

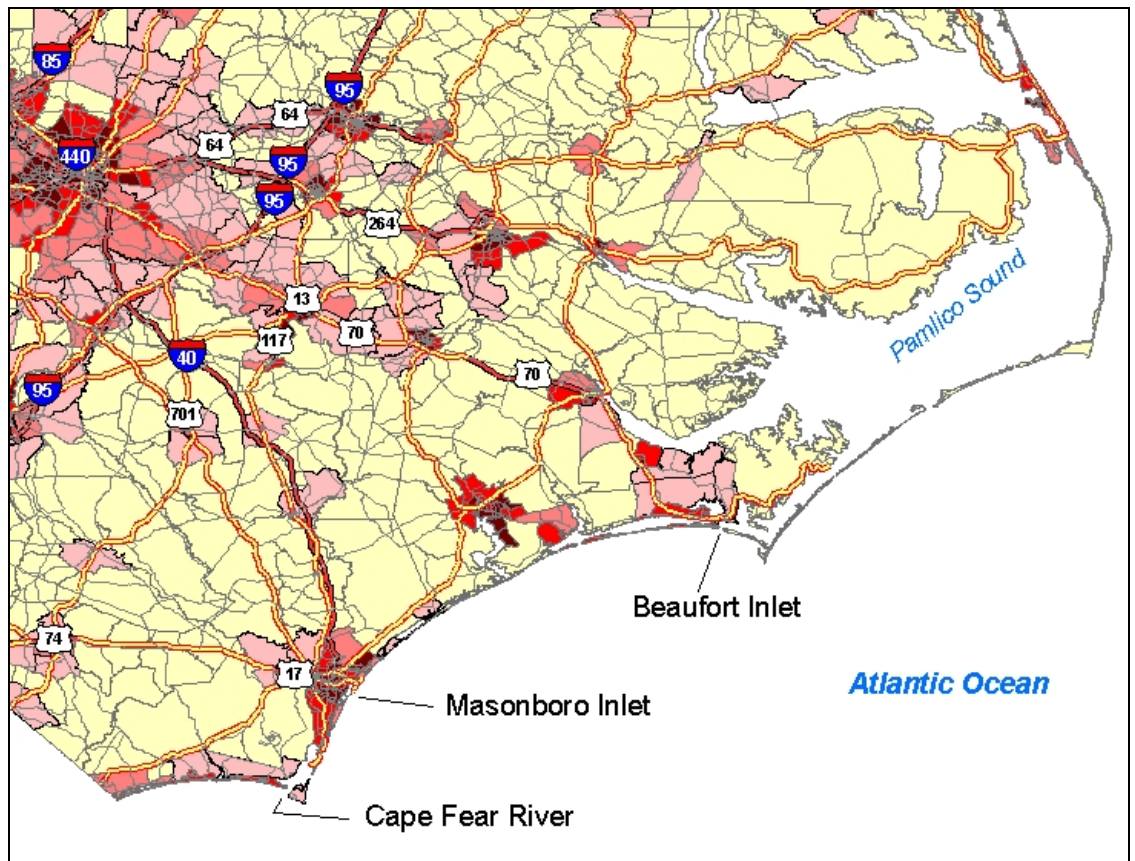


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Evaluation of Potential JHSV Port and Alternative Offload Sites in Coastal North Carolina

Andrew Morang and Donald T. Resio

August 2006



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Abstract: The purpose of this study was to evaluate conventional (port) and nonconventional offload sites for the Joint High Speed Vessel (JHSV) in coastal North Carolina, and compare the potential throughput rates at these sites to throughput rates typical of Joint Logistics over the Shore (JLOTS) operations conducted in exercises in Camp Lejeune. North Carolina was selected as a test site both due to its proximity to Camp Lejeune and also because of its environmental (geomorphic) similarity to many coastal regions in Asia. Another goal was to evaluate the quality and appropriateness of maps, bathymetry data, and aerial photography from various sources to conduct offload alternatives studies with the intent of eventually applying these techniques to other (overseas) sites.

The analysis of offload sites demonstrated that the total length of shoreline suitable for the JHSV to unload in North Carolina was surprisingly limited. In the Cape Fear River estuary, the total length accessible either directly or via 180-m causeway was 27.9 km; in Morehead City/Beaufort area, 5.4 km; and in Masonboro Inlet, 1.0 km. The reasons for the limited access are both geological and developmental. On this low-gradient, soft sediment, trailing edge coast, only these three inlets are dredged deep enough to accommodate the JHSV, which requires a channel of 4.6 m. Once within the inlets, the only water deep enough for the JHSV is in the dredged navigation channels and some naturally-deep areas near the mouth of the Cape Fear River. Finally, offload sites must be within a suitable distance from paved roads or railroads (in this analysis, 150 m), and these sites, too, proved to be unexpectedly limited. Despite the flexibility of the JHSV, planners considering operations in lesser-developed parts of the world will have to contend with even more limited infrastructure, along with geological and oceanographic constraints.

JLOTS exercises are particularly sensitive to wave climate and are restricted to significant wave heights less than 0.9 m, the lower limit of sea state 3. Throughput diminishes rapidly when seas are above 0.6 m. Based on hindcasts of Atlantic waves, the likelihood of the North Carolina coastal waters not experiencing sea state 3 waves in March for 1 day is only 0.31. For a 10-day period, the likelihood drops to only 0.03. Therefore, conventional JLOTS is not a good option for force projection in this area in March.

Modeling JLOTS versus JHSV throughput for the three North Carolina entrances demonstrates that as few as one or two JHSVs can potentially provide vehicular throughput comparable to a conventional "bare-beach" JLOTS operation, even at distances between the coastal discharge site and an Intermediate Staging Base (ISB) of up to 400 nautical miles. This is striking when one considers the great differences in the naval assets and personnel required to accomplish each of these operations. Another advantage of the JHSV is that it has the potential to continue up to sea state 6; whereas, conventional JLOTS continues only up to sea state 3. Therefore, the JHSV operations are potentially much less susceptible to weather disruptions.

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Preface¹

Since 2002, the U.S. Marine Corps (USMC) and the U.S. Army have been testing a new class of vessel that could significantly increase both the number of sites available for force projection and the potential throughput rates at these sites. Analyses have shown that these High-Speed, Shallow-Draft (HSSD) vessels, the Marines' High-Speed Connector (HSC) and the Army's Theater Support Vessel (TSV), could substantially reduce force closure times in theaters of operation. The TSV and HSC programs have now been merged into a single, joint program, the JHSV (Joint High Speed Vessel) program.

Work on this report (funded under USMC MIPR to ERDC – M9545004MPR43M8) represents a pilot study conducted at the Coastal and Hydraulics Laboratory (CHL), U.S. Army Engineer Research and Development Center, Vicksburg, MS, with two primary focus points:

- a. Evaluation of nonconventional offload sites for the JHSV in coastal North Carolina.
- b. Comparison of potential throughput rates at these sites to throughput rates typical of Joint Logistics over the Shore (JLOTS) operations conducted in exercises in Camp Lejeune.

This study area in North Carolina is of interest both due to its proximity to Camp Lejeune and also because of its environmental (geomorphic) similarity to many coastal regions in Asia (trailing-edge, low gradient shores with broad continental shelves, marshy, low coastal plains, and drowned river valleys).

This report was prepared by Drs. Andrew Morang and Donald T. Resio of CHL.

Work was performed under the general supervision of Dr. Yen-Hsi Chu (retired) and Edmond J. Russo, Chief, Coastal Engineering Branch, CHL, Dr. William D. Martin, Deputy Director, CHL; and Thomas W. Richardson, Director, CHL.

The authors wish to thank the following individuals and organizations for data and assistance with this project:

- a. Richard P. Lockwood, U.S. Army Military Ocean Terminal, Sunny Point, Southport, NC.

¹ Adapted from U.S. Army Acquisition Corps Web page: http://asc.army.mil/docs/pubs/alt/current/issue/web_edition/03_Force_Projection_From_the_Sea.cfm 25 Jan 2005.

b. Joseph Wade, Howard Varnam, and Robert Sattin, U.S. Army Engineer District, Wilmington, Wilmington, NC.

Dr. James R. Houston was Director of ERDC, and COL Richard B. Jenkins was Commander and Executive Director.

1 Introduction

The purpose of this study was: (a) to develop and test a methodology to identify potential offload sites for the U.S. Marine Corps' (USMC) Joint High-Speed Vessel (JHSV) based on remote-sensing and other forms of commonly-available topographic and geomorphic data and (b) to compare potential throughput rates at these sites to those obtainable through conventional "bare-beach" Joint Logistics Over-the-Shore (JLOTS). This report describes an initial test case to examine potential sites on the Atlantic coast of North Carolina. The project included several phases as follows:

- a.* Evaluate the quality and appropriateness of maps, bathymetry data, and aerial photography from various sources to conduct offload alternatives studies.
- b.* Develop methods to organize and display the data.
- c.* Identify inlets in coastal North Carolina accessible by the JHSV and identify ports and nonport sites to offload cargo.
- d.* Based on field verification, evaluate validity of suggested sites.
- e.* Estimate potential throughput rates for JHSVs at these sites and compare these rates to those obtainable in "bare-beach" JLOTS operations.

Documentation of the work conducted for phases 1-4 is contained in Chapters 2-4 of this report. Description of the work on phase 5 is in Chapter 5 of this report. Chapter 6 contains a summary of all work and recommendations for directions in this area of analysis.

2 North Carolina Study Areas

Background

The Atlantic shore of North Carolina consists of a series of barrier islands and spits that separate the open ocean from broad coastal ponds (known as sounds) and marsh-wetland complexes (Figure 1). Numerous inlets and river mouths interrupt the barriers, but only four have channels deeper than 4.6 m (15 ft). One of these, Oregon Inlet, is notorious for its shifting and unstable channels and is unsuitable for the JHSV. Two others, the Cape Fear River and Beaufort Inlet, have deep-draft navigation channels that are dredged by the U.S. Army Corps of Engineers (USACE). The last, Masonboro Inlet, is stabilized by rock jetties and is also regularly dredged.

Area A: Cape Fear River Estuary

The Cape Fear River winds for 300 km (190 miles) through the heart of the North Carolina Piedmont, crosses the coastal plain, and empties into the Atlantic Ocean near Southport (Figure 2). The river begins near Greensboro and Winston-Salem at the junction of the Deep and the Haw rivers. The Black River joins Cape Fear River 24 km (15 miles) above Wilmington, and the Northeast Cape Fear River enters the system at Wilmington. The 56 km (35 miles) of river between Wilmington and the ocean is called the Cape Fear Estuary because of the tidal influence and saline waters. This area of the river is important for saltwater fauna because of its function as a nursery for juvenile fish, crabs, and shrimp. The Cape Fear is North Carolina's largest river system; its basin covers 23,000 sq km (8,900 square miles), encompasses streams in 29 of the state's 100 counties, and is the most industrialized of North Carolina's rivers.¹

The area evaluated for JHSV potential was the Cape Fear River Estuary, between the Atlantic Ocean mouth and the city of Wilmington. The study area is between latitudes 33.8° and 34.3°N and approximately 79.5°W longitude. The estuary runs north-south and is separated from the Atlantic Ocean to the east by a coastal plain and barrier complex. Popular resorts are located on the barrier including Carolina Beach and Kure Beach. Much of the terrain along the Cape Fear Estuary is low and marshy, and numerous low islands consisting of dredged material line the navigation channel.

¹ Adapted from Lower Cape Fear River Program Web page, <http://www.uncwil.edu/cmsr/aquaticceology/lcfrp/> 24 November 2004.

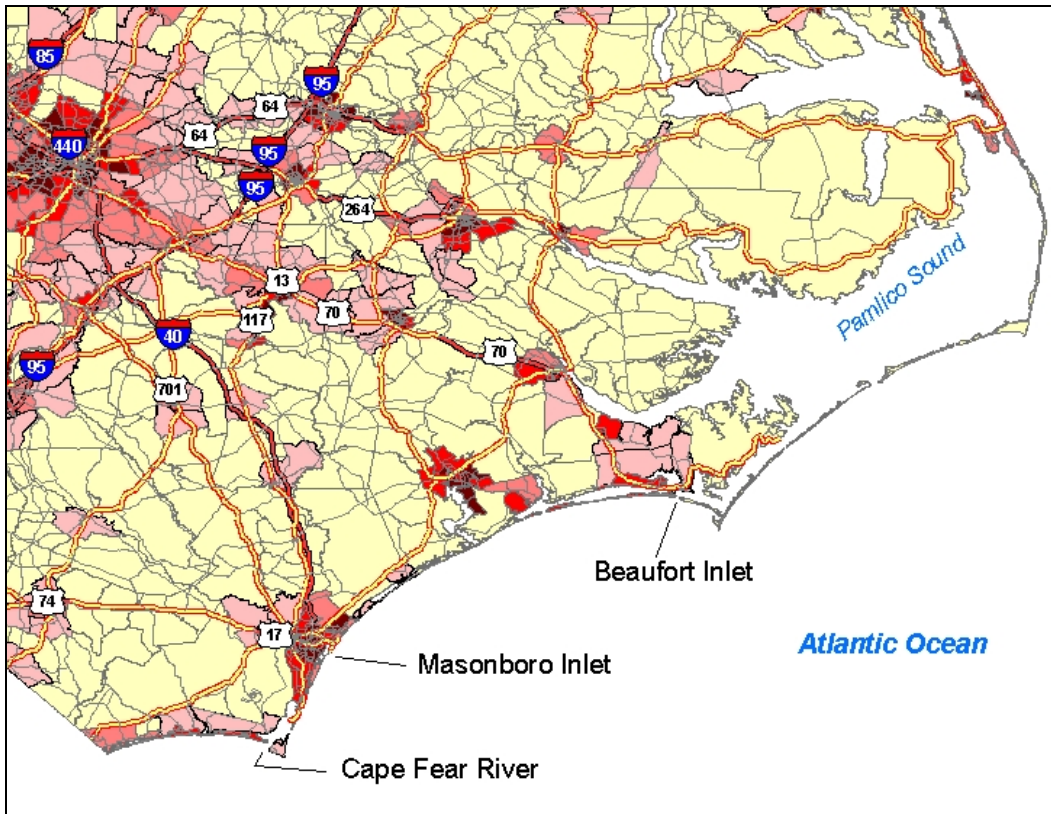


Figure 1. Coastal North Carolina has three inlets suitable for JHSV passage

The Cape Fear River Navigation Project is maintained by the USACE. The dredged channel extends from the ocean bar southwest of Bald Head Island to beyond the city of Wilmington, a total distance of over 48 km (30 miles). Channel depth currently is 13.4 m (44 ft) from the ocean to the Horseshoe Shoal area southwest of Kure Beach. Proceeding further north, the channel depth is 12.8 m (42 ft) as far as the Cape Fear Bridge in Wilmington. These depths were achieved between 2000 and 2004 by a series of dredging contracts under the Wilmington Harbor, NC - 96 Act Project, which was authorized by the Energy and Water Appropriations Bill of 13 October 1998. Under natural conditions, the Cape Fear River was less than 4 m (11 ft) deep, and for almost 180 years, the USACE has labored to increase the channel depth and stabilize its position (Appendix A).

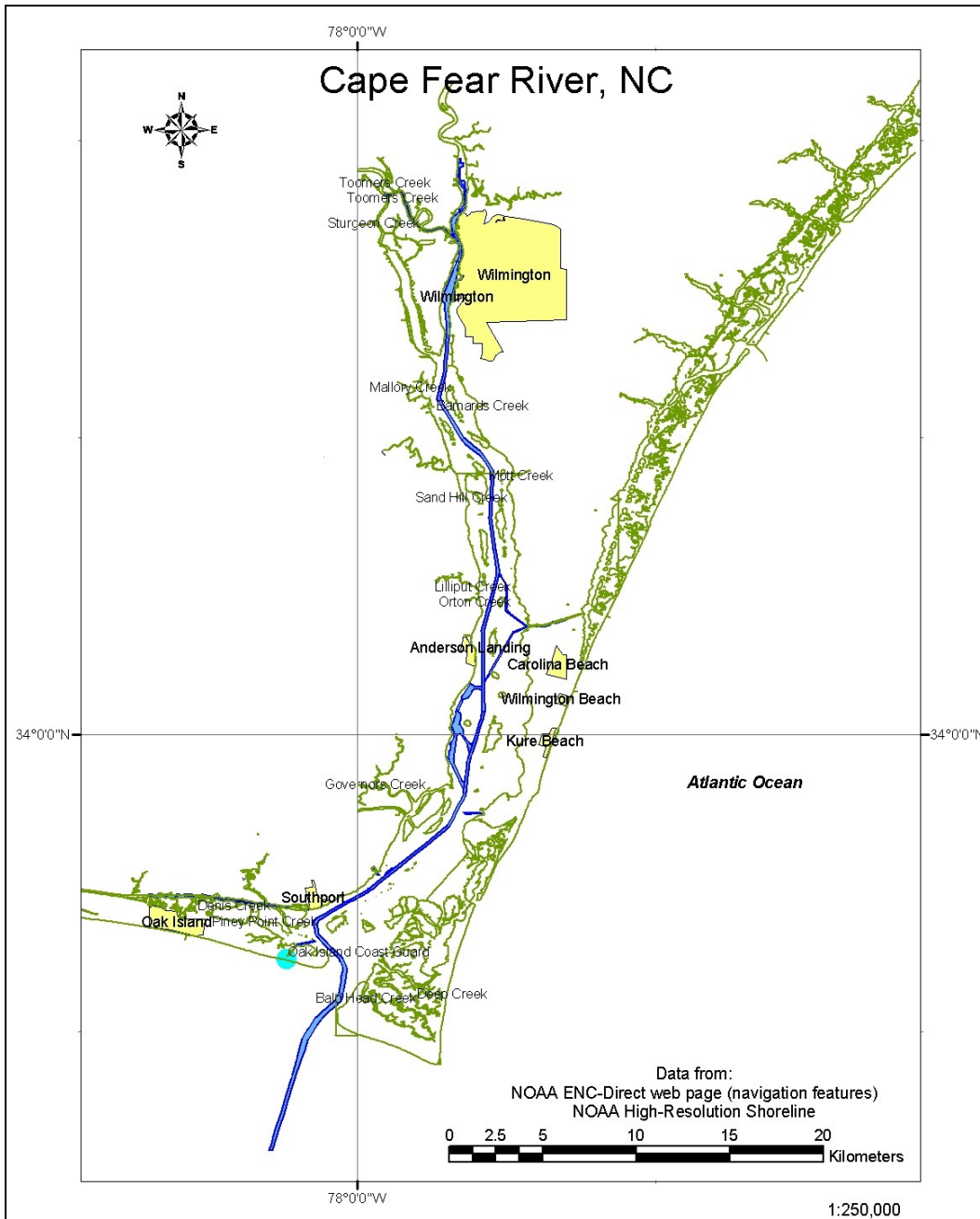


Figure 2. Study area A, Cape Fear River Estuary

Area B: Beaufort Inlet/Morehead City

Located just west of Cape Lookout, Beaufort Inlet is sheltered from the open Atlantic to the east but is exposed to south and southeast waves. The barrier island to the west, Bogue Banks, separates the Atlantic from Bogue Sound, while to the east, Shackleford Banks provides protection to the historical city of Beaufort (Figure 3). A Federal navigation project maintains a deep-draft channel through the inlet to provide shipping access to Morehead City.

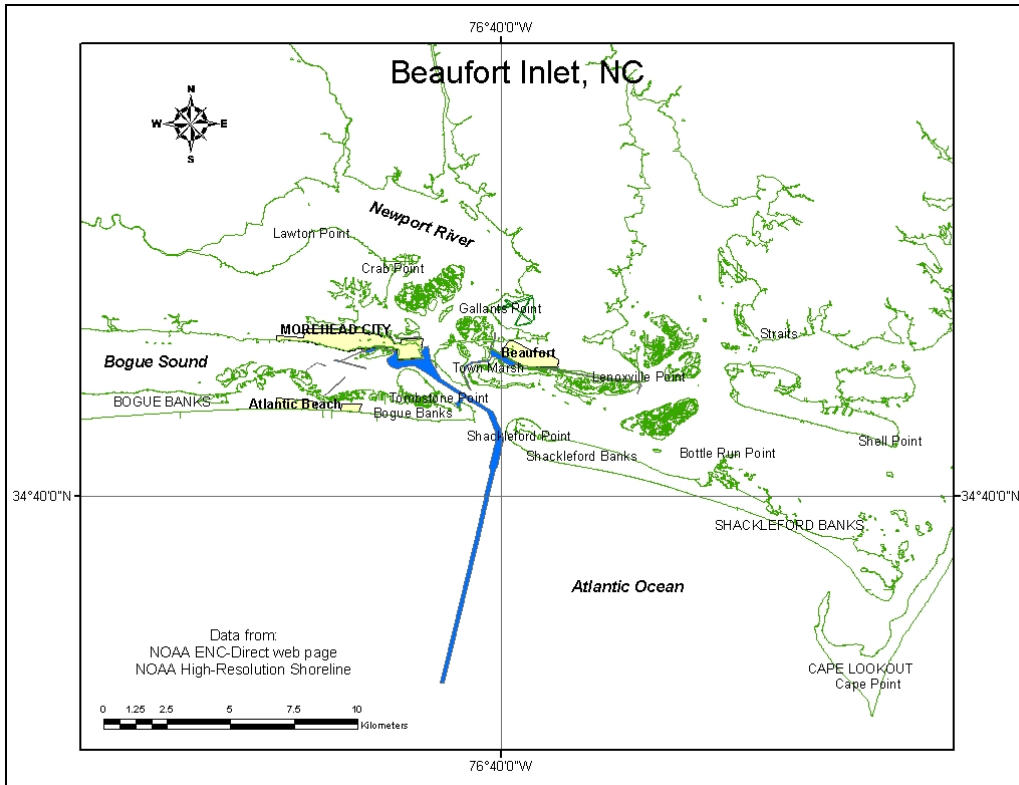


Figure 3. Study Area B, Beaufort Inlet and vicinity

The city of Beaufort has a colorful history. Known as “Fish Town” in the early 1700s when Blackbeard frequented the coast, “Beaufort Town” was established as a seaport with the right to collect customs in 1722. During the American Revolution, it was the state’s third largest port. Because of expansive stands of timber in eastern North Carolina, Beaufort’s early trade centered on lumber products. These were shipped from rich Newport River plantations to the West Indies in exchange for glassware, cloth, furniture, coffee, rum, and slaves. Beaufort continued to prosper into the nineteenth century as a port and as an agricultural, commercial, and governmental center. Fort Macon, a large brick fortress, guarded the eastern end of Carteret County. Beaufort became a favorite

summer retreat for the well to do.¹ Beaufort was relatively unscarred by the Civil War because of its occupation by Union forces. Following the war's conclusion, Beaufort again resumed its importance as a summer retreat. Trade was strong for a time; with lumber, barrel staves, rum, and molasses as Beaufort's most important exports. However, the port declined as a trade center, and commercial fishing became its primary business. Beaufort served as homeport for a fishing fleet and as the site of processing plants for the menhaden trade. In the 1970s, Beaufort became a popular summer resort as the town and waterfront were restored. The waterfront is now lined with docks and marinas for sport fishermen.

In contrast to Beaufort, Morehead City is one of North Carolina's two deep-water ports. It also serves as the port of the Second Division of the USMC at Camp Lejeune. Morehead City serves as an early example of urban planning in the United States. John Motley Morehead, governor of North Carolina from 1841 to 1845, envisioned "a great commercial city" where Shepherd's Point intersected with the Newport River and Beaufort Inlet. The first lots were sold at public auction in 1857. When the railroad was completed a year later, the area seemed destined for rapid development as a major port. However, the Civil War interrupted Morehead City's development, and the town languished. Following the war, the shipping terminal deteriorated, but the railroad continued hauling vast quantities of seafood inland.² World War II brought an increase in shipbuilding and industry, and in recent years, a large charter-fishing fleet has developed.

Morehead City's port is located 6 km (3.7 miles) from the open sea and offers 1,700 m (5,500 ft) of continuous wharf. The deck height averages 3 m (10 ft) above mean low water (MLW). The Federal project consists of a 14-m (47-ft) channel across the ocean bar, and channel depths of 13.7 m (45 ft) mean lower low water (MLLW) across the inner harbor and the turning basin.

Area C: Masonboro Inlet

Masonboro Inlet breaches the coastal barrier northeast of Wilmington. The inlet separates the developed barrier of Wrightsville Beach from undeveloped Masonboro Island (Figure 4). Masonboro Island, west of the inlet has no road access and the channel is not dredged. The USACE dredges the inlet and part of Banks Channel to allow pleasure craft, fishing boats, and the U.S. Coast Guard's vessels to berth at Wrightsville Beach.

Wrightsville Beach has long been a popular and fashionable vacation resort. A 1920s post card declared, "Wonderful Wrightsville Beach, the Atlantic City of the South, an island 1.5 miles from the main land is unique, being free from mosquitoes and flies, offers splendid entertainment features, motion pictures over the waves, concerts, music for dancing, surf and still water bathing, boating,

¹ Historical information adapted from: <http://www.beaufort-nc.com/history/bn-his02.htm>, 21 December 2004.

² Historical information adapted from: <http://www.morehead.com/history/>, 22 December 2004.

sailing, fishing, golf and motoring on splendid drives.”¹ The channel side of the town is now lined with docks for pleasure craft, and this entire stretch of barrier is so developed, it is essentially urban.



Figure 4. Masonboro Inlet, NC, town north of inlet is Wrightsville Beach

¹ Wrightsville Beach merchants' Web page, <http://www.wrightsville.com/wbcchis.htm>, 30 December 2004.

3 Data Sources

Web-Based Data Sources

Numerous mapping tools, accessible to anyone with Internet service, now exist on the World Wide Web. Some of these sites, like Mapquest®, allow a user to generate a map when he searches for a particular address or town, but, these sites are not designed to serve as a source of data that the user can download to his computer. A second class of Web sites are aimed at a more technical user and not only allow him to generate a map online based on particular criteria, but also let him download the underlying data for use in his own Geographic Information System (GIS) application. The quality of this data is variable. This author found that most of the sites were suitable for a general overview of a broad area, such as a state or county, but contained insufficient detail for the purposes of the JHSV analysis. The following paragraphs list some of the Web sites used in this study.

National Atlas of United States

The National Atlas of the United States® is designed to provide a reliable summary of national-scale geographical information. Though it does not provide detailed map information, the Atlas directs users to other sources for this information. The site is a convenient source of some types of data (e.g., invasive species distributions) that might be difficult to obtain without being a specialist in that particular field. The shoreline data are especially crude and borders on useless. This site may be oriented to school or nontechnical users.

Site address: <http://nationalatlas.gov/>.

TerraServer

TerraServer-USA, sponsored by the U.S. Geological Survey (USGS) and Microsoft Research, is a remarkable resource with topographic maps and aerial imagery available for the entire United States. Maps and imagery can be downloaded at various scales.

The aerial photographs are in the form of digital orthophoto quadrangles (DOQ) and are orthorectified so that they have the geometric properties of a map. The DOQs on the TerraServer-USA site are 1-m resolution images, which is somewhat coarse for evaluating JHSV landing sites. Photograph date varies around the country. The Southport area had March 2000 coverage.

TerraServer's topographic maps are digital raster graphic (DRG) versions of the standard USGS topographic maps. Map dates are typically post-1990. However, the underlying data, such as roads, shorelines, or urban areas, may be much older. These USGS topographic maps appear to be the source used by the National Imagery and Mapping Agency (NIMA) for the Compressed ARC Digitized Raster Graphics (CDRG).

Site address: <http://terraserver-usa.com/>.

The international site, TerraServer@.com, has maps and imagery available for much of the world. Coverage is variable and is fee-based. This resource could be useful for future JHSV studies.

Site address: <http://www.terraserver.com/>.

The National Map

"The National Map is a consistent framework for geographic knowledge needed by the Nation. It provides public access to high-quality, geospatial data and information from multiple partners to help support decision making by resource managers and the public."¹ This site, hosted by the USGS, provides similar data to that available on the TerraServer and the National Atlas, but with additional data layers such as road networks, LANDSAT7 satellite imagery, and various land cover files. The DOQ imagery is obtained from TerraServer as required. The LANDSAT7 resolution appears to be at least 15 m, too coarse for the JHSV evaluation. The site listed the availability of North Carolina 2-ft orthoimagery, but the images did not load for this author.

Site address: <http://nationalmap.usgs.gov/>.

National map interactive viewer: <http://nmviewogc.cr.usgs.gov/viewer.htm>.

Seamless Data Distribution System

The Seamless Data Distribution System is hosted by the USGS Eros Data Center. The interface is similar to the National Map, and it is unclear exactly how this server and the National Map differ, other than providing some different data layers. The digital ortho quarter quadrangles (DOQQ) are finer resolution than the DOQs from TerraServer and could be useful for the JHSV study (Figure 5). In these images, wharfs and piers are clearly visible, and vegetation is distinguished by the red color.

Site address: <http://seamless.usgs.gov/>.

Seamless interactive viewer: <http://seamless.usgs.gov/website/seamless/viewer.php>.

¹ National Map Web page, <http://nationalmap.usgs.gov/>, 30 November, 2004.

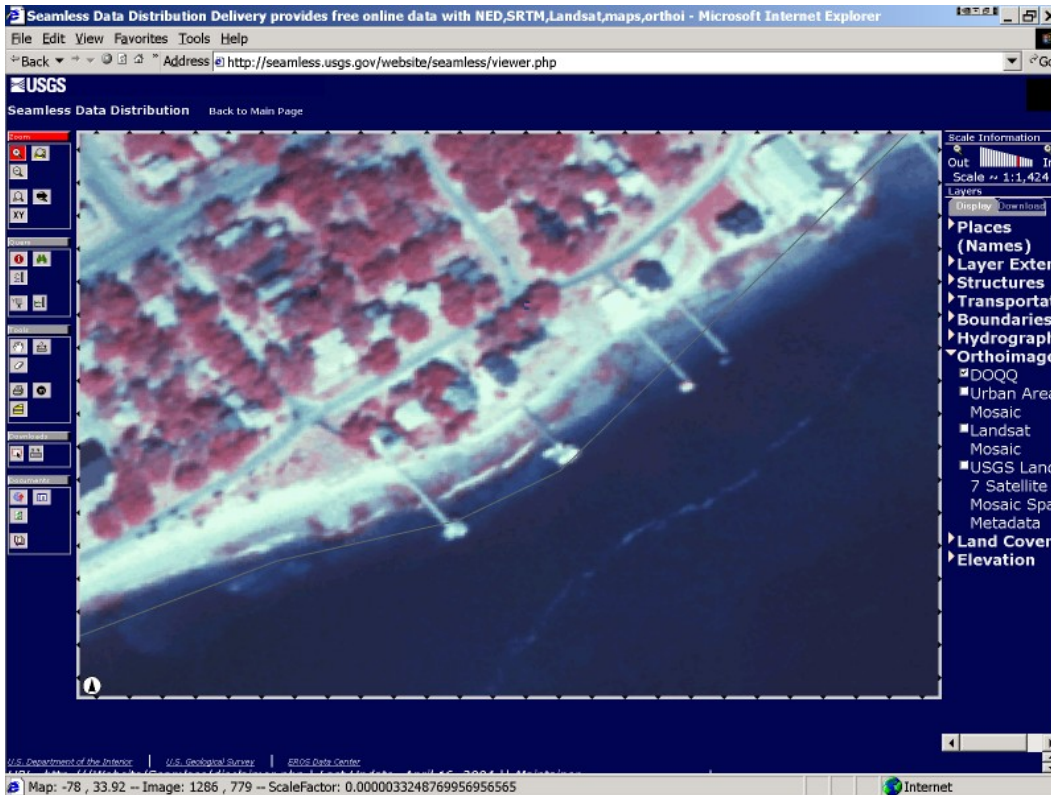


Figure 5. Example of DOQQ ortho-imagery on USGS Seamless Distribution System. All USGS online map tools use a similar interface, with data layers listed on right, and user tools on left. The area in frame is town of Southport, near mouth of Cape Fear River

NC OneMap

NC OneMap is a data coordination and distribution system for the state of North Carolina. Supported by various state agencies, counties, and local governments, it contains a wealth of cadastral, transportation, land use, and demographic data. The interactive viewer resembles the National Map previously described (Figure 6). The Fall 2003 orthophotos with 2-ft resolution are downloaded from a USGS server when requested from NC OneMap. These photographs were some of the most valuable data for this project because they were much finer resolution than the DOQ and DOQQ orthophotos and revealed more details of vegetation, structures, and infrastructure along the coast.

Site address: <http://www.nconemap.com/>.

OneMap interactive viewer: http://gisdata.usgs.net/website/NC_OneMap/viewer.asp.

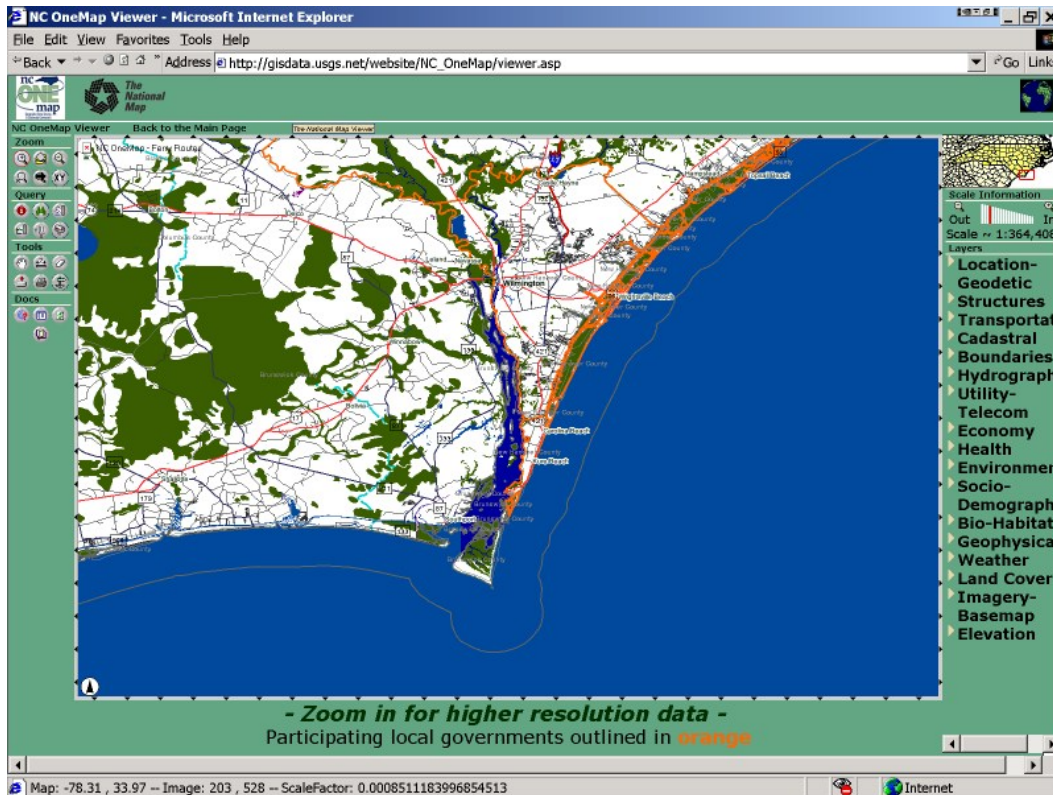


Figure 6. NC OneMap data viewer, showing Cape Fear River

North Carolina Department of Transportation

The North Carolina Department of Transportation (DOT) hosts an on-line data distribution center. From here, a user can download ArcView shapefiles of highway, local roads, railroads, airports, and other features. The road files were more detailed than the equivalents tested from other sources, and the roads overlay the 2003 orthophotos almost perfectly.

Site address: <http://www.ncdot.org/planning/tpb/gis/DataDist/DataDist.html>.

Nautical Charts

Raster-format charts

The National Oceanic and Atmospheric Administration (NOAA) prepares and distributes nautical charts for United States waters. Paper charts can be purchased through numerous vendors. Electronic versions are distributed by a commercial company, Maptech®, Inc.¹ The charts come bundled on Compact Disk (CD) in regional groupings of 10-80 charts and are compatible with most navigation programs. The files are in Maptech BSB format and are accessed

¹ Maptech®, Inc., 1 Riverside Drive, Andover, MA 01810: www.maptech.com.

with the company's software. Charts can be imported into ArcView GIS software, but are only raster images (i.e., pictorial data). Therefore, individual elements, like water depth soundings, are simply images as seen on a paper chart, not vector data points. Maptech's international charts may be valuable for future phases of the JHSV study if digital vector files are unavailable.

Vector-format charts

The ENC® Direct to the GIS Web page is NOAA's source of nautical chart data in vector format. The interface resembles the USGS Seamless Distribution System, where a user selects the area of interest on an outline map (Figure 7). He then selects the type of data that he needs to download. The NOAA ENCs are in International Hydrographic Organization (IHO) S-57 format, which is the data standard developed by the IHO to be used for the exchange of digital hydrographic data. NOAA ENCs can also be used in Geographic Information Systems (GIS). Unlike the raster charts previously described, these ENC files are vector elements, meaning they can be individually selected in the GIS software and manipulated or modified as needed. The individual layers use the IHO S-57 naming convention. These vector charts proved to be some of the most valuable data for this project.

Site address: http://nauticalcharts.noaa.gov/csdl/ctp/encdirect_new.htm.

ENC Direct interactive viewer: <http://ocs-spatial.ncd.noaa.gov/website/test/viewer.htm>.

IHO address: <http://www.iho.shom.fr/>.

Bathymetry Data

NOAA

NOAA bathymetry data is available from the National Geophysical Data Center via an interactive database retrieval system called the GEOphysical DATA System for Hydrographic Survey Data (GEODAS). GEODAS is distributed on CD or online. Table 1 lists the available hydrographic surveys for the three North Carolina study areas.

Site address: <http://www.ngdc.noaa.gov/mgg/geodas/geodas.html>.

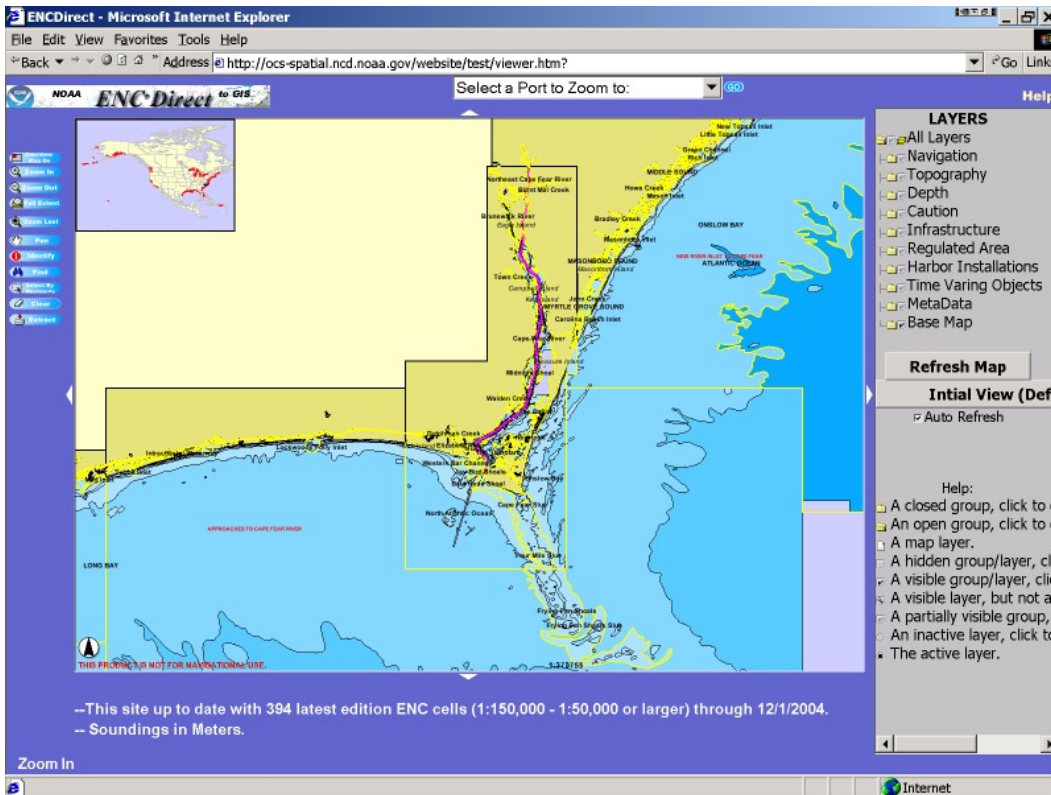


Figure 7. NOAA ENC® Direct interactive viewer Web page showing Cape Fear River study area

Table 1 NOAA Digital Hydrographic Surveys		
Study Area	Survey Number	Survey Date
Cape Fear River	H09359	1973, 1974
	H09489	1974, 1975
	H09500, H09501, H09502	1975
Beaufort Inlet	H09431, H09433	1974
	H07963	1952, 1953
Masonboro Inlet	H09396	1974

USACE

The U.S. Army Engineer District, Wilmington (hereafter, Wilmington District) surveys Federal navigation projects and manages dredging and maintenance of navigation channels. The navigation branch operates a Web page from which electronic charts of survey soundings are available. Within most inlets and rivers, the USACE only surveys the authorized navigation channel, not the entire water body from bank to bank. Universities or state agencies may have conducted surveys in some areas, but the data are difficult to locate. As a result,

in many water bodies, there is no reliable, recent bathymetry data available. For example, in the Cape Fear Estuary, there appear to be no post-1973 soundings covering the shallow portions of the river. However, the USACE does survey some limited areas bank to bank, such as the anchorage basin off the city of Wilmington. Here, the August 2004 chart shows water depths great than 9 m (30 ft) within 30 m (100 ft) of the west shoreline south of the Cape Fear Memorial Bridge. A site visit confirmed that ocean-going vessels moor along the west side of the river, as well as on the east shore at the Port of Wilmington.

Files with MicroStation CAD drawings can be downloaded from the Web page. Bathymetric soundings are available on request from the Wilmington District.

Site address: <http://www.saw.usace.army.mil/nav/>.

Other Data Sources

ESRI data and maps

The manufacturer of ArcView® GIS software, Environmental Systems Research Institute (ESRI), supplies a variety of data on CD to ArcView purchasers. The CDs are a handy source to create maps quickly and assess road networks and the locations of urban areas, parks, wetlands, and political entities. The material that ESRI has provided on CD has varied over the years, and it is worthwhile to keep CDs from older versions of the software. The shoreline files resemble the NOAA medium vector digital shoreline (nominal scale, 1:70,000). The U.S. coverage is much more comprehensive than the international, but other international data can be purchased from ESRI or various partners.

Site address to purchase U.S. and international data: <http://www.esri.com/data/index.html>.

NOAA medium Resolution Digital Vector Shoreline (USA only): <http://sposerver.nos.noaa.gov/projects/shoreline/shoreline.html>.

Digitized raster graphics

The National Imagery and Mapping Agency issues Compressed ARC Digital Raster Graphics (CDRG) at different scales for much of the world. The set of two CDs that cover North Carolina is Series CDRG, Item SEASTUS50K, Edition 001. The maps appear to be based on USGS topographic maps, but have been redrawn in a different cartographic style. The files on the CDs can be opened with the Military Analyst Extension of ESRI's ArcGIS software. When comparing the 0.6-m (2-ft) aerial orthophotos with the 1:50,000 CDRG, it is obvious that photographs show much more detail of the morphology and flora along the shore (Figures 8 and 9). In addition, the CDRGs contain some errors. For example, the state docks at the Port of Wilmington have been extended south since the CDRG was prepared.

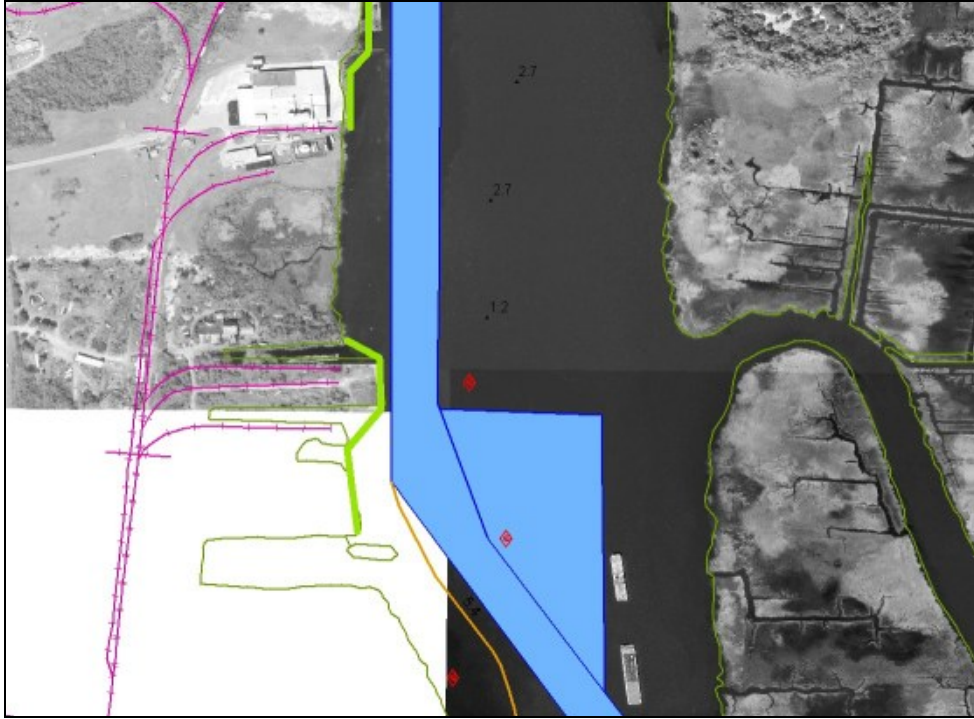


Figure 8. Example of NC 2-ft orthophoto, showing a portion of Cape Fear River. Green lines are areas where JHSV can unload. Fairway (blue area) from ENC-Direct database, railroad lines from NC DOT, and shoreline from National Shoreline Management Study



Figure 9. Detail of CDRG 1:50,000 raster graphic for same section of Cape Fear River shown in previous figure

Shoreline data strings

Trustworthy shoreline data are often difficult to obtain. Since the mid-1990s, various Federal, state, and local agencies have been mapping the shoreline using historical sources as well as new LIDAR data and aerial photography, but the results are diffused through various publications and Web sites, and the shoreline data have been presented in various formats, projections, and coordinate systems. The most comprehensive attempt to compile United States shorelines in one standardized format has been sponsored by the USACE's National Shoreline Management Study (NSMS).

The North Carolina shoreline was compiled by NOAA's Coastal Services Center and is a composite of shorelines from coastal survey maps dated 1930 to 1994.¹ NSMS supplied this composite in the form of ESRI shape files, which were imported into the GIS projects.² Because of the range of dates of the original maps, the NOAA shoreline cannot be used without checking the date of the data strings in the area of interest. For example, in the Cape Fear area, the shoreline matched the 2003 North Carolina orthophotos reasonably well, but differed in minor details, primarily in marshy areas (Figure 6). In the Beaufort area, the shorelines were dated 1946 and 1973 and differed in many locations from the NOAA vector hydrographic chart shore. At Masonboro Inlet, the ocean shoreline was from 1972, while the shoreline for the bays and islands was dated 1933. The new high-resolution shoreline data are much more detailed than NOAA's older medium-resolution (1:70,000) vector shoreline but, in some areas, appears to be based on the same original data sources (e.g., historical U.S. Coast and Geodetic Survey T-sheets).

Site address: <http://www.iwr.usace.army.mil/NSMS/nsmshomeframeset.html>.

Port Information

On-line sources

North Carolina State Ports Authority operates the Ports of Wilmington and Morehead City. Wilmington's facilities are on the east side of the Cape Fear River about 42 km (26 miles) from the Atlantic Ocean, south of the city of Wilmington. The port's Web page contains detailed information on the facilities, cargo capacity, and channel dimensions. The Web site includes figures showing the location of berths, roads, and buildings, and states that dock height averages 3.7 m (12 ft) above MLW.

¹ Stauble, D. (2004). "Development of a national-scale inventory of shoreline change data for identification of erosion and accretion," National Shoreline Management Study Draft Working Paper, January 2004, Institute for Water Resources, U.S. Army Corps of Engineers, Alexandria, VA, available online, <http://www.iwr.usace.army.mil/NSMS/nsmshomeframeset.html>, 6 December 2004).

² Data provided by Dr. Donald Stauble, Coastal and Hydraulics Laboratory, U.S. Army Engineer Research and Development Center, Vicksburg, MS, 15 November 2004.

Site address: <http://www.ncports.com>.

The U.S. Army's 597th Transportation Group operates the Military Ocean Terminal Sunny Point (MOTSU) on a 16,000-acre Army-owned site on the west side of the Cape Fear River. It is the Army's primary east coast deep-water terminal and the key Atlantic Coast ammunition shipping facility. The terminal has three concrete wharfs, of which the southern two are dredged to 11.58 m (38 ft). Because of its military importance, information on the docks is difficult to find in public sources. The most detailed public information is on the globalsecurity.org web page. Several Army Web sites discuss environmental programs at the terminal. During a site visit, the author measured the docks as being about 2 m (7 ft) above high water, while the elevated hardstand areas were about 3.6 m (12 ft) above high water.

Site address: <http://www.globalsecurity.org/military/facility/sunny-point.htm>.

Proprietary databases

The Lloyds Register Fairplay is a database of ports and terminals.¹ For civilian customers, the database is supplied on CD and loaded on the users' computer. For Department of Defense users, the Fairplay database is available online via the Single Mobility System. "The Single Mobility System (SMS) embodies the Mobility Access Portal concept, a Web-based interface or "doorway" to other mobility databases."² The information on North Carolina ports was scanty. The SMS listed Moorhead City and the Sunny Point Army Terminal, but the Port of Wilmington, by far the largest port in North Carolina, was not listed. Few specifics were provided on the capacities of the Sunny Point terminal, but more details were shown for Moorhead City. For U.S. ports, public sources seem to offer more useful information.

Site Address: <https://sms.transcom.mil/sms-perl/SMSWEBStart.pl> (login and password required, only available to Department of Defense users).

¹ Lloyd's Register-Fairplay, 8410 N.W. 53rd Terrace, Suite 207, Miami, FL 33166, USA.

² SMS help page, <https://sms.transcom.mil/sms-perl/smshelpmain.pl>, 1 December 2004.

4 Visual Interpretation

Method

The first phase of the analysis was based on visual interpretation of aerial photographs, NOAA navigation data, and the North Carolina road and railroad data. The analyst viewed the ArcGIS screen at a scale of between 1:6000 and 1:10,000 and used the drawing tool to draw polylines along the shoreline. The polylines were color coded to represent the suitability of the terrain for offloading the High Speed Connector. The ArcGIS distance tool allowed easy measurement of the distance between the navigation channel and the shoreline, but in most cases, it was obvious from the aerial photographs when a vessel could moor right at the shore. The criteria used to color code the following figures are described in the following paragraphs.

Direct offloading at shore: **Green**

Green represents locations where:

- a. The JHSV can directly unload at the shore or on a pier.
- b. The geomorphology is suitable for offloading (i.e., not swamp or wetland).
- c. There is easy access to paved roads or railroads.

Most of these areas are urban, such as the riverfront of the city of Wilmington, the state docks at the Port of Wilmington and the Port of Morehead City. Oil loading docks have been excluded because, although they are dredged to accommodate deep-draft ships, they are not designed to carry multi-ton vehicles.

Offloading via portable causeway: **Orange**

Orange represents locations where the shore:

- a. Is too far from the deep channel for the JHSV to directly drop its ramp.
- b. Is within 180 m (600 ft) of the shipping channel or a waterway with depths greater than 5 m (15 ft).
- c. Is within about 150 m (500 ft) of paved roads.

If the terrain was swampy or otherwise unsuitable for offloading, it was excluded from this class despite its being within the 180-m (600-ft) limit.

Shore too far from channel: **Red**

Whenever the shoreline was greater than 180 m (600 ft) from the navigation channel or 4.6 m (15-ft) water depth, the area was coded **red**. The majority of the Cape Fear River Estuary and the Beaufort Inlet area fell into this category.

Unsuitable geomorphology – **Purple**

Areas within 180 m (600 ft) of the channel but unsuitable for offloading heavy cargo and vehicles have been coded **purple**. In the Cape Fear River area, this classification usually pertained to unsuitable morphology, typically marsh or wetland without paved roads nearby. At Moorhead City, small boat marinas were coded as purple because they were unsuitable for heavy cargo.

Cape Fear River Estuary

Figure 10 shows the Cape Fear Estuary study area with the color-coded shorelines, and Table 2 lists the lengths of each shoreline class. The interpretation was largely based on the contours and bathymetry from the NOAA ENC-direct Web site and the 2003 aerial photographs.

Five potential offload locations in the Cape Fear River Estuary are:

- a. Town of Southport (Figures 11-13). Although there are numerous private docks along the shore, open areas exist that would be suitable for a causeway. Typically the paved road is only 20-30 m (66-98 ft) from the waters' edge. North of town, causeway deployment would be possible at the Bald Head Island barge terminal, which is adjacent to the state ferry dock. The nearest railroad tracks run to the Archer Daniels Midland citric acid plant, north of town.
- b. Military Ocean Terminal Sunny Point (Figures 14 and 15). The terminal has three concrete berths designed for heavy cargo. Currently, the northern berth is not dredged and has water depths less than 4.6 m (15 ft). The decks of the berths are about 2 m (7 ft) above high water, while the hardstand on the southern berth (No. 1) is about 3.5 m (12 ft) above high water. A boat ramp located between berths 1 and 2 would be suitable for a causeway. The ramp has paved road access, but much of the rest of the shore at the terminal is thickly vegetated and difficult to reach because of 3-4 m- (9-13 ft-) high sandy bluffs.
- c. State docks at Wilmington (Figure 16). These are used for container cargo and various commodities. The deck height averages 3.5 m (12 ft) above low water.
- d. Wilmington waterfront north of Highway 17 bridge (Figure 16). This area is used for bulk materials like gravel and cement. The channel is dredged for ocean-going vessels.
- e. West side of Cape Fear River south of Highway 17 bridge (Figure 16 and 17). The USACE maintains a work area just south of the bridge. Further south are docks used for mooring military roll-on/roll-off vessels. These

would be suitable for direct offload of the JHSV. Further south, the peninsula is used for dredge material disposal by the USACE. Access would be possible via causeway.

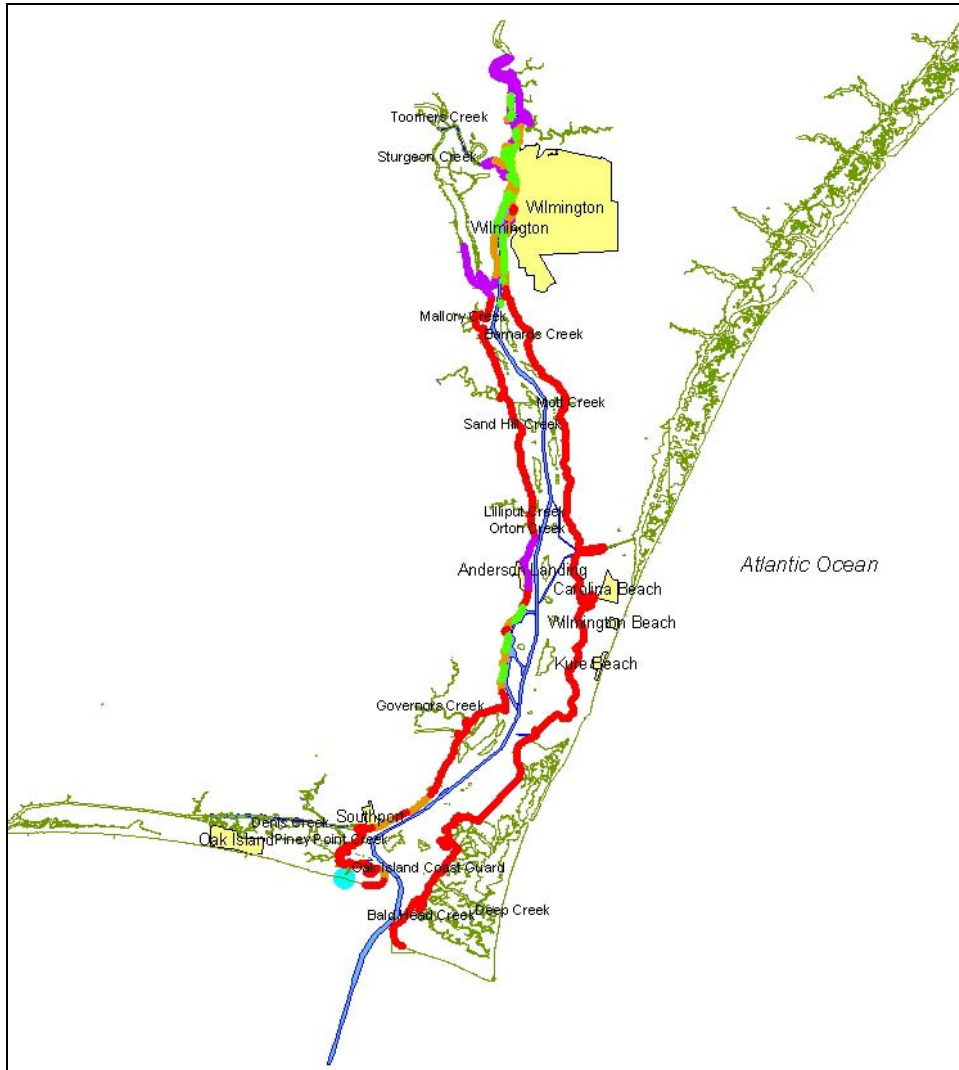


Figure 10. Cape Fear River Estuary with interpreted shore classification (see text for description of color code, north is to top)

Table 2 Shoreline Classifications, Cape Fear Estuary			
Category	Description	Length (km)	Length (statute miles)
Green	Offload directly on shore	12.2	7.8
Orange	Offload via causeway	15.7	10.0
Red	Too far from channel	89.6	57.5
Purple	Unsuitable geomorphology	24.8	15.9
Totals:		142.4	91.3

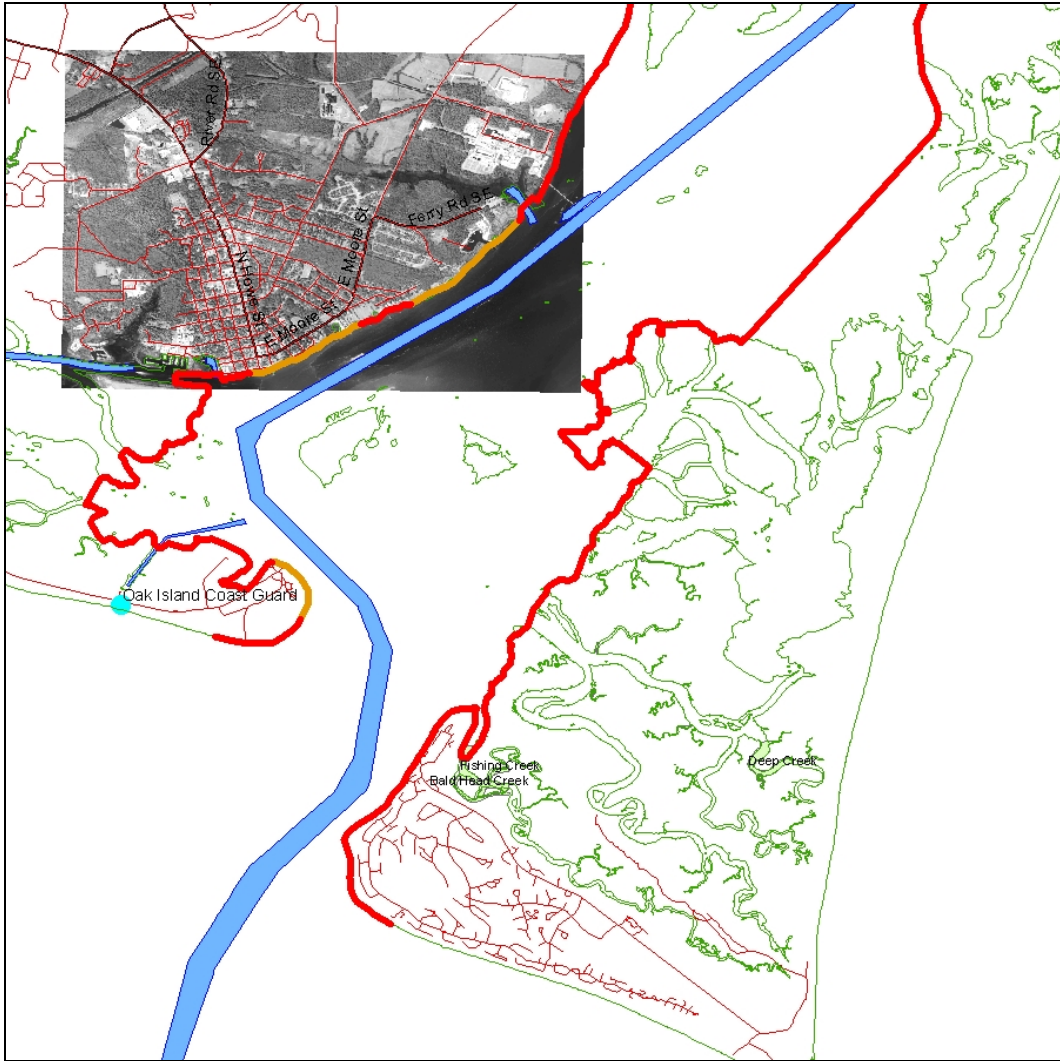


Figure 11. Southern end of Cape Fear Estuary near town of Southport. Sections of waterfront at Southport should be accessible via causeway



Figure 12. View southeast from Southport. Dredged navigation channel is immediately offshore (photograph dated 2 February 2005)



Figure 13. Example of undeveloped shore at Southport, which would be suitable for offload via causeway (photograph taken from paved road, 2 February 2005)

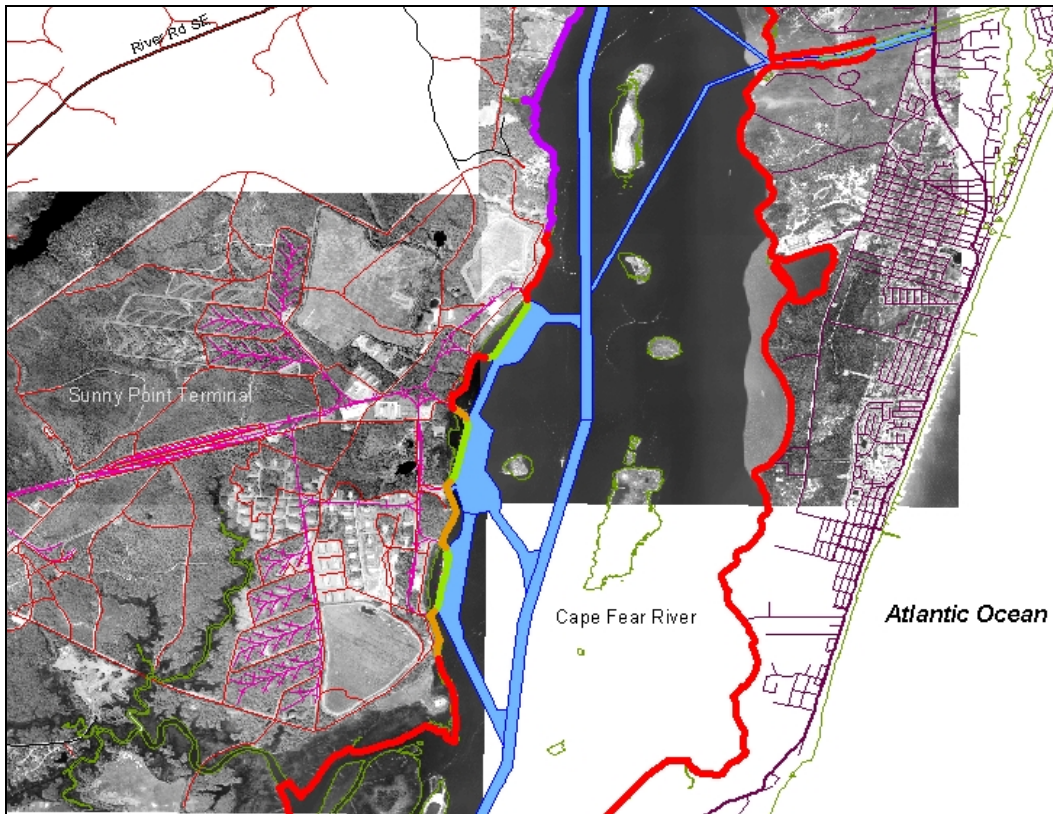


Figure 14. Central section of Cape Fear River Estuary with Sunny Point Army Terminal to the west. Terminal's southern two wharfs are regularly dredged to accommodate deep-draft vessels, but north one has not been dredged in years



Figure 15. Sunny Point Terminal south wharf, view looking north. A boat ramp is located at point of land in right side of photograph dated 1 February 2005

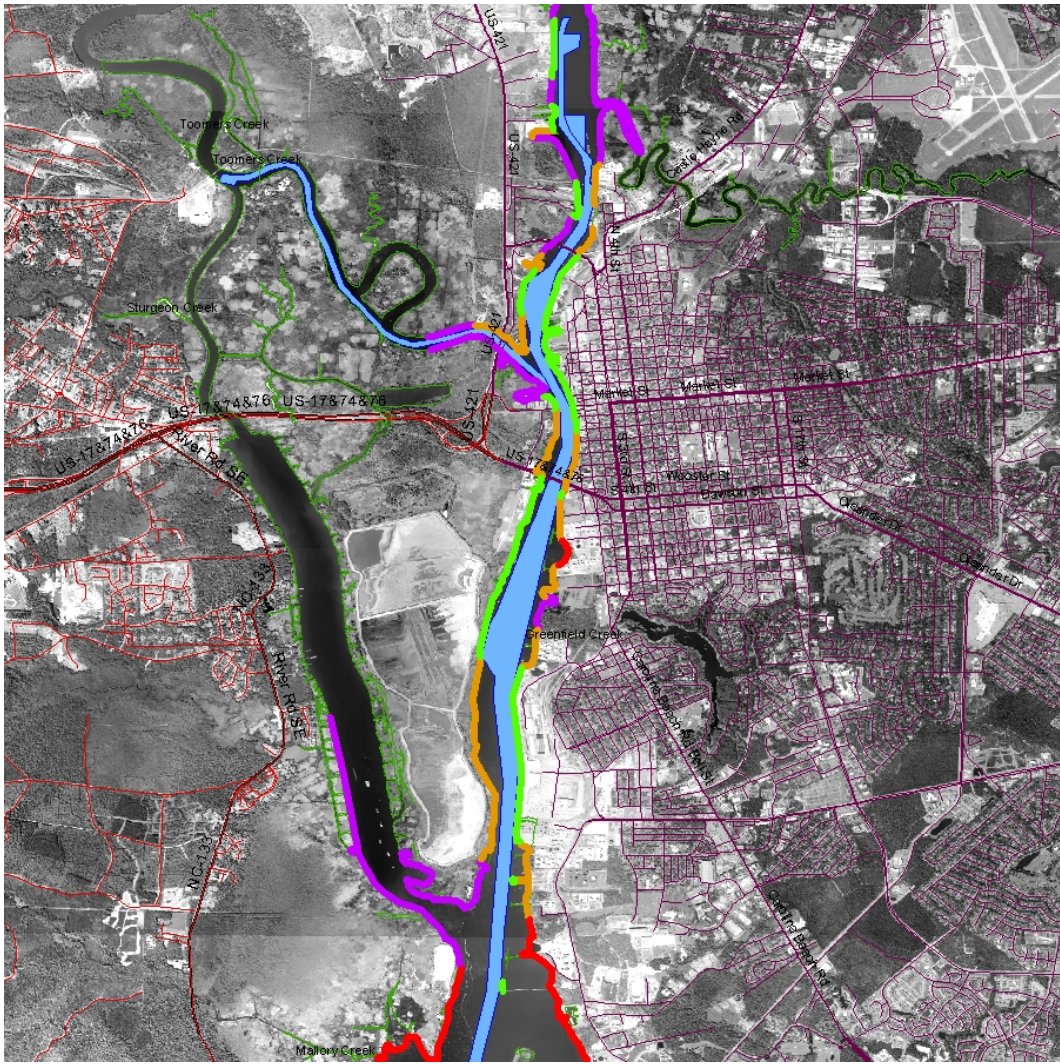


Figure 16. Port of Wilmington and city of Wilmington (north is to top)



Figure 17. West side of Cape Fear River south of Highway 17 bridge. Docks are suitable for JHSV offload

The Cape Fear River Estuary offers a low wave environment in almost all weather conditions, but travel time to the potential offload sites could be a significant factor. Table 3 lists distances from the mouth of the Cape Fear River to the four sites. All the sites have access to paved roads, and all but Southport have access to rail lines (Table 4).

Table 3 Travel Distances, Mouth of Cape Fear River to Potential Offload Sites		
Site	Distance (km)	Distance (nautical miles)
Southport	6.5	3.5
Sunny Point south wharf	17.3	9.3
State docks Wilmington	40.4	22
City of Wilmington	45	24

Table 4 Cape Fear River Road and Rail Access		
Site	Road	Rail
Southport	River Road SE and Southport Supply Road SE	Tracks to Archer Daniels Midland citric acid factory
Military Ocean Terminal Sunny Point south wharf	Paved to River Road, SE	Heavy cargo
State docks Wilmington	Urban congestion, 5.4 km (3.3 miles) to I-74 bridge	Heavy cargo
City of Wilmington	Urban congestion, 1-2 km from I-75 bridge	Heavy cargo

Moorhead City/Beaufort

Figures 18-22 show potential offloading sites in the Morehead City area, and Table 5 lists the lengths of the shoreline classifications. The state docks at Moorhead City are the only facilities suitable for direct offload of the JHSV and have good road and rail access (Tables 6 and 7). The U.S. Navy uses the state docks to embark and disembark USMC elements based at Camp Lejeune and Cherry Point.

On the south end of Radio Island, the U.S. Navy maintains concrete Landing Craft Utility (LCU) ramps. A USMC cargo specialist informed the author that the ramps are seldom used now because facilities are much better at the state docks. Although the ramps are closer to the mouth of Beaufort Inlet, they are susceptible to wave energy and strong tidal currents, which run east to west past the south end of the island. Causeway access would be possible immediately north of the LCU secure zone on both the east and west sides of Radio Island (Figure 22). The condition of the aviation fuel docks is unknown.

Both the state docks and Radio Island have convenient road and rail access, but vehicles must pass through an urban area before reaching Interstate-95 and Interstate-40 further west. The Coast Guard station on Atlantic Beach may have docks suitable for the JHSV to offload, but the station is on the east end of a narrow barrier island, which is heavily developed with condominiums and vacation houses. Road access to the mainland is via a causeway across Bogue Sound.

The city of Beaufort is not accessible by the JHSV. Recreational craft and fishing vessels can reach the city and the basin east of Pivet Island by a dredged channel, but it is too shallow for the JHSV except for a short stretch near the south tip of Radio Island.



Figure 18. Offloading potential for Beaufort Inlet area. Aerial photographs: 2003. Navigation fairway: NOAA ENC-Direct. North is to top



Figure 19. Port of Morehead City. Most of state docks are accessible from 14-m- (45-ft)- deep channels, maintained by USACE



Figure 20. State docks, Morehead City



Figure 21. State Ports of North Carolina and U.S. Navy occupy Radio Island, located between Morehead City and Beaufort. The Navy's LCU ramps are at south end of island. Most of channel leading to Beaufort is less than 4.6 m (15 ft) deep, but an area just north of ramps may be suitable for causeway offloading



Figure 22. East side of Radio Island immediately north of U.S. Navy LCU ramp, channel here is dredged to 4.6 m (15 ft) by USACE and beach would be accessible by causeway

Table 5 Shoreline Classifications, Beaufort Inlet			
Category	Description	Length (km)	Length (statute miles)
Green	Offload directly on shore	2.2	1.4
Orange	Offload via causeway	3.2	2.0
Red	Too far from channel	27.8	17.4
Purple	Unsuitable geomorphology	3.6	2.1
Totals:		37	23

Table 6 Travel Distances, Mouth Beaufort Inlet to Potential Offload Sites		
Site	Distance (km)	Distance (nautical miles)
State docks Moorhead City	3.9	2.1
LCU ramp, Radio Island	2.2	1.2

Table 7 Beaufort Inlet Road and Rail Access		
Site	Road	Rail
State docks Morehead City	U.S. 70 to Arundell Street, urban congestion	Heavy cargo
Radio City	U.S. 70 bridge to Arundell Street, urban congestion	Rail infrequently used, bascule bridge
Coast Guard Station	Paved road through vacation communities, causeway across Bogue Sound	None

Masonboro Inlet

Masonboro Inlet is dredged by the USACE. The channel extends from the open ocean seaward of the jetties through the jetties and into Banks Channel (Figure 23). The latest hydrographic survey, 29 July 1999, showed water deeper than 4.6 m (15 ft) extending about 900 m (3,000 ft) along Banks Channel, as far as the Coast Guard docks. Because Wrightsville Beach is densely developed with docks for pleasure craft, there are no open areas suitable for the causeway. Therefore, a short stretch of the shore within 180 m (600 ft) of the Coast Guard Station has been classified as purple, unsuitable. The west shore of Banks Channel has been classified as red because it is too far from the deep channel. The inner (west) side of the tip of Wrightsville Beach may be accessible by causeway depending on wave energy entering the inlet (Figure 24). This was the only orange classification in the area. Table 8 lists the lengths of shoreline segments for the Masonboro Inlet area. Even if cargo could be offloaded on Wrightsville Beach, access to the mainland is on narrow roads that pass through a densely developed town and over a bridge.



Figure 23. Masonboro Inlet. Most of Banks Channel shoreline at Wrightsville Beach is inaccessible because of wharfs and structures and insufficient channel depth. Two marshy islands and barrier to south have no road access to mainland



Figure 24. Wrightsville Beach, view looking northeast to Coast Guard facility. Banks Channel is to left. Discharge is possible on this beach via causeway (photograph 2 February 2005)

Table 8 Shoreline Classifications, Masonboro Inlet			
Category	Description	Length (km)	Length (statute miles)
Green	Offload directly on shore	0.0	0.0
Orange	Offload via causeway	1.0	0.6
Red	Too far from channel	8.5	5.3
Purple	Unsuitable geomorphology	0.1	0.08
Totals:		9.5	5.8

5 Comparison of Potential JHSV Throughput Rates at Alternative Offload Sites to Throughput Rates Associated with Conventional (Bare-Beach) JLOTS Operations

JLOTS Operations

Onslow Beach near Camp Lejeune has been the site of several Joint Logistics Over the Shore (JLOTS) exercises, the most notable, perhaps, being JLOTS III during 1991-1993. Most of the operations conducted during JLOTS III at Camp LeJeune were done during 1993 and focused on what is commonly termed “bare-beach” JLOTS. In this mode of operations, cargo from deep-draft vessels (typically strategic sealift ships) is unloaded onto smaller vessels (lighters) that convey the cargo to shore, where it is discharged directly onto a beach or onto an expedient pier and then onto the beach. Figure 25 shows an example of JLOTS cargo transfer from a Fast Sealift Ship (FSS) onto a Roll On/Roll Off Discharge Facility (RRDF) and then onto a causeway ferry. As can be seen here, these operations are complex, involving many different vessels and pieces of equipment along with a large personnel contingent.

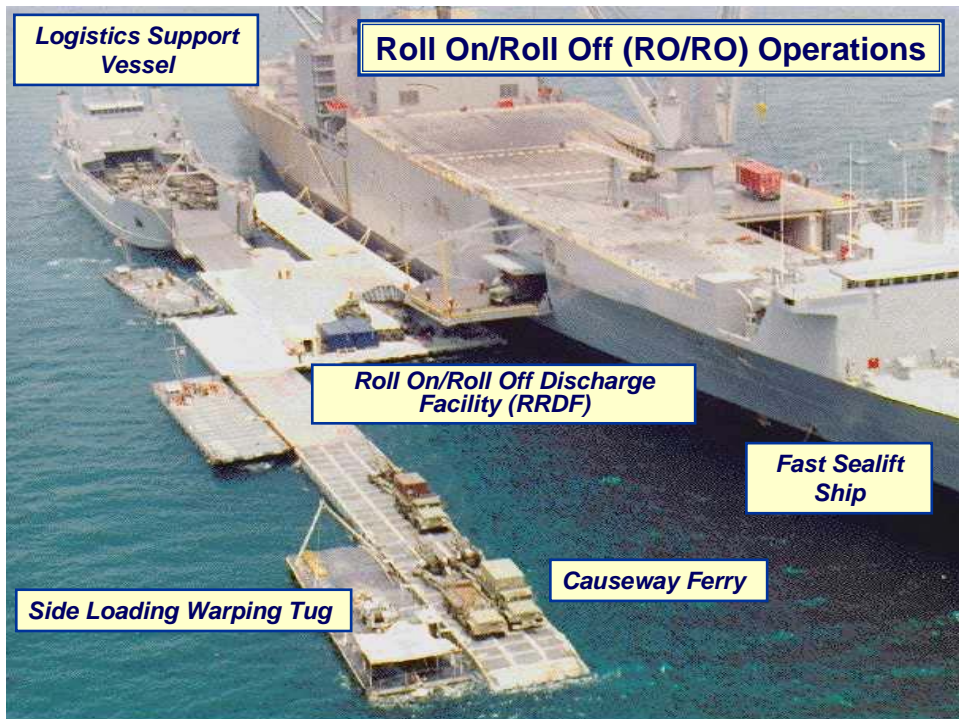


Figure 25. Typical JLOTS “discharge-at-sea” operation using RRDF

Figure 26 shows an example of a typical JLOTS operation on a floating causeway. In this case, a Rough-Terrain Cargo Handler (RTCH) is carrying a container from the end of the pier to the beach. Given the low freeboard of the floating causeway and the notorious susceptibility of floating systems of this type to wave action, it is easy to see that this operation is dependent on calm water.



Figure 26. Rough-Terrain Cargo Handler moving container along floating causeway as part of JLOTS operation

From the figures shown here, it is not surprising that the major problem observed in JLOTS operations is the sensitivity of cargo transfers (both at the offshore and the beach transfer points) to sea state. In general, conventional JLOTS operations are limited to sea conditions characterized by significant wave heights less than about 0.9 m (3.0 ft); however, the rate of cargo transfer starts to diminish as wave heights become much more than 0.6 m (2.0 ft). Because the upper limit of JLOTS operability roughly corresponds to the standard military definition of the lower limit of Sea State 3, problems with wave conditions in JLOTS exercises as well as in attempts to use JLOTS in actual operations became known as the “JLOTS Sea-State 3 Problem.”

The extreme sensitivity of JLOTS operations to wave conditions makes it imperative to know the wave climate for any area in which JLOTS operations are being considered. For the Onslow Bay area of North Carolina, wave information is available from the Wave Information Study (WIS) conducted by the U.S. Army Engineer Research and Development Center’s Coastal and Hydraulics Laboratory (CHL). Figure 27 shows the location of points for which wave information is available in the vicinity of Onslow Bay.

Information from the WIS database can be used to investigate the climatological characteristics of wave occurrences in this area. As one might expect for midlatitude sites exposed to the open ocean, wave conditions in Onslow Bay exhibit strong seasonality, with waves greater than or equal to Sea State 3 occurring an average of 70 percent of the time in winter, 46 percent of the time in spring, 34 percent of the time in summer, and 49 percent of the time in autumn. From these statistics, it is easy to see why JLOTS exercises were typically scheduled during the summer months. However, even during summer, one finds that the probability of encountering Sea State 3 conditions is certainly not negligible.

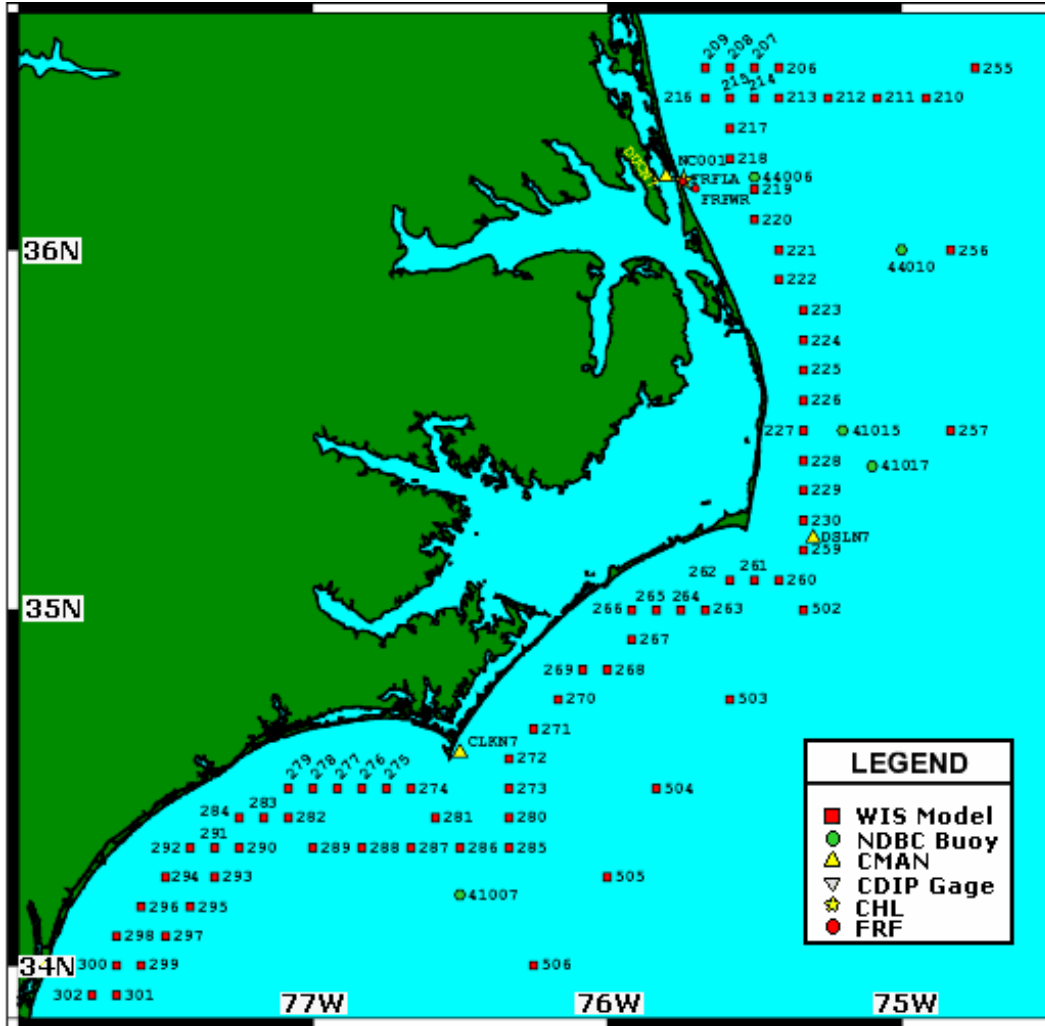


Figure 27. Locations of wave information points in WIS study

The risk of encountering an above Sea State 2 condition during a JLOTS operation is critically dependent on the duration of that operation. A straightforward method to estimate these probabilities is to define the expectation, $E(\dots)$ of the duration of waves below a threshold as:

$$E(t_s | H < H_i) = \frac{1}{N_s} \sum_1^{N_s} (t_s | H < H_i)$$

where

H = is wave height

H_i = is the lower limit of the i^{th} wave height (Sea State) category

$E(t_s | H < H_i)$ = is the average duration of all sequences of wave heights remaining lower than H_i

t_s = is the duration of waves less than H_i for a single event

N_s = is the total number of discrete events

Tables 9 and 10 provide the probability of not encountering specific sea states over some given durations for the Onslow Bay coastal area, for the months of March and July, respectively. As can be seen here, even for an operation of only 1-day duration in March, there is slightly less than a 1 in 3 chance (0.31 probability) that waves will remain under State 3 during this interval, or viewed from a different perspective, there is about a 2 in 3 chance that Sea State 3 will occur in this interval. The notation “0” in Tables 9 and 10 denote the fact that no events were found in the 20-year sample for this category. For example, in row 1 of Table 9, there are no intervals in March of at least 10 days in which the sea state remained below Sea State 1 during the entire period. The notation “1.0” in these tables denotes the fact that all of the events remained under a particular sea state for a given duration in the 20-year sample.

Table 9 Likelihood of Period of Time Not Experiencing Wave Heights Above Given Threshold in March				
	1 Day	5 Days	10 Days	20 Days
Sea State 1	.05	.01	“0”	“0”
Sea State 2	.19	.07	.01	“0”
Sea State 3	.31	.18	.03	“0”
Sea State 4	.76	.62	.47	.06
Sea State 5	.98	.89	.73	.38

Table 10 Likelihood of Period of Time Not Experiencing Wave Heights Above Given Threshold in July				
	1 Day	5 Days	10 Days	20 Days
Sea State 1	.09	.04	.01	“0”
Sea State 2	.83	.67	.38	.13
Sea State 3	.93	.86	.69	.35
Sea State 4	.99	.97	.88	.77
Sea State 5	“1.0”	“1.0”	“1.0”	.98

It is apparent from Table 9 that conventional JLOTS is probably not a good option for Force Projection in the Onslow Bay area in March. A JLOTS operation that must shut down in Sea State 3 conditions would have a 50-50 chance of being able to run continuously only for a duration of less than a day. In July, the expected 50-50 chance for Sea State 3 falls somewhere between 10 and 20 days. If a given Sea State condition not only interrupts operations but also produces some damage and/or problems, this situation is exacerbated. For example, Sea State 4 conditions in some of the JLOTS exercises proved capable of inflicting serious damage and disruption. In July, such conditions are expected

only once every few years; but in March, there is an expected 50-50 chance of encounter in any 10-day interval.

JHSV Operations

Although the JHSV is a relatively new system, several experiments (USMC Limited Objective Experiments as well as experiments conducted by the U.S. Army) have documented upload and discharge rates in various situations. In general, these have been established only for the case in which the JHSV can drop its ramp onto a surface for discharge. Presently, this is the only practical option available to the JHSV, as existing causeway systems cannot be carried/handled onboard the JHSV and require separate assets (tugs, additional personnel, sealift ships, etc.) in order to deploy at a site. An option that may become available in the near future is a floating causeway (LMCS) that can be transported aboard and installed from a JHSV using only assets that are organic to the JHSV (i.e., no additional logistics support required).

As shown earlier in this report, multiple options for JHSV discharge exist in the Camp Lejeune area, with access through Beaufort Inlet, Masonboro Inlet, and the Cape Fear River. Certainly the final selection of a site for a real-world operation would involve a number of factors that are beyond the scope of this report, for example: perceived enemy threat at each site, proximity to the military objective, and potential hazards between the discharge site and the objective. For this report, it is probably sufficient to note that all of the sites described in the previous sections are connected to a good inland road network. Because the travel time to Camp Lejeune is relatively fast on these roads, it is assumed that any of these sites could provide adequate access to the Camp Lejeune area.

The purpose of this section of the report is primarily to compare throughput potential of JHSV operations to JLOTS operations in this area. Toward that end, it is sufficient to examine only a couple of the possible sites for JHSV discharge relative to JLOTS operations. To accomplish this, two sites are examined, one with ramp-ready access (the state docks in Wilmington), and another that would require an LMCS to enable discharge (the Southport area).

Estimation of JLOTS Throughput

The estimation of throughput for a JLOTS operation is accomplished via the application of a time-stepping model of the type developed by CHL, the Coastal Integrated Throughput Model (CITM). This model has been calibrated by and verified against past JLOTS exercises and produces reliable estimates of total throughput. For the simulations conducted here, it was assumed that the initial setup time was 4 days and that the wave climate was defined by the time series of data from the WIS database. It was also assumed that two strategic sealift ships were available along with an auxiliary crane ship, six LCUs, two causeway ferries, and two splash points on the beach. With these assets, several simulations with distances from the shore ranging between 3.2 and 6.4 km (2 and 4 miles) and different experience levels assumed for the operators predicted that the throughput of a mixture of Stryker and other vehicles varied between 8 and 16 per hour in calm water.

As a global “calm-water” average, assume that this set of JLOTS assets can achieve a throughput of about 12 vehicles per hour. In actual situations, the effects of sea state on throughput during a JLOTS operation occur not only during the time that Sea State 3 exists, but occurs also due to time lost in the shut-down and start-up intervals surrounding the Sea State 3 occurrence. For simplicity, assume that the reduction in throughput in a JLOTS operations is only due to the percentage of time that Sea State 3 conditions exists. In this simplified case, over a reasonable time interval, the throughput rates for JLOTS with sea state considered can be estimated as the throughput rates in calm water multiplied by a reduction factor equal to the percentage of time with wave conditions less than Sea State 3. For the month of March, this is equal to 0.35 and for the month of July this reduction factor is equal to 0.71.

Estimation of JHSV Throughput

CHL is in the process of developing a new model to estimate throughput potential for JHSV operations in both existing small ports as well as alternative offload sites. This model has a similar time-stepping structure to the CITM model developed previously for modeling JLOTS operations. In the case of the JHSV, it is assumed that the vessel is transiting between an intratheater upload site (i.e., an Intermediate Staging Base, or ISB, which could be a Sea Base) and the coastal discharge site. The major time factors in such a situation can be divided into four primary elements:

- a. Operations at the ISB.
- b. Transit time in open water.
- c. Transit time in coastal/inland waters.
- d. Operations at the coastal discharge site.

Each of these elements can be further subdivided into subelements, such as approach and moor time and the ISB or coastal site, initial setup time at the coastal site, and actual time to upload/discharge cargo.

For simulations described herein, the following assumptions were made:

- a. The average speed of the JHSV was 40 knots in open water.
- b. The speed in inland waters was reduced to an average of 7 knots.
- c. The average approach and moor time and castoff and departure time was set at 20 min each.
- d. The first vessel arriving at Southport deployed 61 m (200 ft) of LMCS in 3 hr.
- e. Upload of the JHSV at the ISB is at a rate of 25 vehicles per hour.
- f. Discharge at either Southport (via the LMCS) or the state docks is at a rate of 35 vehicles per hour.

Given these listed assumptions, the primary remaining variables in the JHSV throughput simulation are:

- a. The number of JHSV vessels in the operation.

- b. The distance from the ISB to the start of the coastal inland-water reduced speed region.
- c. The distance within the reduced-speed region.
- d. The number of discharge points at the coast.

In simulations conducted for this study, the number of JHSVs was allowed to vary from 1 to 10. Three different distances [185.3 km (100 n.m.), 370.6 km (200 n.m.), and 741.2 km (400 n.m.)] from the ISB to the start of coastal/inland waters were also considered. The distance in the coastal/inland waters was 7.4 km (4 miles) for Southport and 40.8 km (22 miles) for the state docks. The number of discharge points was treated as an internal variable such that the system was optimized for the number of vessels being used. It was also assumed that the number of upload points at the ISB was always greater or equal to the number of discharge points. The capacity of the JHSV was assumed to be 105 vehicles on all JHSVs, except for the first in which the storage of the LMCS (assumed equivalent to five vehicles) was subtracted from the total number of vehicles. For simplicity, the discharged vehicles were only added to the total once all of them were unloaded from a vessel.

Comparison of JLOTS and JHSV Throughput

Tables 11-13 show the number of discharge sites, as a function of number of JHSVs and the discharge site (Southport or state docks), required to avoid a bottleneck at the discharge site. As can be seen here, a single discharge site can handle up to four JHSVs at Southport and up to five at the state docks (since the average cycle time for a vessel is somewhat longer due to the additional travel time in restricted waters). The state docks certainly have the capacity to handle this many discharge sites; and there is sufficient space available in the Southport area to install this number of LMCS systems. Tables 14 and 15 give the estimated total number of vehicles discharged at Southport from the JHSVs as a function of number of vessels (assuming that the number of discharge points noted in Tables 11-13 are available, for simulated travel distances of 185.3 km (100 n.m.) and 741.2 km (400 n.m.), respectively. The last two columns in each of these tables is the number of vehicles discharged in simulated JLOTS operation in March and July, respectively.

Because the state docks are substantially upriver from the coast, the cycle time for JHSVs is somewhat longer for this site. Table 16 provides estimates of the number of vehicles discharged at this site for a distance of 185.3 km (100 n.m.) between the ISB and the entrance to the Cape Fear River. As can be seen here, the extra distance in restricted water (i.e., reduced speed) leads to a reduction in throughput by about 25 percent compared to the throughput at Southport.

Table 11 Number Of Discharge Points Required to Avoid Bottleneck for Distance of 100 n.m. Between Site and ISB		
Number of Vessels	Southport	State Dock
1	1	1
2	1	1
3	1	1
4	1	1
5	2	1
6	2	2
7	2	2
8	2	2
9	3	2
10	3	2

Table 12 Number of Discharge Points Required to Avoid Bottleneck for Distance of 200 n.m. Between Site and ISB		
Number of Vessels	Southport	State Dock
1	1	1
2	1	1
3	1	1
4	1	1
5	1	1
6	2	1
7	2	2
8	2	2
9	2	2
10	2	2

Table 13 Number of Discharge Points Required to Avoid Bottleneck for Distance of 400 n.m. Between Site and ISB		
Number of Vessels	Southport	State Dock
1	1	1
2	1	1
3	1	1
4	1	1
5	1	1
6	1	1
7	1	1
8	1	1
9	2	1
10	2	2

Table 14
Comparison of Estimated JHSV (Southport Discharge Site) and JLOTS Throughputs for Case of Separation of 100 n.m. Between ISB and Entrance to Cape Fear River

	JHSV 1 vessel	JHSV 2 vessels	JHSV 10 vessels	JLOTS July	JLOTS March
1 day	100	205	1,130	0	0
2 days	310	625	3,230	0	0
5 days	730	1,560	7,435	191	94
10 days	1,570	3,245	15,950	1,145	562
20 days	3,250	6,,600	32,850	3,037	1,497
30 days	4,930	9,960	49,755	4,943	2,434

NOTES:
1. The first column denotes the number of days in the operation.
2. Columns 2-4 contain the JHSV throughputs for 1, 2, and 10 vessels, respectively.
3. Columns 5 and 6 contain the estimated JLOTS throughput for July and March, respectively.

Table 15
Comparison of Estimated JHSV (Southport Discharge Site) and JLOTS Throughputs for Case of Separation of 400 n.m. Between ISB and Entrance to Cape Fear River

	JHSV 1 vessel	JHSV 2 vessels	JHSV 10 vessels	JLOTS July	JLOTS March
1 day	0	0	0	0	0
2 days	100	205	1,045	0	0
5 days	310	625	3,135	191	94
10 days	730	1,465	7,445	1,145	562
20 days	570	3,340	15,850	3,037	1,497
30 days	2,410	4,820	24,345	4,943	2,434

NOTES:
1. The first column denotes the number of days in the operation.
2. Columns 2-4 contain the JHSV throughputs for 1, 2, and 10 vessels, respectively.
3. Columns 5 and 6 contain the estimated JLOTS throughput for July and March, respectively.

Table 16
Estimated JHSV (State Docks Discharge Site) Throughput for Case of Separation of 100 n.m. Between ISB and Entrance to Cape Fear River

	JHSV 1 vessel	JHSV 2 vessels	JHSV 10 vessels
1 day	0	0	0
2 days	210	420	2,100
5 days	525	1,050	5,460
10 days	1,155	2,415	11,865
20 days	2,415	4,935	24,675
30 days	3,780	7,770	38,745

NOTES:
1. The first column denotes the number of days in the operation.
2. Columns 2-4 contain the JHSV throughputs for 1, 2, and 10 vessels, respectively.

The results of these comparisons indicates that as few as 1 or 2 JHSVs can potentially provide vehicular throughput comparable to a conventional “bare-beach” JLOTS operation, even at distances between the coastal discharge site and an ISB of up to 741.2 km (400 n.m.). This is truly striking when one considers the differences in the naval assets and personnel required to accomplish each of these operations. Although these numbers might vary somewhat, depending on the mix of vehicle types, they represent a reasonable first look at the potential of the JHSV to provide effective access to inland areas. In all of the areas examined, the JHSV could likely find ramp-accessible sites to discharge its cargo; and, in conjunction with the LMCS, literally miles of coast could be accessible to this vessel. This level of access could provide effective maneuver support/advantage for a wide range of military missions, from small insertions to major actions.

An important point that should not be missed here is the difference between JHSV throughput and JLOTS throughput in terms of their susceptibility to disruption. Passage through the entrance of either the Cape Fear River and Beaufort Inlet can accommodate Sea State 5 conditions without much hazard to the vessel. According to local Coast Guard personnel, passage through Masonboro Inlet can also accommodate Sea State 5 conditions but might require a person with knowledge of the navigation channel onboard. Thus, JHSV has the potential to continue up to Sea State 6; whereas, conventional “bare-beach” JLOTS continues only up to Sea State 3. It is easy to see that the frequency of Sea State 3 will lead to frequent shutdowns in JLOTS operations; but it is not only the frequency of the disruption, but the duration of the disruption that may be important. During March in this area, several episodes of Sea State 3 and higher waves were found to last for over 2 weeks. For all of that time and probably some additional time in which the system would have to be reestablished, JLOTS throughput would be zero. This could have a negative effect on both force projection and sustainment in this area. In contrast to this, Sea State 6 conditions lasted at most for about 2 days in this area.

A final point that should be considered in estimating the potential utility of the JHSV for force projection concerns the effect of wave action on JHSV discharge. It has been assumed in this study that wave conditions do not limit discharge at the selected sites. However, it should be recognized that JHSV discharge is presently considered to be limited to calm conditions (Sea State 1 or less). Major ports are either located in naturally sheltered areas or have been designed with breakwaters to have essentially calm conditions within them. This is not necessarily true of austere ports or alternative sites of the type analyzed here. At such locations, waves, either due to the penetration of ocean waves into a port or harbor or due to local wind generation of waves, can affect JHSV discharge. For example, in some regions of the world affected by strong seasonal winds (such as parts of the Persian Gulf), ports can only be used seasonally. In other areas, sheltering by breakwaters and natural features is often incomplete, so waves from certain directions can create substantial agitation within semisheltered anchorages. A rudimentary hindcast of wave conditions at the Southport discharge site in the Cape Fear River indicates that waves above Sea State 1 could occur about 10 percent of the time during winter. During the site visit to Southport, local observers commented that waves in the 0.6- to 0.9-m (2- to 3-ft) range were not uncommon during these months.

6 Conclusions and Recommendations

This study shows that the JHSV could significantly impact coastal throughput in the Camp Lejeune area. Since this area is geomorphically similar to much of Southeast Asia, it can be inferred that the JHSV might be of significant value in maneuver operations and force projection in that area as well. Several of the key conclusions regarding the potential impact of the JHSV in such areas are given as follows.

- a.* Depths in most natural inlets (though barrier islands and/or between islands) in regions such as coastal North Carolina are too shallow for a vessel with 4.6-m (15-ft) draft to pass through safely. Most commercially viable sites depend on periodic dredging to maintain depths suitable for commercial shipping.
- b.* Several commercial sites are available in the Wilmington and Beaufort areas that afford direct ramp access to JHSV class vessels.
- c.* Many miles of coast in this area (12.6 stat. miles) are suitable for discharge via a causeway that could be deployed from a JHSV. Such sites require between 30.5 and 61 m (100 and 200 ft) of causeway and terminate on land within tens of feet of paved roads.
- d.* Additional miles of coastline in this area (18.1 stat. miles) could provide coastal access for JHSV discharge if additional length of causeway were available or if wetlands at the landside point of the causeway could be crossed.
- e.* It is estimated here that as few as one or two JHSVs can provide throughput rates for coastal discharge that are comparable to a conventional bare-beach JLOTS operation. Additionally, JHSV throughput in this area is much less susceptible to disruption by waves, since JHSV throughput can continue up to Sea State 6 whereas JLOTS throughput can only continue up to Sea State 3. Both the frequency and duration of shut down due to waves could have serious impacts on force projection and sustainment.

Based on what we have learned here, it can also be concluded that the following information is needed to obtain reliable estimates of JHSV accessibility to the coast. These include:

- a.* High-resolution aerial photographs.

- b.* Recent bathymetric data.
- c.* Access to a suitable GIS environment. This allows convenient overlay, measurements, and display of various types of data, some of which were originally collected at different scales and coordinate systems.
- d.* Information on local infrastructure (dock characteristics, pier conditions, etc.). In this study, consultation with local specialists provided additional information that was not evident from the remote sensing data. Examples included information on the status and condition of the LCU ramps on Radio Island and the condition of the north wharf at the Sunny Point Terminal.

This work should be regarded as a first look at a complex problem. The ability of the JHSV to access the coast is of critical interest to a wide range of military missions, ranging from the insertion of small expeditionary forces to a role in major force projection operations. This report indicates that JHSV can offer considerable maneuver advantage by greatly increasing the number of sites where forces can enter a theater. Additional work is necessary in the following areas to help quantify the potential impact of this vessel in different situations, for example:

- a.* A similar study to the one conducted here focusing on some selected sites in Southeast Asia.
- b.* An improved analysis method for determining the suitability of existing infrastructure to support direct ramp access by the JHSV.
- c.* An improved analysis of potential wave impacts on JHSV discharge in austere ports and in alternative (nonport) sites, because waves can penetrate into the interior regions of many austere ports around the world and because JHSV discharge is limited to calm conditions.
- d.* An improved model for estimating JHSV upload, transit and discharge processes during typical missions.

Appendix A

History of Wilmington Harbor

Wilmington Harbor has been a maintenance challenge since the 1700s. The following list summarizes endeavors to improve the channel and aid commerce.¹

Colonial times: North Carolina was the world's largest producer of Naval Stores--tar, itch, rosin, and turpentine--from 1720 to 1870. Yet shipping from the Cape Fear soon turned difficult. A severe storm in 1761 opened New Inlet, thus creating decades of challenge for engineers. The inlet continually deepened, while the bar at the harbor's mouth, once 4.3 m (14 ft) deep, eventually shoaled to depths as shallow as 2.3 m (7.5 ft).

The early republic: Until the middle 1900s, the State of North Carolina strove to improve harborage on the Cape Fear, with little success. An 1830 legislature report described North Carolina as "a State without foreign commerce."

The 1830s: At the beginning of the 1830s, the channel into Wilmington Harbor was about 3.4 m (11 ft) deep. Engineers aiming for 4.3 m (14 ft) of depth began constructing six jetties. In August 1830, a storm destroyed the jetties and swamped the dredge being used to deepen the channel. Depth at the mouth of the river continued to decrease.

1840-53: The New Inlet continued to deepen, and the bar to shoal, so that by 1853, depth at the bar was only 2.3 m (7.5 ft). An 1853 report by the U.S. Army Corps of Engineers recommended a depth of 6.1 m (20 ft).

1850-57: Unsuccessful projects attempted to close inlets and deepen the channel.

1857-70: During the Civil War years, New Inlet proved militarily advantageous to Confederate blockade runners and their small cargo ships. No significant project work occurred.

1870-81: At the start of 1870, only 40 foreign ships were registered in Wilmington. Having learned from the failures of the pre-war period, the U.S. Army Corps of Engineers undertook to close New Inlet. Their massive project, "The Rocks" closed the inlet by 1881, and in that year the channel was dredged to a depth of 4.9 m (16 ft). In 1975, at its 200th Anniversary, the Corps named The Rocks as South Atlantic Division's most significant project in history.

¹ Adapted from the U.S. Army Engineer District, Wilmington, Web page: http://www.saw.usace.army.mil/wilmington-harbor/historic_highlights.htm, 29 November 2004.

1881-91: The Corps-built Swash Defense Dam further protected the harbor channel. By 1885, the number of foreign ships registered in Wilmington had risen to 230.

1891-1945: By the end of this period, the Corps had deepened Wilmington Harbor's channel to 9.8 m (32 ft).

1950: The U.S. Army Corps of Engineers began to deepen the harbor to 10.4 m (34 ft).

1964: The Corps initiated a project to deepen the channel to its present 12.2 m (40-ft) depth.

2000: The first of a series of contracts was awarded to increase channel depth to 13.4 m (44 ft) over the ocean bars and 12.8 m (42 ft) thereafter to the city of Wilmington. The Energy and Water Appropriations Bill on 13 October 1998 combined three separate projects (Wilmington Harbor, Northeast Cape Fear River project; Wilmington Harbor, Channel Widening project; and Cape Fear, Northeast Cape Fear Rivers project) were combined into one, the Wilmington Harbor, NC - 96 Act project.

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14. ABSTRACT <p>The purpose of this study was to evaluate conventional (port) and nonconventional offload sites for the Joint High Speed Vessel (JHSV) in coastal North Carolina, and compare the potential throughput rates at these sites to throughput rates typical of Joint Logistics over the Shore (JLOTS) operations conducted in exercises in Camp Lejeune. North Carolina was selected as a test site both due to its proximity to Camp Lejeune and also because of its environmental (geomorphic) similarity to many coastal regions in Asia. Another goal was to evaluate the quality and appropriateness of maps, bathymetry data, and aerial photography from various sources to conduct offload alternatives studies with the intent of eventually applying these techniques to other (overseas) sites.</p> <p>The analysis of offload sites demonstrated that the total length of shoreline suitable for the JHSV to unload in North Carolina was surprisingly limited. In the Cape Fear River estuary, the total length accessible either directly or via 180-m causeway was 27.9 km; in Morehead City/Beaufort area, 5.4 km; and in Masonboro Inlet, 1.0 km. The reasons for the limited access are both geological and developmental. On this low-gradient, soft sediment, trailing edge coast, only these three inlets are dredged deep enough to accommodate the JHSV, which requires a channel of 4.6 m. Once within the inlets, the only water deep enough for the JHSV is in the dredged</p> <p style="text-align: right;">(Continued)</p>					
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navigation channels and some naturally-deep areas near the mouth of the Cape Fear River. Finally, offload sites must be within a suitable distance from paved roads or railroads (in this analysis, 150 m), and these sites, too, proved to be unexpectedly limited. Despite the flexibility of the JHSV, planners considering operations in lesser-developed parts of the world will have to contend with even more limited infrastructure, along with geological and oceanographic constraints.

JLOTS exercises are particularly sensitive to wave climate and are restricted to significant wave heights less than 0.9 m, the lower limit of sea state 3. Throughput diminishes rapidly when seas are above 0.6 m. Based on hindcasts of Atlantic waves, the likelihood of the North Carolina coastal waters not experiencing sea state 3 waves in March for 1 day is only 0.31. For a 10-day period, the likelihood drops to only 0.03. Therefore, conventional JLOTS is not a good option for force projection in this area in March.

Modeling JLOTS versus JHSV throughput for the three North Carolina entrances demonstrates that as few as one or two JHSVs can potentially provide vehicular throughput comparable to a conventional "bare-beach" JLOTS operation, even at distances between the coastal discharge site and an Intermediate Staging Base (ISB) of up to 400 nautical miles. This is striking when one considers the great differences in the naval assets and personnel required to accomplish each of these operations. Another advantage of the JHSV is that it has the potential to continue up to sea state 6; whereas, conventional JLOTS continues only up to sea state 3. Therefore, the JHSV operations are potentially much less susceptible to weather disruptions.