

## **Appendix F - Addition of Waypoints Along the Route**

After releasing the proposed route for public consideration and comment, the Coast Guard identified a concern with the route design that could potentially increase risk of collision for vessels navigating the route but using different methods of generating track lines. Adding waypoints to the final proposed two-way routes address this concern. This issue is somewhat complex and deals with nuances in navigation methods, inherent characteristics of map projections and spherical trigonometry. The following explanation illustrates the identified concern and the proposed solution.

A typical vessel navigation scenario would begin with the vessel planning the voyage from the starting point to the final destination. This process involves identifying and plotting on a chart the intermediate waypoint positions where course changes occur and determining the course (heading) to be steered between each of those waypoints. Most vessels will then follow these predetermined headings from waypoint to waypoint until reaching the intended destination. A vessel navigating in this manner is following a line of constant bearing (heading) known as a rhumb line. Rhumb lines are not technically straight lines, but rather slightly curved arcs along the earth's surface that follow an unchanging bearing.

Most nautical charts use a Mercator map projection because this particular projection has inherent characteristics that are well suited for vessel navigation. On mercator projection charts rhumb lines appear as straight lines and compass headings remain constant over the entirety of the chart. These features make the Mercator projection ideal for sea navigation because straight track lines are easy to plot and the navigator can easily determine the appropriate course and steer on this fixed heading until reaching the next waypoint. Use of NOAA's Mercator projection nautical charts and rhumb lines for navigation are widely adopted and most mariners do not utilize any other manner of navigation.

There is however, another method of navigation more commonly used by large vessels transiting great distances, such as transoceanic voyages. Great circle navigation uses a spherical trigonometry equation to calculate the shortest distance between two points on a sphere (the earth). The resulting great circle line is actually an arc along the surface of the earth connecting the two points by the shortest possible line. This great circle line is not the same as a rhumb line. The great circle line has a constantly changing bearing (heading), so to follow a great circle line a vessel must steer in a slightly different direction every few miles to follow the curve of the great circle route. Plotting this great circle line on a nautical chart is labor intensive because the transit is a true arc. It appears as a curved line on a Mercator projection chart. Manually plotting the great circle course requires the navigator to approximate this curved line on the paper chart by breaking the line into many short segments to create a series of shorter straight lines and then calculating the proper waypoints and headings for each. Once plotted, the navigator then follows these shorter segments as rhumb lines through a series of frequent but small course changes. Larger commercial vessels commonly use sophisticated navigation software to follow great circle routes in order to capitalize on the savings of

time and fuel that the shorter route offers, but most other vessels choose to follow the simpler rhumb line method.

The actual distance a vessel can save by following a great circle route vs. a rhumb line route is highly variable and depends on the direction, latitude and distance of travel. A vessel could shave 200-300 miles off an east/west transoceanic voyage spanning multiple thousands of miles or conversely save nearly no distance if the route is in a north/south direction.

When the Coast Guard initially developed coordinates for the proposed two-way route, we did not expect that these two methods of voyage planning would yield significantly different results since the route runs in a mostly north/south direction. Closer investigation revealed that was not the case. The southernmost leg of the proposed route is nearly 350 NM in length. The maximum divergence between a vessel track line generated using the great circle method versus the rhumb line method is near the halfway point of this leg, and is approximately two nautical miles. In a four-mile wide route, this can be significant particularly if the two vessels are traveling the route in opposite directions and using different methods of generating navigational track lines.

Ships navigating along a two-way route generally stay on the starboard (or right) side of the route. The Coast Guard expects that most mariners following the proposed four-mile wide two-way route would generate navigational track lines that would keep them in the middle of their respective sides. This affords a 2NM wide separation between opposing traffic utilizing the route, as well as at least a mile of sea room for situations where one vessel overtakes another travelling in the same direction.

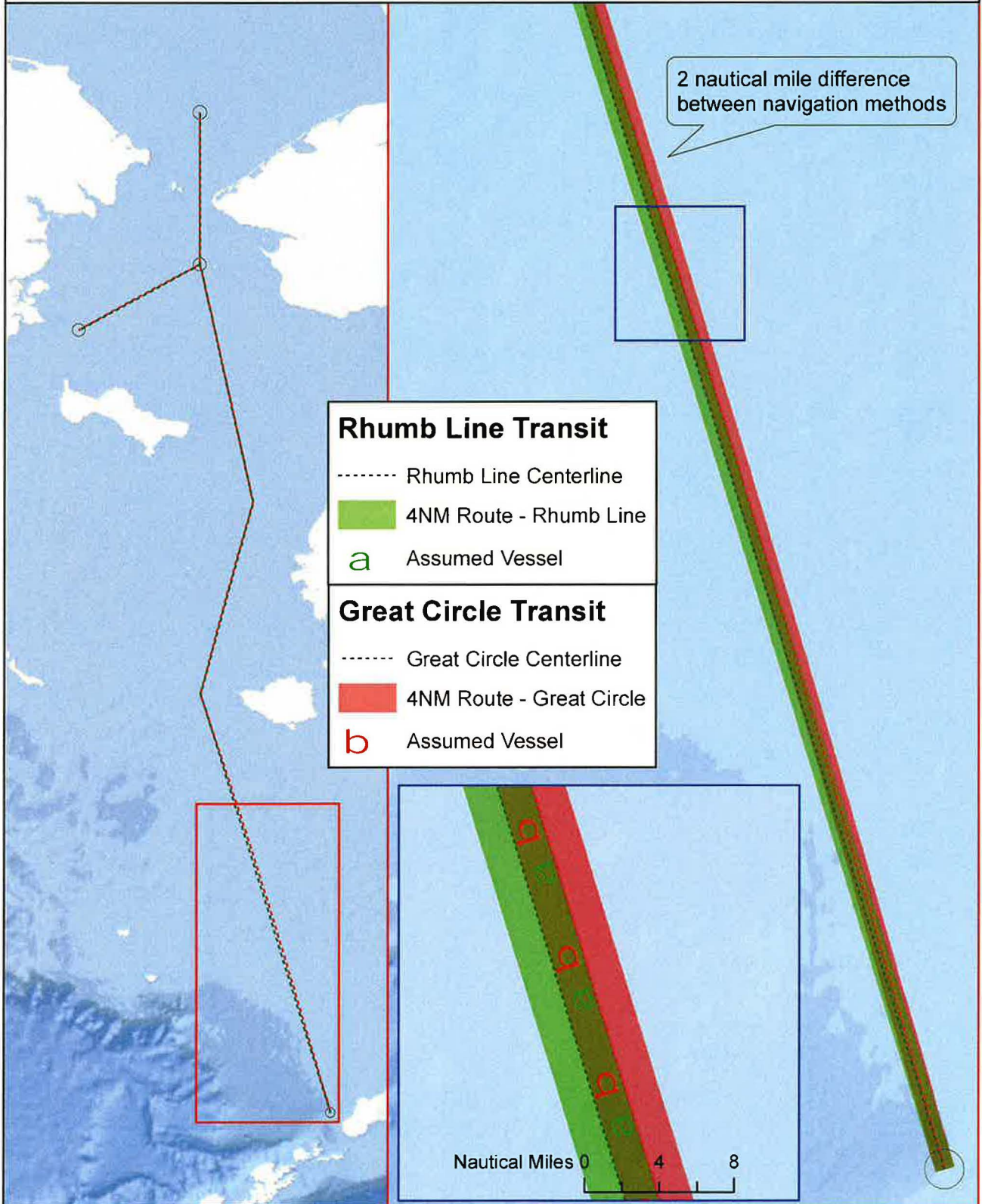
The worst-case scenario involves the southernmost leg of the route, a northbound vessel following a rhumb line track line and a southbound vessel following a great circle track line. If these vessels both generated track lines that started and ended in the middle of their respective sides, and met near the middle of that leg, the two-mile eastward deflection of the track line generated using the great circle method could put these two vessels in a "head on" collision situation. The following figure illustrates the difference between the two navigation methods.

It is important to note that the proposed route designed and initially proposed by the Coast Guard through the Federal Register used rhumb line methods to generate a route between the published corner points. It did not take into consideration the possibility that a vessel might use great circle navigation techniques. To mitigate, the Coast Guard is proposing to add four additional intermediate waypoints, displayed in a figure that follows. Shortening individual segments of the route minimizes the effect of vessels utilizing different navigational methods to the point where vessels should not have to take some corrective action to stay on the starboard side of the route. Essentially, vessels using the simpler rhumb line method will actually be following a series of courses that begin to approximate the great circle route.

NOAA nautical charts will display any routing measures as rhumb lines (straight lines) on the chart between the original and four additional waypoints. Charts will also display bounding lines to define the outer perimeter of the route. These bounding lines of the route should provide sufficient detail and

evidence to the mariner transiting via either navigation method whether or not they are remaining on the starboard side of the route. By 2014, when collection of hydrographic survey information began along the proposed route, the ships performing that work followed waypoints and tracklines that closely followed the great circle route. On charts that display hydrographic source information, mariners will also be able to see that the soundings along the proposed two-way route are of a more recent origin.

# Rhumb Line Navigation vs Great Circle Navigation



# Original Route Compared with Additional Waypoint Route

