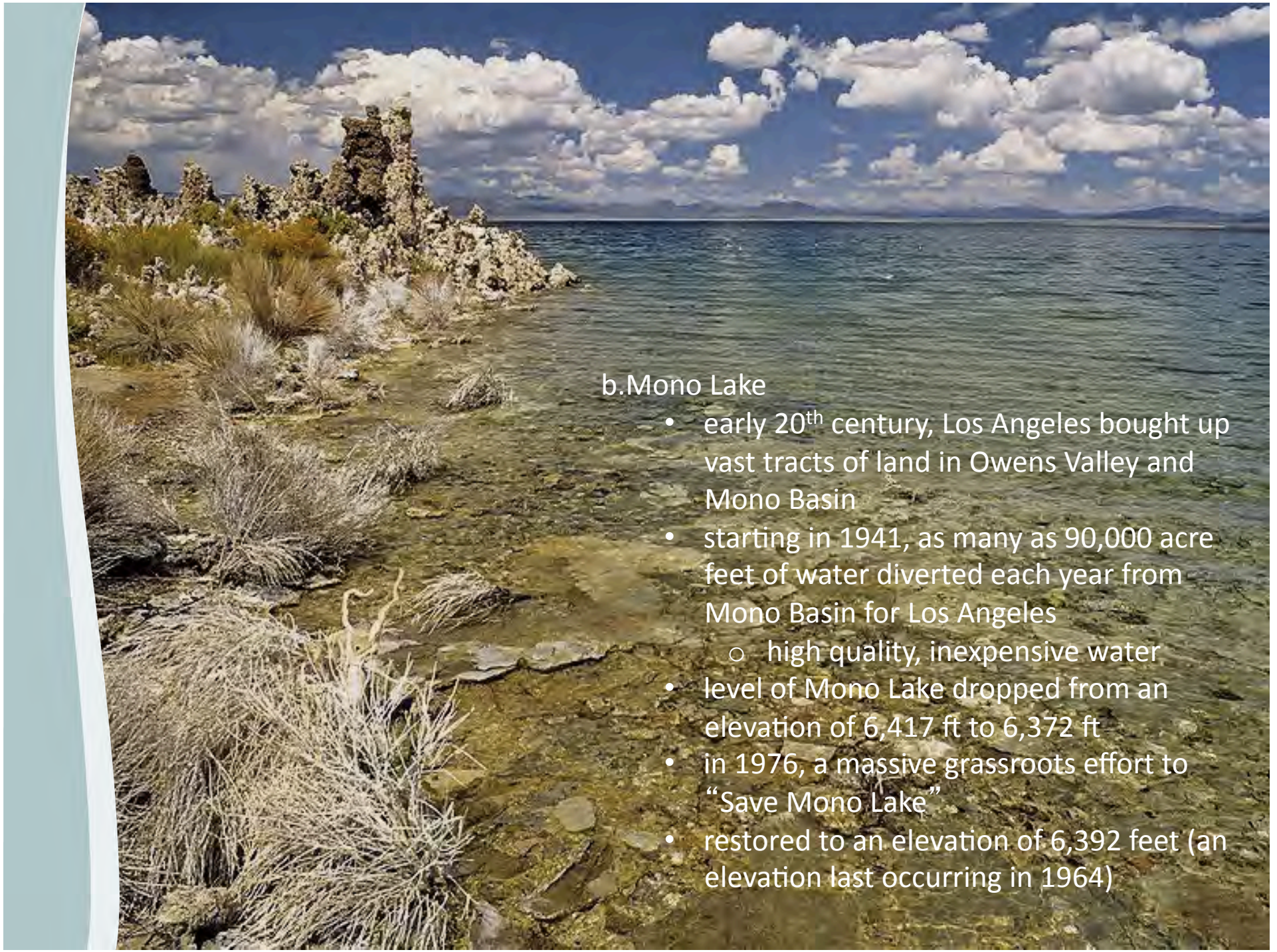
- in 1949, Friant Dam built in 1949 on San Joaquin River
  - resulted in near annihilation of salmon runs

- should we increase flows from Friant Dam to the river to help restore the ecosystem?
  - pro: this will restore the salmon population
  - con: less water available for human consumption
  - how will changes in the snowmelt regime due to global warming effect our decision?



**California's Lakes**

a. Lake Tahoe
   - located in the Sierra Nevada
   - famed for its blueness, clarity, beautiful surroundings
   - trends since 1959
     - lost 1/3 of its transparency
     - algal growth has increased 5% per year
     - loss of native fish and increase in exotic fishes that can tolerate warmer, more polluted waters
     - air pollution
     - nitrogen pollution
     - warming of lake



b.Mono Lake

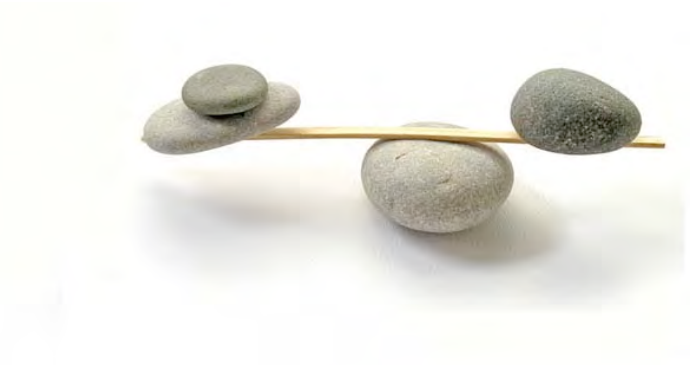
- early 20th century, Los Angeles bought up vast tracts of land in Owens Valley and Mono Basin
- starting in 1941, as many as 90,000 acre feet of water diverted each year from Mono Basin for Los Angeles
  - high quality, inexpensive water
- level of Mono Lake dropped from an elevation of 6,417 ft to 6,372 ft
- in 1976, a massive grassroots effort to "Save Mono Lake"
- restored to an elevation of 6,392 feet (an elevation last occurring in 1964)

c. Clear Lake

- oldest natural lake in North America
- largest freshwater lake entirely within the state borders of CA

**Aquatic Ecosystem Management**

a. reconciling water needs of a growing human population with those of aquatic ecosystems



b. climate change further complicates this problem
   - changes the timing and amount of water available
   - increasing temperatures→ increased demand for water

c. CA water law
   - appropriative water rights: prioritization according to seniority
   - riparian rights: water users divert as needed, in proportion to what is available during times of shortage
   - these rights are particularly important in areas not served by irrigation districts, being the only legal means for obtaining water security

*Discussing Water Rights, A Western Pastime*

- changes over the years in criteria for the granting of water rights have been based on:
  - the recognition of ecological water use as "beneficial use," a legal term designating the right to use of property that is not strictly yours

  - federal laws that protect endangered species
    - state agencies are currently working to finalize guidelines for operating water rights to protect coho salmon and steelhead trout in coastal watersheds

  - California Supreme Court ruling in the 1980s that resulted in the legal recognition of public trust resources
    - foundation for restoring water to Mono Lake

d. Water Quality
   - identification and mitigation of physical & chemical inputs to water bodies that may harm the use of that water either by humans or aquatic organisms ( Total Maximum Daily Load Analysis or TMDL)
     - mandated for polluted water bodies under the federal Clean Water Act, US EPA

- many streams along Northern CA coast are impaired by fine sediment

- one solution at a local scale is to restore riparian zone as a means for ameliorating many of the sediment and nutrient loading problems caused by the watershed
  - plants in riparian zone can take up excessive nutrients, as well as slow the rate of non-point sediment penetrating into the stream

- streams in agricultural and urban areas are often impaired by excessively high nutrient, heavy metal levels, or trash

**Challenges for the Future**

a. as our population grows, our need for water will increase
   - CA's population today is close to 38 million
   - by 2050, it will be 50 million
   - if agricultural use is to remain constant in 2030, an additional 5.9-7.4 million acre-feet of water supply will be required


b. global warming
   - warmer temperatures will increase fraction of precipitation occurring as rainfall
   - less snowmelt in summer→ less water in the reservoir during the growing season

c. possible solutions
   - new dams
   - reducing water use
   - increasing efficiency


- peripheral canal
  - ships water around the Delta from Sacramento River to reach southern part of CA
    - this may have added benefit of restoring proper flow conditions in the Delta

d. one thing we can be sure of: water will remain at the center of economic and policy discussions far into the future.