What are waves?

Water waves are a manifestation of energy moving through the ocean. In their simplest form, waves are sinusoidal in shape. The high water levels are the wave crests and the low water levels are the wave troughs. The vertical distance between a crest and trough is the wave height H. The distance between two crests or troughs is the wave length L and the time it takes for two crests or troughs to pass the same point is the wave period T.

The velocity, C, at which a wave moves through the ocean is related to the ratio of its wave length to wave period: C = L/T. The wave length is proportional to the square of the wave period, L ~ T^2 so longer waves move faster than shorter ones. The amount of energy, E, in the wave is a function of the wave height and is proportional to: E ~ 1/8 H^3.

What causes waves?

A disturbing force is necessary to create waves on the ocean surface. The type of disturbing force determines the characteristics of the generated waves. The 3 main wave generation forces in order of decreasing wave period are:

- Gravitational Attraction of Moon and Sun produces Tides
- Earthquakes and Underwater Landslides generate Tsunami
- Wind Stress over the ocean generates Wind Waves

Tidal Waves

Tides are generated by the gravitational attraction of the earth, moon, and sun. On the side of the earth closest to the moon, the ocean surface bulges out toward the moon. An equal bulge in the surface of the ocean occurs on the side of the earth opposite of the moon due to the centrifugal force generated by the earth’s rotation. In between the 2 bulges the ocean surface is depressed due to the movement of water toward the bulges.

As the moon rotates around the earth, the bulges move as well resulting in 2 high and 2 low tides per day at most locations on the coast with a tidal period of approximately 12 ½ hours.

The exact number of the tides is dependent on the shape of the ocean bottom along the coast. This can have a significant effect on the height and period of the tide along the coast as seen in the tidal curves for the east coast.

Some coastal geometries have the right size and shape to produce amplified tides that result in very large tidal ranges. Some locations in the Bay of Fundy, Nova Scotia experience a tidal range of over 40 ft!

In shallow coastal regions, the currents generated by the incoming tide can produce Tidal Borets, visible waves that move inland from the coast.

Tsunamis

Often misnamed tidal waves, Tsunamis are long period waves that originate when a strong earthquake or landslide occurs under the ocean. The motion of the earth sends a strong impulse of energy into the water generating surface waves with open ocean heights of less than 2 feet but with wave lengths of over 100 miles and wave speeds approaching 500 miles per hour!

As a tsunami approaches the coast, the wave interacts with the shallow bottom. Because of their long wave lengths, tsunami rarely break along the coast. Instead the water runs up along the shore shape to produce amplified tides that result in very large tidal ranges. Some locations in the Bay of Fundy, Nova Scotia experience a tidal range of over 40 ft!

When waves travel out of the region of strong winds, they become sorted as the longer waves propagate across the ocean in groups. Waves lose very little energy as they travel out from the storm faster than the shorter waves. This results in waves of similar characteristics moving together across the ocean in groups. Waves lose very little energy as they propagate across the deep ocean. Removed from the influence of the wind the wave crests of the swell become rounded.

Wind Generated Waves

Wind blowing across the surface of the ocean transfers energy into the water. Initially, light winds generate small Ripples called capillary waves on the water surface.

If the wind increases, the added roughness created by the capillary waves increases the rate of energy transfer and waves begin to form on the ocean surface.

In the the region where wind is blowing across the ocean surface and waves are being generated, the sea surface is characterized by steep waves with many different lengths moving randomly in the direction of the wind. This condition is referred to as sea. How large the waves get is dependent on 3 factors:

The strength of the wind

The amount of time the wind blows

The distance (called fetch) over which the wind blows in a straight line across the ocean

When waves travel out of the region of strong winds, they become sorted as the longer waves travel out from the storm faster than the shorter waves. This results in waves of similar characteristics moving together across the ocean in groups. Waves lose very little energy as they travel out from the storm faster than the shorter waves. This results in waves of similar characteristics moving together across the ocean in groups. Waves lose very little energy as they propagate across the deep ocean. Removed from the influence of the wind the wave crests of the swell become rounded.

The stronger the wind and the longer it blows across the fetch, the larger the sea will become. A fully developed sea occurs when the waves reach the maximum size possible for a specific wind, duration and fetch.

Swell

When waves travel out of the region of strong winds, they become sorted as the longer waves travel out from the storm faster than the shorter waves. This results in waves of similar characteristics moving together across the ocean in groups. Waves lose very little energy as they propagate across the deep ocean. Removed from the influence of the wind the wave crests of the swell become rounded.

The stronger the wind and the longer it blows across the fetch, the larger the sea will become. A fully developed sea occurs when the waves reach the maximum size possible for a specific wind, duration and fetch.

Swell

When waves travel out of the region of strong winds, they become sorted as the longer waves travel out from the storm faster than the shorter waves. This results in waves of similar characteristics moving together across the ocean in groups. Waves lose very little energy as they propagate across the deep ocean. Removed from the influence of the wind the wave crests of the swell become rounded.
Wave Shoaling and Refraction

When waves enter shallow water (water depths equal to ½ the wave length) friction generated by the seabed begins to slow the motion of the waves. If part of the wave is still in deep water, the slower portion of the wave will bend toward the coast. This process is called wave refraction.

As the bottom of the wave slows, the waves crest becomes more peaked and the distance between wave crests shortens. This process is referred to as wave shoaling.

Wave Breaking

When waves reach a critical wave height to length ratio of 1/7, the wave will begin to break. In the surf zone, this critical ratio generally occurs when the wave height is ¾ of the water depth. There are 3 types of breakers that occur along the shore: plunging, spilling and surging. The type of breaker depends on the slope of the seabed offshore of the beach. When waves go from deep water to shallow water quickly the bottom of the wave slows so quickly that the crest of the wave plunges forward creating a tubing wave like those found in Hawaii. (Cartoons courtesy of Office of Naval Research).

On beaches with gentle slopes, the wave crest breaks first and the white water spills down the face of the wave.

On very steep beaches, the does not break at all but surges up the beach instead.

Current Wave Conditions

For real-time information about ocean wave conditions see the following web pages:

Merchant Vessel in fully developed sea.

Surge associated with the 1946 tsunami that struck Hawaii. Notice height of white water along tree trunks.

For additional information contact:

Dr. Thomas Herrington
Coastal Processes Specialist,
Stevens Institute of Technology
Castle Point on Hudson, Hoboken, NJ 07030
PH (201) 216-3320 FX (201) 216-8214
email: therring@stevens.edu
or
http://attila.stevens-tech.edu/%7Etherring/SeaGrant.html

This fact sheet was prepared through the Stevens – New Jersey Sea Grant Coastal Processes Cooperative Extension formed to promote the sustainability and wise use of our coastal resources that provide the basis of a strong coastal economy.

This publication was supported by the National Sea Grant College Program of the U.S. Department of Commerce’s National Oceanic and Atmospheric Administration under NOAA Grant NA16RG1047. The views expressed herein do not necessarily reflect the views of any of these organizations.

NJSG-03-549.

All About Waves