Coastal Geomorphology & Coastal Dynamics
Spring 2007
Field Trip Schedule

Montauk
Saturday March 31th
Sunday April 15th
Saturday April 28th

Chapter 6: Waves

Wave properties, propagation, particle motion

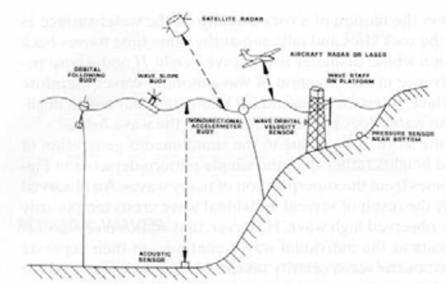
Types of Waves

Distribution & Transfer of Energy

Tsunamis, Standing Waves

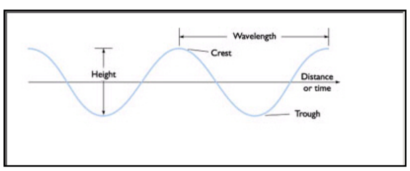
Wave Generated Currents

Coastal Engineering Manual: Coastal Hydrodynamics *(Part II)*
Water Wave Mechanics (*Part 2 - Chapter 1*)
Meteorology and Wave Climate (*Part 2 - Chapter 2*)
Estimation of Nearshore Waves (*Part 2 - Chapter 3*)
Surf Zone Hydrodynamics (*Part 2 - Chapter 4*)
Hydrodynamics of Tidal Inlets (*Part 2 - Chapter 6*)



Wave Generation and Propagation
Nearshore Transformation and Breaking

Wave Form Properties



Linear Wave Equation

$\eta = a\cos(kx \pm \sigma t)$

Wave Number

$k = \frac{2\pi}{\lambda}$ where λ is the wavelength

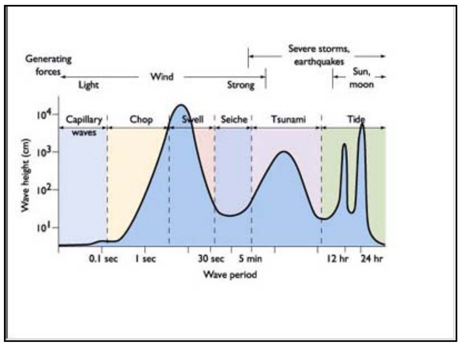
Height and Amplitude

$H = 2a$

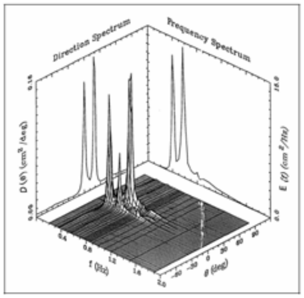
Radian Frequency

$\sigma = \frac{2\pi}{T}$ where T is the period

Period Classification



Wave Nomenclature



Wave Data: is often reported or presented as a **spectrum**. Wave energy is a proxy for wave height

Wave Field are usually described by three variables:

H: height sometimes reported as Hsig or Hrms

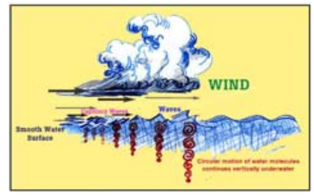
Hsig = average of 1/3 largest waves recoded or observed

Hrms = square root (of the average of the sum ((of all the waves recorded or observed)squared)

T: period

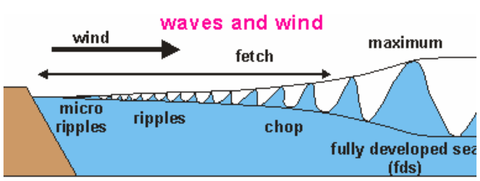
α: angle, either geographic angle with respect to north or incident wave angle with respect to shore normal. Similar to wind the direction is relative to where the wave is coming from

Wave Generation

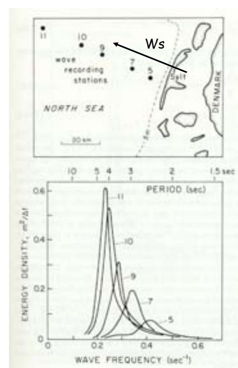


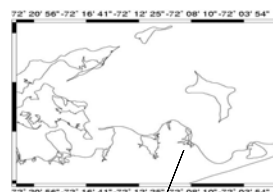
Wind Speed:	velocity at which the wind is blowing
Fetch:	distance over which the wind is blowing
Duration:	length of time wind blows over a given area (fetch)

Fully Developed Sea State



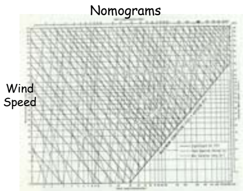
Fetch Limitation





Wave Field Observations, Forecasts and Hindcasts

Nomograms

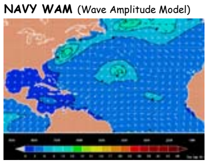


Wind Speed

fetch

NDBC Telemetry Buoys

NAVY WAM (Wave Amplitude Model)



Significant Wave Height (H0):	3.3 ft
Swell Height (SwH):	3.0 ft
Swell Period (SwP):	7.7 sec
Swell Direction (SwD):	SSE
Wind Wave Height (WWH):	1.3 ft
Wind Wave Period (WWP):	3.8 sec
Wind Wave Direction (WWD):	SSE
Wave Steepness (STEEPNESS):	AVERAGE
Average Wave Period (AVP):	5.6 sec

Linear Wave Theory (H/L is small)

$C = \frac{L}{T}$ Wave speed or **celerity**

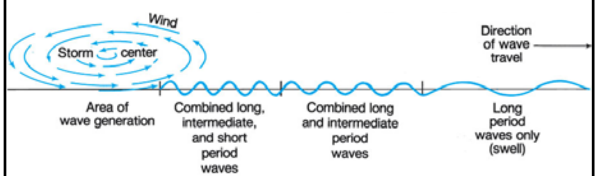
$C = \frac{gT}{2\pi}\tanh\left(\frac{2\pi d}{L}\right)$ **Dispersion Relationship**: relates wave celerity to period, wavelength, and water depth

$C_0 = \frac{gT}{2\pi}$ Deep water wave speed is a function of period only

$L_0 = \frac{gT^2}{2\pi}$ In deep water wavelength is a function of period. In shallow water it is a function of period and water depth, and must be solved iteratively.

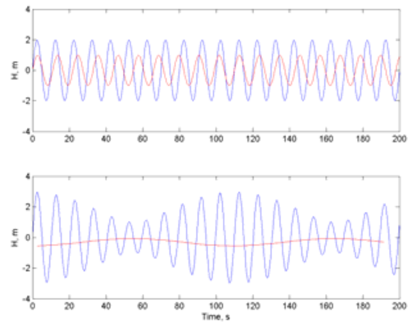
$C = \sqrt{gd}$ Shallow water wave speed is **constrained by water depth**

Dispersion



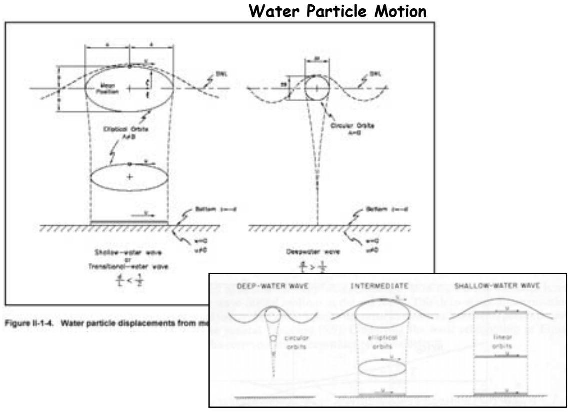
* Waves with longer period move faster

Wave Superposition

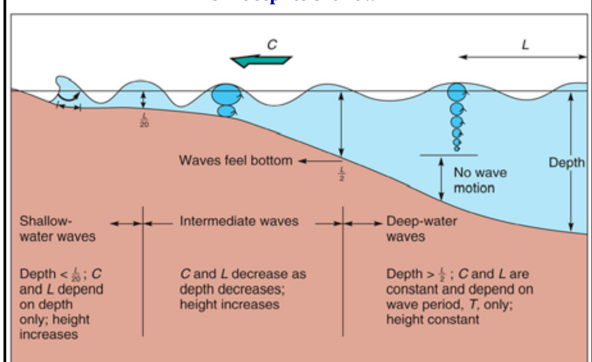


Forced wave

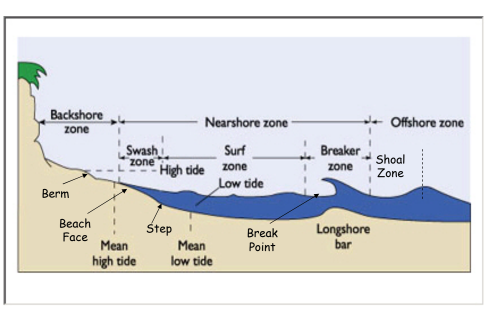
Water Particle Motion



From deep- to shallow-



Wave Transformation Nearshore



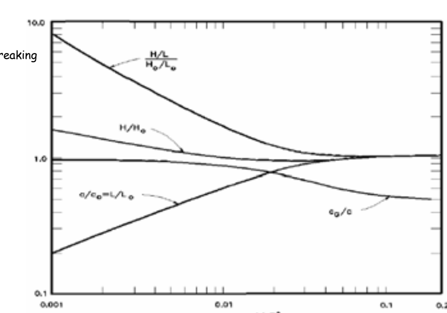
Wave Shoaling: transformation of the wave form due to interaction with bathymetry (intermediate – shallow water)

H: increases up to breaking

T: remains constant

L: decreases

C: decreases



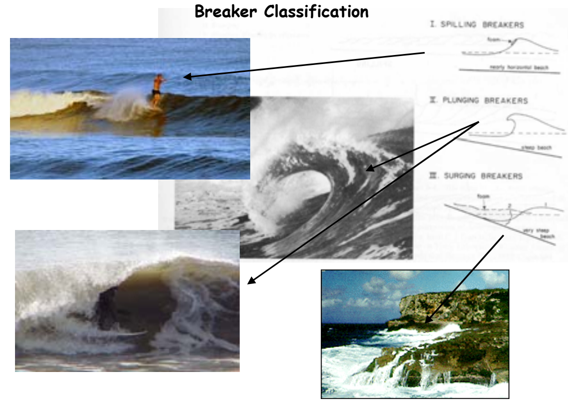
Break Point: point at which wave form becomes unstable and breaks (water particles at the crest travel much faster/farther than water particles in the trough)

$\gamma_b = \dfrac{H_b}{d_b}$ Breaker Index ~= 0.78

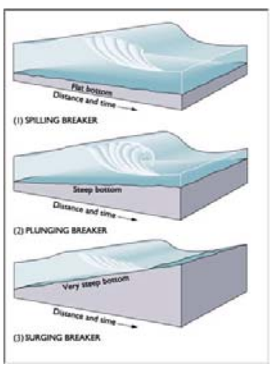
$\Omega_b = \dfrac{H_b}{H_o}$ Breaker Height Index

$\Omega_b = 0.3(H_o/L_o)^{-1/3}$ Note: Rough estimates of breaking wave height and depth can be calculated from deep water wave parameters (ie buoy measurements

Breaker Classification



Breaker Classification



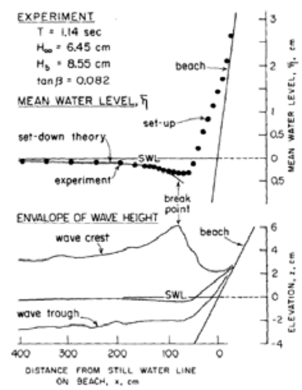
Surf Similarity Parameter ~ Irribarren Number

$$\xi_o = \tan\beta \left(\frac{H_o}{L_o}\right)^{-\frac{1}{2}}$$

Beach Slope ($\tan\beta$); Deep Water Wave Height (H_o); Deep Water Wave Length (L_o)

Surging/collapsing	$\xi_o > 3.3$
Plunging	$0.5 < \xi_o < 3.3$
Spilling	$\xi_o < 0.5$

Wave Setup & Setdown



Wave Refraction: changes in the direction of wave propagation due to along crest variations in wave speed

Wave Rays: lines drawn perpendicular to the crest of the wave in the direction of wave propagation

Wave Refraction

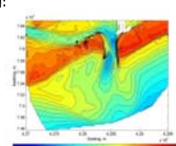
Parallel Contours: refraction results in wave rays approaching normal to shoreline = (wave crests parallel to shoreline (a))

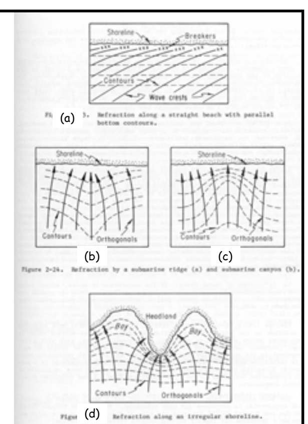
Submarine Ridge: focusing of wave energy toward the ridge (b)

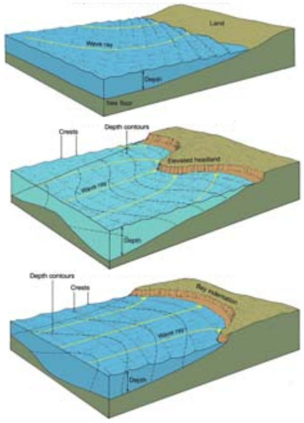
Submarine Canyon: spreading of wave energy throughout the depression (c)

Headland: focusing of wave energy (d)

Ebb-Shoal:







Wave Diffraction: bending of wave crests (changes in direction) due to along crest gradients in wave height

Figure 11. Mound diffraction structure as constructed at Grays Harbor, WA (2000)

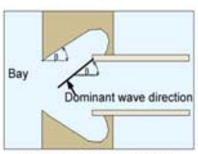
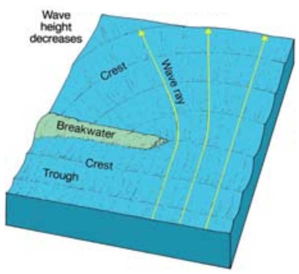


Figure 12. Equilibrium inner bank erosion showing dominant wave angle and shoreline orientation angle, β



Wave Diffraction

Figure 5. Jetty flanking at Half Moon Bay, Grays Harbor, WA

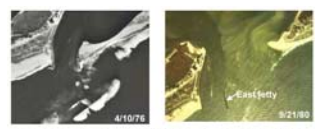
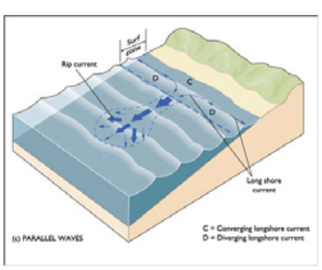
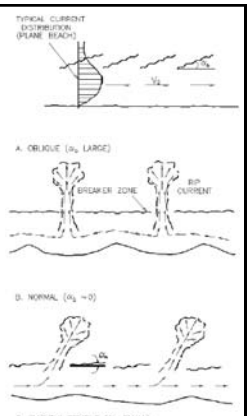


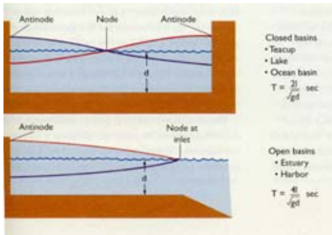
Figure 2. Left panel shows Moriches Inlet, NY, before it breached on 15 January 1980. East jetty was flanked, after it breached, as shown in the right panel

Wave Generated Currents





Seiches



Created By:
Wind
Tsunamis
Tidal Resonance

Fig. 1. Location map for the south shore of Long Island, New York

Potential Mechanisms

Geologic Events

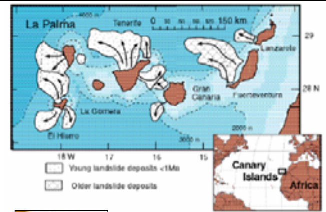
Vertical fault movement

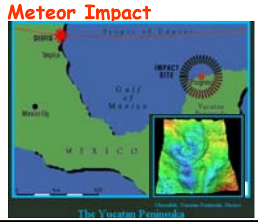
Mass wasting event

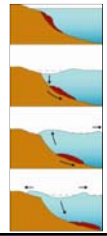
submarine landslides

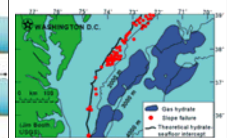
collapsing volcanoes

Meteor Impact

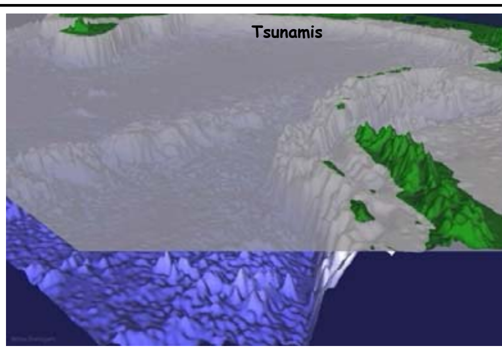






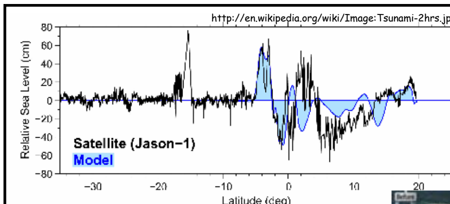


Tsunamis



The Dec 26, 2004 M=9.0 Sumatra earthquake occurred along a subduction zone in which the India and Australia plates to the west are being subducted beneath the Sunda plate and Burma microplate to the east.

http://walrus.wr.usgs.gov/tsunami/sumatraEQ/tectonics.html



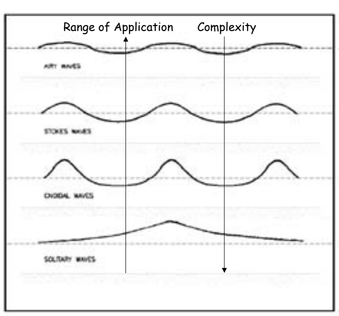
Satellite altimeters

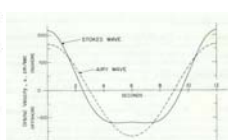
450 mph in deep water

Satellite images of a coastal village in Banda Aceh, Indonesia

http://www.seed.slb.com/en/scictr/watch/living_planet/tsunami.htm

Wave Theories





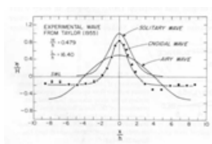
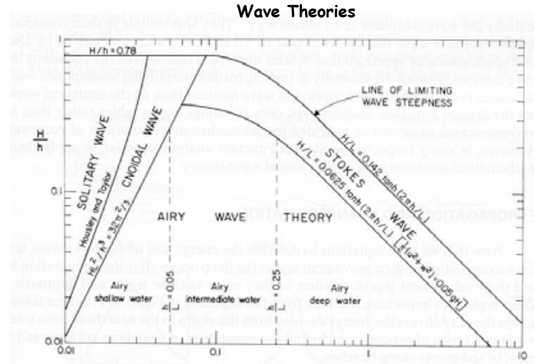
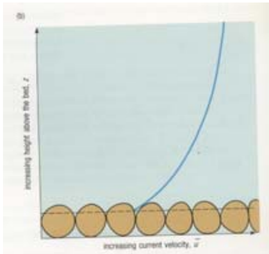


Figure II-1-10. Wave profile shape of different progressive gravity waves

Wave Theories



Sediment Transport

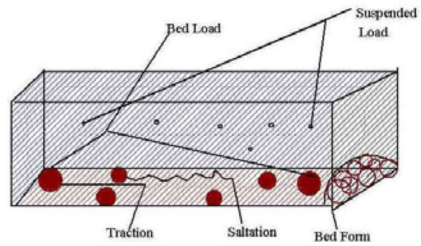


Shearing forces and turbulence exerted on the sand grains by the overlying fluid are responsible for the movement of sediment

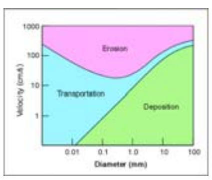
Sediment Transport

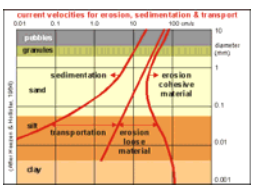
Sediment can be transported in three distinct modes

1. Suspended Load: material is transported up into the water column and advected by currents (both wave and tide driven)
2. Bed Load: material is rolled/moved along the bottom without being suspended. Sand bars and bed forms are transported as bed load
3. Saltation: material is bounced along the bed



Grain Size – Velocity Relationship





Millimeters		µm	Phi (φ)	Wentworth size class	
			-20		
	4096		-12	Boulder (-8 to -12φ)	
	1024		-10		
	256		-8		
	64		-6	Pebble (-6 to -8φ)	
	16		-4	Pebble (-2 to -6φ)	Gravel
	4		-2		
	3.36		-1.75		
	2.83		-1.50	Gravel	
	2.38		-1.25		
	2.00		-1.00		
	1.68		-0.75		
	1.41		-0.50	Very coarse sand	
	1.19		-0.25		
	1.00		-0.00		
	0.84		0.25		
	0.71		0.50	Coarse sand	
	0.59		0.75		
1/2	0.50	500	1.00		
	0.42	420	1.25		
	0.35	350	1.50	Medium sand	Sand
	0.30	300	1.75		
1/4	0.25	250	2.00		
	0.210	210	2.25		
	0.177	177	2.50	Fine sand	
	0.149	149	2.75		
1/8	0.125	125	3.00		
	0.105	105	3.25		
	0.088	88	3.50	Very fine sand	
	0.074	74	3.75		
1/16	0.0625	63	4.00		
	0.0530	53	4.25		
	0.0440	44	4.50	Coarse silt	
	0.0370	37	4.75		
1/32	0.0310	31	5		
1/64	0.0156	15.6	6	Medium silt	
1/128	0.0078	7.8	7	Fine silt	
1/256	0.0039	3.9	8	Very fine silt	Mud
	0.0020	2.0	9		
	0.00098	0.98	10		
	0.00049	0.49	11		
	0.00024	0.24	12	Clay	
	0.00012	0.12	13		
	0.00006	0.06	14		