Fisheries and Oceans Canada
Coast Guard

Pêches et Océans Canada
Garde côtière

SAR SEAMANSHIP REFERENCE MANUAL

Canada

Cat. No.: FS23-392/2000E
ISBN 0-660-18352-8
First Edition – November 2000

Available through your local book seller or by mail from
Canadian Government Publishing
Public Works and Government Services Canada
Ottawa, Ontario
K1A 0S9

Telephone: (819) 956-4800
Fax: (819) 994-1498
Orders only: 1-800-635-7943
Internet: http://publications.pwgsc.gc.ca

Also available on the CCG Web site:
http://www.ccg-gcc.gc.ca

Produced by:
Fisheries and Oceans Canada
Canadian Coast Guard
Search and Rescue
Ottawa, Ontario
K1A 0E6

Disponible en français

FOREWORD

This SAR Seamanship Reference Manual is published under the authority of the Manager, Search and Rescue, of the Canadian Coast Guard. Funds associated for the development of this manual were provided by a generous contribution from the National SAR Secretariat's New SAR Initiatives Fund program. Without this financial contribution, the publication of this manual would not have been possible.

Purpose

To be able to perform safely and effectively, a rescue mission involves a huge amount of operational knowledge. Most of that knowledge is already available. However, in the context of small vessels, it is dispersed under a number of specialised and individually prepared courses or, under bits of documented information. In addition, the background and theory that sustains SAR operational knowledge is in many cases developed for larger ships involved in offshore rescue. Although the information is helpful, it does not always reflect the reality of small boat operations. A prime example would be first aid where all courses are developed around a movement free stable ground, which is quite different from a small bouncing boat deck.

Another issue is standardisation. Search and Rescue is essentially a humanitarian activity with the prime purpose of saving lives. In most cases, it involves the participation of number of dedicated people that may not have the same background. In order to make operations more efficient, it is paramount to have people executing operational tasks the same way. Therefore, this manual is aiming at introducing and standardising small boat operations for SAR. In fact, the purpose is to bring together under one manual all known best operational procedures and practices that usually apply to small boat involved in a SAR mission.

This manual targets two main groups of small boat rescuers. One is the Canadian Coast Guard Auxiliary and the other one is the Canadian Coast Guard Inshore Rescue Boat Program. However, other organized response units such a local Fire Department can certainly benefit from this manual. We hope that it will incorporate and standardise the current best practices employed within the Canadian Coast Guard operations community. It is intended to be the primary reference for the above noted two targeted groups, mainly for shore based boat operations and seamanship training.

The standardised methods and procedures presented in this Manual can apply to all boat operations and crew training and, Commanding Officers, Officers in Charge or Coxswains are encouraged to ensure that personnel tasked with boat crew responsibilities are trained or familiar in all methods and procedures in the Manual.

As the scope of this knowledge is quite vast, it will be under continuous review and will be updated as necessary. In addition, errors, omissions or suggestions should be forwarded to:

Manager, Search and Rescue, Canadian Coast Guard
Department of Fisheries and Oceans
200 Kent Street, Station 5041
Ottawa, Ontario, CANADA K1A 0E6

PEOPLE INVOLVED

Acknowledgements

This manual would not have been possible without the co-operation of several individuals involved in Search and Rescue, many of whom are mentioned in the following list.

Étienne Beaulé, First aid and technical writing consultant
Allen Bilodeau, Project manager
Mathieu Vachon, Project manager

Team SAR Ottawa

Ron Miller
Mike Voigt
Steve Daoust
François Vézina
Johanne Clouâtre
Brian Leblanc
Neil Peet
Kathy Needham

REVIEW AND CONSULTATION

Canadian Coast Guard

Kevin Tomsett
Dave Dahlgren
Greg Sladics
Herman Goulet
Charles Lever
Stephen Sheppard
Howard Kearley
Mike Taber
Deborah Bowes-Lyon
Mark Gagnon
Gaétan Gamelin
Pierre Bossé
Pierre Domingue
Chris Moller
Geoff Sanders
Bill Mather

Canadian Coast Guard Auxiliary

Harry Strong
Garry Masson
Ed Bruce
Rick Tolonen
Rudolph Mulack
Guy Poirier
Ted Smith
Jim Gram
Murray Miner
Cal Peyton
Ed Fulawka
Hubert Charlebois
Duff Dwyer
Don Limoges
Jack Kennedy
Don Mertes
Marvyn Huffman
Jim Presgrave
Robert Petitpas
Sylvio Lagacé
Gilbert Léger

Jeanne Drolet
Jean Péloquin
Marie-France Lavoie
Gaétan Létourneau
Bill Fullerton
Richard Wedge
Lois Drummond
Bruce Falkins

Inshore Rescue Boat (Program)

Mike Cass
Liz Brayshaw
Jen Schnarr
Danielle Dillon
Amy Birchall
Andrew Boyd
Casey Wilson
Tina Sweet
Darryl McKenzie
Marie Tremblay
Sophie-Émanuelle Genest
Nathalie Desjardins
John Johnstone
Scott Davis
Tim Church
Heather Goodwind
David Latremouille
Aaron Macknight
Chris Evers
Steven Shea
Dan Latremouille
Dana Sweeney
Steven Dickie
Gavin Moore
David Willis

OTHER THANKS

The Gordon Creative Group
Point-virgule, inc. (French editing)
Maureen McMahon
  (revised English edition)
Mario Boucher
  (Institut Maurice-Lamontagne)

ABBREVIATIONS AND ACRONYMS

NOTE: The abbreviations are listed alphabetically in the first column, with the French equivalent in brackets. Bold characters indicate that the abbreviation is the same in both languages.

AMVER	Automated Mutual Assistance Vessel Rescue System
CASARA (ACRSA)	Civil Air Search and Rescue Association
CCG (GCC)	Canadian Coast Guard
CCGS (NGCC)	Canadian Coast Guard Ship
CCGA (GCAC)	Canadian Coast Guard Auxiliary
CF (FC)	Canadian Forces
CGRS (SRGC)	Coast Guard Radio Station
COSPAS	Russian for: Space system search for distressed vessels
CSA (LMMC)	Canada Shipping Act
CSS	Co-ordinator surface search
DF	Direction finder
DFO (MPO)	Department of Fisheries and Oceans
DND (MDN)	Department of National Defence
DMB	Data marker buoy
DSC (ASN)	Digital selective calling
ECAREG Canada	Eastern Canada Traffic Zone Regulations
ELT	Emergency locator transmitter
EPIRB (RLS)	Emergency position-indicating radio beacon
ETA (HPA)	Estimated time of arrival
FRC (ERS)	Fast rescue craft
F/V (B/P)	Fishing vessel
GMDSS (SMDSM)	Global Maritime Distress and Safety System
GPS	Global Positioning System
IMO (OMI)	International Maritime Organisation
Inmarsat	International Mobile Satellite Organisation
IRB (ESC)	Inshore rescue boat
kt (nd)	Knot (nautical mile per hour)
LKP	Last known position
m	Metre
MCTS (SCTM)	Marine Communications and Traffic Services Centre
MARB	Maritime assistance request broadcast
Medevac	Medical evacuation
MSI	Maritime safety information
MRSC	Maritime rescue sub-centre
M/V (N/M)	Merchant vessel or motor vessel
NM (MN)	Nautical mile
NSS (SNRS)	National Search and Rescue Secretariat
OBS (BSN)	Office of Boating Safety
OSC	On-scene co-ordinator

PIW	Person in water
PLB	Personal locator beacon
POB	Persons on board
RCC	Rescue co-ordination centre
SAR	Search and Rescue
SARSAT	Search and Rescue Satellite-Aided Tracking
SART	Search and rescue (radar) transponder
SERABEC	Sauvetage et recherche aériens du Québec
SITREP	Situation Report
SKAD	Survival kit air droppable
SLDMB	Self-locating datum maker buoy
SMC	Search and rescue mission co-ordinator
SOLAS	International Convention of the Safety of Life at Sea
SRR	Search and rescue region
SRU	Search and rescue unit
S/V (B/V)	Sailing vessel
UTC	Co-ordinated universal time
VTS (STM)	Vessel traffic services
VHF	Very high frequency (30 to 300 MHz)

CHAPTER 8 – WAVES AND WEATHER

8 WAVES AND WEATHER

8.1 WAVE THEORY

8.1.1 General

An understanding and appreciation of wave action is essential for a competent mariner. Understanding how waves form and behave at sea, over shoals and in the surf zone can help you to know what to expect and how to use a given situation to avoid or minimize danger to both vessel and crew.

The following definitions will assist in understanding the remainder of this section.

8.1.2 The parts of a propagating wave

Breaker
A single breaking wave of either the plunging type or the spilling type.

Breaker line
The outer limit of the surf. Breakers may not all present themselves in a line. Breakers can occur outside of the breaker line and seem to come from nowhere.

Comber
A wave on the point of breaking. A comber has a thin line of white water upon its crest, referred to as "leathering."

Crest
The top of a wave, breaker or swell.

Fetch
The unobstructed distance covered by the wind blowing across the surface of the water.

Foam crest
Top of the foaming water that speeds toward the beach after the wave has broken, popularly known as white water.

Frequency
The number of crests passing a fixed point in a given time.

Interference
Waves that have been refracted or reflected can interact with each other as well as with the incoming waves, and may be additive (or subtractive), resulting in unnaturally high waves. 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.

Period
The time it takes for two successive crests to pass a fixed point.

Series
A group of waves which seem to travel together at about the same speed.

Surf
A number of breakers in a continuous line.

Surf zone
The area near shore in which breaking occurs continuously in varying intensities.

Swell
Swells are the waves that have moved out of the area in which they were spawned. The crests have become lower, more rounded and symmetrical. In this form, they can travel for thousands of miles across deep water without much loss of energy.

Trough
The valley between waves.

Waves
Waves are periodic disturbances of the sea surface, caused by wind, earthquakes, and the gravitational pull of the moon and the sun.

Wave gradient
The slope or angle of a wave from its trough to its crest.

Wave height
The distance from the bottom of a wave's trough to the top of its crest.

Wave length
The distance from one wave crest to the next in the same wave group or series.

Wave 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. When the obstacles are vertical or nearly so, the waves may be reflected in their entirety.

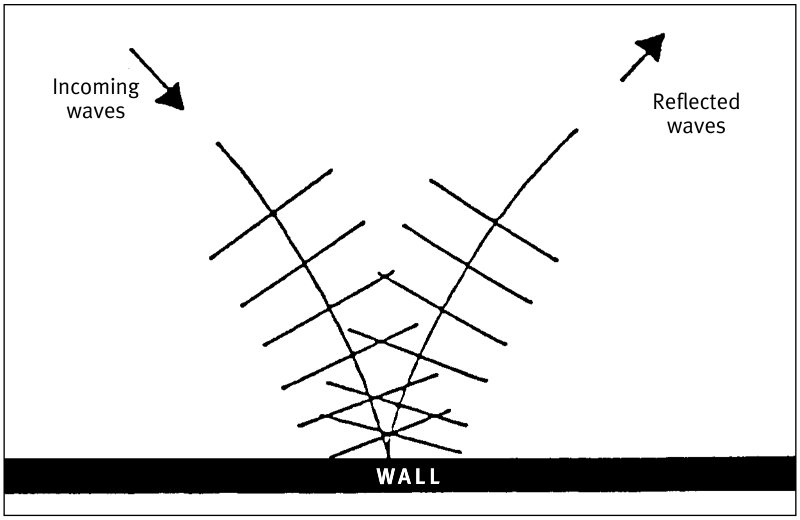

Figure 8.1: Wave reflection

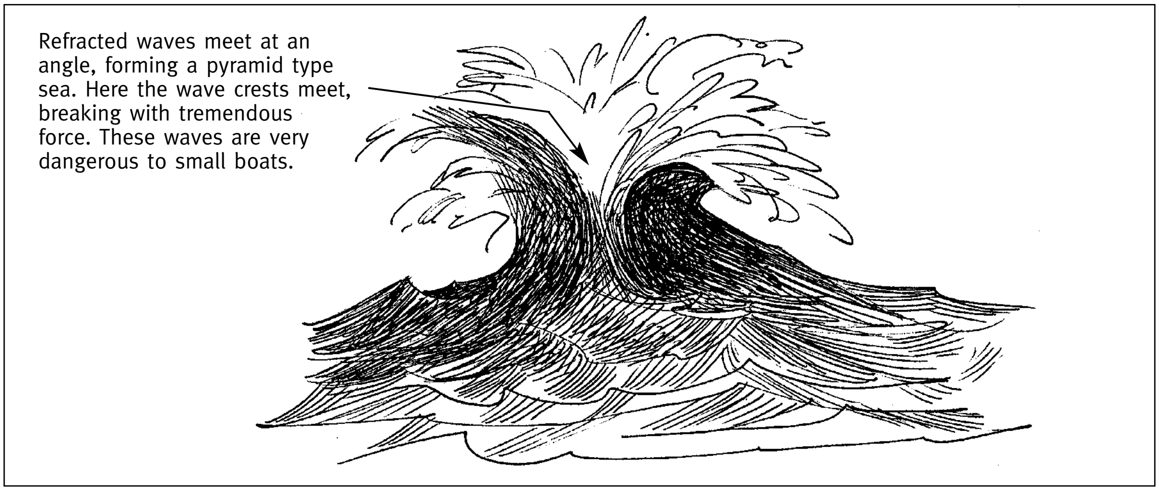

Figure 8.2: Wave refraction

Wave refraction

Refraction means bending. Wave refraction occurs when the wave moves into shoaling water, interacts with the bottom and slows down. Naturally, the first waves encountering the shallows slow down first, causing the crests of the waves to bend forward toward the shallower water. The bottom terrain determines how much refraction occurs. Refraction can also occur when a wave flows past a point of land, a jetty, or an island.

8.1.3 Wave energy

Waves are the visible result of an energy transfer process whereby energy is imparted to the water by displacing forces, usually caused by wind and vessel movement. The energy is transferred from these sources through the water until it is eventually expended by dispersion and decay, as breaking waves, or is transferred to the shore as surf. When waves are formed, certain forces immediately begin to act to bring the water's surface back to a level state. These forces are:

- gravity, which acts on the wave by forcing it to flow back down to a flattened position;
- surface tension, which resists wave formation; and
- elasticity, which resists any change in the total volume of the water. If the force which caused the wave to form were removed, the water's surface would eventually return to level because of internal friction, or by transfer of the energy to another medium, such as floating objects or the shore.

If there were no wave motion, the water would naturally lie at the Still Water Level (SWL).

As the figure shows:

- The depth of the water is measured from the SWL to the bottom;
- The top of the wave is called the crest. The lowest level between two successive wave crests is called the trough;
- The wave height (h) is the vertical distance between the highest and lowest points of a wave;
- The wavelength (l) is the horizontal distance between two successive crests. For the average wave system, this is measured in feet;

- The amplitude (a) is equal to one-half of the wave height;
- The crest angle is the angle formed by the sides of the wave at the crest;
- The steepness of the wave is measured by dividing the height by the length (h/l);
- The wave period (t) is the time interval, in seconds, between one crest and the next from a fixed observation point.

The speed of the wave motion, phase motion (C), is computed by dividing the wavelength by the period, or C=L/T.

The slope (S) of the bottom is an important factor in the wave's steepness. The slope is equal to the vertical change in bottom depth divided by the horizontal distance in which the depth change occurs. Both the wave steepness and the slope of the bottom are important factors in breaking waves and surf conditions.

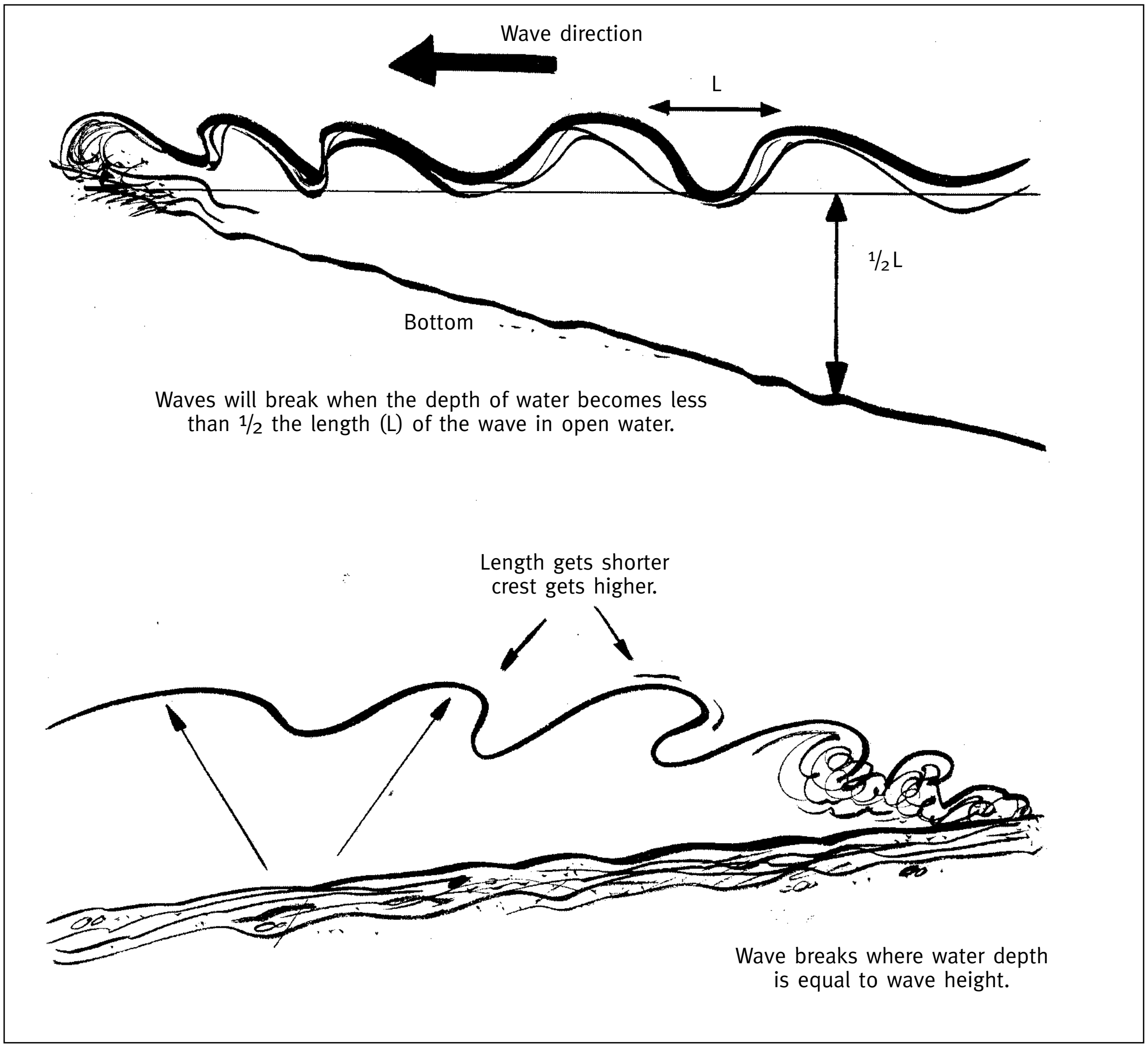

Figure 8.3: Surf

8.1.4 Particle motion

As a wave moves through the water, very little water is actually displaced any distance. Rather, the motion that occurs within the wave is circular in shape (orbital motion). At the wave's crest, the water moves forward at a maximum speed in the horizontal direction of the wave's progress. Halfway down the face on the front of the wave, motion is upward. At the bottom of the trough, it is moving at maximum speed, backward, in the horizontal direction opposite that of the wave's progress. On the rear face of the wave, halfway up from the trough to the crest, it is moving downward, at its maximum speed in the vertical direction. It is this motion which allows a wave to approach a floating object, flow under it and move on while leaving the object in the same place. Remember, it is current and/or wind which moves an object through the water, not the wave.

8.1.5 Factors in creating shape

When the wind imparts its energy to the sea's surface, the amount of energy transferred, and thus the eventual characteristics of the waves generated, depend upon the wind's strength and how long it acts upon the water.

Ocean currents may further affect the shape of the wave. An opposing current will steepen the wave and increase the height while reducing the wavelength. A following current will increase the wavelength and decrease height.

The unimpeded length of the water area over which the wind blows is called the fetch. If the body of water happens to be a lake ten miles long, and the wind blows down its length, the waves generated on the lake have a fetch of 10 miles. If, however, winds blow across the same lake, and it is only five miles wide, the fetch of these waves would be five miles. When wind waves are generated at sea, the fetch may be several thousand miles long. For such long fetches in the ocean, the wind can act for a very long time in the same direction over a vast expanse. In such cases, sea wind waves can receive much energy and grow to immense size. If a large storm such as a hurricane or typhoon is the source of the wind, the resulting waves can be enormous and travel for tremendous distances before they dissipate their energy on some distant shore as surf. Wind waves can be classified into two distinct types that are of major interest to the maritimer:

- When the depth of the water is greater than about one-third of the wavelength, the bottom has little effect on the wave, and it is termed a deep water wave;
- When the depth of the water is less than one eleventh of the wavelength, it is termed a shallow water wave, and the wave is strongly affected by the bottom.

A third class of waves, intermediate waves, are found between these two classes, but an explanation of these waves would be very complicated and beyond the scope of this manual.

As the wind continues to affect a deep-water wave, the wave will continue to grow until its steepness and crest angle approach a critical state, at which point the wave becomes unstable and breaks. These storm-tossed and breaking waves are termed seas while they are still being generated. Deep-water waves originating far out at sea may have wavelengths of hundreds or thousands of feet, periods of many seconds and a speed of advance of dozens of feet per second.

After the deep water waves are generated far out at sea, they move outward, away from their wind source, in ever-increasing curves, and become what is called swells. The further the swell moves from its source, the more uniform its characteristics become, as it travels in a series of relatively equidistant waves moving at a fairly constant speed. Because of this, the smoothness and uniformity of the swells generated from storms far out at sea distinguish them from those which are more coarse (peaked and irregular) and have recently originated nearby. The usual period of these swells is from 6 to 10 seconds. The wavelengths are of 56 to 400 m (184 to 1,310 ft.) and have velocities of 18 to 49 knots.

Interference between different swell systems 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, the 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.

Knowledge of the characteristic clustering of waves into groups is useful during operations 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 manoeuvered while the wave motion is at a minimum, during the space between groups.

When deep-water 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 refraction, 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 water depth roughly equal to 1.3 times the wave height (the actual formula used to determine when the wave will break is $H=0.8d$, i.e. the point when height is equal to 80% of depth ratio), 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.

The motion of the water that occurs within shallow water waves is no longer circular, but tends to become elliptical. Unlike the orbital motion of deep-water waves, these orbits do not decay with depth.

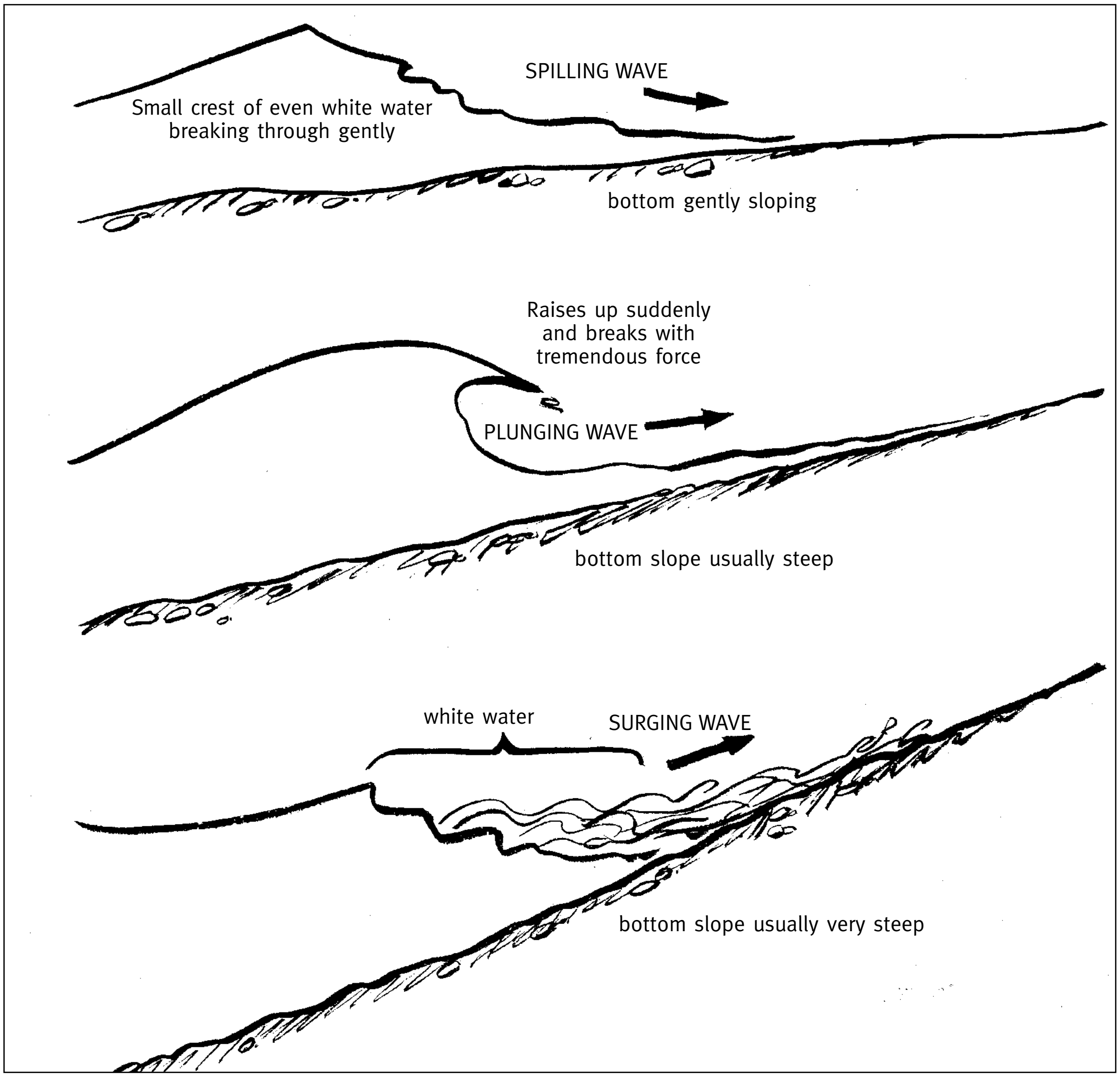

Figure 8.4: Spilling, plunging and surging waves

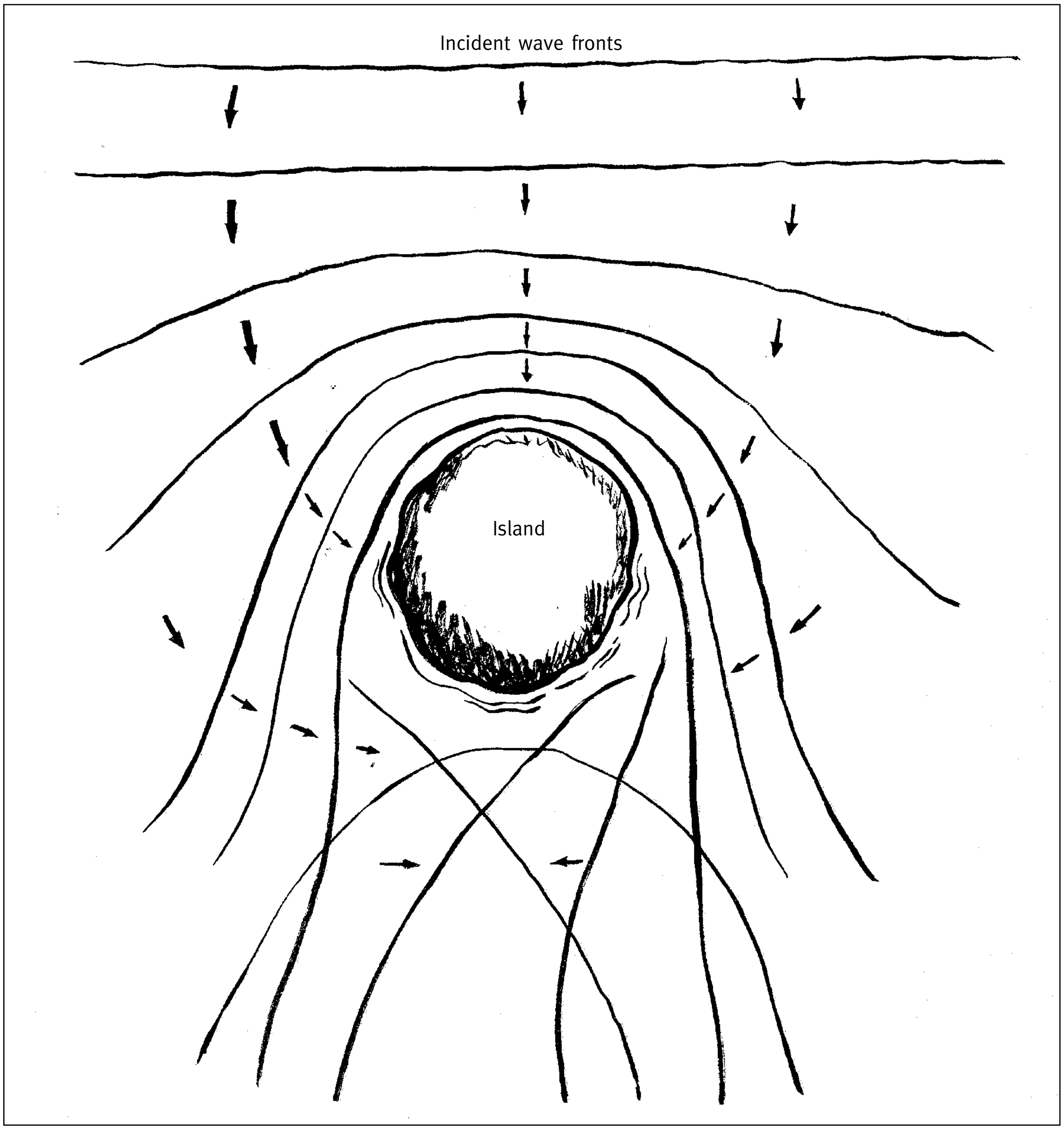

Figure 8.5: Effect of an island on incoming waves

8.1.6 Breaking waves

There are multiple degrees of breaking intensity, depending upon the deep-water steepness of the incoming wave and the slope of the beach or shoal area. Over very gradual slopes, the wave begins to break in a gentle spilling action that dissipates just enough energy to keep the "80% of the depth" ratio constant as the wave moves toward the shore or over the shoal. This kind of breaking action is termed spilling, and is characterized by white water at the crest of the wave. It is the beginning of the phenomenon called surf. The area near shore in which breaking occurs continuously in various intensities is called the surf zone. Vessels engaged in SAR should never go into a surf zone. Many SAR crews have been seriously injured and some have been killed in surf zones. Be extremely careful, since surf zones are more readily visible from the shore than from the sea.

As the underwater slopes become steeper, breaking becomes more intense, and fewer waves break simultaneously. The waves begin to curl as the orbital velocities of the individual water particles at the crest rise with increasing height. When not enough water is available in the shallow water ahead of the wave to fill in the crest and complete a symmetrical wave form, the top of the onrushing crest is unsupported and plunges ahead as an incomplete orbit. This type of breaker is termed plunging. In plunging surf, only one wave breaks at a time, and its intensity is greatly increased by the backwash of the wave that broke before it. Obviously, this is not a good place to operate a vessel. Remember, water is heavy, about one ton per cubic yard. A breaking wave could dump tons of water on you, swamping and/or severely damaging your boat.

When the beach slope exceeds the wave steepness, the breaker builds up as if to form a plunging breaker, but the base of the wave surges up on the beach before the crest can plunge forward. This form of breaker is termed surging. When the depth ratio approaches about 1.2 (that is, I/d=1.2), the limit of breaking at the shoreline is reached, and all similar waves will surge up steeper slopes without breaking at all.

If the slope of the beach is uniform, the effect of the tide would be to move the entire surf zone in (on a high tide) or out (on a low tide) with little other change. On an offshore bar, or in an inlet with a bar, the changing tide modifies the depth of the water, and the bottom thus influences incoming waves. Breaking waves and surf may form over these shoaling waters at low tide, whereas no such action is present at higher tides.

Current can affect speed of wave movement through the water. When the current is against the wave direction, it acts to reduce the wave’s speed, and thus increases the wave’s steepness. In this case, the wavelength decreases and the height increases. The result is breaking where it was not occurring before, or more violent surf. Certainly, tidal height and currents should be considered when surf is a possibility.

As indicated earlier, wave characteristics are modified when deep-water waves make the transition to shallow-water waves. As depth decreases, so do wave length and speed of advance, (while the wave period remains constant) and the result is called refraction, in which the wave front (the line of the crest) bends or curves toward the shallows. If the wave crests are approaching the shoreline at an angle, they will be curved toward the slope by refraction of the wave front by the bottom, and eventually arrive nearly parallel to the shoreline.

8.1.7 Refraction and reflection

Refraction causes divergence (moving away) and results in lower waves over offshore troughs and holes on the bottom. It also causes convergence (coming together) and higher waves over ridges and shoals on the bottom.

Refraction can occur around islands with sloping shores, too, and cause the wave fronts to “wrap around” the island, creating a shadow zone, confused seas, and even focused wave energy at a distant shoreline point.

8.1.8 Combining wave fronts

When two or more wave fronts interact, or when a fast-moving wave overtakes a slower one, the resulting effect is called interference. When the water in each of these waves is moving in the same direction at the point of interaction, the motion accumulates and the result is an increase in the wave motion at that point. The wave height also increases ,and constructive interference occurs. When the respective water particles are moving in opposite directions at the point of interaction, they act destructively, and may even cancel each other's motion out. This is called destructive interference. Obviously, interference can result in a considerable increase in wave motion and change relatively moderate swells into breaking waves at the points of crossing or collision. Interference can also cause the waves to be suddenly stilled, or reduced, making the location much calmer and possibly useful as a point at which to enter or leave the water in relative safety.

When a wave front bounces off a deep vertical surface, such as the face of a sea cliff or the side of a breakwater, or even a very steeply sloped beach, the wave energy may be turned back or diverted in some other direction. This process is termed reflection. If the reflected waves react with the oncoming waves, causing constructive interference, the resulting wave motion can be intensified. If the conditions are just right, standing waves may be formed, in which the water particles move up and down under the wave crests and back and forth at the mid points of the trough. Both the crests and troughs remain in the same horizontal location: the progress of the wave is essentially terminated.

When a wave front travels between two close islands, or through a gap in a breakwater, the waves produce very complicated interference patterns by the process of diffraction, particularly when they approach the gap at an angle. When this happens, the wave height within the area beyond the breakwater gap may exceed that of the wave outside of the breakwater.

In towing operations off a beach where there is running surf, rip currents (more popularly and incorrectly called "rip tides" or "undertows") can be used to great advantage. Rip currents are produced as a result of the movement of large volumes of water by waves or surf upon the beach face. The raised level of water produced by the waves on the beach flows away in what is called a longshore current parallel to the beach and in the same general direction as the waves as they angle in on the shoreline.

8.1.9 Rip currents

If the wave fronts or crests are running parallel to the beach, the longshore current can flow up or down the beach. Such longshore currents can have magnitudes of several knots. As the longshore currents flow along the beach, they reach points where, for various reasons, the water returns to the sea. Rip currents made up of this outflowing water are produced at these points. Channels, sometimes with steep sides, are produced by these rip currents. Although rip currents may become dangerous to swimmers, a knowledgeable boater can use them to advantage.

At the rip currents, the breakers are usually smaller because of refraction (decrease in wavelength and speed where the wave curves or bends). Both the deep water in the channels and the decreased breaker height are helpful to a small craft manoeuvering in the surf zone. Furthermore, the outflowing current can be substantial, approaching several knots, and can substantially assist in moving a towing vessel and the tow rapidly out to safer waters.

Rip currents can be easily recognized from the beach. The observer can generally see a place where the waves are breaking less actively because of the deeper water. The rip current has highly agitated water with small, slapping waves. Sometimes roll-up water being carried out along the rip current can be seen in contrast to the cleaner water on either side. The colour of the turbid water extending out along the course of the rip can be seen from the seaward side. Often there is also a concentration of foam that develops along the boundary of the outward surging masses in the rip current.

Remember, there is no relation between a “rip tide” and a “tide rip.” A tide (or tidal) rip is caused by a swift tidal current flowing over a rough bottom. If this current meets an opposing wave, a violent reaction occurs, causing the water to shoot into the air. This area is to be avoided.

Wind is not the only energy source that creates wave motion on the surface of the sea. Severe and sudden displacements (uplift and subsidence) of the ocean floor during earthquakes can inject huge amounts of energy into the water in the form of short, impulsive disturbances. These impulses generate waves that are popularly but incorrectly called tidal waves. Their correct name is tsunamis (sue-naa-me), or seismic sea waves. Tsunamis radiate in all directions as a system of shallow-water waves, with rings of waves spreading out like the pattern created by a stone dropped in a calm pond. The longest wave is at the front, the leading edge of the system, with shorter waves following. The velocity of the leading wave is very high and is limited only by the depth of the water. Each tsunami wave front retains its identity as it moves away from the source area with its height slowly decreasing as the energy is dissipated by the circular spreading from the source.

8.1.10 Tsunamis

Tsunami waves may travel thousands of miles, moving very rapidly on the sea surface. Contrary to popular belief (and the movies), the tsunami waves on the high seas have very little height (0.3 to 0.6 m / 1 to 2 ft.) and very long wave lengths (50-250 miles) with periods of more than 15 minutes. Given these characteristics and the ever-present swells, the wave is imperceptible. Thus, tsunamis at sea are rarely noticed. They race by ships at sea, which remain totally unaware of their presence. Indeed, tsunami characteristics are very difficult to measure at sea, even with sophisticated instrumentation and advance knowledge of their approach.

Tsunamis are of greatest concern, and most dangerous, when, behaving like the shallow water waves that they are, they enter areas with sloping shores and shoaling waters. Here, because of the influence of the bottom topography causing refraction, reflection, diffraction, interference, rapid cresting and breaking, they are modified and enhanced to form tremendous waves that flow over harbors and nearby shore areas with devastating results.

Coastal regions which have a relatively wide, shallow, offshore shelf, such as southern California, experience much less intense wave action from tsunamis than areas such as Hawaii and Japan, where shores slope steeply to great depths. Local activity depends very much on bottom topography and orientation with respect to the incident wave front. Most of the devastation from tsunamis occurs as the first and largest of the waves arrives. Following the initial wave, the surge intensity gradually diminishes, although oscillations can be detected on tidal measuring instruments for several days.

Wave facts

- The longest waves in the world are the lunar tides that sweep across the oceans with periods of between 12 and 24 hours;
- The highest wave ever recorded was near Juneau, Alaska, in 1958. The wave was caused by a massive fall of rock into an enclosed inlet and measured 525 m high (1,720 ft.);
- The most people ever killed by a single wave was in East Pakistan (Bangladesh) in 1970. Between 300,000 and 500,000 people perished when a 15 m (50-ft.) storm wave devastated the low-lying coastline;
- The highest wind-generated wave ever accurately assessed at sea was aboard the USS Ramapo on February 6, 1933. The wave was measured at 34 m high (112 ft.). The ship was on passage from Manila, Philippines, to California during a hurricane. The wind force was measured at 68 knots;
- The most powerful tsunami ever recorded in modern times originated on the Island of Krakatoa near Sumatra in Indonesia. The tsunami was generated when the Mount Perboewaten volcano (thought to be extinct) exploded on August 27, 1883. The wave was over 40 m (130 ft.) when generated and advanced at speeds up to 700 mph across deep oceans. The shock waves circled the world seven times, once every 36 hours. The sea level in San Francisco Bay, 11,000 miles away, was affected. The sound from the massive explosion was heard in Perth, Western Australia nearly 2,000 miles from the volcano.

8.2 UNDERSTANDING WEATHER

8.2.1 General

Each day, millions of people begin their day by looking out the window or reading or listening to weather forecasts to see what the weather is like. Knowing what kind of weather to expect in the next hours or days is essential for planning any kind of outdoor activity. In SAR operations, knowing the weather is often much more than convenient: it may very well become a survival issue. Knowing that things will become nasty provides the opportunity to prepare for the worst and bring additional equipment (e.g., raingear, boots or dry suits).

Over the past decade, tremendous advances have been made in the field of computing. With the increased capabilities of today's computers, it is now feasible to achieve quite accurate forecasts. But nature will continue to surprise us: it is impossible to predict every local phenomenon. Published forecasts offer useful information about the general weather for the day in a given area. But there are also several accurate tricks for determining what the weather may look like within the next 30 minutes. This section will explain some of the tricks that can be used to your advantage in your daily operations.

8.2.2 The atmosphere – general concepts

One of the important characteristics of gas is that it is compressible. Air can be compressed, and when it is, the density of the gas increases and so does the barometric pressure. Another thing that can affect the density of gases is temperature. When the temperature of a gas increases, its density decreases (the gas becomes lighter and the barometric pressure decreases). When the temperature decreases, density increases (the gas becomes heavier and the barometric pressure increases).

Another important property of air is its capacity to hold water vapour. The amount of water vapour that air can hold is influenced by temperature. Hot air can hold more water vapour than cold air. This explains why air is drier during winter. The term "relative humidity" is used to express how much water vapour is present. Relative humidity is a percentage (%). At 100% relative humidity, the air is completely saturated with water vapour. At 0%, absolutely no water vapour is present: the air is completely dry.

Consider, for example, the origin of rain (or any other form of precipitation). Imagine hot air at 99% relative humidity. Clouds form and eventually cover the whole sky. Since the sun can no longer reach the land, the temperature will drop. As the temperature decreases, so does the "water-holding capacity" of the air, and soon, too much water vapour is present in the air. This water vapour thus condenses to form small droplets. These will then become too heavy to remain suspended in the air, and will eventually fall. This phenomenon explains why high-pressure systems are associated with clear skies and low probabilities of rain, while low-pressure systems are associated with clouds and high probability of rain.

Winds are caused by movements of gaseous masses. Many factors may influence wind strength and direction. The rotation of the earth is one factor. It is the key factor in determining the average direction of wind (dominant wind direction). Local factors can also be involved. One such important factor is, once again, temperature. Hot air has a tendency to rise, while cold air has a tendency to sink. When a layer of hot air rises, a vacuum effect is produced. Air in the surroundings will rush toward this vacuum to take the place of the now elevated hot air. This is one of the ways in which winds are produced. On the other hand, the cooling of an air mass will cause it to drop toward the ground. As this occurs, air is displaced and wind will result. When air masses are displaced in this manner, the barometric pressure will respectively decrease or increase rapidly. The quicker the change in barometric pressure, the stronger the winds.

Another means by which wind can be produced is the movement of two air masses. When two air masses meet, they can slide onto each other or displace each other. In both cases, winds may result.

8.2.3 Applied knowledge

These explanations represent a very limited portion of weather science. While they may not transform you into an expert, they should help you to understand how you can predict major meteorological events a few minutes in advance.

The following paragraphs will tell you what to expect from what you observe. This knowledge may help you to be ready for the worst instead of being caught by surprise.

Expect cloudy skies and uncertain weather when:

- barometric pressure decreases;
- night temperature is higher than usual;
- clouds are moving in different directions at different altitudes;
- small hair-like clouds are present high up in the sky;
- in summertime, clouds turn dark in the afternoon.

Expect showers when cumuli (small cotton wool-like clouds) form rapidly in early afternoon (spring or summertime).

Expect good weather when:

- barometric pressure rises;
- temperature decreases rapidly during the afternoon.

Expect prolonged good weather when:

- the setting sun is like a fire ball and you can look at it directly;
- barometric pressure remains constant or rises slowly;
- morning fog dissipates within two hours of sunrise;
- the sun turns red when it sets.

8.2.4 Special weather conditions

8.2.4.1 Thunderstorms

The strongest winds in a thunderstorm usually precede the storm centre itself, in a zone up to three miles long. Gusts up to 50 knots can be expected in this zone. The winds blow downwards from the cloud, and they are especially dangerous for small vessels.

The heaviest rain occurs directly under the thunder cloud, leading to poor visibility. Heavy rain lasts from five to 15 minutes. Thunderstorms normally last less than one hour.

Waterspouts may occur during a thunderstorm. A waterspout is a funnel of cloud reaching from the base of the thunderstorm cloud to the water, which may suck up water into the air. It usually lasts less than 15 minutes. Although immature waterspouts may be very small, they can become extremely violent without warning.

8.2.4.2 Fog and snow

Fog is a common problem at sea. The major hazard is reduced visibility. Vessels should proceed with caution. Monitor radar carefully if possible.

Snow also reduces visibility, and can be especially hazardous if it falls as melting snow. Melting snow not only reduces visibility, but interferes with radar signals, making radar less effective. This usually occurs during arctic air outbreaks, and is a serious problem in mainland inlets.

8.2.4.3 Icing

Accumulations of ice on a vessel may lead to serious stability problems. Substantial icing can occur when temperatures are between –3 and –8°C with winds of 16-30 knots. The danger increases with colder temperatures or stronger winds.

Freezing sea spray is the most common and the most hazardous form of icing. Spray blown by winds can cause heavy icing on a vessel, producing a heavy list. Freezing spray usually occurs when the air temperature is less than –2°C, and the water is less than 5°C. Freezing spray warnings are included in maritime weather forecasts.

With freezing rain, a film of ice forms over the deck railings and stairways. This form of icing is the least likely to cause stability problems, but it can be a serious hazard for the crew moving on deck.

A similar glaze of ice can be caused by sea smoke. Sea smoke forms when very cold air moves over warmer water, and it can freeze on contact with the vessel. It is not usually a severe problem, but if the sea smoke is very dense, substantial ice may accumulate.

8.2.5 Maritime weather information

8.2.5.1 Maritime weather forecasts

Maritime weather forecasts are available on:

- VHF Channel 21B, 25B and 83B (Atlantic Coast and Great Lakes);
- VHF Channel 21B and WX1, WX2, WX3 (Pacific Coast);
- Environment Canada Weatheradio VHF broadcasts in Vancouver, Toronto, Montréal and Atlantic Canada;
- regular AM and FM radio weather forecasts;
- the Maritime Weather Services Bulletin, obtained by calling the nearest Environment Canada weather office;
- MAFOR Code on the Great Lakes and St. Lawrence River.

A receiver for continuous weather forecasts is available on the market through maritime supply outlets.

8.2.5.2 Weather warnings

Maritime weather forecasts include four types of severe weather warnings: small craft, gale, storm, and hurricane force winds. The meanings of these warnings are:

- Small Craft Warning: winds 20-33 knots and wave heights 2-3 m (7-10 ft.);
- Gale Warning: winds 34-47 knots and wave heights 6-9 m (20-30 ft.);
- Storm Warning: winds 48-63 knots and wave heights 9-16 m (30-52 ft.);
- Hurricane Force Warning: winds 64 knots and over; wave heights over 16 m (52 ft.).

8.2.5.3 Effect of wind

In the maritime environment, wind speed is usually expressed in knots or as a unit of the Beaufort scale. The following table shows the two methods.

Table 8.1: The Beaufort scale

Beaufort wind force	Mean wind speed in knots	Limits of wind speed in knots	Descriptive term	Sea criterion	Probable height of waves in metres*	Probable maximum height of waves in metres*
	Measured at a height of 10 m above sea level					
0	00	< 1	Calm	Sea like a mirror.	–	–
1	02	1-3	Light air	Ripples with the appearance of scales are formed, but without foam crests.	0.1	0.1
2	05	4-6	Light breeze	Small wavelets, still short but more pronounced, crests have a glassy appearance and do not break.	0.2	0.3
3	09	7-10	Gentle breeze	Large wavelets. Crests begin to break. Foam or glassy appearance. Perhaps scattered white horses.	0.6	1.0
4	13	11-16	Moderate breeze	Small waves, becoming longer; fairly frequent white horses.	1.0	1.5
5	19	17-21	Fresh breeze	Moderate waves, taking a more pronounced long form; many white horses are formed. (Chance of some spray.)	2.0	2.5
6	24	22-27	Strong breeze	Large waves begin to form; the white foam crests are more extensive everywhere. (Probably some spray.)	3.0	4.0
7	30	28-33	Near gale	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind.	4.0	5.5
8	37	34-40	Gale	Moderately high waves of greater length; the edges of crests begin to break into spindrift. The foam is blown in well-marked streaks along the direction of the wind.	5.5	7.5
9	44	41-47	Strong gale	High waves. Dense streaks of foam along the direction of the wind. Crests begin to topple, tumble and roll over. Spray may affect visibility.	7.0	10.0
10	52	48-55	Storm	Very high waves with long overhanging crests. The resulting foam in great patches is blown in dense white streaks along the direction of the wind. The whole surface of the sea takes a white appearance. Tumbling of the sea becomes heavy and shock-like. Visibility affected.	9.0	12.5
11	60	56-63	Violent storm	Exceptionally high waves. (Small and medium ships may be lost to view behind the waves for a time.) The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere the edges of the wave's crests are blown into froth. Visibility affected.	11.5	16.0
12	–	> 64	Hurricane	The air is filled with foam and spray. Sea completely white with driving spray; visibility is seriously affected.	> 14	–

* These columns are added as a guide to show roughly what may be expected in the open sea, remote from land. In enclosed waters, or when near land off-shore wind, wave heights will be smaller, and the water steeper.

Another effect of wind is cooling. The greater the wind, the greater the cooling effect. Vessels engaged in SAR should remember that when a vessel is going at speed, hot days may become considerably cooler. The following chart expresses the cooling effect of the wind with an equivalent temperature.

Table 8.2: The cooling effect of wind

Estimated wind speed (knots)	Actual thermometer reading (°C/°F)									
	50/10	40/4	30/–1	20/–7	10/–12	0/–18	–10/–23	–20/–28	–30/–34	–40/–40
	Equivalent chill temperature (°F/°C)									
Calm	50/10	40/4	30/–1	20/–7	10/–12	0/–18	–10/–23	–20/–28	–30/–34	–40/–40
0-5	48/9	37/3	27/–3	16/–9	6/–14	–5/–21	–15/–26	–26/–32	–36/–38	–47/–44
5-10	40/4	28/–2	16/–9	4/–16	–9/–23	–24/–31	–33/–36	–46/–43	–58/–50	–70/–57
10-15	36/2	22/–6	9/–13	–5/–20	–18/–28	–32/–36	–45/–43	–58/–50	–72/–58	–85/–65
15-20	32/0	18/–8	4/–16	–10/–23	–25/–31	–39/–39	–53/–47	–67/–55	–82/–63	–96/–71
20-25	30/–1	16/–9	0/–18	–15/–26	–29/–34	–44/–42	–59/–51	–74/–59	–88/–67	–104/–76
25-30	28/–2	13/–11	–2/–19	–18/–27	–33/–36	–48/–44	–63/–53	–79/–62	–94/–70	–109/–78
30-35	27/–3	11/–12	–4/–20	–21/–29	–35/–37	–51/–46	–66/–54	–82/–63	–98/–72	–113/–81
35-40	26/–3	10/–12	–6/–21	–21/–29	–37/–38	–53/–47	–69/–56	–85/–65	–100/–73	–116/–82
Wind speeds greater than 40 knots will have little additional effect	Little danger of frostbite. Moderate danger for hypothermia after prolonged exposure.				Moderate danger of frostbite. Exposed flesh may freeze within 1 minute.			Extreme danger. Flesh may freeze within 30 seconds.		

Note: The equivalent chill temperature represents the temperature that would cause the same rate of cooling under calm conditions. Regardless of the cooling rate, humans do not cool below the actual air temperature unless they are wet.

Avoiding Human error among SAR Personnel, IMO LSR 26/5, 1994.

Beaulé,Étienne: Module de formation Chefs d'équipe, Canadian Coast Guard, Laurentian Region, 1998.

Bridge Resource Management – Student's Workbook, Edition 6, Sweden, SAS Flight Academy AB, 1993.

Canadian Coast Guard Auxiliary, Central and Arctic region: Fundamentals of SAR, 1996.

Canadian Coast Guard Auxiliary, National Guidelines Respecting Canadian Coast Guard Auxiliary Activities, 1998.

Canadian Coast Guard, Bridge Resource Management Course, Canadian Coast Guard College, 1998.

Canadian Coast Guard, Central & Arctic Region IRB Training Manual.

Canadian Coast Guard, Courtesy examination manual for small craft.

Canadian Coast Guard, Gaetan Gamelin, Mécanique préventive, Laurentian Region.

Canadian Coast Guard, Jacky Roy & Jean-Michel Boulais, L'équipage ESC devant la loi, Laurentian Region.

Canadian Coast Guard, Mathieu Vachon, Formation des équipages en embarcation rapide de secours, Laurentian Region, 1999.

Canadian Coast Guard, Operational guidelines for Search and Rescue units,1993.

Canadian Coast Guard Regional Manual for Marine Rescue Operations, Laurentian Region, DFO 5675/1998.

Canadian Coast Guard, René Paquet, Les effets du stress post traumatique, Laurentian Region.

Canadian Coast Guard, Robert Jinchereau, Notes de cours, Laurentian Region.

Canadian Coast Guard, RHIOT Manual, Pacific Region, Bamfield RHIOT Shool.

Canadian Coast Guard, SAR Skills Training Standard, TP-9224E, 1994.

Canadian Coast Guard: Small fishing vessel safety manual, 1993.

Canadian Power Squadron, Pleasure Craft Operator Course, Motor and Sail, 1990.

Fisheries and Oceans Canada, Coast Guard, Maritime Search and Rescue in Canada, T 31-87/1996E.

Fisheries and Oceans Canada, Coast Guard / Transport Canada Marine Safety: Global Maritime Distress and Safety System, 1997.

Fisheries and Oceans Canada, Coast Guard, Safe Boating Guide, 2000.

International Civil Aviation Organisation and International Maritime Organisation: International Aeronautical and Maritime SAR Manual, IAMSAR Vol. I, II, III.

National Defence / Fisheries and Oceans Canada / Coast Guard: National Search and Rescue Manual, B-GA-209-001, DFO 5449, 1998.

North Pacific Vessel Owner's Association, Vessel Safety Manual, 1986

St. John Ambulance, First Aid, First on the scene, standard level, activity book, 1999.

Stanley R. Trollip, Richard S, Jensen, Human Factors for General Aviation, Englewood, Jeppesen Sanderson, 1991.

United States Coast Guard, Boat Crew Seamanship Manual, U.S. Department of transportation.

World Health Organisation, International Medical Guide, 1989.

Zodiac Hurricane Technologies, Technical Manual, 733 OB Rescue, British Columbia.