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Weather and Oceanography

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CHAPTER 5
Weather and Oceanography

Introduction

Boat crews operate in constantly changing environments. Weather and sea conditions interact causing many different types of situations. It is important to understand these conditions and how to operate in them. The information in this Chapter will concentrate on the effects the environment has on the water and the problems these effects can cause. It will not provide an explanation of advanced meteorology or oceanography.

Wind, fog, rain, and cold temperatures (sea and air) can be very dangerous. Any of these can complicate the simplest mission, not only increasing the danger, but also lessening the survival probability of persons in distress.

Effects of wind, current, and tide can also dramatically affect a boat's behavior. A coxswain must understand how outside influences cause the boat to react in different ways.

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Section A. Weather

Introduction

One of the greatest hazards to the boat crew occurs when its members must work close inshore or in heavy weather. The waves, seas, and surf can present the greatest challenges to seamanship and survival skills. The operating AOR will provide its own unique weather characteristics. Some major distinct conditions occur in various regions of the United States in predictable patterns. For example:

(01) Bermuda High: A semi permanent high-pressure area off of Bermuda. It affects the general wind circulation and the weather of the East Coast, especially summer heat waves,

(02) Santa Ana Wind: On the southern California coast, a dry, warm wind that blows through a pass and down the Santa Ana Valley which are prevalent in September and October. It may blow so strongly that it threatens small craft near the coast,

(03) Taku Wind: A strong east-northeast wind, in the vicinity of Juneau, Alaska, between October and March that can threaten small craft near the coast. It sometimes reaches hurricane force at the mouth of the Taku River.

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Wind

A.1. Air

High winds account for considerable destruction in the marine environment every year. Everyone knows water seeks its own level; the same is true with air. Air tends to equalize its pressure by flowing from a high-pressure area to a low-pressure area, producing wind.

A.2. Afternoon Wind Increases

Members of the boating public often get underway in the calm waters of the cool early morning. By afternoon, when they try to get home, the bay or ocean is so choppy that they may find themselves in need of assistance. The wind changes so drastically because the sun warms the earth. The land warms faster than the surface of the water and radiates heat to the overlying air, warming it. This warm air rises, reducing the atmospheric pressure in that area. The air offshore over the ocean is cool, and cool air is dense and heavy.

The cool air from offshore flows inland in an attempt to equalize the pressure differential caused by the rising warm air. This flow produces wind, known as sea breeze. After sunset, the inland area cools more quickly than the water, and the wind diminishes.

Sea breezes typically reach their highest speeds during the period of maximum heating (i.e., during mid-afternoon). In some areas a land breeze can be established late at night or early in the morning. For this breeze to occur, the sea surface temperature must be higher than the air temperature over land, along with weak winds prior to the breeze.

NOTE

Wind direction is the compass heading from which the wind blows.

A.3. Beaufort Wind Scale

The Beaufort Wind Scale (see **Table 5-1**) numbers define a particular state of wind and wave. The scale allows mariners to estimate the wind speed based on the sea state.

NOTE

The Beaufort Wind Scale extends to force 18. For boat operating purposes, **Table 5-1** is limited to force 10.

Table 5-1
Beaufort Wind Scale

Beaufort Scale	Wind Speed (Knots)	Indications	Approximate Wave Height		Davis Sea State
			(Feet)	(Meters)	
0	Calm	Mirror like.	0	0	0
1	1-3	Ripples with appearance of scales.	0.25	0.1	0
2	4-6	Small wavelets that do not break. Glassy appearance.	0.5-1	0.2-0.3	1

Table 5-1 (continued)
Beaufort Wind Scale

Beaufort Scale	Wind Speed (Knots)	Indications	Approximate Wave Height		Davis Sea State
			(Feet)	(Meters)	
3	7-10	Large wavelets. Some crests begin to break. Scattered whitecaps.	2-3	0.6-1	2
4	11-16	Small waves becoming longer. Fairly frequent whitecaps.	3.5-5	1-1.5	3
5	17-21	Moderate waves. Pronounced long form. Many whitecaps.	6-8	2-2.5	4
6	22-27	Large waves begin to form. White foam crests are more extensive. Some spray.	9.5-13	3-4	5
7	28-33	Sea heaps up. White foam from breaking waves begins to blow in streaks along the direction of the waves.	13.5-19	4-5.5	6
8	34-40	Moderately high waves of greater length. Edges of crests break into spindrift foam blown in well-marked streaks in the direction of the waves.	18-25	5.5-7.5	6
9	41-47	High waves. Dense streaks of foam. Sea begins to roll. Spray affects visibility.	23-32	7-10	6
10	48-55	Very high waves with over-hanging crests. Foam in great patches blown in dense white streaks. Whole surface of sea takes on a white appearance. Visibility affected.	29-41	9-12.5	7

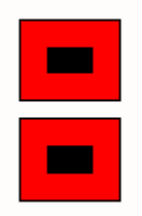
A.4. Weather Warning Signals

The National Weather Service provides radio weather broadcasts. Beginning June 1, 2007, the U.S. Coast Guard formally re-established a Coastal Warning Display program at selected boat stations which will hoist display flags to warn of small craft advisories, gale warnings, storm warnings and hurricane warnings. These weather warnings and their flags and lights signals are summarized in **Table 5-2**.

Table 5-2
Marine Advisories and Warnings Included in Coastal and Offshore Forecasts

Marine Advisories and Warnings	Winds	Day Signal Onshore	Night Signal Onshore
Special Marine Warning	A severe local storm warning affecting coastal water areas, or a warning of potentially hazardous weather conditions usually of short duration (2 hours or less) and producing wind speeds of 34 KT or more, that is not adequately covered by existing marine warnings.		
Small Craft Advisory (conditions dangerous to small craft operations)	An advisory in coastal waters for winds from approximately 18 to 33 KT inclusive (lower limit may vary by region) or for sea conditions, either predicted or occurring, that are considered potentially hazardous to boats. There is no legal definition for “small craft.”	Red pennant 	Red-over-white light 
Gale Warning	A warning of sustained winds in the range 34 to 47 KT (39 to 54 MPH) inclusive either predicted or occurring, not associated with tropical cyclones.	Two red pennants 	White-over-red lights 
Storm Warning	A warning of sustained winds of 48 to 63 KT (55 to 73 MPH), not associated with a tropical cyclone.	Square red flag with black center	Two red lights

Table 5-2 (continued)
Marine Advisories and Warnings Included in Coastal and Offshore Forecasts

Marine Advisories and Warnings	Winds	Day Signal Onshore	Night Signal Onshore
Hurricane Force Wind Warning	A warning for sustained winds of 64 KT (74 MPH) or greater either predicted or occurring, not associated with a tropical cyclone.		
Tropical Storm Warning	A warning of sustained winds from 39 to 73 MPH inclusive either predicted or occurring, associated with tropical cyclones.		
Hurricane Warning	A warning for sustained winds of 74 MPH or greater either predicted or occurring, associated with a tropical cyclone.	Two square red flags with black centers 	Three vertical lights - red, white, red 

Thunderstorms and Lightning

A.5. Thunderstorms

Thunderstorm**,** a violent, short-lived weather disturbance that is almost always associated with lightning, thunder, dense clouds, heavy rain or hail, and strong, gusty winds. Thunderstorms arise when layers of warm, moist air rise in a large, swift updraft to cooler regions of the atmosphere. Thunderstorms are dangerous not only because of lightning, but also because of the strong winds and the rough, confused seas that accompany them.

A.6. Lightning

Lightning is a potentially life-threatening phenomenon associated with some storms. Not all storms are thunderstorms, but all thunderstorms have lightning. Lightning occurs when opposite electrical charges within a thundercloud, or between a cloud and the earth, attract. It is actually a rapid equalization of the large static charges built up by air motion within the clouds. Lightning is very unpredictable and has immense power. A lightning "bolt" usually strikes the highest object on the boat, generally the mast or radio antenna. A mast with a full grounding harness affords excellent protection.

A.7. Distance From a Thunderstorm

In addition to using the radar to find the range of a thunderstorm, the boat's distance from a thunderstorm can be estimated by knowing it takes about five seconds for the sound of thunder to travel each mile.

(01) Observe the lightning flash,

(02) Count the number of seconds it takes for the sound of its thunder to arrive,

(03) Convert to miles by dividing the number of seconds by 5.

NOTE Counting "one thousand one, one thousand two, one thousand three, one thousand four, one thousand five" will aid in correctly counting seconds.

A.8. Safety

If caught in a lightning strike area, the following procedures apply:

Step	Procedure
1	Head for shore or the nearest shelter.
2	While underway, stay inside the boat, keep crewmembers low, and stay dry.
3	Avoid touching metal, such as metal shift and throttle levers and metal steering wheels.
4	Avoid contact with the radio.
5	If lightning strikes, expect the compass to be inaccurate and onboard electronics to suffer extensive damage.

A.9. Waterspouts

A waterspout is a rotating column of air, usually pendant from a cumulus or cumulonimbus cloud, that forms over water and whose circulation extends to the surface. There are two types of waterspouts:

(01) Violent convective storms over land moving seaward (tornadoes),

(02) Storms formed over sea with fair or foul weather (more common than tornadoes).

Waterspouts develop as a funnel-shaped cloud and when fully developed extend from the water's surface to the base of a cumulus cloud. The water in a waterspout is mostly confined to its lower portion. The air in waterspouts may rotate clockwise or counterclockwise, depending on the manner of formation. Waterspouts vary in diameter, height, strength and duration, and are found most frequently in tropical regions.

NOTE

While waterspouts are found more frequently in tropical areas, they are not uncommon in higher latitudes.

Fog

A.10. Description

Fog is a multitude of minute water droplets suspended in the atmosphere, sufficiently dense to scatter light rays and reduce visibility. Fog makes locating anything more difficult and also makes the voyage to and from the scene more hazardous.

A.11. Advection Fog

The most troublesome type of fog to mariners is advection fog. Advection means horizontal movement. This type of fog occurs when warm, moist air moves over colder land or water surfaces. The greater the difference between the air temperature and the underlying surface temperature, the denser the fog. Sunlight hardly affects advection fog. It can occur during either the day or night. An increase in wind speed or change in direction may disperse advection fog; however, a slight increase in wind speed can actually make the fog layer thicker.

A.12. Radiation (Ground) Fog

Radiation fog occurs mainly at night/early morning with the cooling of the earth's surface, which cools faster than the surrounding air. The air near the surface is stagnated by light winds, and then cooled to its dew point by the colder surface, producing a shallow layer of fog. It is most common in middle and high latitudes, near the inland lakes and rivers, which add water vapor to the fog. It clears slowly over water because the land heats and cools three times faster from night to day than water. Sunlight burns off radiation fog by warming the air. Surface winds break up the fog by mixing the air.

A.13. Fog Frequency

Along the Pacific Coast fog appears most frequently in areas from the northern tip of Washington State to around Santa Barbara, California. The nation's Atlantic Coast fog is most common from the northern tip of Maine to the southern tip of New York. Fog appears, on the average, more than 10% of the time in these waters. Off the coasts of Maine and Northern California it averages more than 20%. The fog frequency near Los Angeles, California, on the other hand, is about three times that of Wilmington, North Carolina.

A.14. Operating in Fog

When operating in fog, utilize the following procedures:

Step	Procedure
1	Slow down to allow enough time to maneuver or stop (i.e., operate the boat at a safe speed).
2	Display the proper navigation lights and sound appropriate sound signals.
3	Employ all available navigation aids.
4	Station a lookout well forward and away from the engine sounds and lights, to listen and look for other signals. Navigation rules require the use of a proper lookout.
5	Besides listening for other boats, the lookout should listen for surf in case the navigational plot is incorrect.
6	If the facility has dual steering stations, one inside and one exposed, use the exposed one in restricted visibility conditions. Being outside allows the lookout and operator the best chance to hear dangers to the boat. If only one station exists, if practical, open windows to increase sound awareness.

NOTE Consider anchoring to await better visibility, especially if transiting congested areas or narrow channels. Remember, fog increases the chance of a collision or grounding.

Ice

A.15. Salinity

Temperature and salinity govern the freezing point of water; however, winds, currents, and tides can slow the formation of ice by mixing in warmer water from below the surface. Fresh water freezes at 0° C/32° F, but the freezing point of seawater decreases to -2° C/28° F because of its salinity, which is the concentration of the dissolved solutes (often referred to as salt) in the water.

Shallow bodies of low-salinity water freeze more rapidly than deeper basins because a lesser volume must be cooled. Once the initial cover of ice has formed on the surface, no more mixing can take place from wind/wave action, and the ice will thicken. As a result, the first ice of the season usually appears in the mouths of rivers that empty over a shallow continental shelf. During the increasingly longer and colder nights of late autumn, ice forms along the shorelines as a semi-permanent feature and widens by spreading into more exposed waters. When islands are close together, ice can cover the sea surface between the land areas.

A.16. Topside Icing

One of the most serious effects of subfreezing air temperatures is that of topside icing, also known as ice accretion, particularly if the ice continues to accumulate. This icing is caused by freezing spray, which is an accumulation of freezing water droplets on a vessel, caused by some combination of cold seawater, wind, or vessel movement. Precipitation may freeze to the vessel as well. Ice will continue to accumulate as long as freezing spray continues to occur, in turn, causing increased weight on decks, superstructures, and masts. Ice also produces complications with the handling and operation of equipment, and creates slippery deck conditions. The ice accumulation causes the boat to become less stable and may lead to capsizing.

A.17. Frazil Ice

These first stage ice formations start with disk-shaped crystals that form and grow suspended in the water. These crystals eventually form a thin, oily, or opaque looking film that floats to the surface. Water movement interrupts the crystals' growth. When this happens, the crystals cannot join together to form a solid sheet of ice. Unpredictable while forming, it can be difficult to transit if collected in an area, and will not support a rescuer's weight.

A.18. Brash Ice

Brash ice is the accumulation of small ice fragments broken off from other ice formations caused by weather or vessel passage. Brash ice thickness can range from mere inches to 8 feet or more. It can be loose or refrozen. Very loose brash ice is called drift ice.

A.19. Ice Floe

Flat pieces of ice, 10 feet in diameter or larger. Can consist of one or many combined fragments of ice. Results from offshore winds and currents. Time is a critical factor when dealing with this type of formation.

A.20. Pancake Ice

The accumulation of ice floes formed by wind, waves, or current. Ice fragments are larger than those used to describe brash ice. Can be loosely or densely packed.

A.21. Clear Ice

Clear ice forms by long hard freezes, is usually the strongest type of ice formation (depending on ice thickness), and can be blue, green, or black

(depends on the color of the water visible though the ice). Clean, smooth, plate ice is sometimes referred to as "glare ice."

NOTE The easiest and most effective way to minimize icing is to slow down.

NOTE Ice can be broken away by chipping it off with mallets, clubs, scrapers, and even stiff brooms. Use special care to avoid damage to electrical wiring and finished surfaces.

Forecasting

A.22. Sources of Weather Information

Listening to either a news media broadcast meteorologist or NOAA Weather Radio, coupled with local knowledge, should make everyone informed weather-wise. Also, many old common weather "hunches" are often correct, but should not be the only source without some basic weather knowledge and a tool (e.g., barometer or thermometer) with which to crosscheck the belief. Using multiple sources to confirm personal hunches is recommended.

Section B. Oceanography

Introduction

Oceanography is a broad field encompassing the study of waves, currents, and tides. It includes the biology and chemistry of the oceans and the geological formations that affect the water. Boat crewmembers must have an appreciation of all these factors to safely operate in an ever-changing environment. Some major distinct conditions occur in various regions of the United States. For example:

(01) **Great Lakes** tend to freeze ove the winter,

(02) **Gulf Stream**: A powerful, warm ocean current flowing along the East Coast. In the Straits of Florida, it greatly affects the speed of advance of vessels underway and drifting objects; off of Cape Hatteras, North Carolina, it "collides" with weather systems and can cause dangerous wave conditions,

(03) **West Coast**: in general, has a narrow continental shelf (a gentle bottom slope) followed by a sharp drop into great ocean depth. It receives its weather from off shore. A long fetch and often long duration are a significant influence on the sea conditions likely to be encountered,

(04) **East Coast**: The east coast is often in the path of tropical storm systems, strong arctic low pressure systems and Nor'easters. The Gulf Stream and a wide, shallow continental shelf are significant influences on the sea conditions encountered,

(05) **Gulf Coast**: The gulf coast also has the Gulf Stream and a wide, shallow continental shelf to influence waves. With relatively little fetch, the major source of heavy weather are tropical storm systems.

Area-specific weather patterns can include, gap winds, dynamic fetch, strong currents, thunderstorms, lightning, freezing spray, steep seas with very short periods, as well as many other phenomenon. Any of these conditions can make operations more difficult and hazardous for the boat and crew.

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Waves and Surf

B.1. Description The ability to recognize wave patterns and characteristics is essential to safe operation in heavy weather and surf. A coxswain operating in these conditions must be able to determine the timing of lulls, series, and estimate wave heights accurately.

NOTE

The terms "Knockdown" and "Rollover" apply specifically to self-righting boats. A **knockdown** is when a boat has rolled in one direction 90º or greater but does not completely roll over (360º) to right itself. (Example: Boat rolls to port 120º and rights itself by rolling back to starboard.) A **rollover** occurs when a boat rolls in one direction and rights itself by completing a 360º revolution.

Wind Velocity, Fetch and Duration

B.2. Wind Velocity, Fetch and Duration Wind velocity, fetch, and duration is the speed of the wind, the amount of ocean surface area affected by wind blowing in the same direction, and the amount of time the wind blows over the same part of the ocean. Ideally, to make a huge swell, one would want strong, steady winds blowing at maximum velocity over thousands of miles in the same direction for days on end. But, our atmosphere is highly dynamic, and rarely do such conditions exist or persist for long. During a typical open ocean winter storm, one could expect to see winds of 50-60 kts blowing for 600-1000 NM for 36 hours. In such a storm, the highest average wind waves (or seas) can commonly reach 30 ft towards the center of the fetch area.

As the seas build under a storm, the speed of individual wind waves start accelerating as they combine. The higher the wind velocity, the larger the area and the longer the wind blows, the greater the opportunity wind waves have to combine and grow. Within the storm, waves of many different energy levels are created. Eventually either the storm dies or the wave speed exceeds the forward speed of the storm, and these seas escape into relatively calm waters. However, they are rough, ragged and cover a wide energy spectra. Now the waves have inertia and they're moving forward.

Chop has little inertia or energy, so it dissipates when traveling long distances. This works against swell production when a wind wave has little energy, because it dissipates. However, when a wave has lots of time to accumulate energy, inertia works in its favor. In short, as a wind wave moves away from the storm, the choppy components dissipate, leaving only the pure swell energy to travel.

B.2.a. Heavy Weather Waves

Heavy weather waves and seas are generated by weather systems, either local or distant. There are many factors that determine what conditions will be generated by a weather system or series of weather systems. Some factors that will effect wave height include:

(01) State of the tide: Ebb currents often cause wave speed to decrease and wave height to increase. Conversely, flood currents often cause waves to gain speed and loose height,

(02) Rainfall: Heavy rainfall can reduce the size of waves, but large runnoffs from rivers may stop the flood current or drastically change the conditions at inlets or bars,

(03) The width of the body of water: The greater distance the body of water is allows for larger waves to be generated,

(04) Depth of water: Deeper water allows for larger swells to be generated. As these swells approach shallow water on the coast, they will loose speed and gain height,

(05) Air temperature: Cold air is denser, causing greater impact on the water and building larger swells than warm air.

B.2.b. Breaking Seas

Breaking Seas, also known as "Sea Breaks," are wind driven waves that form crests, which tend to become unstable and topple forward, or "break," creating a ridge of turbulence, white water, or foam (**Figure 5-1**).

CAUTION ! Depending on conditions, breaking seas can carry sufficient energy to affect the stability of a boat causing it to broach or be knocked down.

NOTE Breaking seas are not to be confused with surf, which is a type of breaker, whose formation is largely dependent on the topography of the seabed over which it passes.



Figure 5-1
Breaking Seas

B.3. Wave Systems

After the deepwater waves are generated far out at sea, they move outward, away from their wind source, in ever-increasing curves, and become what are called swells. The farther the swell moves from its source, the more uniform its characteristics become, as it travels in a series of waves, relatively equidistant, and moving at a more or less constant speed. Because of this, swells generated from storms far out at sea can be distinguished by their smoothness and uniformity from those that are coarser (peaked and irregular) which have recently originated nearby. The usual period of these swells is from 6 to 10 seconds. This corresponds with wave lengths of 184 to 1310 feet and velocities of 18 to 49 knots.

Interference between different swell systems, which are traveling in nearly the same direction, causes groups of waves to travel outward in patches. As these groups of several waves (normally 7 to 12) progress outward, those waves in the forefront disappear and new waves, of the same characteristics, appear at the rear of the patch. This process continues until the waves dissipate their energy at sea, or transfer it to the shore as surf.

The ability to recognize wave patterns and characteristics is essential to safe operation in surf and heavy weather. A coxswain operating in these conditions must be able to determine the timing of lulls and series, and estimate wave heights accurately. Some factors that affect wave patterns are:

(01) Refraction,
(02) Reflection,
(03) Interference,
(04) Shoaling water.

B.3.a. Refraction

Refraction means bending. Wave refraction occurs when the wave moves into shoaling water, interacts with the bottom and slows down. As the waves encounter the shallows, they slow down, causing the crests of the waves to bend forward toward the shallower water (**Figure 5-2**). The key to the amount to refraction that occurs is the bottom terrain. This can also occur when a wave passes around a point of land, jetty, or an island (**Figure 5-3**).

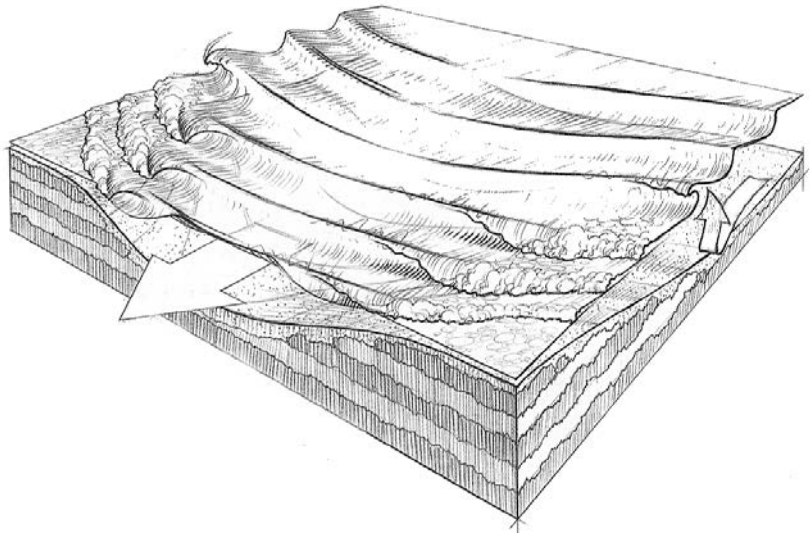

Figure 5-2
Submarine Valley

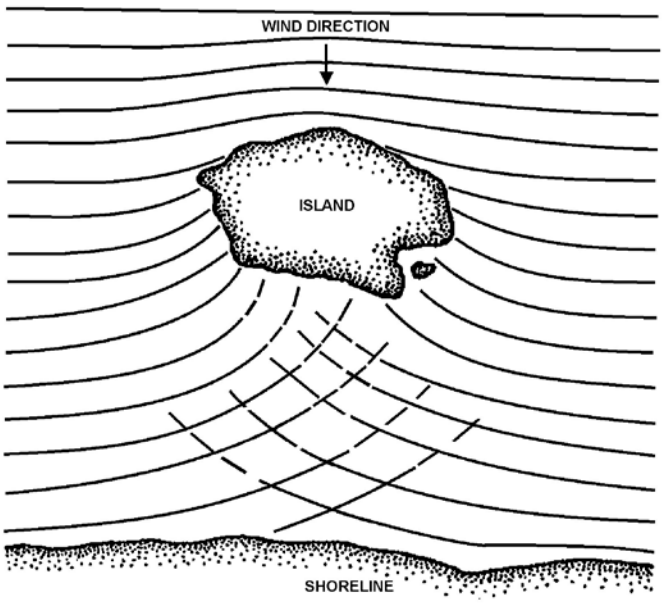

Figure 5-3
Wave Refraction

B.3.b. Reflection

Almost any obstacle can reflect part of a wave, including underwater barriers such as submerged reefs or bars, even though the main waves may seem to pass over them without change. These reflected waves move back towards the incoming waves (**Figure 5-4**). When the obstacles are vertical or nearly so, the waves may be reflected in their entirety.

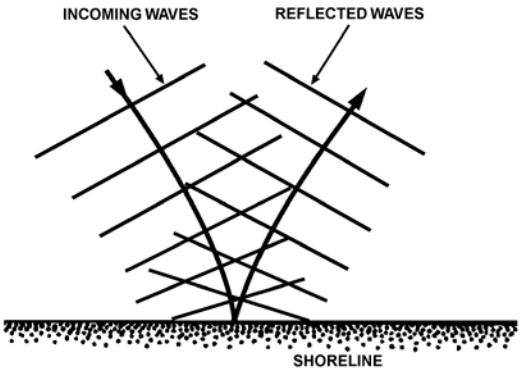

Figure 5-4
Wave Reflection

B.3.c. Interference

Waves which have been refracted or reflected can interact with each other. Waves can also interact with incoming waves resulting in higher wave heights. Interference may even result in standing wave patterns (waves that consistently appear to peak in the same spot). Interference can be of particular concern because it may result in a boat being subjected to waves from unexpected directions and of unexpected size (**Figure 5-5**).

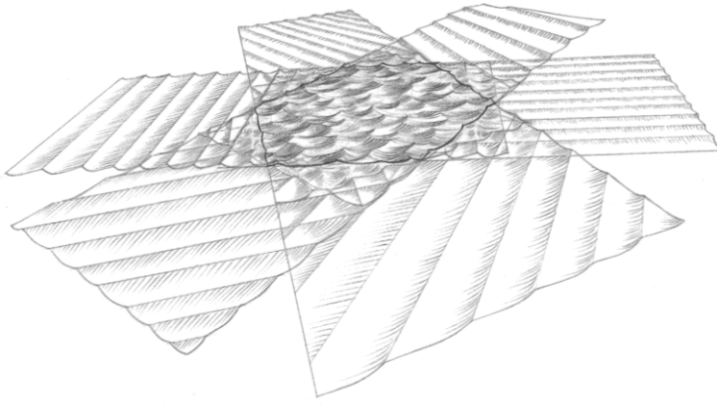

Figure 5-5
Wave Interference

B.3.d. Shoaling Water

Knowledge of the characteristic grouping of waves is useful when operating in shoaling waters such as over bars, in inlets, or working in surf. The wave groups can be observed and their group periods determined. The boat or boats can be best maneuvered during that time when the wave motion is at a minimum, during the space between groups.

When deepwater waves move into shallow waters, the waves are influenced by the bottom, becoming shallow-water waves. In the approach to shore, the interaction with the bottom causes the wave speed to decrease. This decrease causes refractions, and one effect is to shorten the wavelength. As the wavelength decreases, the wave steepness increases and the wave becomes less stable. Also, as the wave moves into water whose depth is about twice the wave's height, the crest peaks up; that is, the rounded crest of a swell becomes a higher more pointed mass of water with steeper sides. This change of waveform becomes more pronounced as the wave moves farther into shallow water. These changes in wavelength and steepness occur before breaking. Finally, at a depth of water roughly equal to 1.3 times the wave height (the actual formula used to determine when the wave will break is when the height is equal to 80% of the depth ratio, H=.8d), the wave becomes unstable. This happens when not enough water is available in the shallow area ahead to complete the crest and the wave's symmetrical form. The top of the onrushing crest is left unsupported and collapses. The wave breaks, resulting in surf.

B.4. Timing

The lull period in a wave system is the safest time to transit a bar, inlet, or shoal area in heavy weather/surf. By timing the duration of the lull, a coxswain can be prepared to make a transit while the waves are smaller. They will also have some idea of how much time is available before the next big set comes through. The basic technique is to use a stopwatch. After the last big wave of a series has passed, the time is started. When the first big waves of the next set arrive, the time is stopped. This is the duration of the lull, which may range from less than a minute to several minutes. This pattern should be observed for as long as possible until arriving at a useful consistent time. It may also be useful to time the duration of the series and number of waves in the set.

NOTE

The lull is the time between a series of swells.

B.5. Estimating Wave Height

An accurate estimate of wave height is subjective and sometimes difficult to accomplish, but there are a number of methods that, with practice, will give good results.

B.5.a. Height of Eye or Freeboard	With the boat in the trough and on a level and even keel, any wave that obscures the horizon is greater than the height of a person's eye. One can compare a wave to the deck edge or a structure such as the handrail. The wave face is observed while bowing into it, with the boat on an even keel in the trough.
B.5.b. Comparison with Floating Structures or Vessels	This technique is most useful when observing from land, but may be applied while underway. If the freeboard of a buoy is known to be 13 feet, that information can be used to determine the height of the waves passing it. A buoy can also be used to determine the wave period. One can observe a vessel underway and by estimating the freeboard of the vessel and observing its motions on the water, he or she can gain a fair estimate of the seas in which it is operating.
B.5.c. Comparison with Fixed Structure	Observation of waves as they pass a fixed structure, such as a break-wall, jetty, or pier, can be very accurate and can also provide wave period.
B.5.d. Depth Sounder	Using a digital depth sounder with a fast update speed can be very accurate for determining wave height. By comparing the depth in the trough on even keel with the depth at the crest on even keel, an accurate measurement can be obtained. All of these methods can be useful and reasonably accurate, but they require practice and experience. By comparing a local Weather Service buoy report with the crew's observations, they can fine tune their sense of wave height. With enough practice, they should be able to judge wave heights simply by looking at the waves themselves.
B.6. Breakers	A wave or swell of the sea breaking on the shore, shoal, reef, bar, or inlet. Breakers are a result of wave interaction with the bottom contour of the sea, shoal, reef, bar, or inlet. With each of these waves/swells the bottom of the wave slows on the ocean floor, shoal, reef, bar, or inlets while the top of the wave moves ahead of it causing it to break.

B.7. Types of Breakers

There are three basic types of breaking waves:

(01) Plunging (**Figure 5-6**),

(02) Spilling (**Figure 5-7**),

(03) Surging (**Figure 5-8**).

Each type of breaking waves brings its own hazards, such as suction currents, dropping huge quantities of water, and exerting a great deal of force. It is important to remember that when operating in heavy weather, these hazards are magnified beyond those found during calm water operations.

NOTE A 20 foot breaker will drop 1,500 tons of water on a boat.

B.7.a. Plunging Breaker

Plunging breakers are created when a wave encounters a sudden decrease in depth, such as a reef or a steep rise of the ocean floor. The momentum caused by the breaking top of the wave will cause the water to curl.



Figure 5-6
Plunging Breaker

B.7.b. Spilling Breaker

Spilling breakers are created when wave energy encounters a gentle sloping ocean floor. The spilling breakers normally have a crest of white water spreading down the wave face.



Figure 5-7
Spilling Breaker

B.7.c. Surging Breaker

Surging breakers are created on very steep beaches. The wave builds very quickly and expends its energy on the beach.

NOTE

It is unlikely you will encounter surging breakers while aboard a boat unless you are beaching it on a very steep beach.



Figure 5-8
Surging Breaker

B.8. Wave Series

Wave series are irregular because of constant shifting of wind direction and speed. Storms at sea create masses of waves that build up in groups higher than other waves. Breakers vary in size and there is no regular pattern or sequence to their height. But while the space or interval between series of breakers may vary, it is fairly regular. Despite the interval, breakers tend to stay the same for hours at a time.

The height and period of a wave depends on:

(01) The speed of the wind,

(02) The amount of time the wind has been blowing,

(03) The distance over water which the wind travels unobstructed, known as fetch. Nearness to land will limit fetch, if the wind is blowing offshore.

The lifecycle of a wave consists of its:

(04) Generation by wind,

(05) Gradual growth to maximum size,

(06) Distance traveled across the sea,

(07) Dissipation as wind decreases or when the wave impacts against the shore or an object.

NOTE

Tidal currents going against the waves will make the waves steeper.

B.9. Surf

Irregular waves of deepwater become organized by the effects of the contact with the bottom. They move in the same direction at similar speeds. As the depth of water decreases to very shallow, the waves break and the crests tumble forward. They fall into the trough ahead usually as a mass of foaming white water. This forward momentum carries the broken water forward until the wave's last remaining energy becomes a wash rushing up the beach. The zone where the wave gives up this energy and the systematic water motions is the surf (see **Figure 5-9**).

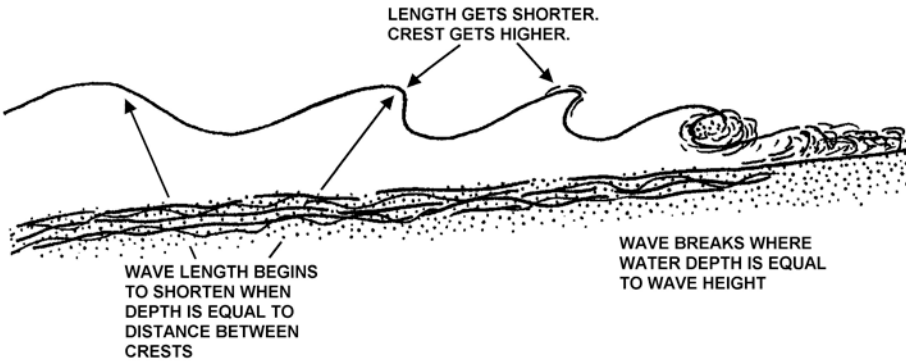

Figure 5-9
Surf

Sometimes there are two breaks of surf between the beach and the outer surf line. These breaks result from an outer sand bar or reef working against the wave causing the seas to pile up. The movement of water over such outer bars forms the inner surf belt as the water rolls toward the shore. The surf that forms around an inlet depends on the size of approaching swells and the bottom contours. The waves' speed and shape change as they approach shallow coastal waters. They become closer together (as their speed slows) and steeper as they contact the bottom. This change typically happens at a point where the water is approximately one half as deep as the wave's length.

As a wave steepens, its momentum will cause it to fall forward or curl. It is this momentum that gives a curl of breakers its tremendous force.

WARNING

Stay out of the wave's curl. Boats not authorized to operate in breaking surf or bar conditions should remain well clear of these hazards.

B.10. Surf Definitions	Following are descriptions and definitions relating to breakers encountered during surf conditions.
B.10.a. Surf	Several waves or swells of the sea breaking on the shore, shoal, reef, bar, or inlet.
B.10.b. Comber	A wave on the point of breaking. A comber has a thin line of white water upon its crest, called feathering.
B.10.c. Crest	The top of a wave, breaker, or swell.
B.10.d. Surf Line	The outermost line of waves that break near shore, over a reef, or shoal. Generally refers to the outermost line of consistent surf.
B.10.e. Surf Zone	The area where surf exists, between the outermost and innermost breaking waves.
B.11. Surf Zone Characteristics	In normal operations and especially in heavy weather, there are a number of conditions created in the surf zone and in individual waves of which the coxswain must be aware. These include: (01) Windows, (02) High/low side of a wave, (03) Wave saddles, (04) Closeouts, (05) Wave shoulder, (06) Rip currents.

B.11.a. Windows

A window is an area where the waves have momentarily stopped breaking, opening up a safer area of operation for your boat. Windows often form in the area of aerated water where a large set of waves has just finished breaking. The window may remain for a long time or may begin breaking again almost immediately. It is preferable to operate the boat in the windows whenever possible.



Figure 5-10
Window

B.11.b. High/Low Side of a Wave

The "high side" is defined as the section of a wave which carries the most potential energy. The "low side" is where the least potential energy exists and represents the safest direction to turn when facing the wave/swell (**Figure 5-11**).These high and low sides often change rapidly, and the ability to quickly navigate the high and low sides is a critical skill for surf operations.

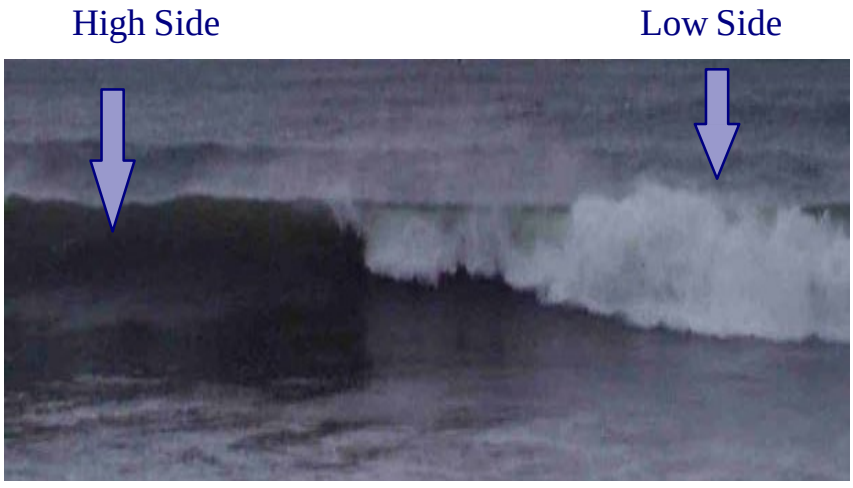

Figure 5-11
High/Low Side of a Wave

B.11.c. Wave Saddles

The "saddle" is the lowest part of a wave, bordered on both sides by higher ones. Often it is a small, unbroken section of a wave that is breaking. It is preferable to drive a boat in the saddles if possible, thus avoiding the white water. While saddles are very useful, they must be watched carefully, because they easily turn into "close-outs."



Figure 5-12
Saddle

B.11.d. Closeouts

"Closeouts" occur when a wave breaks from the ends toward the middle, or two waves break towards each other. The middle may look like a good saddle, but can quickly turn into whitewater. Closeouts should be avoided because they can create more energy than a single break.



Figure 5-13
Closeout

B.11.e. Wave Shoulder

The "shoulder" is the edge of a wave. It may be the very edge of the whitewater on a breaker, or the edge of a high peaking wave that is about to break. The shoulder is usually lower in height than the middle of the wave. Driving on the shoulders can be particularly useful in a narrow surf zone because it allows driving very close to a break in relative safety.



Figure 5-14
Shoulder

B.11.f. Rip Currents

Rips are created along a long beach or reef surf zone. The water from waves hitting the beach travels out to the sides and parallel to the shoreline, creating a "long-shore current" that eventually returns to sea. This seaward flow creates deep channels in the sand offshore that can shift from day to day. In the case of a reef, the channels are permanent parts of the reef, but otherwise behave the same. In these channels, the waves or surf are usually smaller because of refraction over the deeper water. Because of this, a rip channel often represents a safer route into or out of a surf zone. A rip current may also carry a person-in-the-water or a disabled vessel clear of the surf zone (**Figure 5-15**). If using a rip current, great care should be taken to stay in the channel by watching the depth sounder. Boat crews should always be alert for debris, which tends to concentrate in these areas.

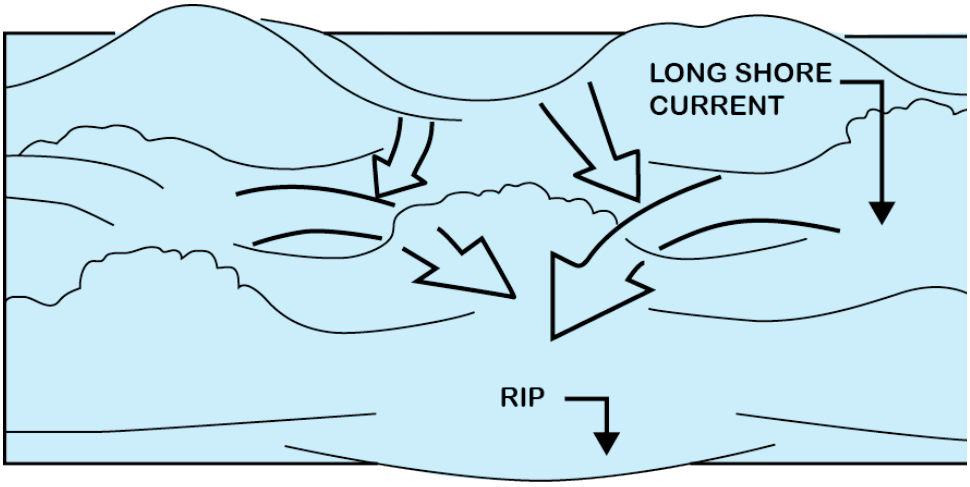

Figure 5-15
Rip Currents

Currents

B.12. Description Tide is the vertical rise and fall of the ocean water level caused by the gravitational attraction of the sun and moon. A tidal current is the horizontal motion of water resulting from the change in the tide. It is different from ocean currents, river currents, or those created by the wind. Tidal currents are of particular concern in boat operations.

NOTE Current direction is the compass heading toward which the water moves.

B.13. Flood, Ebb, and Slack Currents Flood current is the horizontal motion of water toward the land, caused by a rising tide. Ebb current is the horizontal motion away from the land, caused by a falling tide. Slack water is the period that occurs while the current is changing direction and has no horizontal motion.

An outgoing or ebb current running across a bar builds up a more intense sea than the incoming or flood current. The intense sea results because the rush of water out against the incoming ground swell slows the wave speed and steepens the wave prematurely.

B.14. Longshore Currents Longshore currents run parallel to the shore and inside the breakers. They are the result of the water transported to the beach by the waves.

CAUTION ! Pay close attention to longshore currents. They can cause a boat to broach or the object of a search to move further than expected.

B.15. Eddy Currents Eddy currents (eddies) occur at channel bends, near points of land, and at places where the bottom is uneven.

CAUTION ! Watch for and avoid eddies. They can abruptly change speed and steering control of boats.

B.16. Wind Effects on Current Wind affects the speed of currents. Sustained wind in the same direction as the current increases the speed of the current by a small amount. Wind in the opposite direction slows it down and may create a chop. A very strong wind, blowing directly into the mouth of an inlet or bay, can produce an unusually high tide by piling up the water. Similarly, a very strong wind blowing out of a bay can cause an unusually low tide and change the time of the high or low tide.

B.17. Effects on Boat Speed When going with the current, a boat's speed over ground is faster than the speed/RPM indication. When going against the current, a boat's speed over ground is slower than the speed/RPM indication.

B.18. Effects on Boat Maneuverability

When working in current, the boat's maneuverability depends on its speed through the water. Although a boat has significant speed in relation to fixed objects (e.g., a pier) when going with the current, a boat lacks maneuverability unless there is sufficient water flow past the rudder. When going into the current, maneuverability is usually improved as long as enough headway is maintained. However, at slow speeds, even a small change in course can have the bow swing greatly as the water flow pushes on one side of the bow.

B.19. Crossing the Current

When crossing the current to compensate for the set, a boat may be put into a crab (i.e., the boat may be forced off course by the current or wind). Because of this maneuver, the boat heading and the actual course made good will be different. When the boat is crabbing, the heading will not be the intended course of the boat. Therefore, navigate the current or wind by sighting on a fixed object (such as a range) or by marking the bearing drift on an object in line with the destination.

B.20. Tide and Tidal Current Changes

The change of direction of the tidal current always lags behind the turning of the tide. This difference occurs by a time period that varies according to the physical characteristics of the land around the body of water, as well as the bottom topography. For instance, with a straight coast and only shallow indentations, there is little difference between the time of high or low tide and the time of slack water. However, where a large body of water connects with the ocean through a narrow channel, the tide and the current may be out of phase by as much as several hours. In a situation such as this, the current in the channel may be running at its greatest velocity when it is high or low water outside. Times of high and low tide can be found utilizing NOAA's *Tide Tables.*

B.21. Tidal Current Tables

It is important when operating in tidal waters to know the set (direction toward) and drift (speed expressed in knots) of the tidal currents in the area. This information can be obtained from the *Tidal Current Tables* for the area.

B.22. Time and Speed

Boat crews should select the tidal or current station closest to their area of concern. Sometimes it may be a reference station, which means no calculating is needed. If using a subordinate station, its time differences should be applied to the time of slack and maximum current at the reference station to obtain the corresponding times at the subordinate station.

The maximum speed at the subordinate station is calculated by multiplying the maximum speed at the reference station by the appropriate flood or ebb ratio.

B.23. Current Velocity

Flood direction is the approximate true direction toward which the flooding current flows. Ebb direction is generally close to the reciprocal of the flood direction. Average flood and ebb speeds are averages of all the flood and ebb currents. This information can be obtained from NOAA's *Tidal Current Tables* for the area.

B.24. Actual vs. Predicted Conditions

Actual conditions frequently vary considerably from predicted conditions. Changes in wind force and direction, or variations in atmospheric pressure, produce variations in the ocean water level, especially the high-water height. The actual heights of both high-water and low-water levels are higher than the predicted heights with an on-shore wind or a low barometer. With a high barometer or offshore wind, those heights usually are lower than predicted.

When working with the Current Tables, the actual times of slack or maximum current sometimes differ from the predicted times by as much as half an hour. Occasionally, the difference may be as much as half an hour. However, a comparison between predicted and observed times of slack shows that more than 90% of slack water predictions are accurate to within half an hour. To get the full advantage of a favorable current or slack water, the navigator should plan to reach an entrance or strait at least half an hour before the predicted time of the desired condition of the current.