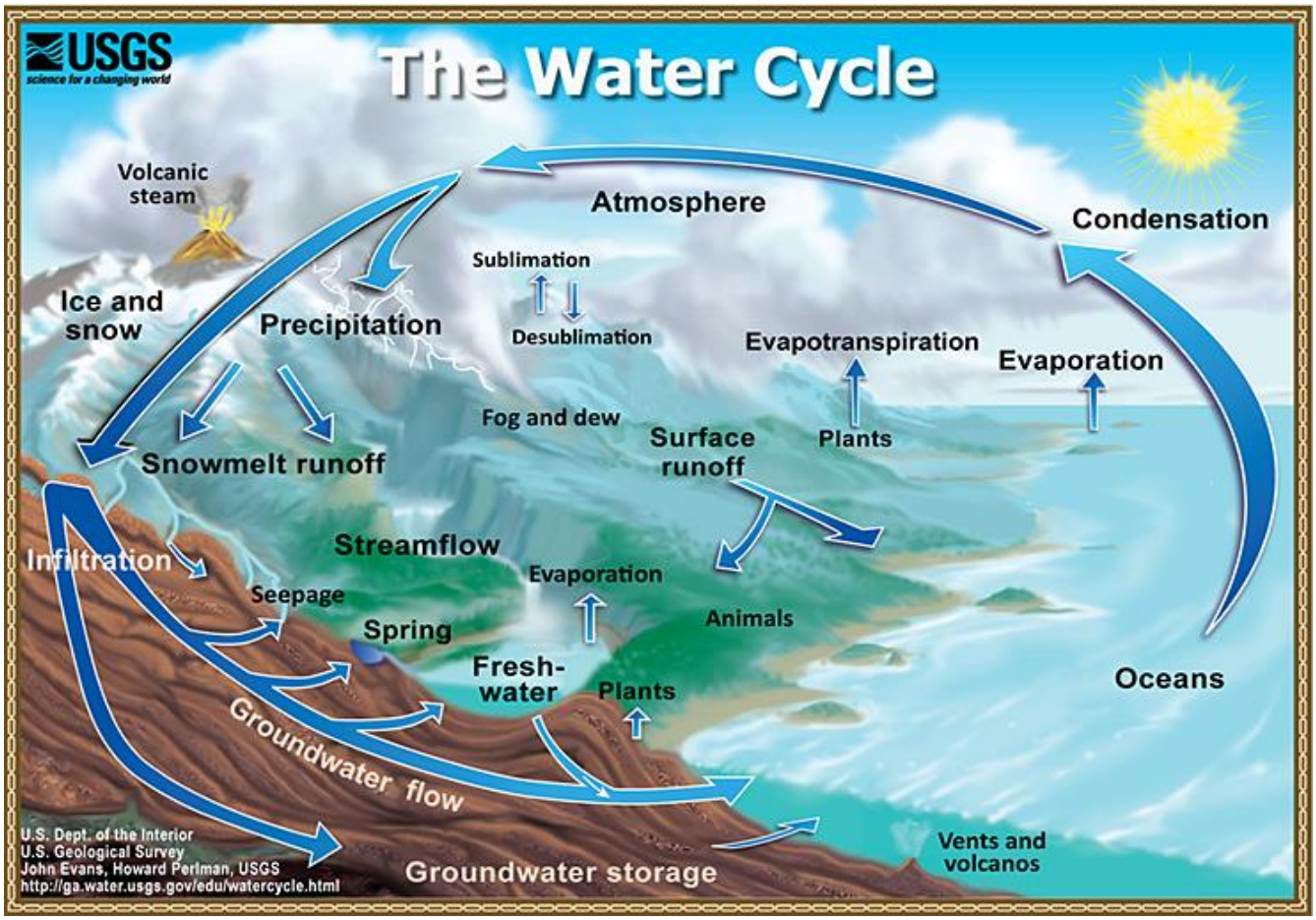
APES CHAPTER 9 NOTES (MRS. BAUCK): WATER RESOURCES

MODULE 26: The Availability of Water



I. Hydrologic Cycle Review (REVIEW ALL TERMS)

A. evaporation, condensation, and purification

1) **hydrology**—*the study of Earth's water*
2) **hydrosphere**—*water found on, in, or above the Earth*
3) **evaporation**—*phase change from a liquid to a gas or vapor above Earth*
4) **transpiration**—*water vapor being given off by plants*
5) **condensation**—*phase change from a vapor or gas to a liquid*
6) **aerosols**—*microscopic particles in the air which promote condensation; natural or from pollution*
7) "loops"— *Evapotranspiration Loop (green water); Surface Runoff Loop (blue water); Groundwater Loop (blue water)*

B. human impact

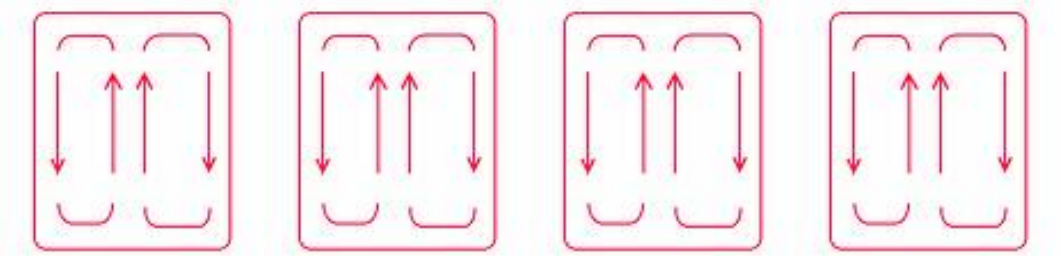
1) changes to Earth's surface
   a) contributing factors: *overgrazing, improper irrigation, deforestation*
   b) consequences: *flooding, erosion, sediment deposition, possible decreased*

infiltration, erratic rainfall, depleted groundwater, depleted surface water, decreased evapotranspiration

2) climate change
   a) hydrologic cycle affected by increasing global temperatures
   b) evaporation increases exponentially with increased temperature

from http://www.sustainableenergy.qld.edu.au/
… "The natural rhythm of the water cycle may be being disturbed by global warming because:
It has increased the amount of water vapor in the atmosphere.
It has increased the extent of cloud formation.
It has produced higher rainfall in many areas.
This could lead to even greater warming because water vapor is itself a greenhouse gas, and it is more efficient at absorbing heat energy than carbon dioxide. This increased warming could result in even more water vapor being taken up by the atmosphere, leading to still greater warming. This cycle has been described as a *runaway greenhouse effect*."

C. **convection currents**—*warm rising, cool sinking…* can happen with water and air
   1) mountain ranges block air current flow
      a) *High precipitation* on the **windward** side
      b) *Low precipitation* on the **leeward** side (**rain shadow** effect)
   2) **Hadley cells**—*"loops"* of warm air rising and cool air sinking



II. Water Above and Under Ground
   A. Global water stats
      1) *water covers ~70% of Earth's surface*
      2) *~ 97% of Earth's water is salt water*
      3) from the remaining ~2.78%...
         a) 0.617% is groundwater
         b) 0.013% is in lakes and streams
         c) 2.148% is in glaciers and icecaps
         d) 0.000834% is water vapor

   B. **groundwater**—*accumulated water below the surface*
      *** REVIEW POROSITY and PERMEABILITY ***
      1) **fresh water** = *water containing < 1000 ppm salt content*
      2) two paths for precipitated water
         a) i**nfiltration**—*water seeping into the surface*
         b) **runoff**—*water flowing over the surface*
      2) infiltration-runoff ratio—comparison
      3) two paths for infiltrated water
         a) **capillary water**—*water held in the ground*
            - released by *evapotranspiration (green water flow)*

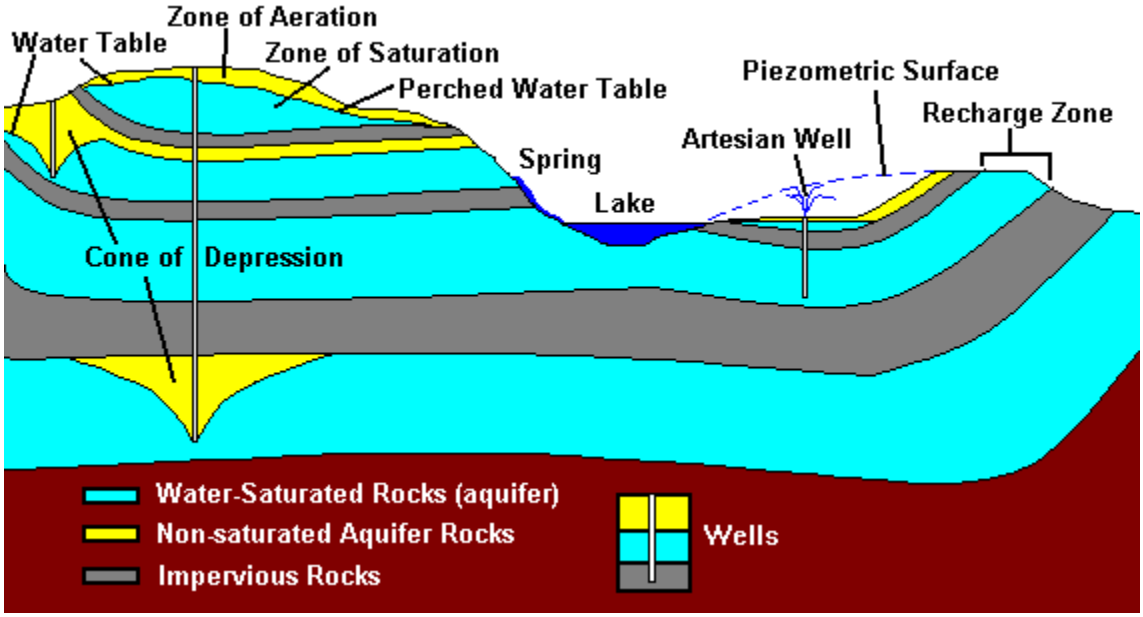
b) **percolation**—*gravitational water moves downward through pore spaces (blue water flow)*

4) **watershed**—*all land that drains into a body of water*
5) **surface water**—*bodies of water on the surface of Earth* (as opposed to groundwater)
6) other terms
   a) **water table**—*top of the groundwater*
   b) **aquifer**—*layer of porous, permeable rock and sediment through which water flows*
      i.) **confined aquifer** *is surrounded by layers of rock or clay, hindering water flow*
      ii.) **unconfined aquifer** *is covered by soil, which assists water flow*
      iii.) *largest aquifer in the U.S.* = **Ogallala aquifer**

https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/initiatives/?cid=stelprdb1048809 The Ogallala Aquifer Initiative
"Underlying the Great Plains in eight states, the Ogallala supports nearly one-fifth of the wheat, corn, cotton and cattle produced in the United States. It has long been the main water supply for the High Plains' population and is being used at an unsustainable rate. The reservoir was created more than a million years ago through geologic action and covers about 174,000 square miles."

   c) **recharge area**—*where water enters an aquifer through percolation*
   d) **spring**—*natural "percolation" of water from an aquifer up to the surface*
   e) **seep**—*water flowing from a larger, wider area*
   f) **Artesian well—***water flowing from a confined aquifer from a drilled hole*
   g) **cone of depression**— *any area with insufficient groundwater due to well water withdrawal*

A TYPICAL AQUIFER



Source: www.uwgb.edu

FLORIDA HAS MORE THAN ONE AQUIFER

Source: http://www.ufl.edu

"Florida's aquifers vary in depth, composition, and location, and are divided into two general categories: *Surficial* and *Floridan*. **Surficial aquifers** *are shallow beds of shells and sand that lie less than 100 feet underground.* They are separated from the Floridan aquifer from a confining bed of soil. Some have been contaminated by saltwater, yet they provide most of the public freshwater supply southwest of Lake Okeechobee and along the Atlantic coast north of Palm Beach.

In surficial aquifers, the groundwater continuously moves along the hydraulic gradient from areas of recharge to places of discharge. Surficial aquifers are recharged locally as the water-table fluctuates in response to drought or rainfall. Therefore, the temperature and flow from water-table springs varies. Important surficial aquifers include:

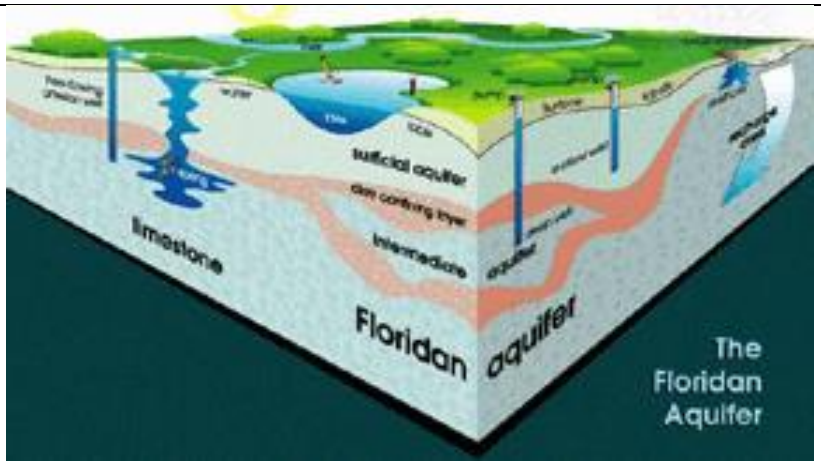
1) *The Biscayne aquifer is a surficial aquifer located in southeast Florida. It covers over 3,000 square miles, and is the most intensely used water source in Florida,* supplying water to Dade, Broward, Palm Beach, and Monroe counties. The aquifer lies close to the surface and is extremely vulnerable to pollutants that leach through the shallow limestone bedrock. In some areas, it has been contaminated by fuel spills, industrial discharge, landfills, and saltwater.

2) The *sand and gravel aquifer* stretches 2,400 square miles across the Panhandle. Although this surficial aquifer is replenished with rainfall, water levels have dropped due to water-well use (pumping), and it has been contaminated by industrial waste and saltwater instrusion.

3) The *Chokoloskee aquifer* is another surficial aquifer in the state; it covers 3,000 square miles in southwest Florida. It is recharged by rainfall. It is believed that artificial drainage canals have lowered water levels and increased saltwater intrusion.

The **Floridan aquifer**, *in contrast to surficial aquifers, is the portion of the principal artesian aquifer that extends into Florida.* The principal artesian aquifer is the largest, oldest, and deepest aquifer in the southeastern U.S. Ranging over 100,000 square miles, it underlies all of Florida and parts of southern Alabama, southeastern Georgia, and southern South Carolina. The Floridan portion developed millions of years ago during the late Paleocene to early Miocene periods, when Florida was underwater. Unlike water in surficial aquifers, groundwater in the Floridan aquifer is contained under pressure by a confining bed of impermeable sediments. When the water pressure is great enough, the groundwater breaks to the surface and a spring flows. Water temperature and flow from a Floridan spring is relatively constant. The Floridan aquifer supplies fresh water to many cities such as Daytona, Gainesville, Jacksonville, Ocala, St. Petersburg, Tallahasse, and numerous rural communities. In areas where the Floridan contains saltwater, due to saltwater intrusion along the southwest Florida coast, it is injected with sewage and industrial waste.

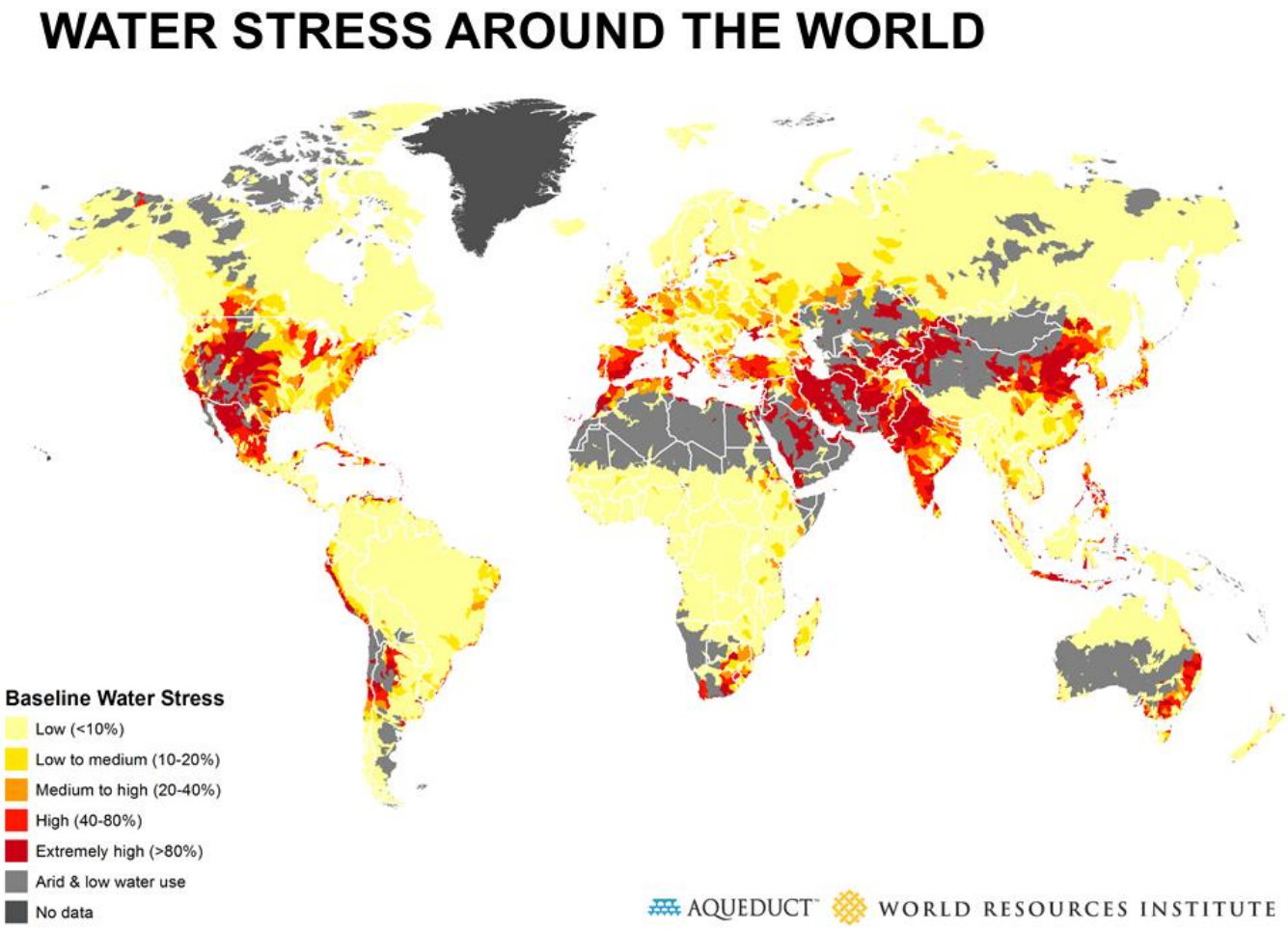
In addition to the surficial and Floridan aquifers, several **intermediate aquifers** comprised of limestone beds lie between the surficial and Floridan aquifers, and a variety of **undifferentiated aquifers** store approximately ten percent of Florida's groundwater."



Source: www.usgs.gov

C. surface water and aquatic biomes (more in chapter 4)
   1) surface water: *lakes, ponds, pools, rivers, streams, wetlands*
   2) *lakes can form from glaciation and tectonic activity*
   3) largest wetlands in the world by surface area
      a) Pantanal (South America)
      b) Everglades (Florida)
   4) largest rivers in the world by water volume
      a) Amazon (South America)
      b) Congo (Africa)
      c) Yangtze (China)
   5) **floodplain**—*any land adjacent to a river*
   6) **saltwater intrusion**—*salt water infiltrating an area due to excessive withdrawal of ground water*

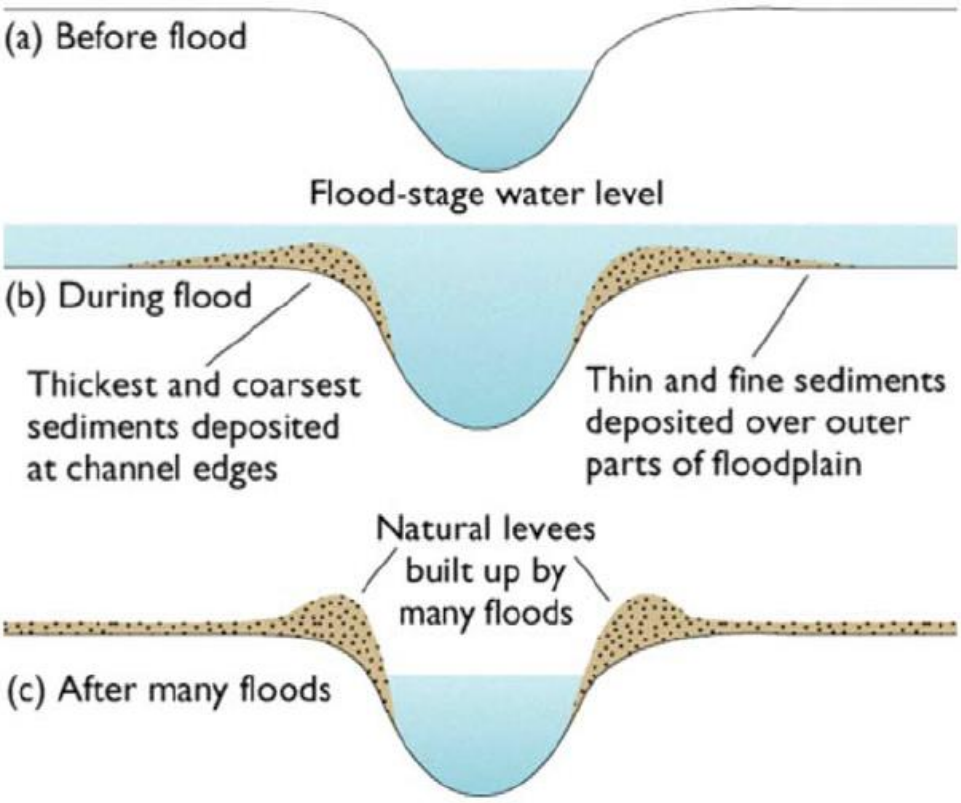
D. **precipitation**—*water returning to the earth's surface*; rain, snow, hail, etc.
   MAJOR DROUGHTS:
   1) Australia, 1995-2009
   2) Spain, 2008 (imported water from France)
   3) Northern India, 2002-2008 (so severe it could be seen from space)
   4) China, ongoing
   5) Syria, 2006-2011
   6) SE Brazil, ongoing
   7) California, ongoing



MODULE 27: Human Alteration of Water Availability

I. Flood Prevention

A. **Levees** https://www.nationalgeographic.org/encyclopedia/levee/

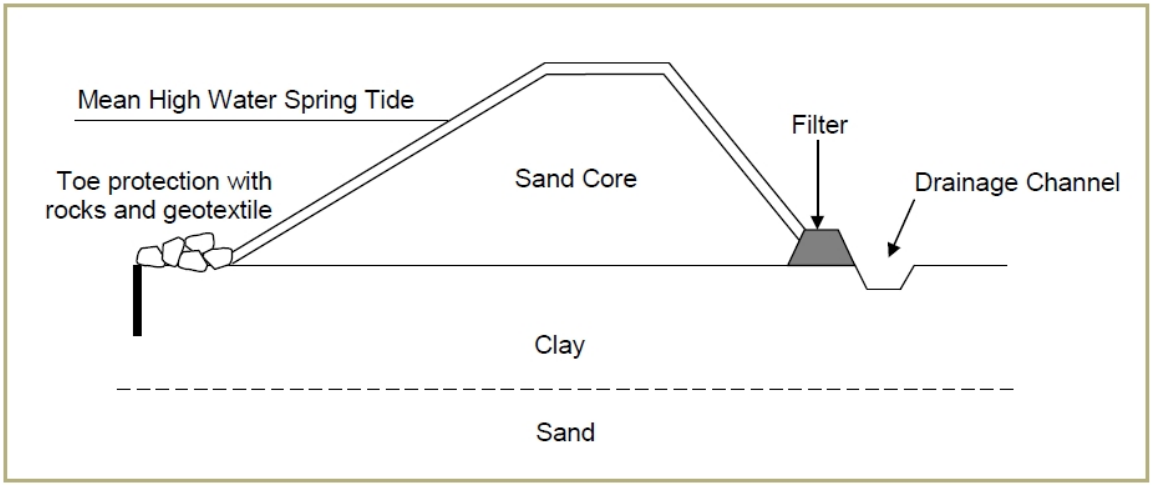


Source: researchable.net

1) *enlarged banks built up both sides of a river*
2) can occur naturally as well
3) pros – flood prevention and safety
4) cons
   a) reduction of land fertility from lack of sediment deposition
   b) sediments are carried further downstream
   c) may cause flooding further downstream
   d) area which are rendered habitable by the levee may still flood
   e) can cause major flooding when they overflow or break

B. **Dikes** https://www.nationalgeographic.org/encyclopedia/dike/

1) *enlarged banks built on one side of a river to prevent ocean water from flowing in*
2) *in geology, a sheet of rock that is formed in a fracture in a pre-existing rock body*
3) can be igneous (magmatic) or sedimentary (clastic) in origin



Source: ClimateTech Wiki

II. Water Flow Restriction

A. General terms and information
   1) **dam**—a barrier built across a stream or river for water flow control
      a) large dams are 4 stories tall or taller
   2) **reservoir**—*any body of water crested by damming a stream or river*
   3) Guideline: only 30% or less of a river's flow should be withdrawn yearly.

B. Dam information
   1) U.S. Dams http://www.usdams.info/
   2) Florida Dams http://www.usdams.info/USA/Florida/
   3) World Commission on Dams
   https://www.internationalrivers.org/campaigns/the-world-commission-on-dams
   4) *world's largest dam: Three Gorges Dam, across the Yangtze River in China*

C. Pros and cons of dam building
   1) *pros*
      a) *irrigation water*
      b) **hydroelectric power** *(turbines)* – more later
      c) *flood control*
      d) *increased accessible water supply*
   2) *cons*
      a) *requires a substantial amount of time to construct*
      b) *depletes the underlying areas of water, affecting the water table*
      c) *disrupts food chains of area*
      d) *possible drying up of the body of water*
      e) *may displace residents of the affected area*
      f) *can cause damage to ecosystems and disrupt natural river systems*
         - *disrupts fish migration for those swimming upstream*
            - **fish ladder**—*stair-like structures with flowing water installed in some dams*
         - lack of seasonal flooding and its cleaning effects negatively affects some species
      g) *not a sustainable practice (does not ensure long-term success)*
      h) *repairing a dam is not easy*

i) *removing a dam is not easy*
j) *diminishes fresh water flow to **estuaries**—areas where fresh water flows into salt water*

National Estuary Program

The National Estuary Program (NEP) was established by Congress in 1987, as an amendment to the Clean Water Act, to recognize and protect "estuaries of national significance." The NEP targets a broad range of issues and engages local communities in the process of identifying problems affecting their estuary and coming up with solutions. The program focuses not just on improving water quality, but on maintaining the character of the entire ecosystem.

The NEP is administered by the U.S. Environmental Protection Agency (EPA), which provides money to local communities to study their estuary. Each NEP has a management committee that is made up of representatives from federal, state and local government agencies responsible for managing the estuary's resources, and often include other members of the community: conservation advocates, business leaders, educators and researchers. These stakeholders work together to

- Identify the major threats facing an estuary.
- Develop a comprehensive conservation and management plan (CCMP) as part of a consensus community process that sets forth specific actions to restore and maintain the estuary.
- Encourage implementation of the CCMP.
- Monitor the progress that has been made toward the achievements of the CCMP's goals.

A monitoring review is typically completed every two years following the CCMP's adoption.

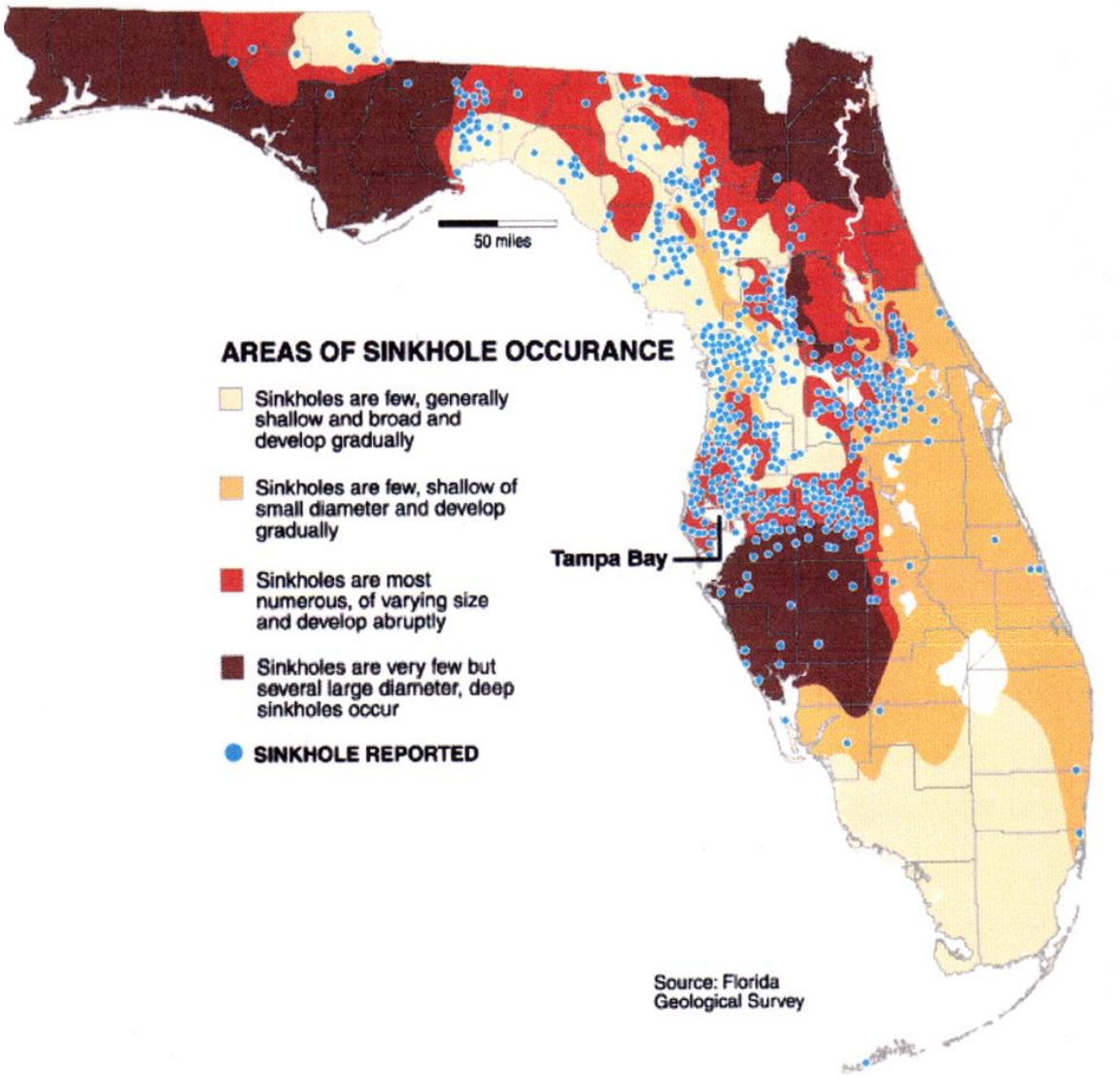
Individual estuaries are nominated to participate in the NEP by their respective Governors. The EPA Administrator approves or disapproves the nominee. *Of the 28 estuaries in the NEP, four are found in Florida: Charlotte Harbor, Indian River Lagoon, Sarasota Bay and Tampa Bay.*

D. Consequences of Overdrawing Groundwater
1) *falling water tables and depletion*
   a) diminished crop harvest
   b) Ogallala aquifer is overdrawn, twice as much as the recharge rate!
2) *diminishing surface water*: possible drying up of wetlands, springs, seeps, streams, rivers
3) *saltwater intrusion* caused by aquifer depletion and lowered water table
4) **land subsidence**—*natural settling of the land*; can be caused by dropping water levels underground creating a loss of support
5) **sinkhole**—*deep subsidence*
   a) a common problem in FL due to the reaction of slightly acidic water with limestone
   b) example: $\mathbf{2HNO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + CO_2 + H_2O}$

SINKHOLE

Source: http://sjr.state.fl.us

SINKHOLES IN FLORIDA



III. Water Flow Transportation: Aqueducts

A. **aqueducts**—*canals or ditches used to transport water from one location to another*

B. ancient aqueducts https://www.ancient.eu/aqueduct/

1) structure

"*The earliest and simplest aqueducts were constructed of lengths of inverted clay tiles and sometimes pipes which channeled water over a short distance and followed the contours of the land.*

2) timeline https://www.ancient.eu/aqueduct/

a) c. 1900 BCE – first aqueducts in Mesopotamia and Minoan Crete
Mesopotamia = mostly modern Iraq; some of Iran, Turkey, and Syria

b) c. 1400 BCE – the Mycenaeans, at Tiryns and Mycenae

c) c. 850 BCE – long-distance aqueducts with tunnels, Assyrian empire
d) c. 750 BCE – sophisticated network of aqueducts, Babylon
e) c. 580 BCE – long-distance aqueducts, Athens and Samos
f) c. 312 BCE – first aqueduct in Rome: Aqua Appia
g) c. 272-269 BCE – Anio Vetua aqueduct, Rome
h) c. 250 BCE – three aqueducts in Syracuse (Sicily; Italy)
i) c. 200 BCE – sophisticated aqueduct network in Pergamon (in modern Turkey)
j) c. 144-140 BCE – Aqua Marcia aqueduct, Rome
k) c. 80 BCE – aqueduct at Pompeii (Roman Empire)
l) c. 50 CE – largest Roman aqueduct, 49 m high, at Pont du Gard Roman

4) Rome details – http://romancolosseum.org/roman-aqueducts/

"The first aqueduct in the city of Rome was the Aqua Appia, built in 312 (BCE) during the Roman Republic. The combined length of all the aqueducts built in ancient Rome is about 800 km (500 miles). However, only 47 km (29 miles) were above ground, as most Roman aqueducts ran beneath the surface of the ground."

C. Modern aqueducts
1) general – http://www.industrytap.com/worlds-largest-aqueducts-moving-billions-of-gallons-of-water-daily/3525
2) global and U.S. list – https://en.wikipedia.org/wiki/List_of_aqueducts
3) major U.S. aqueducts
a) Catskill Aqueduct – from Catskill Mountain streams and lakes to New York City
b) Colorado River Aqueduct – from Colorado River to Los Angeles, CA

IV. Desalination – desalting sea water

***** SUPPLEMENT TO THESE NOTES*****
http://kwanga.net/apesnotes/DESAL%20ARTICLE%20%20-%20NOTES%20SUPPLEMENT.pdf

A. **desalination** ("desal")—*the removal of salts from sea water*
B. main processes: *reverse osmosis (RO) and distillation*
C. Tampa Bay Seawater Desalination Plant
background info: www.water-technology.net/projects/tampa
https://www.tampabaywater.org/tampa-bay-seawater-desalination-plant

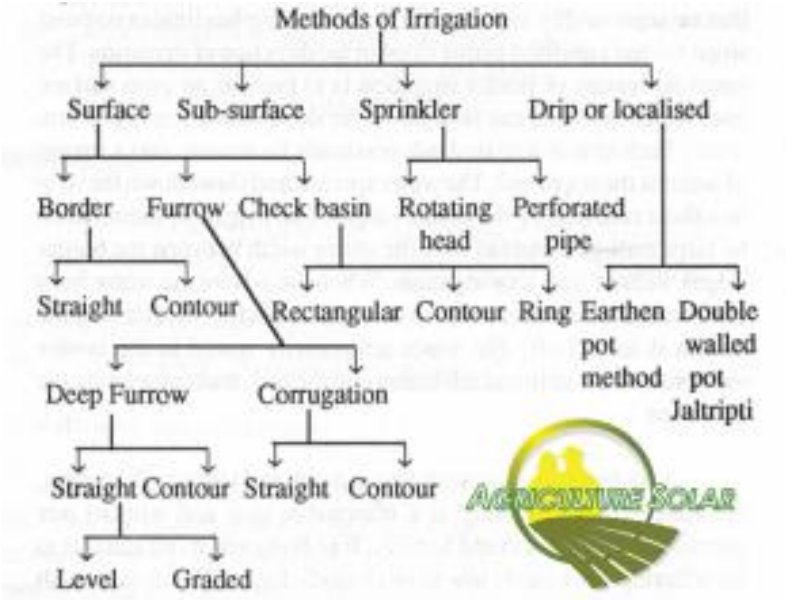
… "2.4 million west-central Florida residents are benefiting from a project pioneered by their regional water utility, Tampa Bay Water. The Tampa Bay Seawater Desalination Plant, now fully operational, is providing millions of gallons of clean drinking water from the sea every day. At 25 *million gallons per day (mgd)*, the plant provides about 10 percent of the Tampa Bay region's drinking water supply…

The plant uses about 44 mgd of seawater from a nearby power plant's cooling system. The seawater is pretreated to remove algae and other particles. Then, *reverse osmosis* filters separate 25 mgd of freshwater from the seawater. The unused concentrated seawater is diluted with up to 1.4 billion gallons of cooling water before it is discharged to the bay. That dilution is why environmental studies show no measurable salinity change in Tampa Bay related to plant production. Protecting the environment was a big concern for Tampa Bay Water… The plant was built to meet the stringent U.S. environmental regulations and overcame the challenges they presented…"

MODULE 28: Human Use of Water Now and in the Future

I. General information: Uses and Sources of Fresh Water
- A. **water footprint**—*total daily per capita use of water*
- B. *quantitative (shortage concerns) vs. qualitative (purity issues)*
- C. *U.S. water usage: agricultural (irrigation), industrial, residential*
  1) **nonconsumptive**—*the water is still available to use afterward*
  2) **consumptive**—*the water is inaccessible afterward*
  3) U.S. water use: ~ half comes from groundwater and ~ half from surface water
  4) U.S. water use: ~85% of freshwater is used for irrigation
- D. worldwide water usage http://www.worldometers.info/water/
  1) ~70% for agriculture/irrigation, ~20% for industry, ~10% for domestic use
  2) over one billion people do not have regular access to fresh, clean water
  3) 80% of diseases in developing countries are from water-borne pathogens

II. Traditional Agricultural Water Use
- A. **irrigation—***controlled water flow* ***** review module 32 notes *****
- B. methods: *furrow, drip, flood, spray*
- C. *water loss of 30-50% (with usual methods: flood and center-pivot)*
  a) evaporation
  b) percolation
  c) runoff
- D. improvements
  a) **surge flow**—*computerized control over water flow; saves water*
  b) **drip irrigation**—*plastic pipes with tiny holes through which water seeps*
  c) **treadle pumps** (like step machines) available in developing countries
- E. hindrances
  a) government subsidies for traditional irrigation: almost free for the farmer
  b) pipe network installation is costly



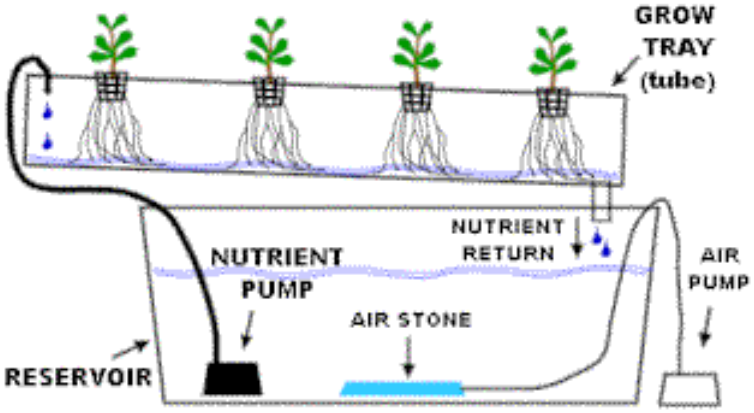
III. Hydroponics

A. **hydroponics**—*growing plants in greenhouse conditions by immersing the roots in a nutrient-rich solution*

B. pros

1) water can be reused
2) controlled temperature and humidity inside
3) higher level of yield than traditional agriculture
4) reduced or eliminated use of pesticides

C. cons – more expensive than traditional agriculture



Source: simplyhydro.com

IV. Industrial Water Use https://water.usgs.gov/watuse/wuin.html

A. industrial uses (more later on power plants)

1) *hydroelectric power plants (~50% industrial water use in U.S.)*
2) *thermoelectric (traditional) power plants*
3) machinery coolant
4) metal processing/refining
5) paper production/refining
6) textile manufacturing
7) *hydraulic fracturing ("fracking") - more later*

B. review **consumptive use** vs. **nonconsumptive use**

V. Residential (household) water use – Municipal Systems

A. water use in U.S. http://www.data360.org/dsg.aspx?Data_Set_Group_Id=757
~ 159 gallons per person per day (FL = ~134 gal total, ~85 gal residential)

B. water use today https://www3.epa.gov/watersense/our_water/water_use_today.html

C. WATER USE CALCULATOR
https://www.swfwmd.state.fl.us/conservation/water-use-calculator

D. WATER Q & A https://water.usgs.gov/edu/qa-home-percapita.html

E. common uses

1) *showers and baths*
2) *washing laundry by hand or machine*
3) *washing dishes by hand or dishwasher*
4) *swimming pool maintenance*
5) *lawn watering*

6) *flushing toilets*
   a) National Energy Policy Act of 1992
   b) 1997: illegal to sell old toilet styles with large tanks
   c) 1.6-gal toilet; 1.1-gal or less toilet

F. *recycling of* **gray water** *(slightly dirty water from sinks, showers, washing clothes, etc.)*
G. treatment of wastewater to use for watering lawns
H. **xeriscaping** (landscaping with native, drought-resistant plants) is encouraged to cut down on water required

VI. Water Ownership and Stewardship
A. key points
   1) We must realize we have a large impact on the hydrologic cycle.
   2) We must conserve what we can.
   3) We must take responsibility for our actions.
B. public policy and challenges
   1) *Water Wars*—water needed for irrigation vs. water needed for drinking
      https://news.nationalgeographic.com/2016/07/world-aquifers-water-wars/
   2) **The Clean Water Act (CWA) of 1972**
      https://www.epa.gov/laws-regulations/summary-clean-water-act
      a) the cornerstone of surface water quality protection in the U.S.
      b) does not deal directly with ground water or water quantity issues

"The Clean Water Act (CWA) *establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters*. The basis of the CWA was enacted in 1948 and was called the Federal Water Pollution Control Act, but the Act was significantly reorganized and expanded in 1972. 'Clean Water Act' became the Act's common name with amendments in 1972.

Under the CWA, EPA has implemented *pollution control programs such as setting wastewater standards for industry*. EPA has also developed *national water quality criteria recommendations for pollutants in surface waters.*

The CWA made it *unlawful to discharge any pollutant from a point source into navigable waters, unless a permit was obtained*. EPA's *National Pollutant Discharge Elimination System (NPDES) permit program* controls discharges. Point sources are discrete conveyances such as pipes or man-made ditches. Individual homes that are connected to a municipal system, use a septic system, or do not have a surface discharge do not need an NPDES permit; however, industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters."

3) **World Water Council – WWC**

World Water Council (WWC) http://www.worldwatercouncil.org/en

"The World Water Council was established in 1996 in response to increasing concern from the global community about world water issues. Its mission is to promote awareness, build political commitment and trigger action on critical water issues at all levels, including the highest decision-making level, to facilitate the efficient management and use of water in all its dimensions and on an environmentally sustainable basis… The Council focuses on the political dimensions of water security, adaptation and sustainability."

4) **World Water Forum - WWF**
meets every three years in different venues all over the globe

"The World Water Forum is an initiative of the **World Water Council** that has the aim of raising the awareness on water issues all over the world. As the main international event on water, it seeks to enable multi-stakeholder participation and dialogue to influence water policy making at a global level, thus assuring better living standards for people all over the world and a more responsible social behavior towards water issues in-line with the pursuit of sustainable development.

The World Water Forums are built on the knowledge, experience and input of different types of organizations active in the global water polity. It is a venture founded on the principles of collaboration, partnership and innovation."

VII. Conservation

50 WAYS TO SAVE WATER http://kwanga.net/apesnotes/50-ways-to-save-water.pdf

EPA Region 4 https://www.epa.gov/aboutepa/about-epa-region-4-southeast

EPA Everglades Restoration https://www.epa.gov/everglades