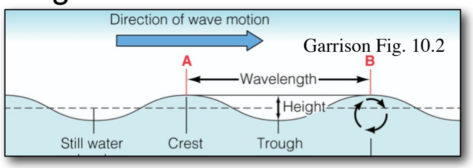
Review: Waves

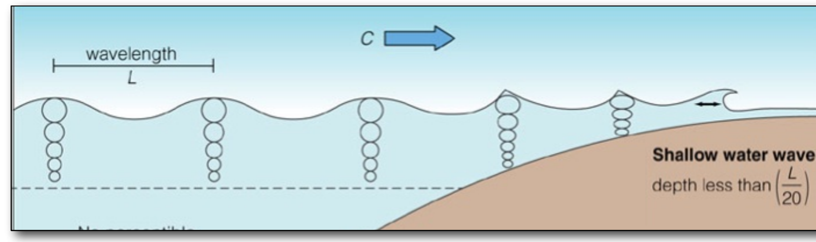
- Progressive wave **"train"** (waves series)
  - Crest = high point
  - Trough = low point
  - **H**eight = vertical elevation of crest above trough
  - Wave**L**ength = horizontal distance between crests or troughs
  - Period = **T**ime passage between successive crests or troughs
    - = Time to travel 1 wavelength



Garrison Fig. 10.2 p, 230

Wave Speed

- "Shallow-water wave"
  - Defined as wave with **L**ength >20 times depth
    - Or depth <1/20 (5%) of wavelength L
  - Speed controlled by depth of water
    - Friction against the bottom



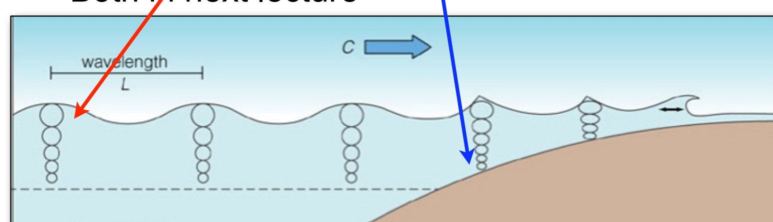
Garrison Fig. 10.6 p. 233

Shallow-Water Wave Speed

- Speed calculated from water depth
  - C (m/sec) = "Celerity" $\sqrt{gd}$
    - g = gravitational acceleration 9.8 m/sec^2
    - d = depth in meters
    - C = 3.1$\sqrt{d}$ (d in meters)
    - Garrison p. 233
- Most wind-driven waves much slower than tsunami in deep water
  - Speed depends on period (T) & wavelength (L)
  - But speed (C) is same in shallow water
    - Friction with the bottom dominates

Waves Shoaling

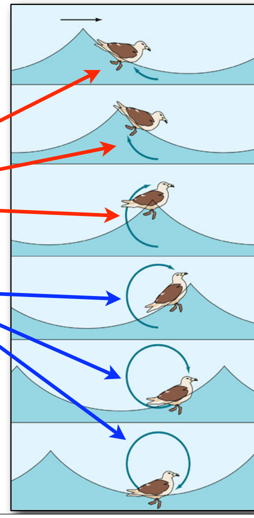
- Speed in "deep" water independent of depth
  - Wave motion does not contact bottom
- "Transition" zone from deep to shallow
  - Bottom friction begins to affect wave
  - Both in next lecture



Garrison Fig. 10.6 p. 233

“Orbital” Wave Motion

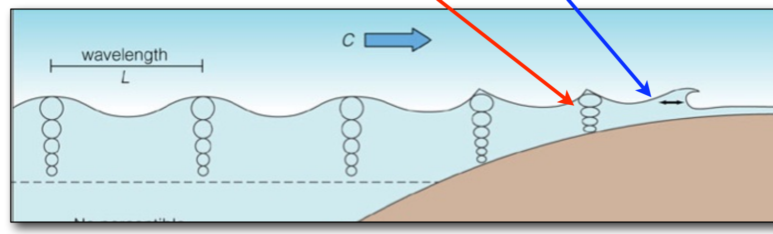
- “Move energy, not water”
  - Ideally no *net* movement of water as wave form passes
    - Exception next lecture
  - Up & back as crest approaches
  - Down & forward as crest passes
  - A circular or “orbital” motion of a water molecule...
    - ...or a floating object



Garrison Fig. 10.11 p. 230

Wave Motion Shoaling

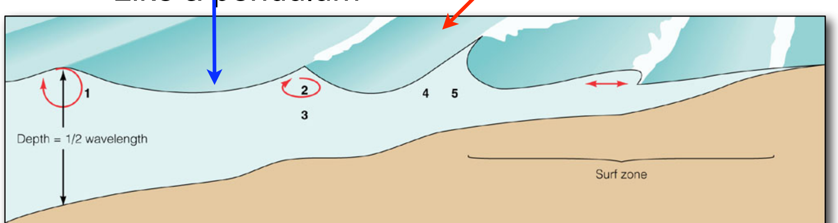
- “Orbits” become compressed vertically
  - Form ellipses rather than circles
  - In shallow water back & forth, not up & down
  - At same time, waves get higher
    - Water motion confined to shallower depth



Garrison Fig. 10.17 p. 241

Wave Motion Shoaling

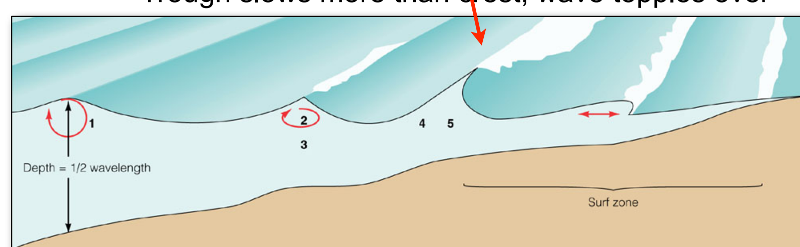
- Wavelength L decreases as wave slows (C)
  - Faster waves catch up from behind
  - Helps raise wave height
- Period (T) does not change
  - Like a pendulum



Garrison Fig. 10.17 p. 241

Wave Motion Shoaling

- Wave steepens as H higher & L shorter
  - Waves break when H≥L/7
    - Ratio of H:D ~3:4
    - “Surf zone”
    - Trough slows more than crest, wave topples over



Garrison Fig. 10.17 p. 241

Wave Shape

- High, steep waves (Plunging, "Tubes")
  - Result from deep water close to shore
  - Shelf narrow & steep (or absent)
    - Wave slows very abruptly near shore
    - While still very high
    - Trough slows while crest is still moving fast
    - High tide

Wave Shape

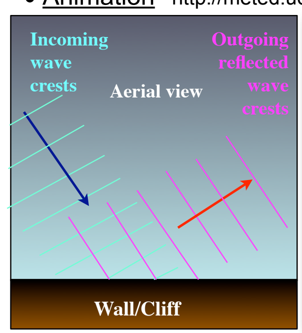
- Lower, more gradual waves (Spilling)
  - Result from shallow water far from shore
  - Shelf broad & gradual
    - Wave slows far offshore
    - Energy absorbed
    - Trough & crest speed more similar
    - Less steep
    - Low tide

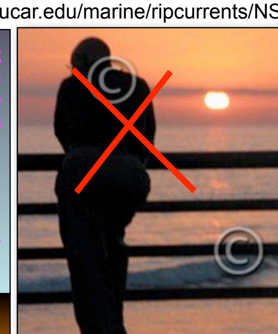
Wave Interactions with Shore

- Three types of alterations in wave direction
  - All three may occur together or separately
  - Reflection
    - Waves bounce off a vertical cliff or wall
  - Diffraction
    - Waves pass an obstruction & propagate into quiet water
  - Refraction
    - Waves change direction because of slowing
- Longshore currents
  - Also rip currents

Wave Reflection

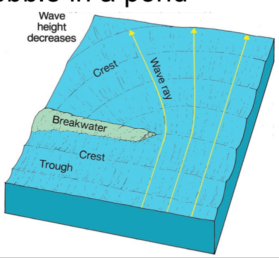
- A vertical hard surface in deep or shallow H_2O
  - Wave crests bounce like a billiard ball
    - Minimal loss of energy
    - Animation http://meted.ucar.edu/marine/ripcurrents/NSF/reflection.htm

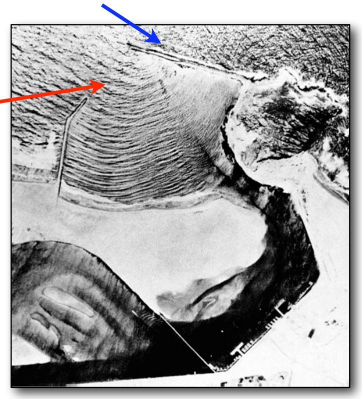




Wave Diffraction

- Waves pass an obstruction, e.g. offshore breakwater
  - Propagate into quiet water behind obstruction
    - Radial pattern
    - “Pebble in a pond”

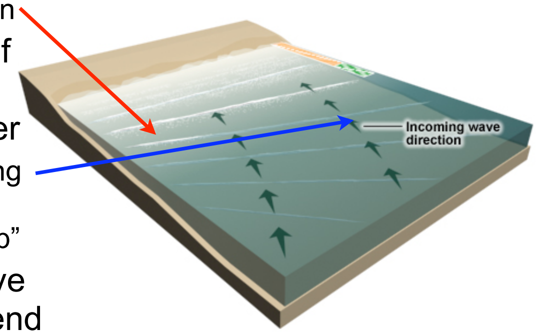




Garrison Fig. 10.22 p. 243

Wave Refraction

- Wave approaches shore at an angle
  - One end of wave crest is in shallower water
    - Slows down
  - Other end of crest is in deeper water
    - Keeps going faster & “catches up”
  - Causes wave to turn or bend toward shore



http://meted.ucar.edu/marine/ripcurrents/NSF/print.htm

Important Distinctions

- Two processes can occur in deep water
  - Reflection
    - Waves bounce off a vertical cliff or wall
  - Diffraction
    - Waves pass an obstruction
  - Either can also happen in shallow water
- Refraction occurs only in shallow water
  - Waves change direction because of slowing
    - Near shore or over a shoal or seamount
  - All three may occur together or separately

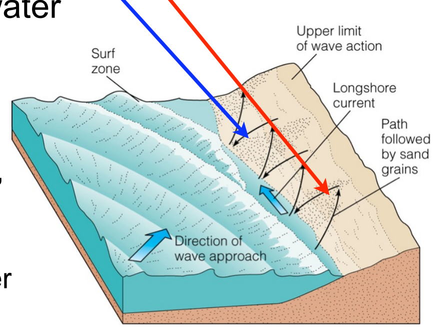
Views of Refraction

- Wave approaches shore at an angle & bends toward shore

Garrison Fig. 10.20 p. 243

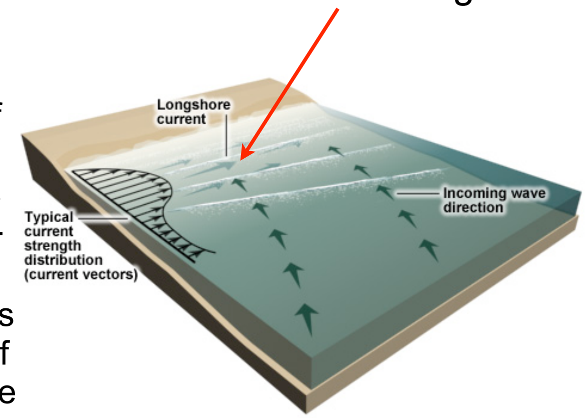
Longshore Transport

- Waves approach shore at an angle
  - Run up beach at an angle
  - Run down at a different angle
  - Net movement of water & sand
  - Occurs only in surf zone
    - When waves break, they move both energy & water
    - Unlike in deep water



Longshore Transport

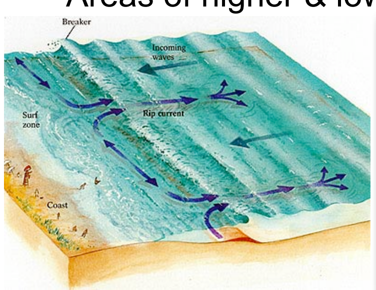
- Transports sand “downstream” along the beach
  - From areas of erosion to areas of depo-sition
  - Changes shape of shoreline



 http://meted.ucar.edu/marine/ripcurrents/NSF/print.htm

Rip Currents

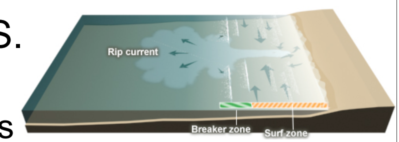
- “Rip tides” a common misnomer
- Areas where water & sand move offshore
  - Convergence of longshore currents
  - Areas of higher & lower wave energy



 http://phuket-tourism.com/rip/index.htm Garrison Fig. 12.16 p. 285

Rip Currents

- 100 deaths/year in U.S.
  - 2nd only to heat
  - Ahead of flood & storms
    - www.ocean.udel.edu/ripcurrents/Safety/index.html
    - www.ripcurrents.noaa.gov/index.shtml
  - Can move 3-5 mph
    - Can carry away even a strong swimmer
  - What to do if you are caught in a rip current?
    - DON’T try to swim against it
    - Swim to the side: 50–150 feet wide
    - Animation http://meted.ucar.edu/marine/ripcurrents/NSF/rip_pulsation.htm

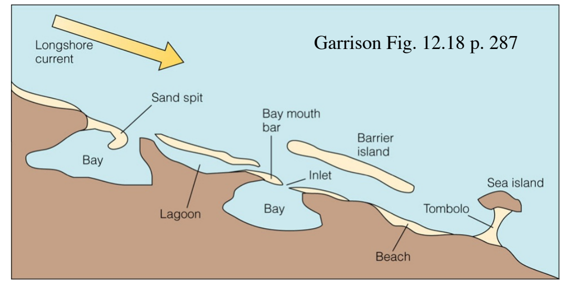


Wave Energy

- The key to analyzing shoreline effects
- High wave energy keeps sediment particles suspended in the water
  - The higher the energy, the more & larger particles transported
- Low energy allows sediment particles to deposit
  - The lower the energy, the more & finer particles can deposit
- Big waves = high energy

Wave Energy

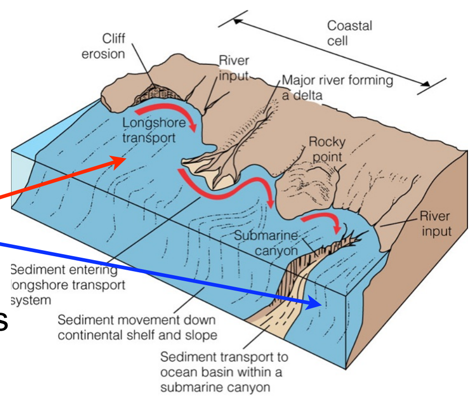
- Longshore transport high to low energy
  - HIGH wave energy erodes the shore
    - “Erosional coast” Garrison p. 277
  - LOW wave energy builds the coast
    - “Depositional coast Garrison p. 281



Garrison Fig. 12.18 p. 287

Wave Energy

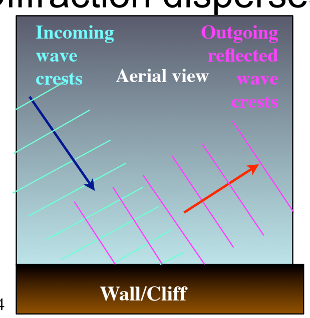
- “Coastal cell”
  - Longshore transport carries eroded sediment from high energy to low energy areas
  - Sediment sources
    - Rivers
    - Eroding bluffs

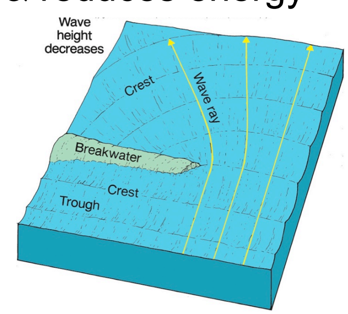


Garrison Fig. 12.17 p. 286

What Controls Wave Energy?

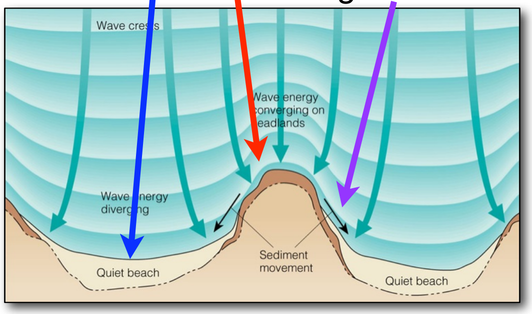
- Reflection creates high energy areas
  - Shore does not absorb much energy
  - Energy is nearly doubled
- Diffraction disperses & reduces energy





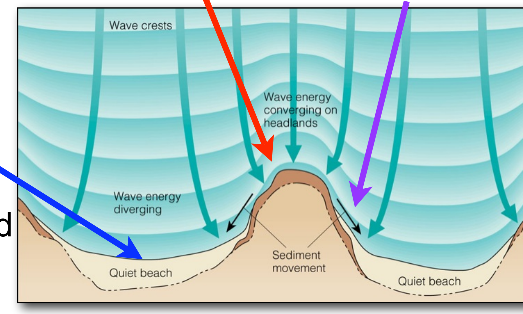
What Controls Wave Energy?

- Refraction creates high & low energy areas
  - Convex shores high-energy
  - Concave shores low-energy
  - LST carries eroded material from high to low energy
  - Headlands erosional
  - Bays depositional
  - Straightens shoreline



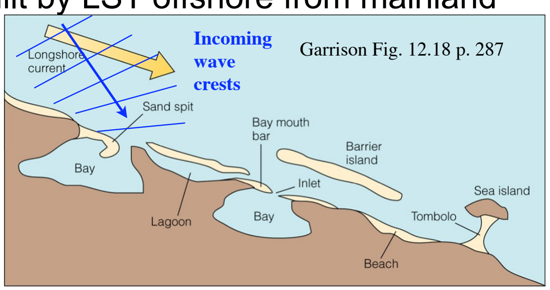
Sediment size

- High & low energy areas affect sediment size as well as abundance
  - High energy keeps fine particles suspended
    - Only coarse sand or gravel can stay on beach
  - Low energy allows fine particles to deposit
    - Silt & mud
  - Both depend on wave climate



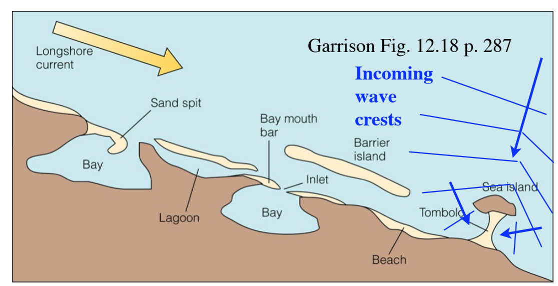
Natural Shoreline Structures

- Sand spit
  - Peninsula created by longshore transport
    - Note curved shape: refraction & diffraction
- Barrier island
  - Built by LST offshore from mainland



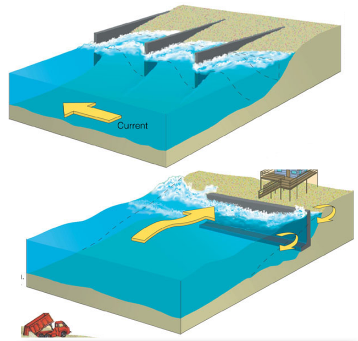
Natural Shoreline Structures

- Tombolo
  - Peninsula connecting solid offshore rock ("sea island") to mainland
    - High energy seaward of island
    - Refraction & diffraction = low energy behind island



Built Shoreline Structures

Garrison Fig. 12.34 p. 299



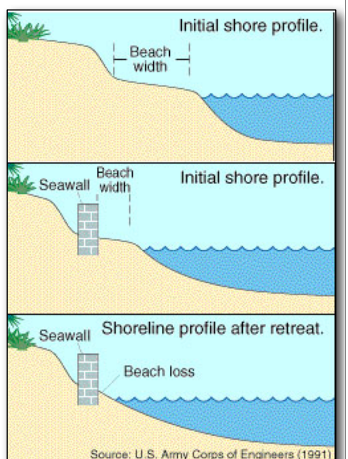
- Groins
  - Walls built perpendicular to the shore
- Sea walls
  - Walls built parallel to the shore behind the beach
- Breakwaters
  - Walls built offshore or connected to shore

Groins

- Built to trap sediment in longshore transport
  - Blocks LST
  - Reduces energy
  - Forces sand to deposit
  - Builds beach upstream
  - But starves beaches downstream

Seawalls

- Built to block erosion of land behind the beach
  - Causes wave reflection
    - Unless carefully designed
  - Increase energy & erosion
  - Narrow & destroy the beach
  - Make land more vulnerable & dependent on artificial protection
    - Worse off if wall falls



www.cofc.edu/CGOInquiry/human.htm

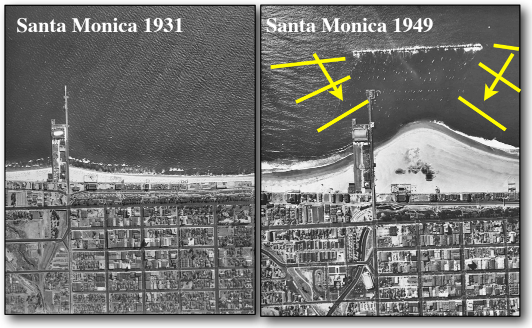
Breakwaters

- Built to reduce wave energy for mooring boats
  - Causes sediment deposition
    - Like a tombolo
  - Can fill or block a marina
    - May require dredging to maintain usefulness

www.cofc.edu/CGOInquiry/human.htm

Breakwaters

- 2 major causes of sand deposition
  - Disruption of longshore transport
    - Low energy because waves don't reach shore
    - No surf zone
  - Diffraction
    - Also causes lower energy
    - Converging waves
    - Affected by groin too



Garrison Fig. 12. 33 p. 299

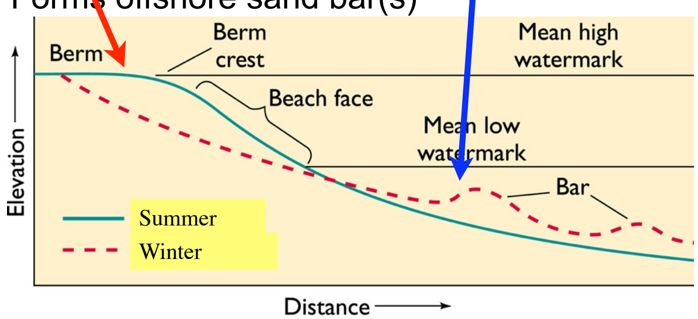
Seasonal Beach Changes

- More storms & stronger winds in winter
- Winter: High wave energy erodes beach
  - Beach narrows & steepens, coarser material
- Summer: low energy allows sand to deposit
  - Beach is wider & more gradual, finer material

Garrison Fig. 12. 13 p. 283

Seasonal Beach Changes

- Summer: sand accumulates on beach
- Winter: Sand deposits deeper in water
  - Lower energy
  - Forms offshore sand bar(s)



Bar Conditions

- Sand bars can occur at river mouths
  - Deposition of river-borne sediment
- Notoriously dangerous locations
  - Columbia R. one of worst "Graveyards"
  - Waves steepen in shallows
  - River & tide outflow act like shallows
    - Very steep waves @ ebb tide