and cause cooling (dampen effect of global warming) = NEGATIVE feedback

(2) OPTION TWO: more water vapor in warm atmosphere → more greenhouse gas → more insulation → traps more heat → more warming = POSITIVE feedback

c) But either way, no matter what, the earth IS warming, and the Earth WILL have a more vigorous water cycle
d) Also: We can predict where precipitation will change
   (1) Wet places get wetter; dry places get dryer

III. Watersheds and Geology Basics
   A. Watersheds
      1. An area of land bounded by divides (ridges) that contribute to the flow of the body of water (river, lake, bay, sea)--synonyms = drainage basin, catchment
   B. Channels and Hillslopes
      1. Channels: General term for the lower, trough-shaped parts of a watershed where water flow is concentrated
      2. Hillslopes: The unchanneled part of a watershed; i.e. most of the land surface
   C. Chemical and Physical Weathering
      1. Chemical
         a) Chemical weathering (also known as decomposition or decay) is the breakdown of rocks by chemical mechanisms, the most important being carbonation, hydration, hydrolysis, oxidation, and ion exchange in solution.
         b) Chemical weathering changes the composition of the rock material toward surface minerals, such as clays. It attacks minerals that are relatively unstable in surface conditions, such as the primary minerals of igneous rocks like basalt, granite or peridotite.
      2. Physical
         a) Physical weathering, also known as mechanical weathering, is the class of processes that causes the disintegration of rocks without chemical change. The primary process in physical weathering is abrasion (the process by which clasts and other particles are reduced in size).
         b) However, chemical and physical weathering often go hand in hand. Physical weathering can occur due to temperature, pressure, frost etc. For example, cracks exploited by physical weathering will increase the surface area exposed to chemical action, thus amplifying the rate of disintegration.
   D. Sediment Grain Size
      1. In rivers & channels (sediment transport): The result of weathering bedrock
         a) Examples: gravel, sand, mud, silt, clay (→ in order from coarse to fine)
      2. River depositional sequence (channels sort these):
         a) Deep channel: coarse-grained sediments, large-scale cross-bedding
         b) Shallow channel: fine-grained sand, small-scale cross-bedding
b) Permeability: How connected the pore spaces are; the state or quality of a material or membrane that causes it to allow liquids or gases to pass through it (Connected pores = high permeability; able to flow through)

5. Recharge
a) A hydrologic process where water moves downward from surface water to groundwater. This process usually occurs in the unsaturated zone below plant roots and is often expressed as a flux to the water table surface. Recharge occurs both naturally (through the water cycle) and through anthropogenic processes (i.e., "artificial groundwater recharge"), where rainwater and or reclaimed water is routed to the subsurface.
   (1) A necessary process to keep a groundwater aquifer working

V. Discharge and Floods (Stream Hydrology)
   A. Relationship between hydrographs and hyetographs
      1. Hydrograph:
         a) A smooth, curvy line graph of stream discharge (Y) against time (X)
         b) A result of river data from a discharge gauging station (volumetric flow rate)
         c) The rate of flow is typically expressed in cubic meters or cubic feet per second (cms or cfs).
      2. Hyetograph:
         a) A bar graph of rainfall intensity (Y) against time (X)
         b) A result of data from rain gauge (keeps track of how much rainfall falls in a given place in a given amount of time)

   Relationship between the two graphs:
   a) Lag or peak: Connecting two graphs
      (1) Lag due to the time inbetween the rain hitting the ground and making it to channel
   b) Shows that higher rainfall intensity results in higher discharge
a) \( Q = CIA \rightarrow Q = 3 \times 3 \times 2 \rightarrow Q = 18 \, m^3/s \)

1. \( \) (Units: \( m \times m \times m / s = m^3/s \) \( \rightarrow m^3/s = \) always the unit of discharge

D. How to use gauging stations and rating curves to estimate discharge

1. Measure the velocity at 4/10 of the water depth (4/10 from the bottom)
   a) This is where the mean velocity is located

2. Cableway/Bridge/Wading Measurements: Go to the channel and take measurements of the discharges across the channel (flow velocity at intervals across the channel)
   a) For small rivers, we can literally walk in the river and do this
3. In bigger rivers, it can be done by a cableway
   a) Advantage: You are not standing in the river affecting the velocity
      1. Cableway: measures flow, sediment, and chemistry
      2. Gauge house: measures water depth
      3. (Note: “stage” = depth)
b) Can support the protection and propagation of fish, shellfish, and wildlife and recreation in water
3. Main goal: to keep our rivers “fishable and swimmable”
4. Mostly addresses point sources
5. Allows EPA to set effluent standards on industry-wide bases and water-quality basis
6. People/companies who want to discharge pollutants need to obtain permit (covers point source pollution)
7. Regulates nonpoint source of pollution – mainly from farming and forestry operations
8. Regulates placement of dredged or fill material in wetlands
9. Funds research
10. Provides loans for municipal point and nonpoint course of pollution
11. Water quality standards are set by state agencies
   a) Water-body specific
      (1) Each body of water has designated uses: drinking water (treated/untreated), recreation (how much contact), fishing/eating, aquatic life, agricultural water supply, and industrial water supply
      (a) Water quality standards depend on these
12. Has it been successful?
   a) Reduced non point source of pollution
      (1) Bacterial and nitrogen oxygen demand decreased in rivers
   b) Other contaminants from non point sources increased:
      a) Water entering into rivers from winter use of road salts
      b) Nitrates from fertilizers carried from runoff from farm fields, suburban lawns, and golf courses
      c) Heavy metals and petroleum leaked from underground storage tanks (gas stations)
      d) Salts carried into rivers from irrigation return flow
      e) Reduced flows in rivers increased water temperatures, reduced dissolved oxygen, and concentrated other pollutants
C. Acid Rain
1. Example of point-source pollution
2. From factories, powerplants (this is the “point” acid rain comes from)
3. Review: acids and bases
   a) Acids: yield H+ ions in solution (pH < 7)
   b) Bases: yield OH- ions in solution (pH > 7)
   c) Carbonic acid: most rain is weakly acidic (pH 5.2-5.4)
4. Powerplants release sulfide, oxygen, nitrogen compounds
5. Once in clouds, mix with water to become acids
6. Acid rain pH < 4-5
7. Prevailing wind direction heading northeast (resulting in lower pH (increasing acidity) of rainwater in northeast)
8. Dead trees (forests) from acid rain
9. Cleopatra’s Needle: serves as example of weathering of rock due to weathering from acid rain
10. Other problems:
   a) Fish do not like water with pH less than 5
      (1) Normal rain water high 5
      (2) Acidic stream water affects fish
11. Question: Which of the following is the most important cause of acid rain? (All are causes)
   a) Coal-burning powerplants → answer
   b) Gasoline-burning cars and trucks
      (1) Sort of a point source, but there are quite a lot of them
      (2) Another important source
      (3) But coal is worse than gasoline because involves sulfide → sulfide nitrogen → compound in air
   c) CO₂ from respiration
   d) Biomass burning
      (1) Another way nitrogen added to the atmosphere

D. Dissolved Gases (O₂ and CO₂)
1. Dissolved O₂:
   a) Vital to any aquatic fauna that uses gills to breath
   b) Salmonid species of fish require dissolved oxygen contents greater than 5 mg/L
   c) Important factor in the way we taste water
(4) Decline in oysters → Current oyster populations filter bay waters in years
f) Which of the following pollutants does not cause eutrophication?
   (1) Sewage
   (2) Fertilizers
   (3) Petroleum products → answer
   (4) Detergents
      (a) Lots of phosphorus in them

F. Wastewater Management
   1. Sewage treatment
      a) 3 steps:
         (1) Primary treatment
            (a) Main purpose: physical separation of solids, greases, etc.
            (b) Removes 30-40% of pollutants
            (c) These are dumped or landfilled elsewhere
         (2) Secondary treatment
            (a) Main purpose: reduce organic matter (therefore reduce BOD - biochemical oxygen demand) using bacteria
            (b) 90% of organic matter removed after this
            (c) Produces sludge
         (3) Discharge/ex tertiary treatment
            (a) Wastewater is discharged into bodies of water or can be used as fertilizer if there is any remaining nutrients
            b) Two options:
               (i) 1. Discharge to surface water or groundwater
               (ii) 2. Send to tertiary treatment prior to discharge
                  (a) Main purpose: reduce N and P with filters, chemicals, or soil (with microbes)
                  (b) May also reduce heavy metals, human-made chemicals, or microbes
                  (c) Then, discharge or reuse as reclaimed water
                  (d) Still rare but use is increasing