ENVIRONMENTAL GEOLOGY (GEOLOGY 102)

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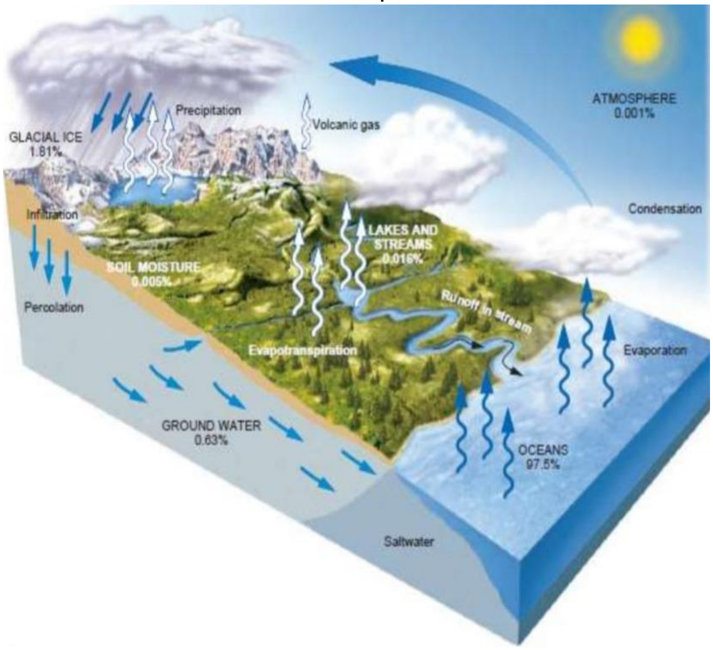
FINAL MATERIALS

CHAPTER SIX

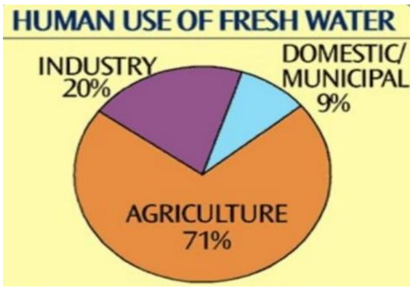
STREAMS & FLOODING

THE HYDROLOGIC CYCLE

- **Hydrosphere** includes all water at & near earth's surface that is caught up in the **hydrologic cycle**
  - **The main processes of the hydrologic cycle** involve evaporation & precipitation
  - **Evapotranspiration**: precipitation onto land can re-evaporate (directly or through plants)
  - **Flows:** Infiltrate into the ground, or run off over the ground surface by streams or overland flow
  - The total water moving through the hydrologic cycle = 100Ma Ba gallons/yr (G = 3.79 L)
  - The oceans is the largest water reservoir (>97%) lakes & streams only 0.016%, & the oceans are principal source of evaporated water because of their vast areas of exposed water surface



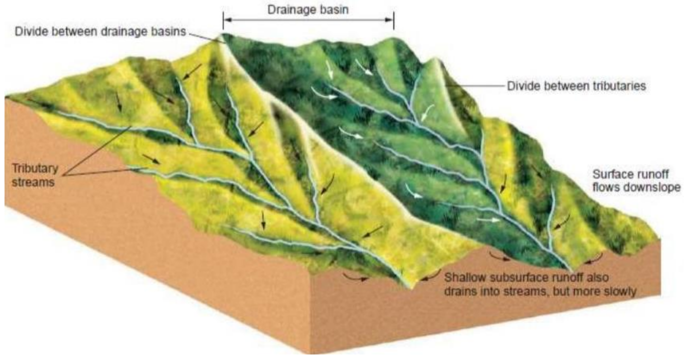
- A portion of water is diverted for human use, but it ultimately makes its way back into the global water cycle by a variety of routes, including:



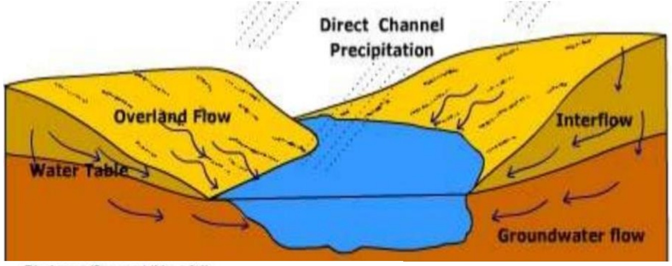
  1. Release of municipal sewage
  2. Evaporation from irrigated fields
  3. Discharge of industrial wastewater into streams
- Water may spend extended periods of time (even 100s of 1000s of yr) in storage in water reservoirs including a glacier, an ocean, & ground water
- **Water participate in other geologic cycles such as:**
  1. Streams eroding rock
  2. Moving sediment
  3. Subsurface waters dissolving
  4. Transporting dissolved chemicals
  5. **Rock cycle**: Most of water have been outgassed from the earth's interior by volcanoes & small amounts returned to mantle with subducted plates, so quantity of water remains constant

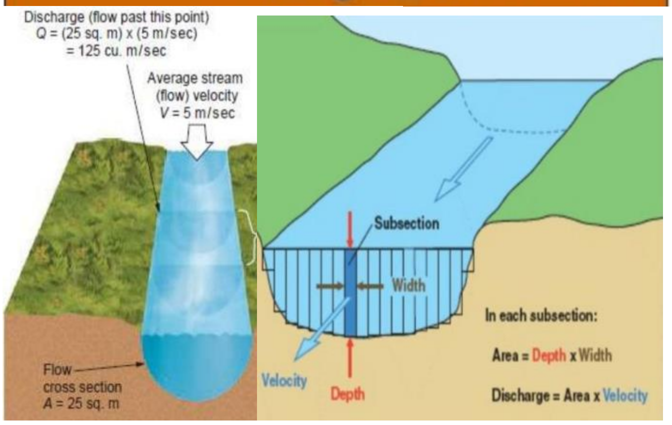
STREAMS

- **Stream**: any body of flowing water confined in channel, regardless of size, flows downhill through topographic lows, carrying away water over surface
- People tend to use river for a large stream
- **Drainage Basin or Watershed**: is the region from which a stream draws water
- **Divide**: separates drainage basins



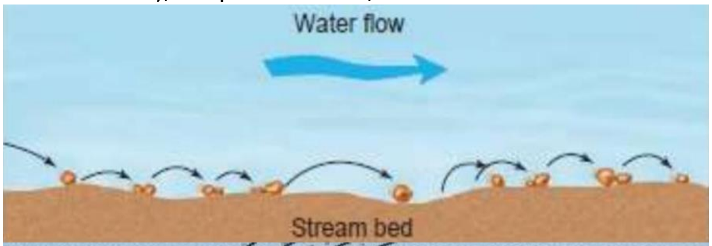
- **The size of a stream is related to:**
  1. **The size (area) of the drainage basin** upstream at point (this determines how much water can be collected into the stream)
  2. **Climate**: amount of precipitation & evaporation
  3. **Vegetation & the underlying geology**
- Stream carves its channel (without human affect) & the channel carved is broadly proportional to the volume of water that must be accommodated
- Long-term, sustained changes in precipitation, land use, or other factors (change the volume of water flowing in the stream) will be reflected in corresponding changes in channel geometry
- **The size of a stream may be described by its discharge**: the volume of water flowing past a given point (cross section) in a specified length of time
- **Discharge (in m³/s)** is the product of channel cross section (area) times average stream velocity
  - **Affected by** season, weather, human activities

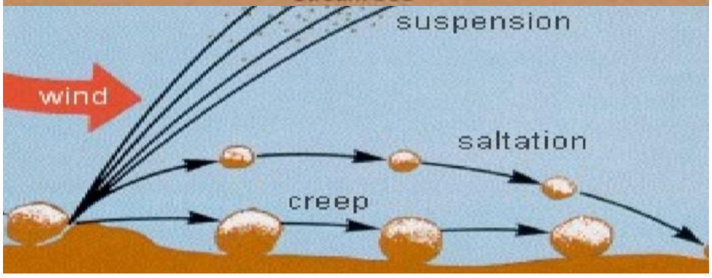




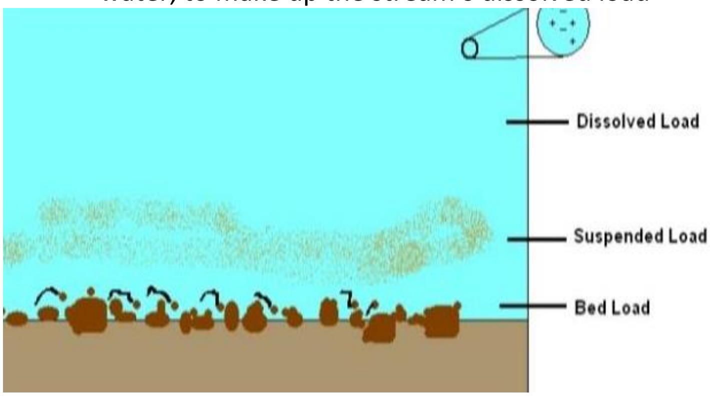
STREAM LOAD

- Water is a powerful agent for transporting material
- **Bed load of stream**: materials moves in a stream
- **Load:** total materials that a stream transports
- **Streams can move material in several ways:**
  1. Heavier debris may rolled, dragged, or pushed along the bottom of the stream bed as its traction load
  2. Saltation: material of intermediate size carried in short hops along the stream bed
- **Types of streams load:** Bed load (traction & saltation), Suspended load, & Dissolved load





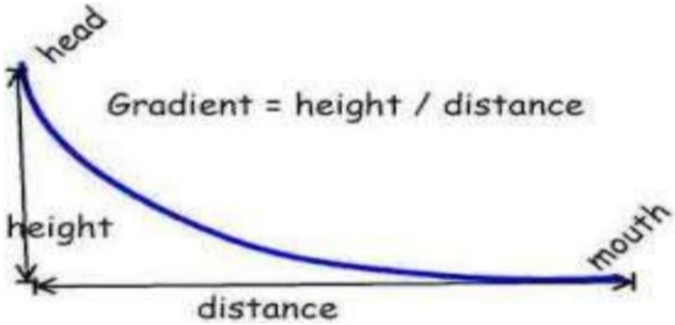
- **Suspended load**: material that is light or fine enough to be moved along suspended, supported by flowing water
  - Suspended sediment clouds a stream & gives the water a muddy appearance
  - some substances completely dissolved in the water, to make up the stream's dissolved load



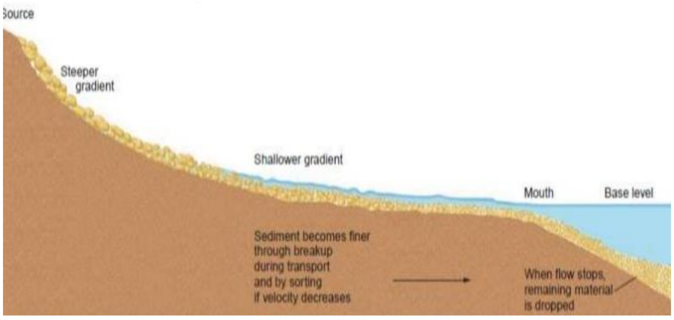
- **Capacity:** total load of material a stream can move
  - ***Capacity is closely related to discharge***: the faster the water flows, & the more water is present, the more material can be moved
- **Load transported depends on**
  1. **The availability of sediments or soluble material**: a stream flowing over solid bedrock will not be able to dislodge much material, while a stream flowing through sand or soil move considerable material
  2. **Vegetation**: preventing sediment from reaching the stream, or blocking movement in a channel

VELOCITY & GRADIENT

- **Stream velocity is related to:**
  1. **Discharge**
  2. **Gradient**: the steepness of the stream channel (difference in elevation between 2 points divided by the horizontal distance along the stream channel)
- The higher the gradient, the steeper the channel, & the faster the stream flows



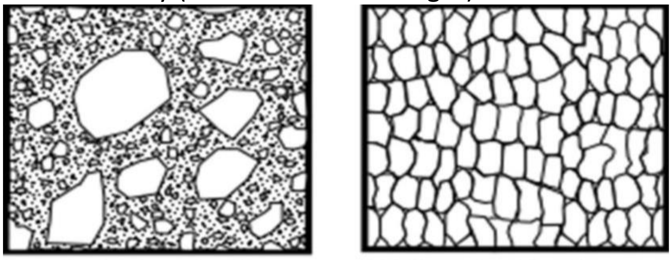
- Gradient & velocity vary along length of a stream
  - **Gradient** is steeper near the source & decrease downstream (became gentler downstream)
  - **Velocity** may or may not decrease correspondingly



- **Velocity of a stream influenced by:**
  1. Decreasing gradient counteracted by increased water volume (by tributaries), which adds to water mass being pulled downstream by gravity
  2. Friction between water & Stream bed
  3. Changes in the channel's width & depth
- **Discharge** tend to increase downstream (at least in moist climate, due to water that added by tributary)
  - Slowing effect of decreased gradient may be compensated by an increase in discharge due to widening of channel (increase in cross section)
- **Mouth**: is the stream end where it flows into another body of water & the gradient is quite low
- **Base level:** is the lowest elevation to which the stream can erode downward near stream mouth
  - Base level is surface level of the body of water into which they flow (for oceans = sea level)
  - The closer a stream is to its base level, the lower the stream's gradient (flow slower)
  - The downward pull of gravity causes a stream to cut down vertically toward its base level
- Counteracting erosion is influx of fresh sediment into the stream from the drainage basin. Over time, a balance between erosion & deposition occurred

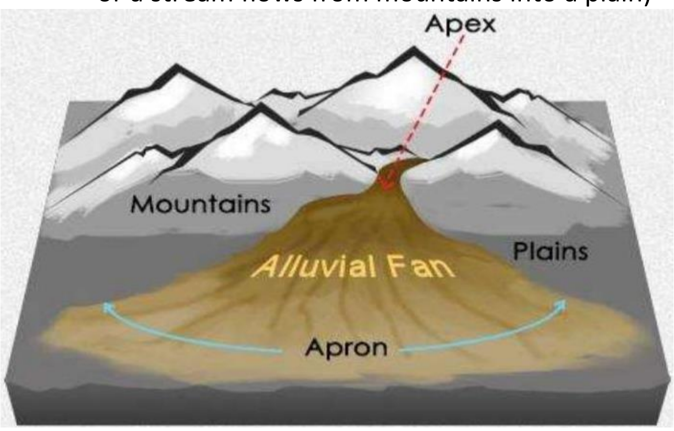
SORTING & DEPOSITION

- Variations in stream velocity are reflected in the sizes of sediments deposited at different points
  - The more rapidly a stream flows, the larger & denser are the particles that can be moved
- Sediments found motionless in a stream bed at any point are too big or heavy for that stream to move
- Where stream flows most quickly, it carries gravel, boulders & finer sediments, & as slows down, it starts leaving behind heaviest (largest) particles & continues to move the lighter (finer) materials along
- If stream velocity decrease, the smaller particles are dropped (sand-sized particles, then clay-sized….)
- In a slowly flowing stream, only the finest sediments & dissolved materials are still being carried
- Stream deposits are commonly well sorted by size or density (similar in size or weight)



Poorly Sorted Sediment   Well Sorted Sediment

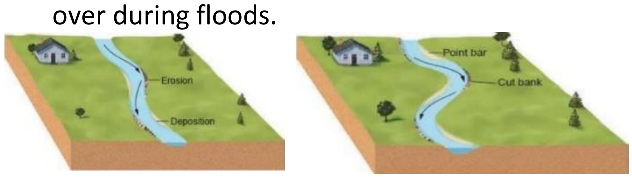
- If a stream flows into a body of standing water (lake or ocean), the stream's flow velocity drops to zero, & all the remaining suspended sediment is dropped
- If the stream moves a substantial load into its mouth, a large fans or deltas, may be built up
  - **Delta** forms as river empties to a body of water
  - **Alluvial fan** forms on land where river emerges from a mountainous area & flows out onto a gently sloping plain (when a tributary stream flows into a more slowly flowing, larger stream, or a stream flows from mountains into a plain)



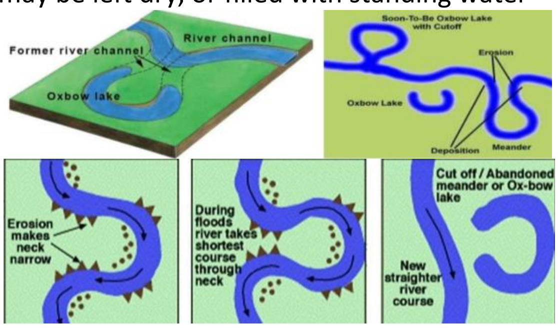
- Additional factor controlling particle size is **physical breakup & dissolution of the sediments**: the farther the sediments travel, the longer they are subjected to collision & dissolution, the finer they tend to become
- Stream transported sediments may tend to become finer downstream, whether or not the stream's velocity changes along its length

CHANNELS & FLOODPLAIN

- When a stream is flowing rapidly & its gradient is steep, downcutting is rapid. & the result is a steep-sided valley, V-shaped in cross section, & straight. But streams do not ordinarily flow in straight lines for very long distance
- **Small irregularities in the channel cause local fluctuations in velocity, which result in:**
  1. A little erosion where the water flows strongly against the side of the channel
  2. Deposition of sediment as it slows down a bit
- **Bends or meanders** begin to form in the stream, that tends to enlarge & shift downstream.
  - It's eroded on outside & downstream side of meander, the cut bank , where the water flows somewhat faster & little deeper as a result
  - point bars, consisting of sediment deposited on the insides of meanders, build out the banks
  - **Rates of lateral movement of meanders** 10s-100sm/yr, <10 m/yr on smaller streams
  - Obstacles or irregularities in channel may slow flow to cause localized sediment deposition
  - If the sediment load is large:
    1. The channel islands can build up until they reach the surface, dividing the channel in a process called braiding
    2. The braided stream may develop a complex pattern of channels that divide & rejoin
  - The effect of erosion (cut banks) & deposition (point bars) downstream meander migration, & sediment deposition produce broad & flat expanse of land covered with sediment around a channel proper, & this is the stream's floodplain, the area into which the stream spills over during floods.

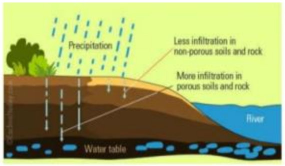
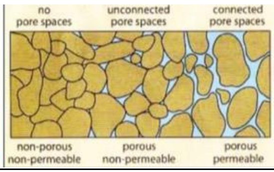


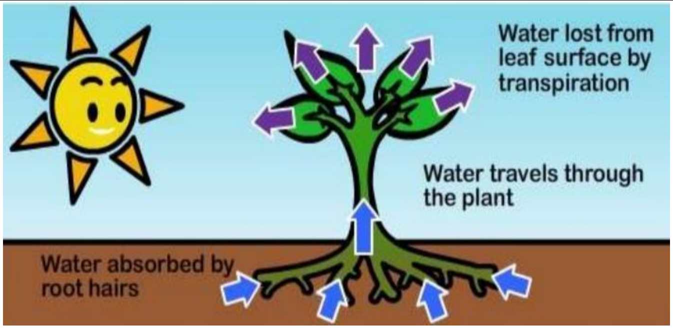
- **Floodplain** is a normal product of stream evolution
- Very large meanders represent major detours for the flowing stream
- During high discharge (floods), stream may make a shortcut, or cut off a meander, abandoning old, twisted channel for more direct downstream route
- **Oxbows**: cutoff meanders, abandoned channels may be left dry, or filled with standing water



FLOODING

- Stream floods linked to precipitation (rain or snow)
  - **Infiltration**: as rain falls or snow melts, some of the water sinks into the ground
  - **Percolation**: moves water through soil & rock
  - Some of water **evaporates**, the rest becomes **surface runoff**, flowing downhill by gravity
- The volume of channel sufficient to accommodate the average max discharge per year, the surface of the water is below the level of the stream banks
  - In times of higher discharge, stream overflow its banks or flood (1 or 2-3yr in humid regions)
- **Factors that determine whether a flood will occur:**
  1. The quantity of water involved
  2. The rate at which it enters the stream system
- When the water input exceeds the capacity of the stream to carry, the water overflows the banks
- The most intense rainfall events occur in SE Asia, where storms have drenched the region with 200 cm of rain in 3 days (double the average annual rainfall for the USA!)

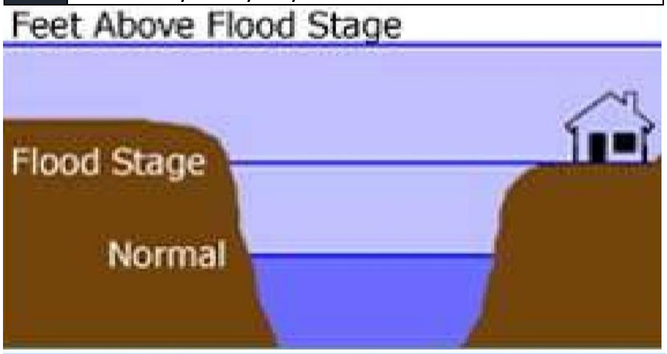
The rate of surface runoff is influenced by the extent of infiltration, which is controlled by the following	
Soil Type & Soil Exposed	**A very porous & permeable soil** allows a great deal of water to sink in relatively fast **In saturated permeable soils** surface runoff increase **If the soil is less permeable** or **covered by artificial structures,** the runoff over the surface increases 
Topography	**Influences the extent or rate of surface runoff**: the steeper the terrain, the less infiltration, the more readily water runs off over the surface **Water infiltrates soil** tend to flows downgradient, & may reach the stream, & **subsurface runoff water** moves much more slowly than the surface runoff **The more gradually the water reaches the stream,** the better the stream discharge to carry the water away without flooding, so the amounts of surface runoff & subsurface flow are fundamental factors affecting the severity of stream flooding **Surface runoff & subsurface flow are influenced by** the near-surface geology of the drainage basin
Vegetation	**May reduce flood hazards in several ways:** 1. Provide physical barrier to surface runoff 2. Roots working into the soil loosen it, tends to maintain or increase permeability (infiltration) 3. Absorb water by evapotranspiration of foliage **Local flood hazard may vary seasonally or as a result of meteorologic fluctuations**: solidly frozen ground of cold regions prevents infiltration; a midwinter rainstorm may produce flooding with a quantity of rain that readily absorbed by the soil in summer **The extent & vigor of growth of vegetation varies seasonally**, as does atmospheric humidity & thus evapotranspiration

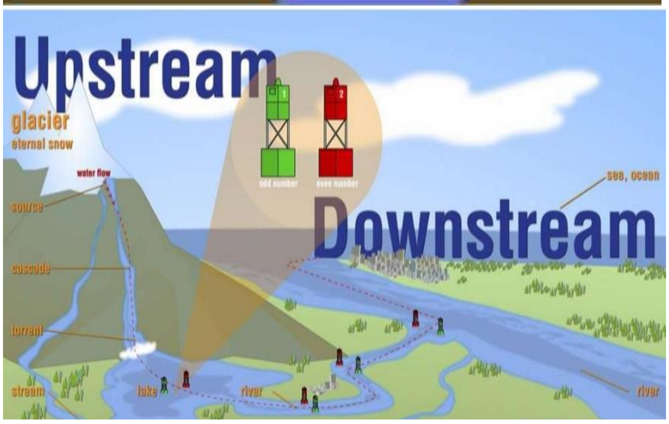


FLOOD CHARACTERISTICS

- During a flood, the water level & velocity is higher & discharge increase. higher volume & velocity produce increased force that gives floodwater destructive power
- **The stage of the stream**: elevation of the water surface at any point, e.g. stream is at flood stage when stream stage exceeds bank height
- **Magnitude of flood can be described by**: maximum discharge or maximum stage reached (crest)

Upstream floods	**Floods that affect small & localized areas** **Caused by:** 1. sudden & locally intense rainstorms 2. events like dam failure **Flash floods:** a variety of upstream flood, characterized by especially rapid rise of stream stage • Occur anywhere that surface runoff is rapid, large in volume, & funneled into restricted area • Canyon are common natural sites of flash floods
Downstream floods	**Floods affect large stream & large drainage basins** **Caused by:** 1. prolonged heavy rains over a broad area 2. extensive regional snowmelt • Last longer than upstream floods because whole stream system is choked with excess water • Mississippi River basin flooding 1993, brought on by many days rainfall over a broad area

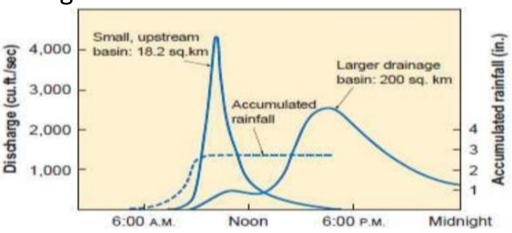




STREAM'S CURVES

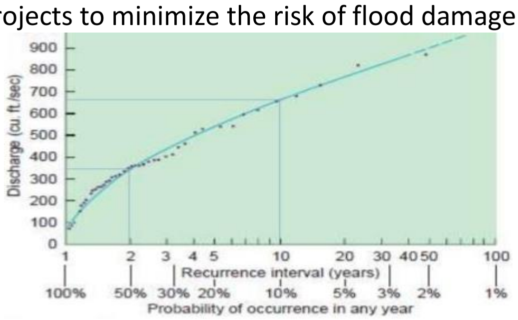
Stream Hydrographs

- Hydrograph explain fluctuations in stream stage or discharge over time. spanning long periods of time are very useful in constructing a picture of normal behavior of stream, response to flood causingevent
- **On hydrograph**: a flood shows up as a peak. height & width of that peak depend on where the measurements are taken relative to excess water
- **In upstream**, drainage basin is smaller & water need not travel so far to reach the stream, the peak is sharper (higher crest & more rapid rise & fall of the water level) & to occur sooner after the water influx
- By time that water pulse has moved downstream (lower point in drainage basin) it will have dispersed so the arrival of the water spans a longer time
- The peak will be spread out, so that the hydrograph shows both a later & a broader, gentler peak
- Short event (e.g. severe cloud burst) produce a sharper peak than a more prolonged event, even if same amount of water is involved, & flood-causing event causes permanent change in drainage system
- Hydrographs can be plotted with either stage or discharge on the vertical axis



Flood-Frequency Curves: Long-term records to construct a curve showing stream discharge as a function of recurrence interval

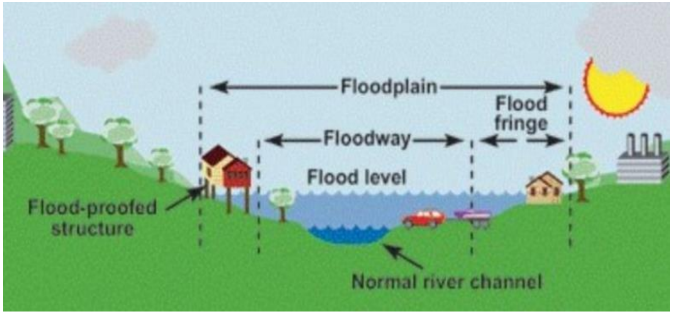
- A flood can be described by **recurrence interval**: how frequently a flood of that severity occurs for that stream
- One can refer to the probability that a flood of given size will occur in any one year (e.g. A ten-year flood meaning a flood of that size occurs about once every 10 years, or has a 10% probability of occurrence in any year)
- **Flood-frequency (or flood-probability) curves** can be useful in assessing regional flood hazards
- Such information is useful in preparing flood-hazard maps that are helpful in siting new construction projects to minimize the risk of flood damage



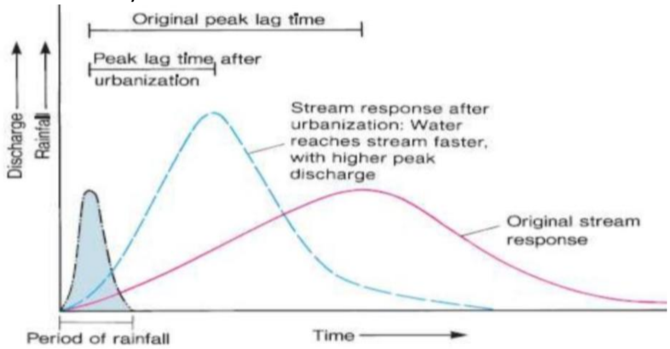
event with a discharge 675 ft^3/s occurs once every 10yr, & event with discharge 350 ft3/s occurs once every 2yr

CONSEQUENCES OF DEVELOPMENT

- **Why would anyone live in a floodplain?**
  1. Flat land to build (easier & cheaper)
  2. Flooding stream deposit fine sediment, replenishing nutrients in the soil & making the soil fertile
  3. Rivers are used for transportation, cities may have been built close to the water as possible
  4. Streams are very scenic features to live near



- **Factors affecting flood severity** are the proportion & rate of surface runoff
- When building cities, ground will be covered by asphalt & concrete (impermeable) which reduce infiltration & increase surface runoff & increasing the risk of flooding
- If peak lag time is time lag between a precipitation event & peak flood discharge (stage), then lag time decrease with increased urbanization (covering land with impermeable materials & installing storm sewers)



- Buildings in a floodplain can increase flood heights: building occupy volume that water could fill & discharge then corresponds to a higher stage (water level)
- Storm sewers in cities & drainage systems in farmland decreasing the time taken by the water to reach the stream channel (increase probability of stream flooding)
- **Consequences of natural vegetation are twofold**
  1. **Vegetation**: decrease flood hazards (physical barrier to runoff, soaking up some water, & root action), keeping soil looser & more permeable
  2. Vegetation prevent soil erosion, when vegetation is removed & erosion increased, more soil washed into streams. so it can fill in, or "silt up" the channel, decreasing the channel's volume & reducing the stream's capacity to carry water away quickly

REDUCING HAZARDS

Strategies for Reducing Flood Hazards

Restrictive Zoning & Proofing

Is approach to reduce the risk of flood damage

1. A first step is to identify the area at risk
2. Careful mapping with stream discharge data e.g., land that could be inundated by 25-year floods, might best be restricted to land uses, not involving much building

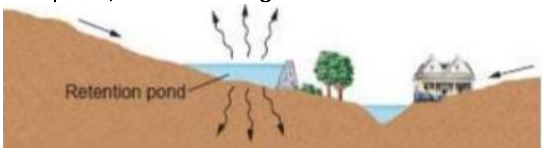
There is economic pressure to develop & build on floodplain. can be done in outer fringes of floodplain (parts threatened only by 100-200-year floods)

New buildings can be raised on stilts (the lowest floor is above the expected 200yr flood stage). A major limitation is that it applies only to new construction

Retention Ponds, & Diversion Channels

Retention ponds: large basins that trap some of surface runoff, keeping it from flowing into stream, reduce flood hazards along a stream in open land

- Elaborate artificial structures; old, abandoned quarries; fields dammed by dikes of piled-up soil
- Latter option allows land to be used for farming
- Retention ponds are a relatively inexpensive option, & not altering character of the stream



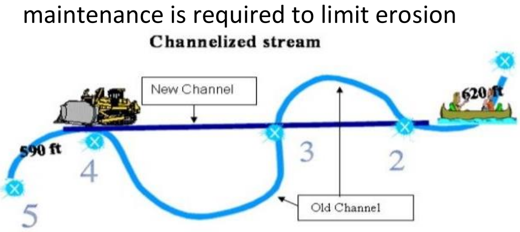
Similar strategy is use of **diversion channel** as stream stage rises; they redirect some of the water flow into areas where flooding will cause minimal damage

- The diversion of water might be into farmland or recreational land and away from built-up areas

Channelization

Various modification of stream channel to increase the velocity or volume of the channel

- Increase the discharge of the stream & the rate at which surplus water is carried away
- Channel can be widened or deepened & not to alter the stream dynamics
- A stream channel might be rerouted (provide a more direct path for the water flow)
- A meandering stream tends to keep meandering or revert to old meanders. so constant maintenance is required to limit erosion



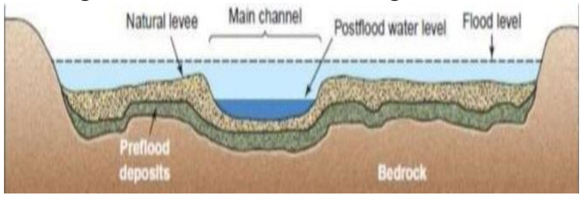
- **Ecological impacts of channelization include:**

1. Wetlands may be drained as water is shifted more efficiently downstream
2. Streambank habitat reduced as channel straightened & shortened (poor fish adaption for new streamflow)

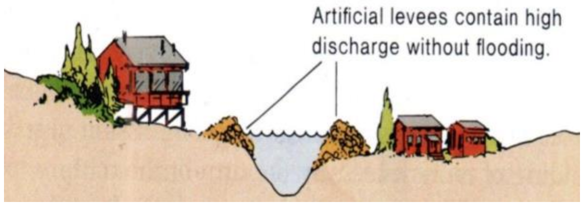
- A drawback common to many channelization efforts is by causing more water to flow downstream faster, increases the likelihood of flooding downstream
- Meander cutoff increases the stream's gradient & velocity, by shortening the channel length

Levees

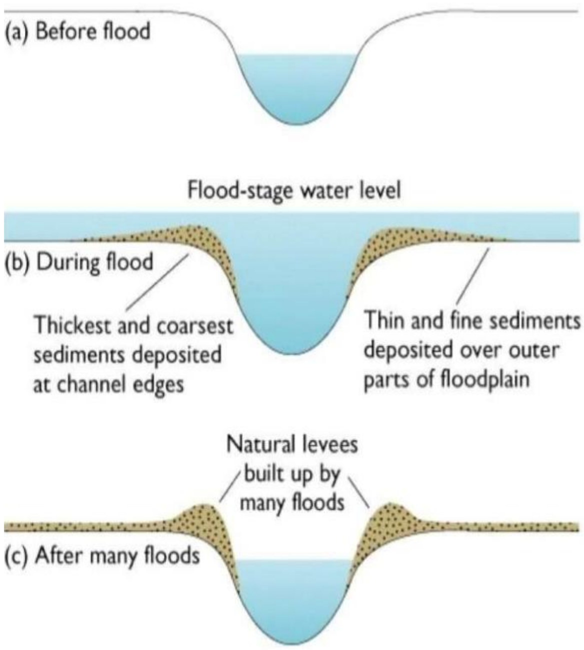
Building of levees, raised banks along stream channel



- Some streams form low levees along the channel through sediment deposition during flood events
- These levees may purposely be enlarged, or created for flood control. Because levees raise the height of the stream banks close to the channel, the water can rise higher without flooding the surrounding country.
- This is an ancient technique, practiced 1000s of years ago on the Nile by the Egyptian pharaohs
- confining water to the channel, rather than allowing it to flow out into floodplain, shunts water down-stream faster (increasing flood risks downstream)
- It artificially raises the stage of the stream, which can increase the risks upstream



- Another problem is that levees may make people feel so safe about living in the floodplain.
- If levees have not been built high enough (or fail) & an unanticipated, severe flood overtops them
- If levees are overtopped, water is then trapped long time outside the stream channel, until infiltration & percolation return it to the stream
- Levees alter sedimentation patterns:
  - During flooding sediment deposited in floodplain
  - If the stream & its load are confined by levees, increased sedimentation may occur in channel



Construction of flood-control dams at points along stream to moderating streamflow, prevent flooding

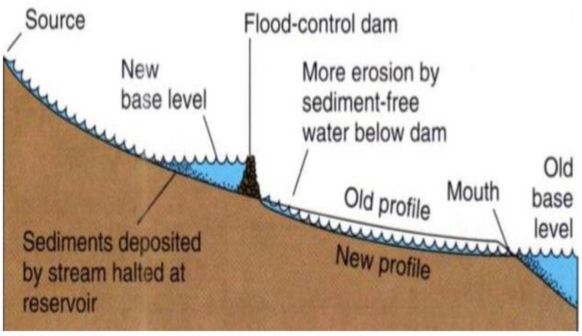
Excess water is held behind a dam in the reservoir formed upstream & may then be released at a controlled rate.

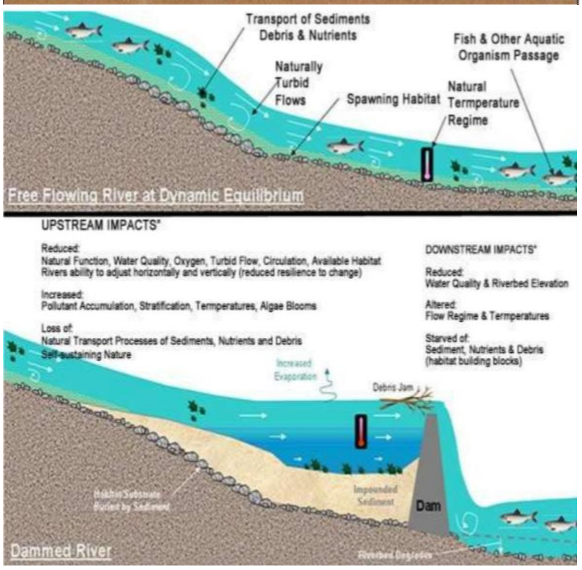
Benefits of constructing flood control dams include:

1. Availability of the water for irrigation
2. Generation of hydroelectric power at dam sites
3. Development of recreational facilities for swimming, boating, & fishing at the reservoir

Drawbacks of these dams (Reservoirs):

- Navigation on river (people & aquatic animals) may be restricted by the presence of the dams.
- The creation of a reservoir floods much of the stream valley behind the dam may destroy wildlife habitats
- Fish migration can be severely disrupted.
- The reservoir represents a new base level for the stream above the dam
- When the stream flows into that reservoir, its velocity drops to 0, it dumps its load of sediment
- Silting-up of the reservoir, in turn, decreases its volume, so it becomes less effective
- Some reservoirs filled completely in a matter of decades & becoming useless (needs dredging)
- The large fraction of water impounded by the dam reduced water volume downstream & may change the nature of vegetation & habitats
- People feel that the flood hazard has been eliminated by the presence of dams, but dams may fail or hold, the reservoir may fill abruptly with a sudden landslide & flooding may occur

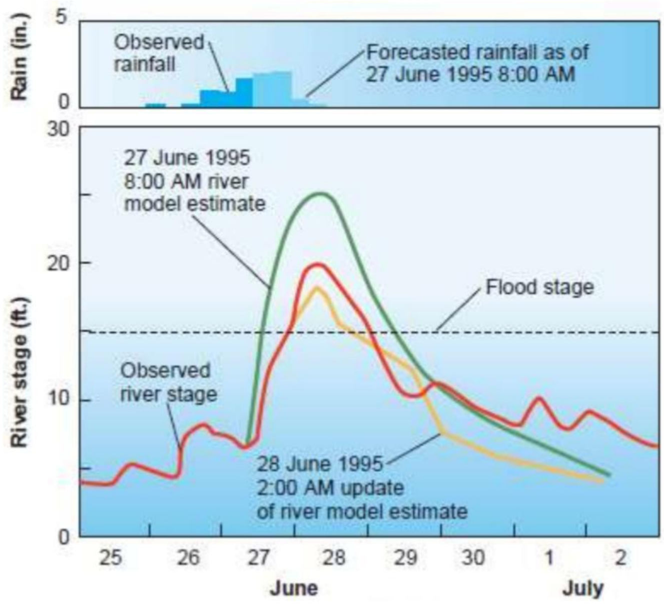




Dams & reservoirs often serve multiple uses (e.g., flood control + hydroelectric power generation + water supply)

FLOOD WARNINGS

- The coastal flooding from a storm surge typically allows time for evacuation as the storm approach
- Dam failures are sudden; rising water from spring snowmelt, much slower.
- As people inhabit areas prone to flooding, property will be destroyed when the floods happen, but with better warning, more lives can be saved
- The U.S. Geological Survey (USGS) provide flood warning by: real-time stream-stage measurements, & data on the relationship between stage & discharge for various streams
- Historical & forecast precipitation data & applies models that relate stream response to water input
- The results identify areas at risk of neartermflooding & issue warnings accordingly
- International flood forecasting, to help the affected nation (Bangladesh) occupies small part of drainage basin & cannot itself do the necessary monitoring



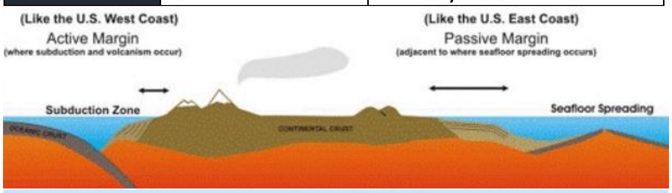
CHAPTER SEVEN

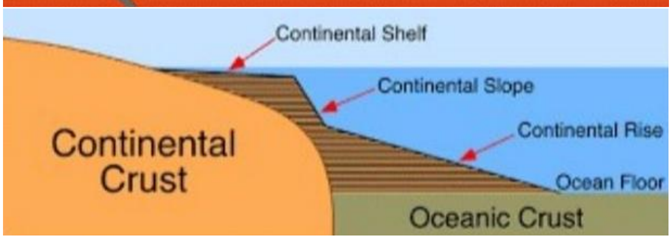
CONTINENTAL MARGINS

NATURE OF COASTLINE

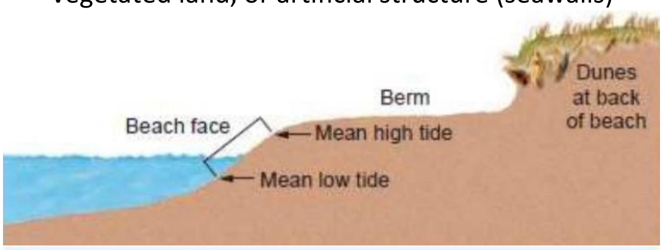
- **Castal areas** vary with geologic processes that occur along them, may be dynamic & rapidly changing under the interaction of land & water, or comparatively stable
- **The nature of a coastal is determined by:**
  1. Tectonic setting or Tectonic activity
  2. The materials present at the shore
  3. The energy with which water strikes the coast

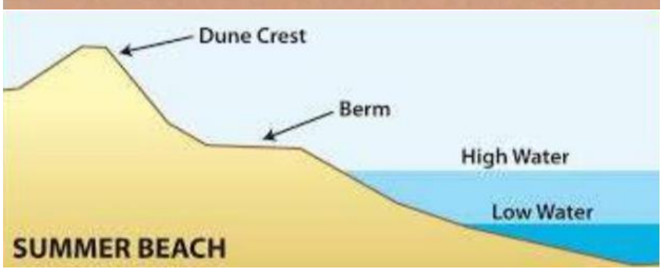
Geometry of coastline is influenced by plate tectonics		
Margins	**Active**	**Passive**
Associated with	Active plate boundary	Removed from active plate boundary
Example	Western margin of N. America	Eastern margin of N. America
Con. Shelf	Narrow	Wide
Con. Slope	Steeper	Gentler
Description	steep drop to oceanic depths offshor	Extensive development of broad beaches & sandy offshore islands





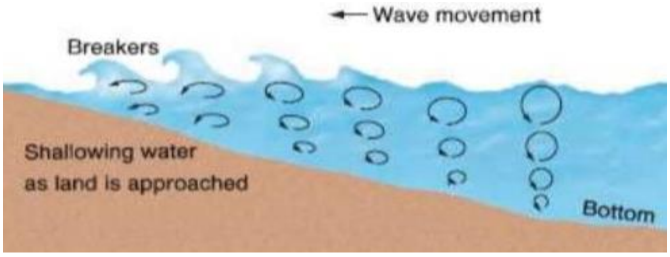
- A beach is a gently sloping surface washed over by the waves & covered by sediment
- The sand or sediment of a beach may have been:
  1. Produced locally by wave erosion
  2. Transported overland by wind of behind beach
  3. Delivered to the coast & deposited by streams or coastal currents
- **Beach face:** portion that washed by waves of tides
- **Berm:** flatter part of beach landward of beach face
- **What lies behind berm**: Dunes, rocky or sandy cliffs, vegetated land, or artificial structure (seawalls)



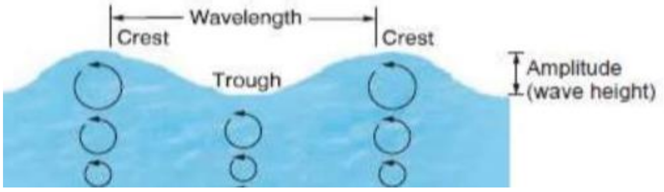


WAVES & TIDES

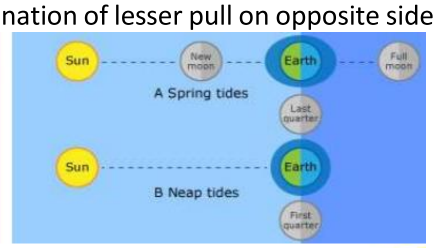
- **Waves & currents are the principal forces behind natural shoreline modification**: waves are induced by the flow of wind across the water surface, which sets up small undulations in that surface.
- **The shape & apparent motion of waves reflect** the changing geometry of the water surface



- While wave form may seem to travel long distances across the water, in the open water molecules are rising & falling in circular orbits grow smaller with depth. As waves approach the shore & feel bottom, or when water shallows to the point that the orbits are disrupted, the waves develop into breakers



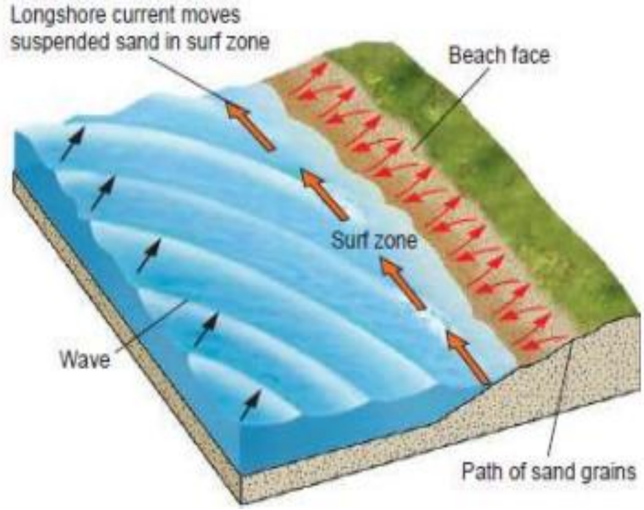
- Wave action causes high erosion. Erosive effects are concentrated at the waterline, where breaker action is most vigorous, & if water is salty, it cause rapid erosion (chemical weathering)
- **Tides**: the periodic regional rise & fall of water levels as a consequence of the effects of the gravitational pull of the sun & moon. The closer an object, the stronger its gravitational attraction (thus the moon exerts more gravitational pull than does the sun)
  1. **Spring tides**: times of full & new moon, greatest tidal extremes, when sun, moon, & earth are all aligned, & the sun & moon are pulling together
  2. **Neap tides**: sun & moon pulling at right angles, difference between high & low tides minimized
- Oceans "bulge" on the side of the earth nearest the moon. A combination of lesser pull on opposite side



- **Over long time, water levels shift as a result of:**
  1. Tectonic processes or from
  2. Changes related to glaciation or
  3. Human activities (e.g., extraction of resources)

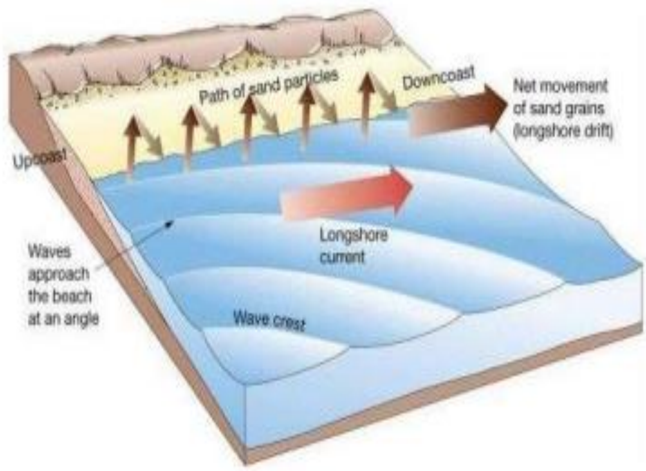
TRANSPORTATION & DEPOSITION

- Faster the currents & more energetic the waves, the larger & heavier the sediment that can be moved
- As waves approach shore & water orbits disrupted, the water tumbles forward, up the beach face
- When waves approach a beach at an angle (as the water washes up onto & down off the beach), there is also net movement of water laterally along the shoreline, creating a longshore current



Longshore currents & thier effect on sand movement. Waves push water & sand ashore at an angle, gravity drains water downslope agine, leaving some sand behind. Net littoral drift of sand is oarallel to longshore current

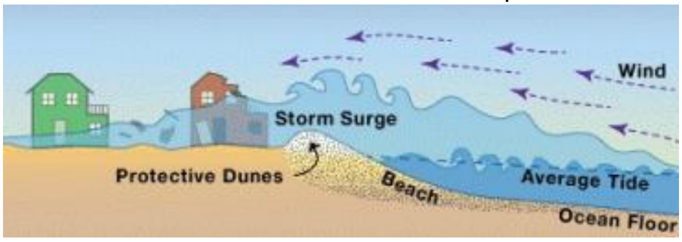
- As the waves wash up the beach face at an angle, the sand is pushed along the beach as well
- The net result is littoral drift, gradual sand movement down the beach in the same general direction as the motion of the longshore current.
- The more energetic the waves & currents, the more & farther the sediment is moved



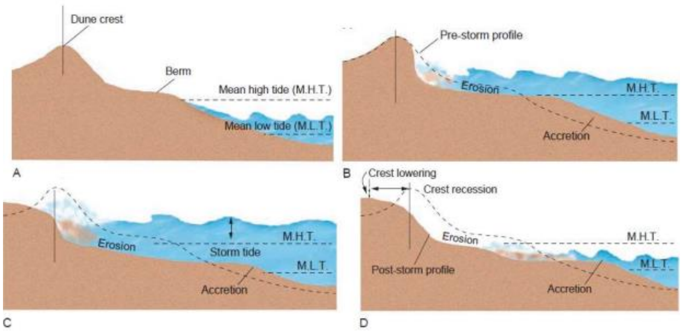
- Higher water levels during storms help the surf reach farther inland (to dunes at the back of the beach), but a ridge of sand or gravel may survive the storm's fury, & may even be built higher as storm (beach ridge).
- Where sediment supply is plentiful, new beach ridges forming seaward of the old, producing a series of roughly parallel ridges that may have marshy areas between them

STORMS & COASTAL DYNAMICS

- Unconsolidated materials (beach sand) are moved & rapidly eroded during storms
- The low air pressure associated with a storm causes a bulge in the water surface. This, coupled with strong onshore winds piling water against the land, result in high water levels called **a storm surge**.
- The temporarily elevated water level, together with energetic wave action & greater wave height, combine to attack the coast with exceptional force



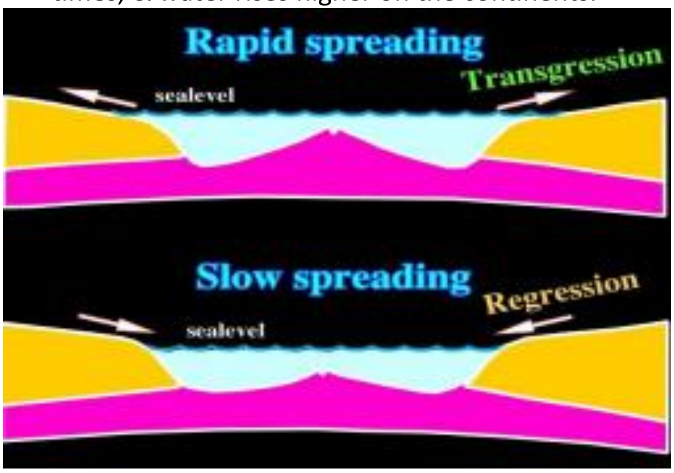
- The gently sloping expanse of beach (berm) along the outer shore above the usual high-tide line may suffer complete overwash, with storm waves begin to erode dunes or cliffs beyond
- **The post-storm beach profile shows**
  1. Landward recession of dune crests, as well as
  2. Removal of considerable material from the zone between dunes & water



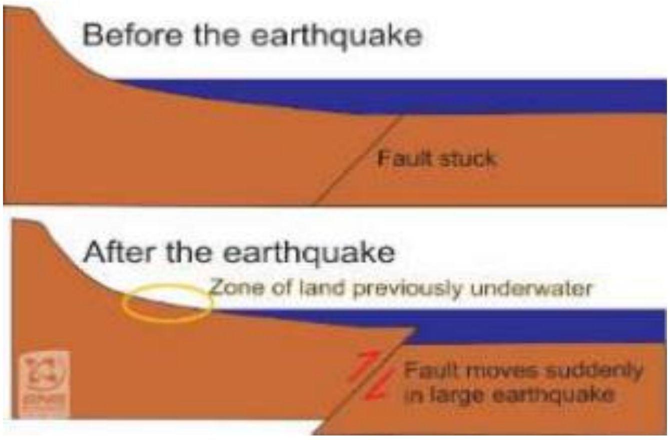
Alteration of shoreline profile due to accelerated erosion by high storm tides

EMERGENT/SUBMERGENT COAST

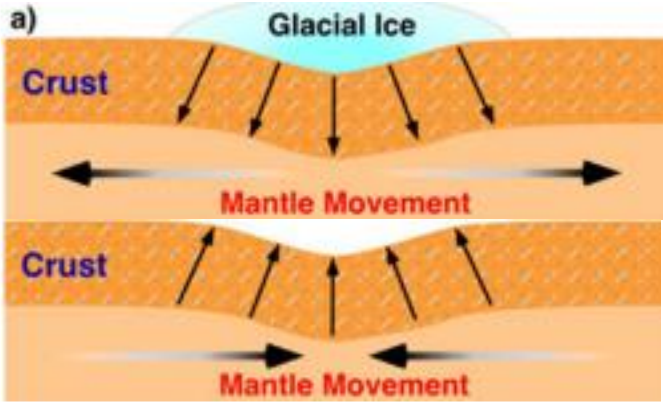
- **Long-Term Sea-Level Change:** caused by tectonic activity. in rapid seafloor spreading, there is more heat that causes material to expand, & warm lithosphere takes up more volume than cold, so the volume of the ocean basins is reduced at such times, & water rises higher on the continents.



- **Short-term tectonic effects:** when plates move, crumple, & shift, continental margins may be uplifted or dropped down. such movements may shift land by several meters, & then cease, abruptly changing the geometry of the land/water interface & the patterns of erosion & deposition.



- The lithosphere sits buoyantly on asthenosphere, & sink or rise in response to loading. e.g. in regions overlain by ice sheets, lithosphere was down-warped by the ice load. The lithosphere (rigid) is still slowly springing back to its pre-ice elevation.
- Where ice extended to sea, the coastline slowly rising relative to sea (e.g., Scandinavia, the rebound still proceeds at rates of 2cm/yr)
- In basins being filled by sediment, the sediment loading can cause slow sinking of the lithosphere.



- Glaciers represent an immense reserve of water. As this ice melts, sea levels rise worldwide.
- Global warming aggravates the sea-level rise in another way: warmed water expands & can cause more sealevel rise than the melting of the ice itself
- Locally, pumping large volumes of liquid from underground has caused measurable subsidence of the land (e.g. Venice). Oil extraction in Long Beach (e.g. California) caused similar subsidence problems

- **Signs of Changing Relative Sea Level**:
  1. Sealevel change depends on the relative heights of land & water, either of which can change
  2. Water getting higher relative to coast (submergent coastline), or reverse (emergent)
  3. A distinctive coastal feature that develops where the land is rising & the water level is falling is a set of wave-cut platforms
- Wave action tends to erode land down to the level of the water surface. If land rises in a series of tectonic shifts, each rise results in erosion of a portion of the coastal land down to new water level

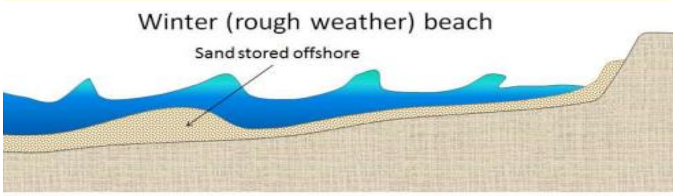
- The eventual product is a series of steplike terraces (developed on rocky coasts)
- The surface of each such step represents an old water level marker on the continent's edge
- When global sea level rises or the land drops, the streams that once flowed out to sea now have the sea rising partway up the stream valley from the mouth.
- A portion of a floodplain may filled by encroaching seawater, & the fresh water backs up above the new, higher base level, forming a drowned valley
- Glaciers flowing off land & into water don't just keep eroding deeper underwater until they melt.
- Freshwater glacier ice floats on denser salt water. The carving of glacial valleys by ice does not extend long distances offshore.
- During the last ice age, alpine glaciers cut valleys into what are now submerged offshore areas.
- With the retreat of the glaciers (rise in sea level), these old glacial valleys were emptied of ice & filled with water (the origin of the steep-walled fjords Scandinavian countries, Norway and Iceland)

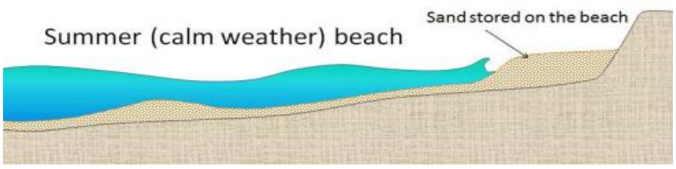
Present & Future Sea-Level Trends

- Much of the coastal erosion result of gradual global sealevel rise (due to melting of glacial ice & water expansion as global temperatures rise)
- Sea-level rise estimated at 0.33 m/century
- While this doesn't sound particularly threatening, we should consider:
  1. Gentle slope (flat) coastal areas, so a small rise in sea level results in a far larger inland retreat.
  2. Rise of atmospheric CO2 (increased greenhouse effect) will melt the glaciers, as well as warming the oceans, accelerating the sea-level rise
- Rising sea level is a major reason why shoreline stabilization efforts repeatedly fail (it brings waves farther & farther inland)

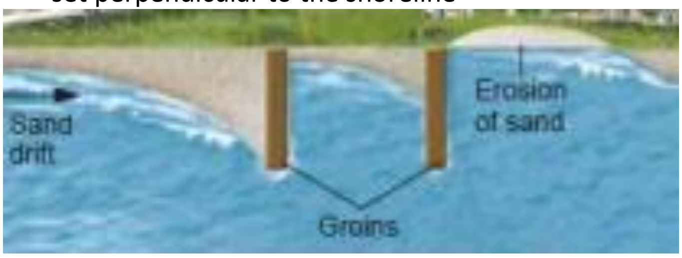
COASTAL EROSION

- Coasts are dynamic, waves washing up onto the beach carry sand from offshore to build up the beach; storms attack the beach & carry sediment back offshore (natural equilibrium)
- Where longshore currents are present, the beach reflects the balance between sediment added & sediment carried away (sandy cliffs supply fresh sediment to beach to replace what is carried away)

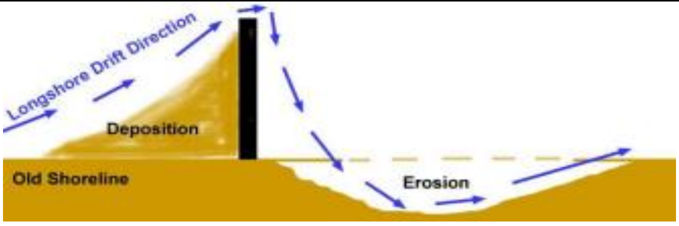




- **Pressure to control (influence) the natural flux of sediment arises when human development appears threatened. The approaches used are:**
  1. **Hard structural stabilization**
  2. **Soft structural stabilization**: such as sand replenishment & dune rebuilding
  3. **Nonstructural strategies**: land-use restrictions, prohibiting development or mandating min. setback from the most unstable or dynamic shorelines
- **Beach Erosion, Protection, Restoration**: Beachfront property owners, concerned that their beaches will wash away, erect structures to try to stabilize beach
- One commonly used method is the construction of one or more groins or jetties long, narrow obstacles set perpendicular to the shoreline

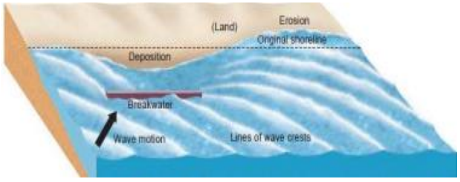


- Longshore currents slowed by a barrier tend to drop load of sand up-curren. Below (downcurrent from) the barrier, the water picks up more sediment to replace the lost load, & beach is eroded
- The common result is formerly stable, straight shoreline develops an unnatural scalloped shape
- The beach is built out in the area up-current of the groins & eroded landward below



The Function of a Groin

- Any interference with sediment-laden waters can cause redistribution of sand along beachfronts
- Breakwaters are constructed to moderate wave action, & they may cause sediment redistribution
- Even modifications far from the coast can affect the beach (e.g., damming large rivers for flood control)

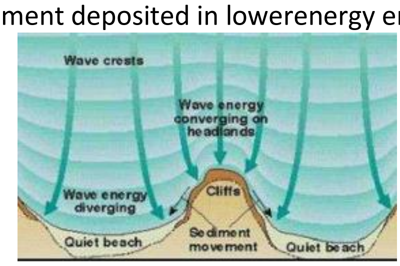


Beach "nourishment" or "replenishment"

- As beach erosion is rapid & development is widespread, efforts have been made to import replacement sand to maintain sizeable beaches or create them if not existed
- The cost is very high, if the erosion is not reduced, the replenished sand will be gone
- The mineralogy or grain size of the replenished sand is very important. When coarse sands are replaced by finer ones, softer & muddier than the original sand, this will cause water turbidity (cloudiness) & can also be deadly to organisms
- Replacing finer sand with coarser, may steepen the beach face, which may make the beach less safe for small children or poor swimmers

Cliff Erosion

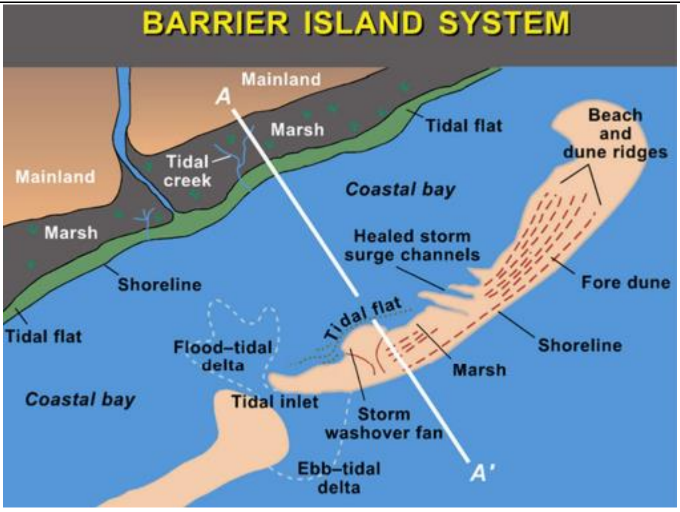
- Both waves & currents can cause rapid erosion of sandy cliffs. Removal of material at or below the waterline undercuts the cliff leading to slumping & sliding of sandy sediments (retreat of the shoreline)
- Jutting points of land (headlands), are more actively under attack than recessed bays because wave energy is concentrated on these headlands by wave refraction, deflection of waves around irregularities
- Wave refraction occurs because waves "touch bottom" which slows the waves down; wave motion continues more rapidly elsewhere
- Net result is deflection of waves around & toward the headlands, where the wave energy is focused
- The long-term tendency is toward a roundingout of angular coastline features, as headlands are eroded & sediment deposited in lowerenergy environment



To combat cliff erosion:

- A fairly common practice is to Place some kind of barrier at the base of the cliff to break the force of wave impact, The protection may take the form of a solid wall (seawall) of concrete or other material, or a pile of large boulders or other blocky debris

Especially Difficult Coastal Environments	
Barrier Islands	**Long, low, narrow islands paralleling a coastline somewhat offshore from it,** provide important protection for the water & shore inland from them because they constitute the first line of defense against the fury of high surf from storms at sea • Barrier islands are extremely vulnerable, partly as a result of low relief during high storm tides • Most barrier islands are retreating landward with time because they are subjected to higher-energy waters on their seaward • Such settings represent particularly unstable locations in which to build, thousands of structures, are at risk • On barrier island, shoreline-stabilization efforts -building groins & breakwaters & replenishing sand- tend to be expensive &, frequently, futile
Estuaries	**is a body of water along a coastline, open to the sea**, in which the tide rises & falls, the fresh & salt water meet & mix to create brackish water • Some estuaries form at the lower ends of stream valleys (drowned valleys). Others may be tidal flats in which the water is more salty • Over time, complex communities of organisms in estuaries have adjusted to water salinity • Salinity reflects balance between freshwater input (river flow), & salt water • Any modifications that alter this balance change salinity, have catastrophic impact on organisms • Water circulation often very limited. This makes eustuaries vulnerable to pollution • many vital wetlands areas are estuaries under pressure from environmental changes • Salinity of this estuaries has been rising as fresh water from rivers flowing is consumed en route • Humans may be changing the estuaries for the worse by changing the water's chemistry • Pollution due to development that will stresses the organisms of the estuary



- **Costs of Construction & Reconstruction in High Energy Environments**: most concentrated damage has resulted from major storms, & the number of people & value of property at risk only increases with the shift in population toward the coast
- **a best setting for building near beach or on island**
  1. At high elevation (5m above normal high tide, to be above the reach of storm tides)
  2. in a spot with high dunes between the proposed building & water, to supply added protection
  3. Thick vegetation help to stabilize beach sand
  4. Information about what has happened in major storms in the past is very useful
- A key factor in determining a safe elevation, is overall water level. On a lake, the long-term range in lake levels must be considered
- On a seacoast, it would be important to know if that particular stretch of coastline was emergent or submergent over the long term.
- Around the Pacific Ocean basin, possible danger from tsunamisshould not be overlooked
- On either beach or cliff sites, important factor is the rate of coastline erosion. Information might be obtained from: people in the area, Better & more reliable guides are old aerial photographs, & Old detailed maps (show how the coastline looked in past times)
- Comparison with the present configuration (photos or maps) made allows estimation of rate of erosion
- Consider faster-rising sea level in the future & on cliff sites there is landslide potential
- Storm commonly accelerate change. Aerial photographs & newer tools such as scanning airborne laser altimetry allow monitoring of changes & suggest the possible magnitude of future storm damage
- It is advisable to find out what shoreline modifications are in place or are planned, Sometimes, aerial or even satellite photographs make it possible to examine the patterns of sediment distribution & movement along the coast