Coastal Processes and Hazards

I. WATER, WAVES AND COASTAL DYNAMICS

A. Beach and coastal areas represent sites of dynamic sedimentation, erosion and re-working of river-borne sediments as they reach coastal regions
   1. Dynamic interaction between wind, waves, sedimentation and erosion
   2. Coastal areas noted for extremely variable meteorologic conditions
   3. Hurricanes and storms profoundly influence coastal morphology

      a. Wave energy and wind energy during coastal storms exhibit great capability to do work in the form of erosion and transportation of sediment

         (1) Eg. storm wash-over processes
         (2) storm surges
         (3) changes in coastal morphology via erosion and sedimentation

   4. Gross coastal configuration primarily a function of plate tectonic history, however relentless wave processes modify coast through erosion and sedimentation

B. The Ocean and Wave Activity
   1. Beach/coastal sand/sediment profoundly influenced by wave action
      a. waves provide motion/energy for transportation and erosion of sediment

   2. Waves generated by wind shear blowing across ocean surface for long distances
      a. shear creates orbital rotation of water to form water waves
         (1) orbital motion = circular to and fro motion, diminishing in intensity at depth from surface

         (2) Although the wave is passed through the water as a medium; actual water molecules are NOT displaced as the wave is propagated

      b. Wave form controlled by:
         (1) wind velocity
         (2) duration of wind
         (3) fetch- distance over which wind blows (length across water) (> fetch, > wave amplitude)

   3. Wave Morphology
      a. Wave crest: high upper peak of wave train
      b. Wave trough: low separating two crests
      c. Wave Height: vertical distance between crest and trough
         (1) Avg. Wave Ht = 1 to 15 Feet
         (2) Storm Waves up to 50 Ft wave height
         (3) "Tsunami" = seismically induced water wave, produced by tectonic displacement of sea floor, accompanied by earthquakes

(a) Very long wavelengths: ~ 100 km, and low amplitudes (1 m or less)
(b) As wave approaches land, breaking to heights of 100 m or more
i) highest "tidal wave" recorded = 278 Ft off coast of Japan.

(4) Storm Surges: piled mass of water pushed shoreward by very high winds
(a) Common by-product of hurricanes

i) upward bulging of ocean surface due to low atmospheric pressure above ocean surface

ii) Wind pile-up
a) Surge in sea level of 2-5 m common

d. Wave Length: horizontal straight line distance between two crests or two troughs
(1) Avg. wave length = 130-1300 Ft

e. Wave Velocity: average 15-55 mi/hr

f. Wave base: depth at which the energy of the wave is totally dissipated in water
(1) Wave Base = 0.5 (Wavelength)

4. "Surf" Zone: zone along coastal area where waves overturn and "break" upon themselves
a. High energy water environment
b. Wave breaking occurs in response to shallowing of water depth as wave approaches beach

(1) As depth < wave base, wave "feels" bottom and wedges water upward

(a) Wavelength decreases as waves approach shoreline, "piling" up of water according to resistance of near-shore beach area.

(b) "Breaker" a wave that is oversteepened to the point of the crest toppling forward (moving faster than main body of wave)

(c) "Surf Zone": coastal zone characterized by numerous breakers

i) high turbulence zone

ii) characterized by to and fro swash action
a) Swash = incoming motion, Backwash = seaward drag of water
b) effective sediment sorting mechanism

C. Nearshore Circulation Processes

1. Wave Refraction: Tendancy of wave to become "refracted" or bent as it reaches shore
a. net result is wave train becoming more parallel to shore

2. Wave Crests usually approach shore at some angle other than parallel.
a. Results in sweeping of wave along coastal interface

3. Longshore Currents:
a. Current established as wave crest approaches beach at some angle to shore

b. Sweeping action of wave along shoreline

c. Longshore Current: current forms parallel to shore as more and more waves refract in that direction

(1) Seaward Edge of Current: outher surf zone
(2) Landward Edge of Current: Shoreline
(3) Longshore currents can effectively transport large volumes of sediment along a shoreline (parallel to shore)

4. Rip-Currents

a. Narrow Currents that flow perpendicular to shoreline in a seaward direction (seaward return flow of water)_
b. Highest velocity at surface, dying out at depth
c. Effective seaward sediment transportation mechanism, moving sediment beyond beach zone onto shelf
d. Characterized by low wave height and variable wave orientations

5. Tides: diurnal, vertical fluctuation of sealevel under the influence of planetary gravity. Results in bulging of sealevel sytematically throughout the day, around the world.
a. tides set in motion by gravitational attraction of the moon and sun (heavenly bodies close and large enough respectively to influence force of gravity on earth).
(1) gravitational pull of sun and moon result in pulling at the ocean surface, causing it to bulge. Since the earth's crust in rigid and relatively unaffected by this gravitational pull, tidal fluctuations of sea level occur relative to land. (tidal pull is relatively negligible in surface bodies of water, i.e. lakes)

(2) Moon has most significan daily impact on tidal levels. Gravitational effectiveness of sun relative to the moon in 44%.

b. Normal tidal bulges: influenced by moon primarily, moon in line with equator, pulling bulge equatorially, low tides at top and bottom, hide tides at equator

(1) tidal bulge follows the moon as it orbits around earth, water facing the moon is drawn/bulged towards the moon, side opposite moon is also bulged outward because the solid portion of the earth (facing the moon) is pulled away from the ocean on the side opposite the moon.

(a) at same time as tidal bulge, there are compensating low tides at 90 degrees to the bulge

(2) Entire effect is complicated by the earth's revolution from east to west, also coupled with moons revolution around earth: result in 2 complete tidal cycles every 24 hours and 50 minutes. (i.e. 2 high and 2 low tides in a little over each day)

c. Spring Tides: sun and moon in alignement equatorially, result in highest tides possible, largest bulge at equator.

d. Neap Tides: sun aligned with equator, moon with poles, perpendicular to one another, results in lowest tides possible at equator.

e. Tidal Cycles: rising tide or flood tide occurs for 6 hr and 13 min, reaches high tide, then falling tide or ebb tide for 6 hr and 13 min, until low tide, happens twice each day about.

(1) tidal range: vertical difference between high and low tide. Height of tidal range varies with configuration of coastline, from several feet to perhaps 50 feet, as the highest tidal fluctuation noted.

f. Tidal Currents: ebb and flood tide sets up currents through tidal channels, inlets and coastal rivers

D. Beach Morphology

1. Beach: strip of sediment (sand or gravel) that extends from low tide line to a zone of permanent vegetation inland (or rock cliff as applicable).

a. Beaches subject to breaking waves

b. Subject to tidal influences

2. Beach Subdivision

a. Foreshore: zone between mean high and low tide
(1) Beach Face: steepest inclination of beach exposed to wave action at high tide level

b. Marine Terrace: gently sloping platform seaward of the foreshore/beachface.
(1) Wave Built Terraces: constructed of wave sorted sediment
(2) Wave-Cut Terraces: rock benches erosionally cut by wave action
(3) Wave Cut Notches: undercutting of steep rock faces along coast line

(a) Landward erosion of seacliffs
i) Undercutting and collapse at cliff-wave face

c. Backshore: upper portion of beach landward of high-tide water line

(1) Beach Berm: wave deposited platforms sloping gently landward

3. Beach Climatic Cycles

a. Seasonal summer-winter cycles

(1) Winter: waves higher and of shorter wavelength
(a) storm waves common
(b) beach erosion high

(2) Summer: low height, longer wavelength waves
(a) berm deposition dominant

E. Longshore Drift

1. "Longshore Drift": Longshore currents move sediment parallel to shore as waves strike shore at angle

2. Surf zone transport of sand and sediment
a. sand transported parallel to shoreline

3. Depositional Features

a. Spit: a "tail" or fingerlike ridge of sediment built by longshore drift off of a point of land, extending out into open water

b. Baymouth bar: ridge of sediment deposited so as to cut a bay off from the open ocean
(1) result of sediment migrating across the mouth of an open bay
(2) storm processes may be effective mechanisms for "closing" off bay inlets.

(3) Back-bar lagoon sheltered from wave energy

c. Tombolo: a bar of sediment connecting a former island to the mainland

(1) result of wave refraction around the island, converging on the landward side of the island forming a depositional bar built outward from the mainland.

4. Beach Erosion Control

a. Jetties: rock walls built along each side of a bay or harbor mouth

b. Groins: rock walls (perpendicular to shore) used to form barriers to longshore drift and sediment erosion

c. Breakwater: energy dissipator built parallel to shore to lessen wave energy

(1) may create "slack water" areas behind breakwater and result in sediment infilling of the area.

d. Rip-Rap

(1) Energy Dissipaters

5. Sediment Sources

a. local insitu weathering of rock (minimal volume)

b. regional drainage/sedimentation from seaward flowing rivers

II. Coast Hazards Overview
- A. Introduction / Hazards
  - 1. Tropical Storms
    - a. Cyclonic Storm Systems
    - b. Hurricanes (Atlantic) / Typhoons (Pacific)
      - (1) high winds
      - (2) heavy rainfall
      - (3) storm surge
  - 2. Floods
    - a. High Tide Events
    - b. Storm Surge
    - c. High Rainfall Events
  - 3. Tsunamis
    - a. seismic seawaves
  - 4. Coastal Erosion
    - a. Beach Erosion
      - (1) Cliff Retreat
      - (2) Dune Erosion
- B. Cyclonic Storm Systems
  - 1. Characteristics
    - a. cyclone - low pressure system
      - (1) inward and upward airflow
        - (a) counterclockwise rotation in N. Hemisphere
      - (2) large-scale
        - (a) up to 640 km in diameter
    - b. high sea surface temperatures
    - c. low-pressure systems
      - (1) high evaporation
      - (2) high heat energy
    - d. high wind
      - (1) >100 km/hr
    - e. high rainfall
  - 2. Hazards / Effects
    - a. Storm Surges
      - (1) wind-driven waves
      - (2) very large wave amplitudes
      - (3) + low air pressure = > sea level surface

- C. Coastal Flooding
  - 1. High Rainfall Events
    - a. high discharge
    - b. low gradient rivers
  - 2. Tiday Flooding
    - a. storm surges
    - b. high tide conditions
      - (1) astronomical alignment

D. Tsunami
    1. Defined - "seismic seawave"
        a. Velocity: up to 800 km/hr in open water
            (1) 60 km/hr near shore (> friction on bottom of shallow water)
        b. wavelengths: up to 100 km
        c. amplitudes
            (1) deep water: ~1 m
            (2) shallow water: up to 20 m
    2. Cause
        a. water displacement during earthquakes
            (1) fault offset on seafloor
            (2) submarine landslides
                (a) may be triggered by shaking
    3. Damage
        a. Coastal Inundation
            (1) "runup" - height of water in wave above normal sea level
            (2) topographically controlled + wave controlled
        b. Wave Energy
            (1) destruction by wave action
        c. Ecosystem / habitat damage
E. Coastal Erosion
    1. Defined - erosion of coastal areas by wave and tidal energy
    2. Beach Erosion
        a. Longshore Drift
        b. Sediment Transport
    3. Cliff Erosion
        a. shoreline retreat
        b. undercutting / stoping

F. Coast Issues
    1. Development
        a. Coastal Areas Highly Populated
            (1) recreation
            (2) urban areas
    2. Land Use
        a. Vegetation / Devegetation
        b. Urbanization
            (1) increased runoff

III. Climate / Coastal Effects
A. Season Storm Cycles
B. Short-Term Climate Cycles
    1. El Nino / La Nina Cycles in Pacific
        a. El Nino
            (1) Warm surface water from western Pacific, flowing eastward to South America
                (a) (normally south America = upwelling of cold ocean water)
            (2) trade winds weaken in eastern Pacific
            (3) high precipitation in coastal S. America

(a) > sea temps, > evaporation, > storms / rain

b. La Nina

(1) unusually cold ocean circulation from west to east, across Pacific