Chapter 8. TABLE OF CONTENTS

Chapter 8. PLANNING STAGE

800 PLANNING STAGE

During this stage effective plans are developed, including the necessary coordination to implement them. This stage may begin immediately after a SAR incident is assigned an emergency phase in the initial action stage, or it may occur after all events of the initial action stage have been completed. Generally its beginning depends directly upon the apparent urgency of the SAR incident reported to the SAR System. It therefore may or may not overlap the initial action stage. This stage ends when all distressed persons or distressed craft have been delivered to safety or the mission is terminated.

801 Search Planning Events

There are five specific events which normally occur sequentially during search planning. These events are: estimating the datum or most probable position of the SAR incident, determining the size of the search area, selecting the appropriate search pattern, determining the desired area coverage and developing an attainable search plan using the available search units.

802 Search Planning Sequence

Search planning involves a series of computations and considerations. Generally the following sequence is followed:

(a) Determine the position of the emergency. Consider effects of wind and water currents moving the survivors from the point of initial distress to where they will be when search craft arrive on scene.

(b) Determine size of area to search to allow for errors in the distress position estimate, navigation errors of the search craft and errors in drift calculations.

(c) Select the best search pattern to use for the circumstances of the particular emergency.

(d) The type of search target is considered and the distance from which it can be detected with available sensors. The target's sweep width is determined, and search track spacing for a desired probability of detection is decided upon.

(e) The number of available SRUs and other limiting factors are considered as necessary to develop a search plan that can be completed under the existing circumstances.

(f) The SMC coordinates with all participating agencies, and advises SRUs of his coordinated search action plan.

803 Search Planning Methods

a. General

Generally the degree of search planning necessary is initially determined by the environment of the SAR incident, the accuracy of the reported location of the incident, the availability of suitable SAR units, and the elapsed time since the incident occurred.

The environment of the SAR incident will dictate specific factors that must be considered in the search planning. For example, several survivor drift factors are involved for missions occurring in oceanic areas while only one drift factor may be involved in mountainous areas.

If the position is known, search planning is relatively simple; if only the intended track is known, search planning is more difficult; but if only the general or possible area is known, search planning can be very difficult. No matter how accurately the incident location is known, search planning is required. It may involve only a rapid but professional consideration of each step or it may involve several hours of continuous evaluation, weighing of influencing factors, computations, and extensive coordination before even one SRU is dispatched. To meet all of these possibilities a number of search planning methods have been developed.

b. Manual Method

The search planning method presented in

this chapter has been designed to be used with manual calculations. Although modern hand and desk calculators can be of great assistance when using this method, they are not required.

c. Computer Methods

Two computerized search planning methods are available from the Coast Guard's central computer. These search planning systems are the Search and Rescue Planning System (SARP) and the Computer-Assisted Search Planning System (CASP).

SARP uses determination methods similar to those presented in this chapter for a manual solution. It is well adapted for use in those cases where the incident position can be readily defined. SARP provides a single datum and recommended search area.

The CASP system uses the simulation method to solve the search planning problem. This method differs from the determinate method used in SARP in that while determination provides only a single value based on best estimates of data, simulation takes into account the uncertainties or inaccuracies in the input and gives a large number of "answers" or datum points. These datum points can then be mapped to provide a graphic picture of all possible target locations. The system is best used when information concerning a particular case is vague—e.g., incident position is not fixed, time of distress is approximate or if conflicting information exists.

Some SAR Coordinators have found it desirable to use both systems on the same case. SARP can be used for an initial solution when the case first breaks, and CASP can be used when its more sophisticated techniques can be applied as time progresses.

CASP can be updated for periods of drift and previous searches accomplished. It will also provide the search planner with the quantities: "Probability of Success" and "Search Effectiveness". Probability of Success is the product of the probability of detection and the probability that the target is in the search area. This can be obtained for each search. The Search Effectiveness is the *cumulative* value of Probability of Success for all searches to date. Thus, the search planner is armed with new quantitative tools which help him to determine how much search effort is required.

The U.S. Coast Guard Computerized Search and Rescue Systems Handbook provides the procedures for all operational computer services. SAR Coordinators without direct access to the computer can make arrangements through the nearest Coast Guard SAR Coordinator for their use.

804 Search Planning Computations

Computations used in search planning require a knowledge of vectors, simple algebra, and the ability to extract data from tables, graphs, and nomographs.

a. Vectors

An understanding of vectors is essential for search planning. All of the various forces that may possibly act to move a survivor from his initially reported position must be accounted for by vectorially solving for their effects. Every force has two essential elements: a direction in which the force is acting and the magnitude of that force. For example, the wind acting upon a descending parachutist will displace the parachute both in direction and in distance depending upon the wind direction and its magnitude, and a raft will also be displaced from its original position by water current forces in a direction and a distance dependent upon the direction and magnitude of the water current.

When working with the various forces that cause drift, the search planner should always remember that he must determine not only the amount of displacement but also its direction. In this regard, one area of confusion exists that trips up many search planners. Wind directions are always reported or spoken of as the direction from which the wind is blowing. For example, a wind reported as 270/30 would be a wind blowing from 270 degrees true at 30 knots and blowing towards 090 degrees true.

Ocean swell systems are reported in the direction from which the swell is moving in a manner similar to wind direction reports. Water currents on the other hand are reported in the direction toward which they are moving. For example, an ocean current reported as 270° T at 2 knots would be moving in a westerly direction. The direction is sometimes referred to as the set of the current. In fact when talking about the direction toward which any force is moving the direction of movement is referred to as the set.

b. Algebra

Algebra involves the substitution of letters and symbols for numerical values in order that an equation may be expressed without actually knowing the numerical value of that condition or equation. The search planner must be able to work with a few simple formulas and to rearrange them for solving for one unknown term.

c. Nomographs

When using any nomograph, a clear plastic straightedge, a pair of dividers, and a sharp pencil are recommended. Place one point of the dividers at the known value of one scale-line, pivot the straightedge against the divider and line up the straightedge with the second known value on its scale-line. Read the unknown value off the third scale-line where the straightedge crosses it. A short pencil mark may be made across the third scale-line if it is desired to remove the straightedge prior to reading the unknown value. A sharp pencil may be substituted for the divider point if preferred. Using a clear plastic straightedge speeds up the sequence by allowing the user to continuously view the complete scale-line values. Where nomographs are to be put to continuous use, copies should be made and encased in matte-finish transparent covers. This will permit the continued use of the nomographs without obliterating or destroying them.

d. Accuracy

All tables, graphs, and nomographs must be interpolated if the entering values are not specifically listed. Angles, headings, courses, and tracks are rounded off to the nearest whole degree. Search radius is rounded off to the next higher whole mile when giving it to search units. Coverage, decay and drift factors are taken to the nearest hundredth. All other values such as hours, miles, knots, and minutes of latitude or longitude, are rounded off to the nearest tenth when practicable.

Statute miles and miles per hour are not normally used in search planning. All miles are nautical miles, and all speeds are usually in knots (nautical miles per hour).

805 SAR Incident Location

Three possible situations may exist with respect to the location of a SAR incident when it is reported to the SAR system.

a. Position Known (Approximately)

The incident may have been witnessed; reported as a navigational fix by a radar net, DF net, another craft, or by the distressed craft itself; or computed by the SMC as a dead reckoning position from a previously reported and reliable position of the distressed craft.

b. Track Known (Approximately)

The distressed craft may have filed a flight plan, or other form of trip plan prior to its departure, which included its intended track or route, but its actual position along the intended track is unknown. Receipt of a single line of position might be treated similarly to a track known situation.

c. Area Known (Generally)

When neither the position nor the intended track is known, at least an area that the distressed craft was probably within can usually be determined. With reasonable detective work by the SMC, this area can usually be reduced to a smaller high probability area for search concentration or, if relatively small, can be used as the initial search area.

806 Definitions Used in Search Planning

a. Initial Location Definitions

As explained in paragraph 805 the initially reported location may be a point, a line, or an area depending upon whether the search object's position is known, a trackline is known, or only a general area is known. When the initial position of the incident is known it may be either an aerospace position, a parachute opening position, a surface position or an underwater position.

An aerospace position is the position of a distressed aircraft or space craft at the time of re-entry, engine failure, aircrew ejection or bailout.

A parachute opening position is the position of the search object at the time of parachute opening.

A surface position is the position of the search object on the earth's surface at the time of initial distress on the surface, or first contact with the earth's surface. Surface position is also sometimes referred to as splash point in bailout cases.

An underwater position is the position of a sunken search object when it first makes contact with the water bottom (ocean floor, lake bottom, river bottom, etc.).

b. Datum Definition

Datum is the probable location of the search object corrected for drift at any particular moment during the mission. From this basic definition of Datum, three types of datums may be derived depending upon how accurately the initial location of the search object is known. These three types are, datum point, datum line, and datum area. Note that a datum area is not necessarily the same as a search area, although in some cases it may be. This relationship is developed further in later sections.

c. Datum Point Definition

A datum point is the datum developed when the initial position of the search object is known.

Notice that a particular clock-time must be stated to meet the definition of datum given in subparagraph b above.

d. Datum Line Definition

A datum line is the line connecting two or more datum points computed for the same specified time, along which the search object is assumed to be located with equal probability. The most common instance when a datum line is developed is when the initially reported location of the search object falls in the trackline-known category.

e. Datum Area Definition

A datum area is an area in which the search object is assumed to be located with equal probability throughout the area. A datum area is most often necessary in those missions in which there is no initial position or trackline known.

f. Drift Definitions

Drift is the vectorial movement (direction and distance) of the search object caused by momentum, drag, wind, water, and other external forces. Drift may be spoken of as individual drift (d) which is the drift occurring in a specified time interval (t); or it may be spoken of as total drift (D) for a specified clock time or total elapsed time since the incident occurred (T). Total drift (D) of a search object is the vectorial sum of all the individual drifts accumulated during a mission, for the elapsed time since the search object was first exposed to any external forces which cause drift movement, to the time of the latest computed datum. Both total drift and individual drifts may be given subscripts to indicate their specified time or time intervals. For example, d_p indicates parachute drift, d_b is balloon drift, d_s is sinking drift, and d_a is aerospace-trajectory drift.

Parachute drift, balloon drift, sinking drift, and aerospace-trajectory drift are normally applied only once during any mission. All other drifts caused by wind and water currents are continually recomputed during a mission to correct the datum, and become greater with the passage of time.

g. Recomputed Datums

Datum is computed periodically during a search mission when drift forces continue to affect the position of the search target. These recomputed datums are usually labeled sequentially: $Datum_1$, $Datum_2$, $Datum_3$, etc.

807 Rescue and Delivery Planning

During the planning stage an effective rescue and delivery plan is developed, including the necessary coordination to implement it.

a. Rescue Planning Events

There are five specific events which normally occur sequentially during rescue planning. These are: evaluation of the environment, selection of a rescue method, selecting rescue facilities, determining an optimum rescue plan, and selecting an attainable rescue plan.

b. Rescue Planning—General

Thorough preplanning for a rescue operation is not always possible. In a mission involving search operations, the SMC should always develop a rescue plan which can be initiated the moment survivors or the distressed craft are located. This might include moving rescue units into the search area or upgrading their alert status. In other missions such as a witnessed aircraft ditching, a rescue operation must be initiated immediately without any delay for detailed development of an optimum rescue plan. For this reason primary SAR facilities are always preferred for the actual rescue operation. Thorough and intensive training of these facilities should be assumed by the SMC unless there are known deficiencies. Primary SAR facilities will normally be able to adapt their training and experience to successfully rescue any survivors, and to provide all assistance possible to prevent loss of lives or property.

c. Delivery Planning

During the planning stage an effective delivery plan may also be developed, including the necessary coordination to implement it. It usually begins early in the cycle; indeed its initial concept should begin to take form as soon as the nature of the emergency is known. Delivery planning may be, and very often is, integral with rescue planning. In many cases, the same units which effect the rescue provide for delivery and emergency care of survivors during delivery.

There are four specific events which normally occur sequentially during the delivery planning. These are: selection of a delivery point, selecting the transporting facility, providing support on scene, and providing transfer support at the point of safe delivery.

810 DATUM

The first step in search planning is to determine Datum. Datum calculations begin with the reported position of the SAR incident. The initially reported location may be a position, a line or an area. The "position known" will be discussed first. The other situations will be discussed in later paragraphs.

Examples of the "position known" category are the reported positions of: pilot ejection from an aircraft, aircraft's radar return fading from a ground-based radar scope, vessel's sinking, boat's engine breakdown, sailboat's demasting, man overboard, etc.

811 Environmental Drift Factors

a. Drift Corrections

External forces may move a distressed craft or distressed person away from the initial position of distress. These include such things as parachute drift, water current drifts, leeway, etc.

b. Types of Drift Forces

Several different types of forces causing drift are used in establishing datum. The environment at the location of the incident determines which drift forces must be corrected for. The possible drifts and drift forces that may be considered are:

1. Aerospace-trajectory (d_a).
2. Balloon drift (d_b).
3. Parachute drift (d_p).
4. Sinking drift (d_s).
5. Leeway (LW).
6. Wind-driven current (WC).
7. Sea current (SC).
8. Tidal current (TC).
9. Lake current (LC).
10. River current (RC).
11. Bottom current (BC).
12. Long-shore current (LSC).
13. Swell/wave current (SWC).
14. Surf current (SUC).

Although this listing may appear overwhelming, it should not be considered as such. Notice that the first three may occur over either land or water, whereas the remaining may occur only in a water environment. In addition, some of the drift forces are used only rarely, for example the last three. Depending upon the circumstances at the scene of the incident and the elapsed time since the incident occurred, the number of drift forces that must be corrected for will range from none to five. Typically, one drift factor is used for aircraft incidents overland, three for surface water incidents and none for surface vehicle land incidents.

c. Aerospace-Trajectory Drift (d_a)

There are several possible forms of aerospace-trajectory drift, but only two normally occur in SAR missions.

1. Bailout Trajectory.

When an airman ejects or bails out from a disabled aircraft there is a certain amount of momentum imparted upon him by the aircraft's movement. This momentum acts on the airman in the direction of flight and occurs before his parachute opens. This trajectory distance is called aerospace-trajectory.

In a high speed ejection, pilots will normally delay their parachute opening until their forward velocity reduces to their terminal speed. In a high altitude ejection, pilots will also free-fall and delay their parachute opening until at least below 20,000 feet.

No exact figure for bailout trajectory may be given to cover all types of aircraft and the different ejection speeds. Aerospace-trajectory is always disregarded for bailouts from propeller driven aircraft other than turbo-prop, and from helicopters. If both the position of bailout and the direction of travel of other types of aircraft are known for the time of bailout, then aerospace trajectory is used in search planning. 0.5 mile may be assumed for bailouts from turbo-prop and medium performance jet aircraft and 0.8 mile may be assumed if the aircraft is a high performance jet aircraft.

Ejection capsules are aerodynamically shaped and may travel much greater distances during the trajectory after ejection and before parachutes are deployed. High-speed pod ejections of this nature may have several miles of trajectory. In missions involving ejection pod aircraft, the SMC should consult the flight handbook for that aircraft to ascertain the probable trajectory limit of the pod prior to parachute opening and descent. The parent agency of the aircraft involved may be able to furnish this information.

2. Aircraft Gliding Distance. Aircraft gliding distance is another form of aerospace trajectory that may be encountered during missions involving aircraft engine failure and doubtful bailout of crew. In moderate or less winds an aircraft can glide further with no engines operating than a parachute may drift. If the position and altitude of engine failure are known, as might be the case when an aircraft reports engine failure and subsequently disappears from ground-based radar scopes, the maximum glide and time of descent can be obtained from that aircraft's flight handbook. Using the last known position and the height above ground, the SMC can determine the ground distance that the aircraft could possibly cover during its descent.

Plot the last known position on a chart. Adjust that position for the effect of average winds aloft that displace the aircraft during its descent as shown in Figure 8–1. Suppose it takes 6 minutes (0.1 hours) for the aircraft to glide to the surface from its known altitude, and the average of the winds that the aircraft is descending through is 270° T at 40 knots. In 6 minutes the aircraft will be displaced 4 miles. The direction of displacement is 90° T, the downwind direction. The last known position is now relocated 4 miles due east of its original location.

Next, construct a circle around the corrected, displaced last known position, using the maximum, no-wind glide distance as the radius. The area enclosed within the circle will be the maximum possible area that the aircraft could be within, assuming that the engines were not restarted.

Radar nets should always be checked in missions involving possible aircraft ejection or bailouts. Determine if the aircraft were being tracked by radar, if any chaff was detected which would indicate the position of bailout, and the position where the aircraft target faded from the ground based radar scopes. (Most attack type and fighter type aircraft are equipped with an automatically-deployed chaff package which is ejected at the same time that the pilot bails out). In addition, if no radar targets were detected by the radar net, this information might be useful in determining where the aircraft is not located, thus reducing the probability area.

Note that this situation can result in a datum area.

d. Balloon Drift (d_b)

There are two situations which require the computation of balloon drift:

1. A distressed person may be adrift in a balloon.

2. An airman of the future may have bailed out of his aircraft equipped with a combination balloon-parachute system.

In the first case, the balloon drift would be determined by the winds aloft acting on the balloon. In the second, it would be necessary to obtain the characteristics of the balloon-parachute combination from the parent activity and to estimate whether, under the circum-

Aircraft Glide Area

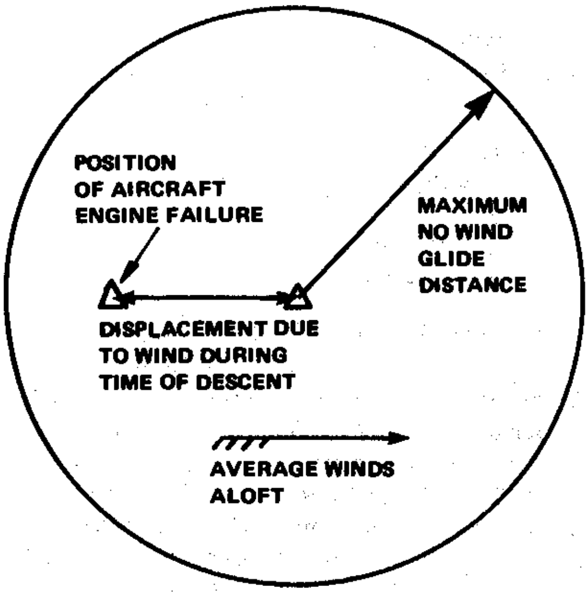


FIGURE 8–1

stances, the airman would remain aloft for the full length of time or would have taken the option to descend. These devices have not become operational as of 1973.

e. Parachute Drift (d_p)

Parachute drift must be considered in all cases where airmen are known or suspected to have ejected or bailed out. It is the combined drift of the parachute's glide ratio and its displacement due to winds aloft as the parachute is descending. As a result of parachute drift, the airman may land on the earth's surface a considerable distance from where his parachute opened.

There are five things to consider when computing parachute drift:

Parachute opening altitude.
Parachute type.
Parachute glide ratio.
Average winds aloft.
Terrain height.

Most U.S. military emergency parachutes have opening devices which automatically deploy the parachutes as the airmen descend through 14,000 feet (Canadian Defense Force parachutes are set to automatically deploy at approximately 16,400 feet). In addition, some aircraft which operate regularly over mountainous terrain will set their automatic opening devices to open the parachute at 2,000 feet above the highest mountain peak in this operating area. The best practice is to check with the parent squadron or agency of the aircraft involved to determine what altitude their parachute opening devices are set to deploy the chute after bailout.

The exact altitude of either parachute opening or bailout may be available from an accompanying wingman, from ground observation, or from radar net observation. Military pilots can be expected to freefall if they bailout above the altitude for automatic parachute opening. The rate of descent in freefall is about 250 feet per second or 4 seconds for each 1,000 feet. Figure 8–2 depicts the terminal velocities and time consumed for freefall.

When exact information is not available, it can be assumed that:

1. Military parachutes opened at 14,000 feet if the pilot bailed out above that altitude.

2. Military parachutes opened at altitude of bailout, if below 14,000 feet.

3. Civilian parachutes opened at the altitude of bailout.

4. If an aircraft is en route at a known altitude below 14,000 feet and reports that he is experiencing an emergency and bailing out immediately, the altitude to which he was assigned may be used for the parachute opening altitude.

5. If an aircraft has engine failure or a similar circumstance which requires his descent, a reasonable allowance should be made for the loss of altitude before he actually bailed out. The parent squadron should be checked for its policy on minimum altitude to attempt engine restarts. It can be assumed that the pilot rode the aircraft to that altitude and then bailed out.

There are many types of parachutes in use today. Figure 8–3 summarizes the more common types in use by U.S. military forces, NASA, and recent experimental types. There are two general categories of parachutes: standard and gliding. Standard types are designed to descend with a zero glide ratio, and if deliberately side-slipped by the airman may get a drift ratio of up to 0.7, with 0.3 a typical average. Most military emergency parachutes are standard types designed to descend vertically in no-wind conditions. Gliding types such as the parawing and parasail may have glide ratios (horizontal distance to vertical distance) of up to 3 to 1.

Figure 8–3 summarizes glide ratios and rates of descent for the most common parachutes used by military, civilian, and NASA pilots.

Average winds aloft which exist between the parachute opening altitude and the earth's surface should be computed vectorially, using the best available information for the winds aloft. Usually the winds in the bailout area for every even altitude (2,000, 4,000, 6,000, etc.) can be obtained from established meteorological facilities. When a specific wind is reported for a particular altitude aloft, the search planner should assume that this wind is constant on both sides of that altitude to a point midway between the next altitude at which a reported wind aloft is available. For example, if winds are reported at every even thousand feet, it should be assumed that the wind reported for 4,000 feet was constant from 3,000 to 5,000 feet, and the wind reported at 6,000 feet would be constant from 5,000 to 7,000 feet, etc. This assumption must be kept in mind when averaging winds aloft.

Suppose the following winds were reported for a bailout incident in which a civilan pilot bailed out over water at 8,000 feet:

8,000—270/30
6,000—300/25
4,000—330/25
2,000—000/23
Sea level—045/44

The wind values of 2,000, 4,000, and 6,000 feet, when used in a vectorial solution, are used twice since they indicate the winds from 7,000 to 5,000 feet, from 5,000 to 3,000 feet and from 3,000 to 1,000 feet respectively. The wind values given for 8,000 feet and sea level are used only once since they are only effective on the descending parachute for the distance from 8,000 feet to 7,000 feet and from 1,000 feet to sea level. Figure 8–4 depicts this situation.

Descent Times

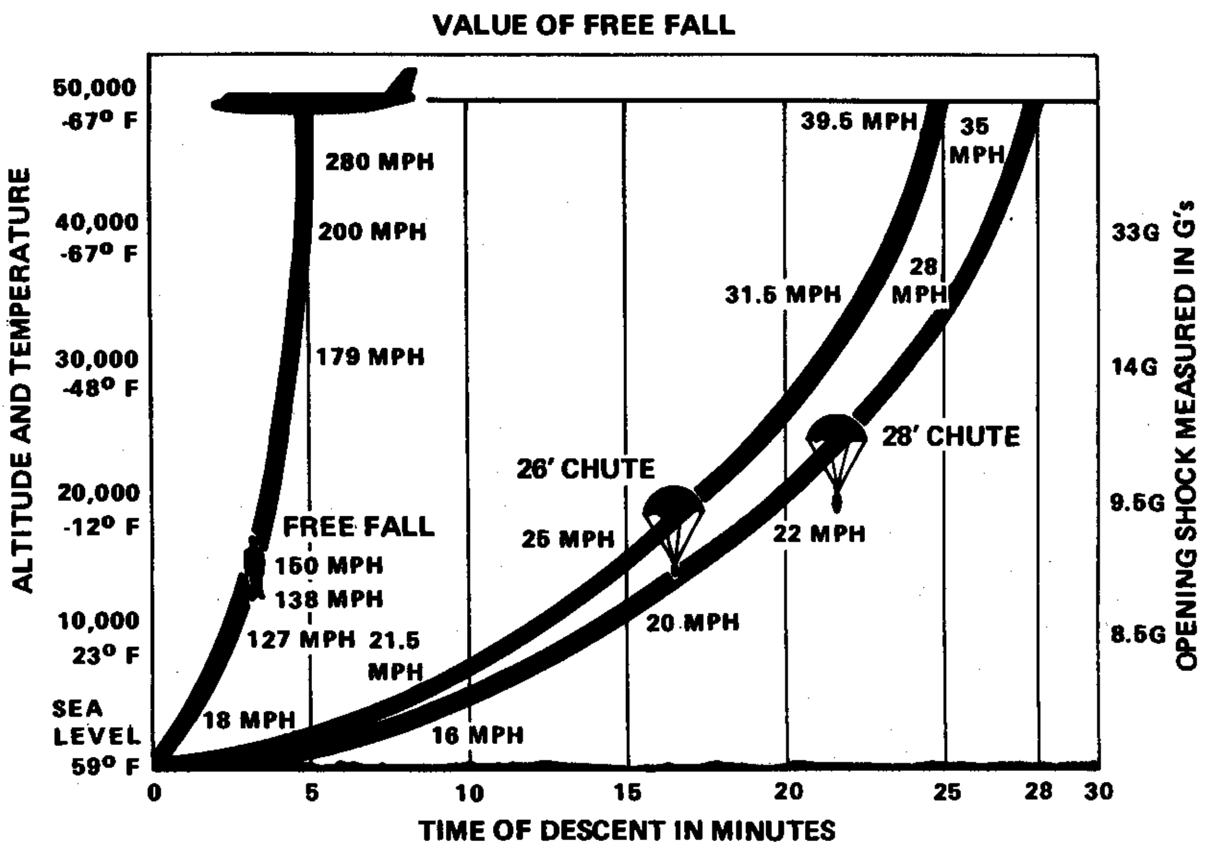


Figure 8–2

Parachute Descent Data

[200-lb. man except Apollo]

Parachute type	Rate of descent at Sealevel (feet per sec)	Rate of descent at 7,000 feet (feet per sec)	Glide ratio hor.: :vert.
28 feet (C–9), escape	19. 6	21. 4	0
28 feet (C–9) w/4 suspension line release, escape	19. 1	21. 0	0. 40
24 feet, paratroop reserve	22. 7	24. 9	0
24 feet, Martin-Baker system	24. 0		0
35 feet (T–10), Army paratroop	15. 3	16. 8	0
35 feet (HALO), AF and Army special paratroop	16. 0	17. 3	0. 35
Skysail (Navy), escape	20. 2	22. 0	0
Paracommander, AF special paratroop	18. 0	19. 7	1. 16
Parawing (experimental)	10–15		3. 0
Parafoil (experimental)	10–15		3. 0
Parasail (experimental)	10–15		2. 7
Apollo: 2 each (83 feet diameter)	35	37. 2	0
Apollo: 3 each (83 feet diameter) (Apollo deployed at 24,000 feet)	30	32. 5	0

Figure 8–3

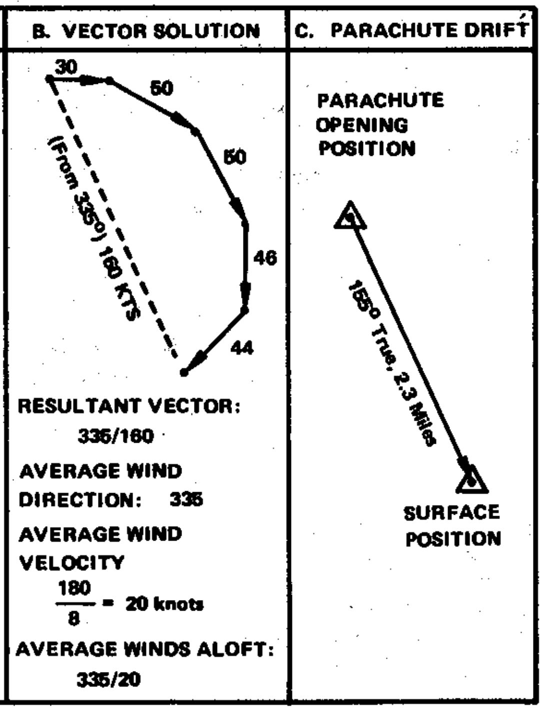
Remember that when winds are reported they are always reported in the direction from which they are blowing and in degrees true. Velocities are reported in knots. When solving average winds aloft vectorially, it makes no difference whether the individual winds are plotted in upwind or downwind directions, providing the search planner is consistent throughout the vector solution, and realizes that the direction of the resultant vector will be consistent with the individual wind vectors. In other words, if all individual wind vectors were plotted in the up-

Average Winds Aloft Example

A. WINDS ALOFT DATA

SPECIFIED ALTITUDE	EFFECTIVE RANGE	DIRECTION/ VELOCITY	VECTOR VALUE
8000	9000–7000	270/30	090/30
6000	7000–5000	300/25	120/50
4000	5000–3000	330/25	150/50
2000	3000–1000	000/23	180/46
SEA LEVEL	1000–SEA LEVEL	045/44	225/44

NOTE: THE VECTOR VALUES FOR 8000, 4000, AND 2000 REPRESENT A RANGE OF 2000 FT. EACH. THEREFORE, THE TOTAL NUMBER OF VECTORS FOR 1000 FT. INTERVALS IS 8.



(PARACHUTE OPENED AT 8000 FEET OVER OCEAN)

Figure 8–4

wind direction (the reported direction), the resultant vector would be pointed in the upwind direction. Figure 8–4B depicts the vectorial solution using a downwind direction. Usually the downwind direction is used by search planners because it helps to visualize the direction of drift during the descent. The resultant of the vectorial solution shows a total speed of 160 knots. However there were eight vectors used to determine this resultant and therefore, the average speed would be 160 divided by 8, or 20 knots. The average winds aloft from 8,000 to sea level is 335° T at 20 knots.

Having determined the average winds aloft through the vectorial solution, the next step would be to determine the distance the parachute will be drifted due to the force of the average wind. The parachute drift table in figure 8–5 is now used. The table is entered with 8,000 feet and 20 knots. An answer of 2.3 miles is obtained. This distance, 2.3 miles, is plotted downwind from the parachute opening position, as shown in figure 8–4C and determines the surface position. If the average wind speed is something other than the speed values given in the table, interpolation is required.

If the airman has bailed out over terrain which is not at sea level, an adjustment must be made for the height of the terrain. This requires an additional entry into figure 8–5. For this situation, figure 8–5 would be entered with the altitude of the terrain and interpolated for the average wind velocity. The difference between the two values of interpolated drift distances will be the actual parachute drift distance.

In rare cases, an incident may involve a bailout using a gliding type parachute. In this case, the parachute glide area is determined in the same manner used to determine an aircraft glide area. First the surface position is computed treating the parachute as a standard, zero glide ratio type. Next, the parachute glide ratio is obtained from figure 8–3. The altitude difference between parachute opening altitude and the terrain altitude is determined. The no-wind glide distance is then computed by multiplying the glide ratio by the altitude difference. A circle is drawn around the surface position using a radius equal to the glide distance. The area enclosed is that which the parachutist could possibly be within.

f. Sinking Drift (d_s)

Sinking drift must be computed any time the search object sinks through various depths of water from its initial position on the water's surface to the bottom. It is applied from the surface position to determine at what point on the bottom the sinking search object will first make contact.

Knowledge of the underwater currents and the layer boundaries, where a change in current velocity or direction occurs, is required to develop the underwater datum. As the search object descends through the different underwater currents the object is offset by water current force in the same manner that a parachute is offset and displaced by wind currents acting on it. An average underwater current is determined in the same manner that an average wind aloft is determined. If the underwater currents

Parachute Drift Distance (Zero Glide Ratio)

[Distance in miles of landing position downwind from position of parachute-opening]

Parachute-opening height	Wind in knots						
	10	20	30	40	50	60	70
30,000 ft. (9,000m)	3.7	7.4	11.1	14.7	18.4	22.1	25.8
20,000 ft. (6,000m)	2.7	5.3	8.0	10.7	13.3	16.0	18.7
14,000 ft. (4,300m)	1.9	3.8	5.7	7.7	9.5	11.4	13.3
10,000 ft. (3,050m)	1.4	2.8	4.2	5.7	7.0	8.3	9.7
8,000 ft. (2,400m)	1.2	2.3	3.5	4.6	5.8	6.9	8.1
6,000 ft. (1,800m)	.9	1.7	2.6	3.5	4.4	5.2	6.1
4,000 ft. (1,200m)	.6	1.2	1.8	2.4	3.0	3.5	4.1
2,000 ft. (600m)	.3	.6	.9	1.2	1.5	1.8	2.1

FIGURE 8–5

are unknown, the usual practice is to assume a vertical descent for establishing an underwater datum.

For search planning purposes it is always assumed that the sinking object continues its descent until contact with the bottom. A typical rate of descent for submersibles not under power is 2 feet per second. In the absence of other information, this rate of descent may be assumed for other sinking objects.

Suppose a submersible collided with a surface vessel and sank in water depth of 360 feet. It would take the submersible about 3 minutes (.05 hour) to sink to the bottom. The average underwater currents were 000° T at 2 knots. Water currents are always reported in the direction they are moving toward. Therefore the sinking submersible would be displaced in a northerly direction from its surface position. To determine the distance it would be displaced, convert the current velocity to either yards/hour (2,000 yds = 1 mile) or feet/hour (6,000 ft. = 1 mile). Two knots would equal 4,000 yards per hour. During the sinking time of 3 minutes, the submersible would be displaced about 200 yards down-current (3 ÷ 60 × 4,000 or .05 × 4,000 = 200). The underwater position would therefore be located in a position 200 yards 000° T from the surface position.

g. Leeway (LW)

Leeway is the movement of a search object caused by being pushed through the water by local winds blowing against the exposed surfaces of the search object. A boat, raft, or any other type of marine craft has a certain proportion of its hull and superstructure exposed above the surface of the water at all times. This exposed surface or "freeboard" is blown against by local winds which in turn have the effect of pushing the marine craft through the water. The greater the freeboard, the more surface the wind will have to blow against, and the greater will be the wind's effect on drift. If the silhouette of a boat were projected onto a flat plane which was perpendicular to the wind direction, the area enclosed by the silhouette would be called the exposed flat-plane area. As the boat's heading changes relative to the wind, its flat-plane area also changes, usually becoming least when the boat is heading directly into the wind or downwind.

The pushing force of the wind is countered by the water drag on the underwater hull. The drag varies with the volume, shape, depth, and orientation of the underwater hull. When a marine craft is parallel to the wind direction, the least amount of underwater drag will exist since the craft will be pushed through the water in the direction that its hull is designed to move. Almost the same conditions will exist when the boat is pointed directly into the wind and is being pushed backwards through the water longitudinally. When the boat's heading is perpendicular to the local wind however, the greatest amount of underwater drag will exist since the boat must now be pushed sideways through the water. Between these extremes the amount of underwater drag will vary depending on the heading of the boat.

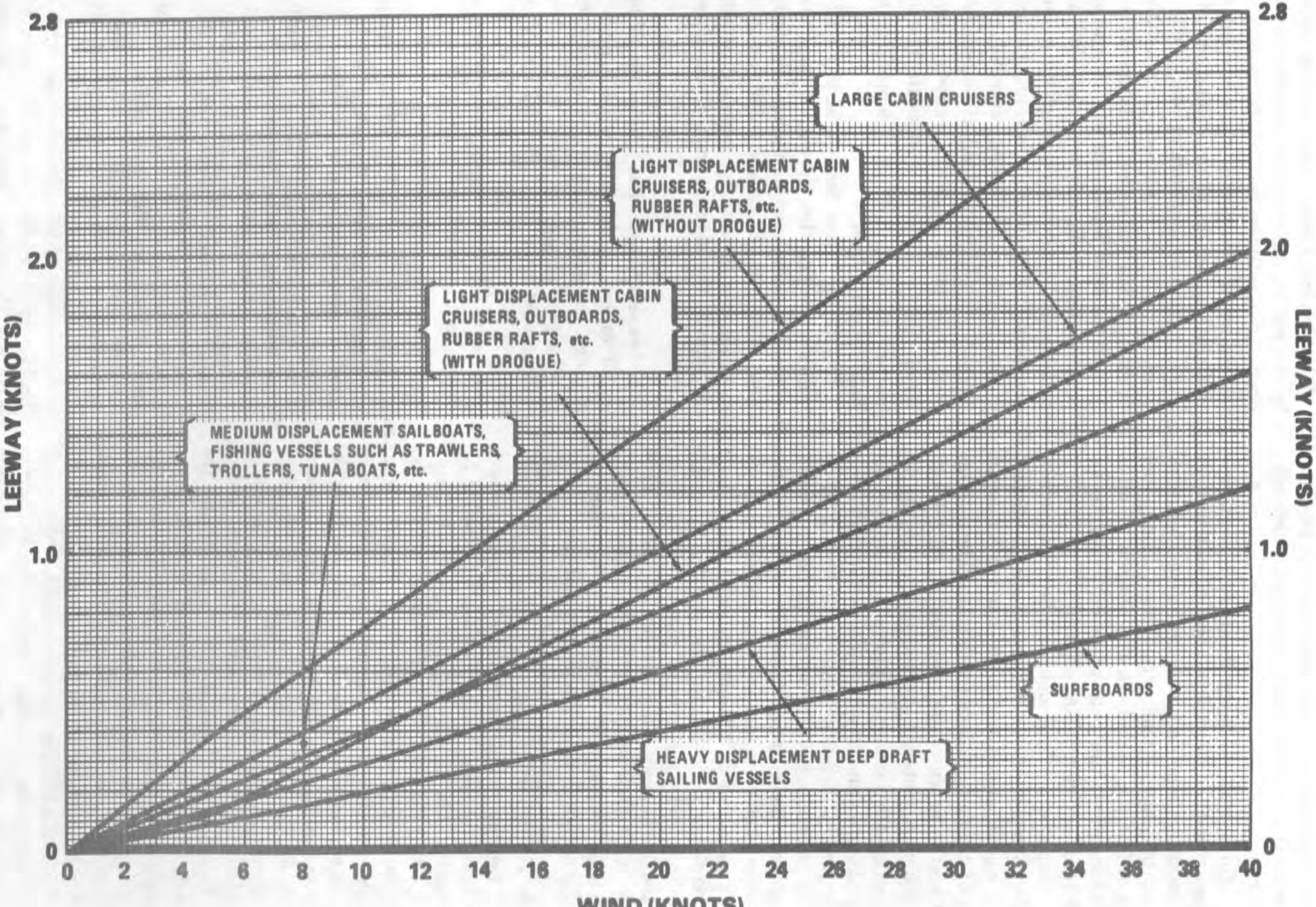
Due to the above factors, leeway will vary with the heading that the marine craft assumes while it is being pushed through the water by local winds. It is extremely difficult to determine the precise value for leeway direction and magnitude for marine craft under these circumstances.

1. Leeway Speed. The magnitude of leeway speed caused by local wind pushing a craft through the water is shown in figure 8–6. The graphs provide leeway speed for wind speeds encountered most often. The following expressions may be used for leeway speed if more precise values are desired. The formulas are reasonably accurate for windspeeds (U) up to 40 knots.

Type of Craft	*Leeway Speed*
Light displacement cabin cruisers, outboards, rubber rafts, etc. (without drogue)	0.07U+0.04
Large cabin cruisers	0.05U
Light displacement cabin cruisers, outboards, rubber rafts, etc. (with drogue)	0.05U−0.12
Medium displacement sailboats, fishing vessels such as trawlers, trollers, tuna boats, etc.	0.04U
Heavy displacement deep draft sailing vessels	0.03U
Surfboards	0.02U

The leeway of liferafts equipped with water pockets or ballast buckets approximates that of a raft with drogue. The owner or operating agency should be contacted to verify the type of

LEEWAY SPEED



liferaft used and whether or not it has ballast buckets.

2. Leeway Direction. The direction of the leeway vector should be considered to be directly downwind. In recent leeway experiments, all of the craft observed exhibited a greater tendency to move off the downwind direction rather than move directly downwind. Angles off the wind line ranged to a maximum of 45° in craft with a relatively large keel plane area (moderate to deep draft), 60° in craft with a relatively small keel plane area (shallow draft), and 35° for rubber rafts. The distribution to the right and left of the downwind line was practically equal. The effect may be allowed for by extending search areas for possible deflections to right and left.

In the case of variable winds, compute the survivor's leeway for suitable periods. Then by means of vector addition, obtain the total leeway for the entire period.

h. Wind Current (WC)

As a wind blows over a water surface, it will tend to push the water along in the same direction. This horizontal movement of the water on the surface results from an exchange of energy from the wind to the water. The effect of this energy transfer grows with wind speed, wind duration, and the distance over which the wind is blowing, eventually reaching a maximum limiting velocity.

Wind current, or wind-driven current, is defined as the current generated by the wind which acts upon the surface of the water for a period of time. Wind current is also sometimes referred to as local wind current since it is the local winds that generate the wind-driven water current in any particular area. The wind-driven current is also called wind drift current by some oceanographers.

1. Wind Information. The wind current existing at a given location at a particular time is the result of the wind forces which have been exerted on the water during the immediate past. For purposes of computation, forecasts or observations of wind speed, direction and fetch should be obtained commencing 48 hours prior to the time that the distressed craft is believed to have started drifting. Fetch is defined as the distance over which the wind has been acting on the water upwind of the datum or last known position.

When using on scene wind estimates, check to see if they agree with the general circulation of the area as shown on surface weather charts. If they do not agree, they should be either verified or disregarded. Generally, in the northern hemisphere surface winds will be approximately 20° to the left of isobars on the surface weather charts and pointing toward the low pressure side of the isobars. In the southern hemisphere they would be approximately 20° to the right and still pointing toward the low pressure side.

Wind current will move a floating target in water areas where local winds are present and where influences of land masses are negligible. Wind currents are usually ignored in coastal, lake, river and harbor areas due to the many variable effects from the water-land interface. In addition the assumptions on which our computation procedures were based, are only valid for the open sea where land masses do not interface with the action of the wind on the water or on the currents generated by them. Wind current is usually not used within 20 miles of a shoreline.

2. Wind Current Speed. Surface wind speeds are normally used to determine wind current. Figure 8–7 is used to determine the speed of the wind current. Enter the figure with wind speed at the top of the graph and drop vertically to the wind duration value. Read the current speed at this point. Repeat this step but use fetch distance instead of duration. Whichever step gives the lower current speed is the limiting case and the associated speed is the correct one to use.

For example, assume a 28-knot wind has been blowing for the past 24 hours over a fetch of 100 nautical miles. Entering figure 8–7 with 28 knots and 24 hours duration, current speed is found to be 0.67 knot. Re-entering the figure with 28 knots and a fetch of 100 miles, current speed is found to be 0.49 knot. The latter, being the smaller quantity, would be the correct value to use. If the fetch is unknown, use the value found with wind speed and wind duration.

Another example is shown in figure 8–8. Suppose a 24-knot wind is forecast for a day with a 200-mile fetch. Desired information is wind current speed after 6, 12, and 18 hours. Dropping vertically from 24 knots, the 6 hour duration will give a current of 0.31 knot; after 12 hours the current has increased to 0.49 knot; and after

Wind Driven Current Speed

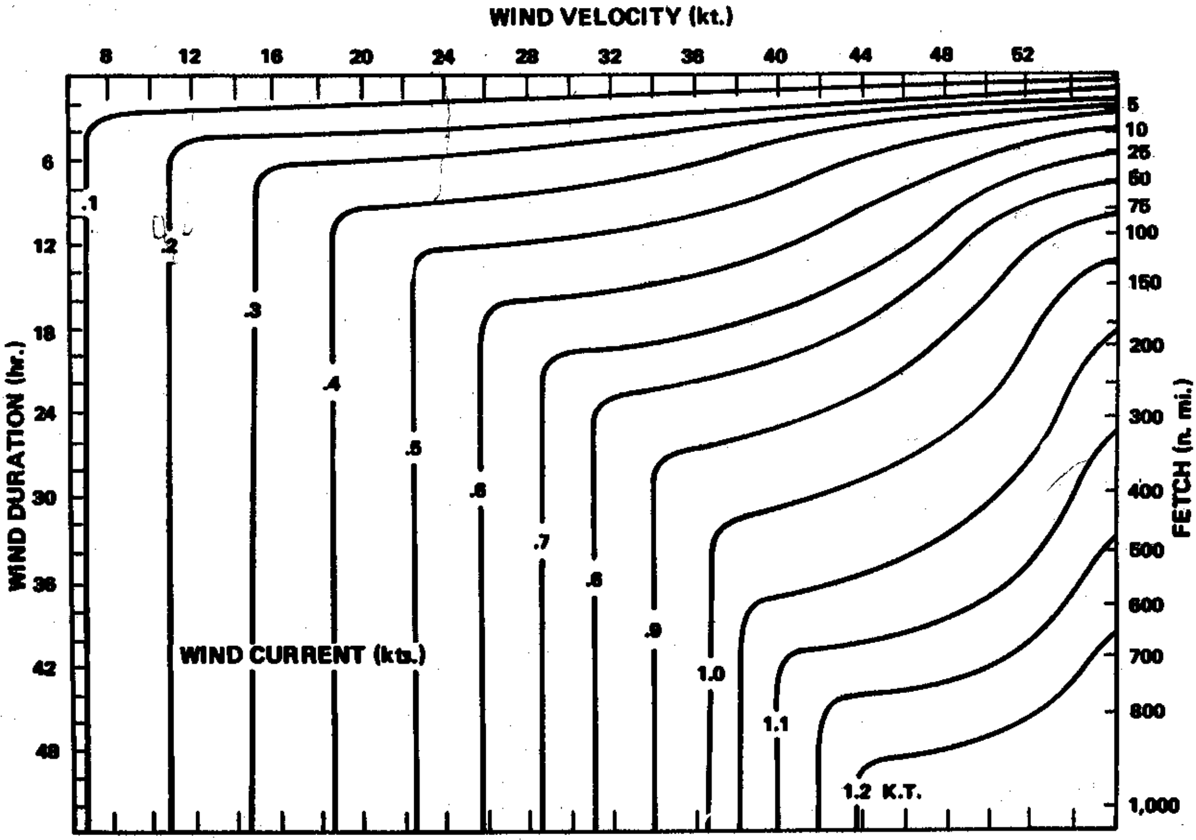


FIGURE 8-7

18 hours the current is 0.55 knot. Fetch is not a limiting factor in this example since its value for current was 0.55 knot throughout the current's development.

3. Increasing Wind Speed. The current for 12 hours of a 40-knot wind is not the same as for the identical wind preceded by 12 hours of a 20-knot wind. Figure 8-7 provides the wind current that is developed by a given wind starting without any wind current already present. When wind speed is increasing, a compensation must be made for the wind current which has already been produced. This value is called the equivalent duration, and is added to the time which has elapsed since the wind increased. This sum of equivalent duration of previous wind and the duration of the existing wind is called the effective duration. The effective duration is used when entering figure 8-7 to find the actual wind current present at that period.

For example, if a wind blows for 12 hours at 12 knots, then for 12 hours at 24 knots, the procedure is as follows. During the first 12 hours, the 12-knot wind generates a current of 0.22 knot. A wind speed of 24 knots could create the same current in 4 hours, a value which is obtained by entering figure 8-7 with a current speed of 24 knots to read 4 hours on the left. Adding this 4 hours duration to the 12 hours the 24-knot wind actually blows gives an effective duration of 16 hours. Using 16 hours, rather than 12 hours with the 24-knot wind speed gives the correct current speed of 0.54 knot. This procedure, in effect, accumulates the energy that has been placed in the water by the wind and is necessary whenever the wind speed changes by more than 10 knots.

4. Decreasing Wind Speed. A decrease in the intensity of the wind usually causes a decrease in the velocity of the wind-driven current. Wind-driven current does not change velocity as quickly as the local winds which generate it. Inertial energy of the water mass acts to continue current speed after its generating force ceases to exist. The decrease in current velocity over time is referred to as current decay. The decay period is the time interval which has elapsed since the wind speed decreased. If the change in wind speed is a decrease to zero or calm, the total decay period required for the current to stop is approximately twice the time that was required to develop the current, i.e. twice the effective duration. The time period for which a current will be undergoing the transition of decay is approximately twice the effective duration which was required to generate the differential of current velocity being decayed. This principle has been incorporated in figure 8–9 which for ease and conformity uses effective duration as one of the entering arguments. When a current decays, it will decay to the maximum limiting current velocity associated with the reduced wind speed provided that the current velocity at the time of the wind intensity change exceeded the maximum limiting velocity associated with the reduced speed.

Consider the example of the preceding section in which 0.54 knot of current was generated by the combined effects of a 12-knot wind and a 24-knot wind. Suppose that the wind became calm after blowing for 12 hours at the 24-knot speed. The amount of decay will be from a current of 0.54 knot to a current of zero knots, a current decay differential of 0.54 knot. To find the current which exists 12 hours after decay commenced, enter figure 8–9 with a decay period of 12 hours; move vertically to intersect the effective duration curve marked 9 to 18 hours duration since our effective duration is 16 hours; read the decay factor (f_d) from the left scale, which for this example is 0.2. The current at the end of twelve hours of decay will be equal to the steady state current after decay (maximum limiting current for reduced wind speed) plus the product of the decay factor times the decay differential: WC speed $= 0 + (0.2)(0.54) \approx 0.11$ knot.

Next consider the same example except that instead of the wind becoming calm it continues to blow but at the reduced speed of 10 knots. As in the above example we wish to determine the current existing 12 hours after decay started. The maximum limiting current supportable by 10 knots of wind as shown in figure 8–7 is 0.18 knot. At the time of the change current velocity is 0.54 knot. The decay differential is 0.54 minus 0.18 or 0.36 knot. The effective duration associated with the decay differential is logically the difference between the effective durations required to generate 0.54 knot and 0.18 knot of current at the higher wind speed of 24 knots. The effective duration of the decay period is 16 minus 4, or 12 hours. Entering figure 8–9 with a decay period of 12 hours and moving vertically to the appropriate effective duration curve we find that the decay factor is 0.2. The current velocity after 12 hours is thus found to be $0.18 + (0.2)(0.36) = 0.25$ knot.

5. Wind-Driven Current Direction. Coriolis effects the direction of wind-driven currents from

Wind-Driven Current Example

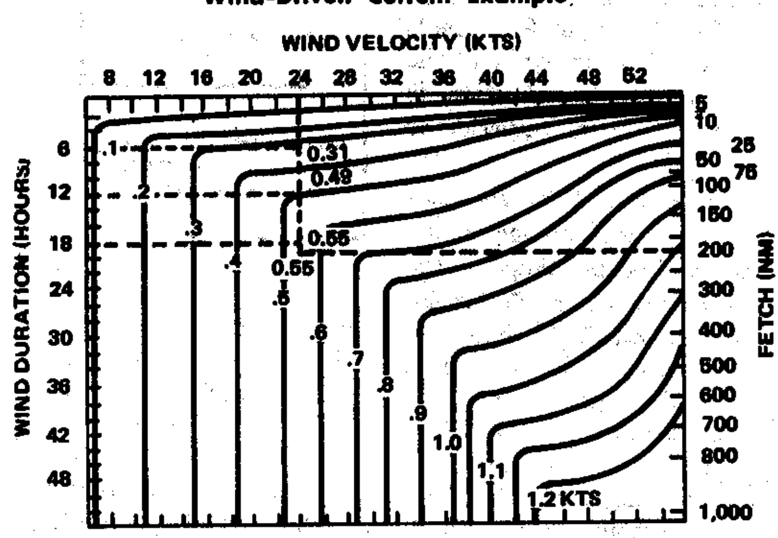


FIGURE 8–8

Wind-Driven Current Decay

CURVES OF EFFECTIVE DURATION

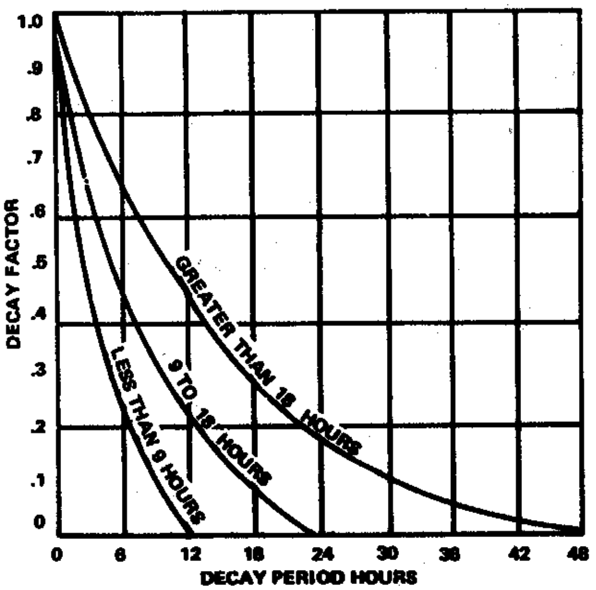


FIGURE 8-9

the beginning of local wind flow. Coriolis causes the current to be deflected to the right of the downwind line in the Northern Hemisphere and the amount of deflection increases with latitude. Deflection is to the left in the Southern Hemisphere.

The magnitude of wind current deflection is determined from figure 8–10. Enter the figure with the latitude of the position of distress and obtain the amount of coriolis deflection. Apply this deflection to the local surface wind's downwind direction. For example, suppose the latitude of the distress was 40° N and surface wind was from 000° T at 15 knots. Figure 8–10 yields a coriolis deflection of 20° to the right of the downwind line. The downwind direction is 180° T; hence the wind current direction is 200° T (180+20).

6. Summary of Wind Current Computational Procedures. Wind currents will change as the weather patterns change. Abrupt changes in the weather will have more pronounced effects than gradual ones. For this reason the method used to compute the wind-driven current is dependent upon the magnitude of wind change. For manual computations, wind current is calculated by determining its components, direction and speed, independently. In order to minimize the error introduced by this computational method, we consider changes in wind direction prior to changes in wind speed thuse identifying wind currents by their direction. If a wind changes direction by 45° or more the current's generating wind is considered to have ceased and the current velocity that was generated is decayed to zero. Simultaneously a new current based on the new wind direction commences its buildup. For directional wind changes less than 45° the mean wind direction is used to determine current direction.

The method of computing current speeds for those currents undergoing transitional stages caused by increasing or decreasing wind speeds need only be used in those instances when the change in wind speed exceeds 10 knots. For changes in wind speed equal to or less than 10 knots the mean value of wind speed should be used to determine the wind driven current velocity.

The computational method described here determines wind driven current direction and speed. For most situations we are more concerned with the distressed craft's drift caused by the wind current. This necessitates conversion of speed to distance which is accomplished by multiplying the current speed by the number of hours which it existed. The final form of our computations expresses the drift vector attributable to wind-driven current in terms of distance (nautical miles) and direction (degrees true).

WIND CURRENT DEFLECTION

LATITUDE	DEFLECTION
0° to 10°	None
10° to 20°	10°
20° to 60°	20°
Greater than 60°	30°

NOTE: DEFLECTION WILL BE TO THE RIGHT IN THE NORTHERN HEMISPHERE AND TO THE LEFT IN THE SOUTHERN HEMISPHERE.

FIGURE 8-10