piece of paper or roller plotter, using the same distance scale as the chart to create a linear record of what you observed on that heading. Then keeping this paper or plotter oriented in the direction traveled, move it around on the chart until you match what you measured, and thus you will have found your track and positions at the times of the logged depths recorded. This type of piloting is referred to as using a *line of soundings*.

An interesting way to practice line of soundings navigation on land is to replace the depth sounder with a barometer and use the barometer to measure elevations. Then, after calibrating it at a known elevation in the present atmospheric pressure, walk off over the local terrain in a steady compass direction, periodically recording distance traveled and measured elevation. Then go to a topo map and determine your final position. Examples are given at starpath.com/navbook.

6.5 Visible Range of Land and Objects

Everyone is familiar with the image of a ship sailing over the horizon. As the ship sails away, less and less of it can be seen because the curvature of the earth limits the line of sight to the ship. The last thing you see with binoculars is the tip of the mast. The taller the ship, the farther off it can be seen; likewise, the higher you are when looking, the farther you can see. From the deck of a small vessel, you can easily see a freighter 10 nmi off, but you cannot see another small vessel traveling along beside it. Knowing how to estimate the actual visible range of other vessels, rocks, peaks and islands, and elevated lights is fundamental to marine navigation. It is important for navigation, and it is important for safety.

During daylight in clear weather and flat water, the visible range of an object is called its *geographic range*. It is determined by the curvature of the earth and the heights of the object and the observer. The mathematical solution to the geometry problem is presented in tabular form in the *Light List*. The table gives geographic ranges for various heights of objects and observers. These results, however, are needed more often than the *Light List* is, so it pays to know how to figure geographic range without a table. In clear weather and flat water, geographic range in miles can be estimated from:

$$\text{geo range (nmi)} = 1.17 \times \left(\sqrt{\text{H (ft)}} + \sqrt{\text{HE (ft)}} \right),$$

where H = light height and HE= eye height above the water (see Figure 6-13).

Eye height from a small vessel might be about 9 ft, so your own elevation would add 3.5 nmi to the geographic range of landmarks.

If an islet is 81 ft tall, the top of it would be first discernible on the horizon at 1.17 × (9 + 3), or about 14.0 nmi off. The square roots of less convenient heights should be computed with a calculator or can be approximated by squaring a few guesses. High precision is not required because even the best theories of what this range should be are only accurate in practice to within 10% or so. Likewise, beyond 14 nmi off, an 81-foot-high island could not be seen, even if it had a bright light on it (at ground level) and you looked with binoculars. The heights of shoreline cliffs, peaks, and inshore rocks that are needed to figure their geographic ranges are charted or listed in *Coast Pilots*.

For unlit landmark remember this estimate is for when the tip of the object is just on the horizon and there is often haze on the horizon. A slight chop on the water can also limit its visible range. These predictions are also naturally limited by the prevailing atmospheric visibility. If the atmospheric visibility is 15 nmi—a very clear day—you could not see a peak 2,500 ft high until you were within about 15 nmi of it, even though the tip of it is over the horizon at 50 nmi off. This is, in effect, the definition of *atmospheric visibility*.

The formula can be used not only to predict when an island or peak should first be seen (depending on atmospheric visibility), but it can also be used to tell how close you must be to it if you do see it. If a bright navigational light, for example, is charted as 25 ft high, whenever you can see the light at all viewed from an eye height of 9 ft, you must be within 1.17 × (5+3), or 9.4 nmi of the light, although you do not know the actual distance off by just seeing the light. On the other hand, when you *first see the light*, you can assume you are approximately 9.4 nmi off.

Predictions of the geographic-range formula are also of interest to safety. A ship that is about 81 ft high would be seen first (looking carefully in best conditions) at a distance of 1.17 × (9 + 3), or about 14 nmi off. Two small vessels will lose complete sight of each other at a separation of about 7 nmi in flat water. In rough seas or swells, however, they would have only intermittent sights of each other at much

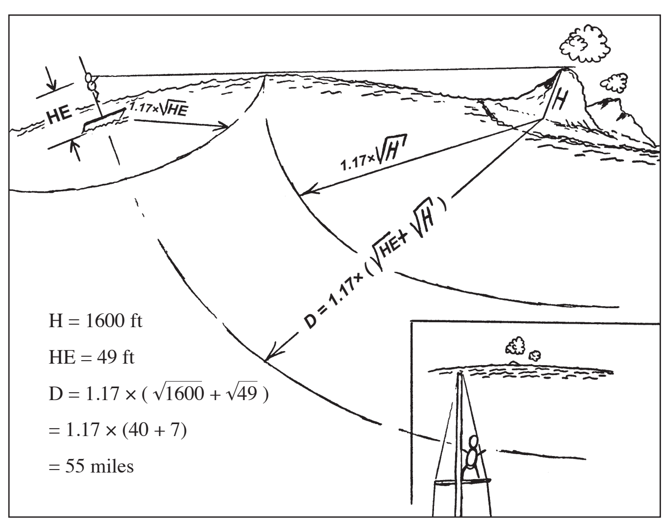

Figure 6-13. *A landmark will first appear above the horizon when you approach it to within the geographic range (D), provided the atmospheric visibility is at least as far as that geographic range. The sailor's eye height (h) and the height of the land (H) are in feet above the water.*

light often cannot be seen from this distance because its view is blocked by the curvature of the earth (see Figure 11-15). The *geographic range* of a light is how far it can be seen over the horizon. As explained in Section 6.5, the geographic range of a light is *approximated* by:

$$\text{geo range (nmi)} = 1.17 \times \left(\sqrt{\text{H (ft)}} + \sqrt{\text{HE (ft)}} \right),$$

where H = light height and HE = eye height.

A light cannot be seen from farther off than its geographic range, nor from farther off than its nominal range—assuming average "clear weather," which is defined as atmospheric visibility of 10 nmi. (For exceptionally clear skies, we should replace the nominal range with the luminous range.)

For each light in question, it is the smaller of these ranges that determines the *visible range* of the light. In the example above, the light shines 13 nmi out into space (its nominal range), but from an eye height of 9 ft, it can only be seen out to a distance of 9.4 nmi, 1.17 × (sqrt 25 + sqrt 9). Geographic range must always be calculated (or figured from tables); nominal range is charted or listed in the *Light List*. Recall the potential uncertainties and assumptions made in Section 6.5 about the accuracy of these predictions.

When planning nighttime navigation, determine the visible ranges of all lights to be used and sketch these limits on the chart, as shown in Figure 11-16. Also mark where lights are blocked by local terrain and, when applicable, when they switch from white to red. Some lights have red sectors that mark rocks or other hazards in the vicinity. The boundaries of red sectors are charted as dotted lines, but it

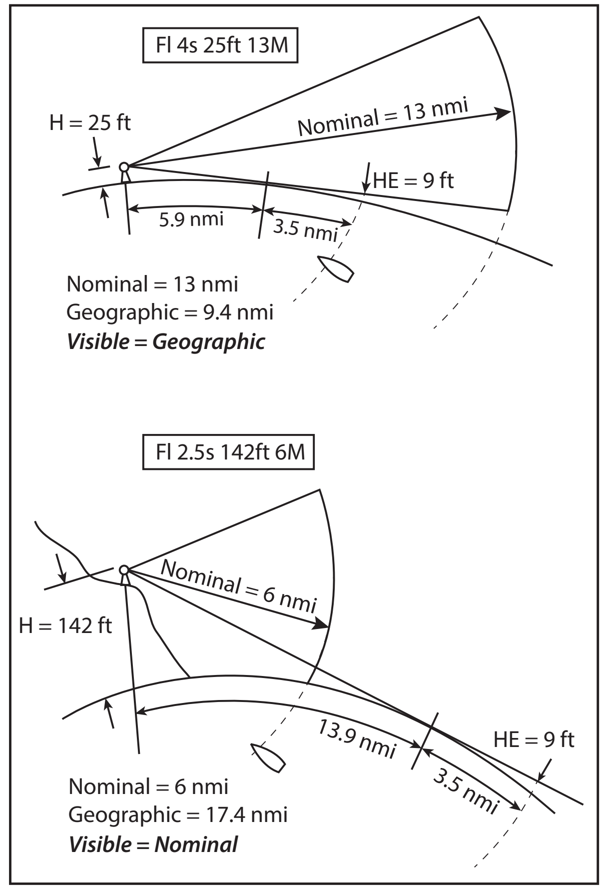

Figure 11-15. *The approximate visible range of a light as determined from the smaller of its nominal range and geographic ranges. The visible range of the top light (low but bright) is limited by geographic range; the bottom light (high but not so bright) is limited by nominal range.*

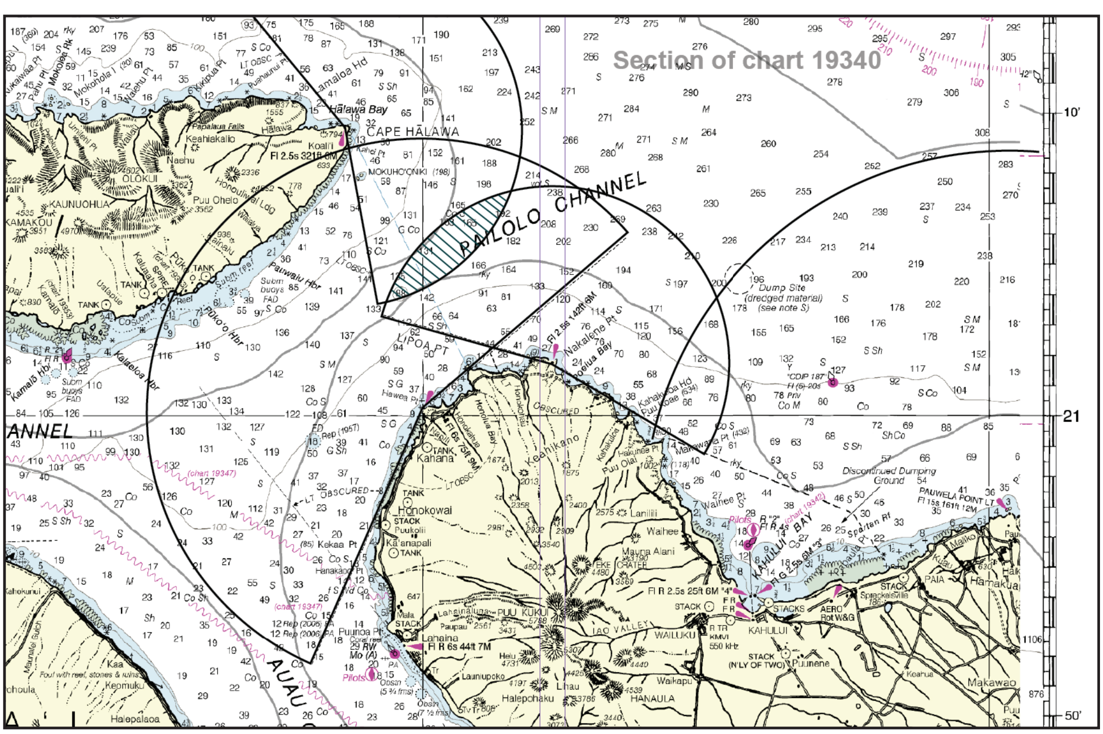

Figure 11-16. *Planning nighttime navigation by determining the visible ranges of lights to be used and sketching these limits on the chart. This is the ocean approach to NW side of Maui, HI. The shaded area marks the only place where three of the major lights can be seen at once. When anticipating reduced visibility or exceptionally clear skies, we should replace the nominal range with the luminous range.*