Naval Research Laboratory
Stennis Space Center, MS 39529-5004

NRL/MR/7440--03-8295

Analysis of Global and Selected Geographic Areas with Depths Between 50 and 100 Feet

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February 14, 2003

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
February 14, 2003

2. REPORT TYPE
Memorandum Report

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE

Analysis of Global and Selected Geographic Areas with Depths Between 50 and 100 Feet

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
0603704N

6. AUTHOR(S)

John T. Sample, Chad A. Steed, Frank P. McCreedy, and Michael M. Harris

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
74-7441-B3

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Research Laboratory
Marine Geosciences Division
Stennis Space Center, MS 39529-5004

8. PERFORMING ORGANIZATION REPORT NUMBER

NRL/MR/7440--03-8295

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

SPAWAR PMW 155
4301 Pacific Highway
San Diego, CA 92110

10. SPONSOR / MONITOR'S ACRONYM(S)

SPAWAR

11. SPONSOR / MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This report identifies additional areas of the ocean that shallow draft Littoral Combat Ships (LCS) could sail which are beyond the safe operating depth of conventional deep draft warships. Depth limits used in this report are 50 feet (15.24 meters) for the LCS and 100 feet (30.48 meters) for deep draft vessels. Approximately .91% of the world's ocean area lies between the 50-foot and 100-foot depth contours, or 1.27×106 square miles (3.29×106 sq km). For 13 small areas identified, the percent with this depth range varies from a low of 1.09% for the Ionian Sea to a high of 25.75% for the Persian Gulf. The Persian Gulf and the Yellow Sea have the largest percent increase in accessible area for a shallow draft vessel, 56.01% and 36.65%, respectively.

15. SUBJECT TERMS

Littoral Combat Ship; Hypsometry; Digital Bathymetric Data Base; GIDB

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			John Sample
Unclassified	Unclassified	Unclassified	UL	27	**19b. TELEPHONE NUMBER** *(include area code)* (228) 688-4995

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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TABLES

Analysis of Global and Selected Geographic Areas with Depths Between 50 and 100 Feet

1. Introduction

The Navy's future Ship Requirements Branch was tasked by Congressional Staff Members of the Senate Armed Services Committee to provide a graphic representation of the littoral regions of the world showing areas of the ocean that a shallow draft Littoral Combat Ship (LCS) could operate. Specifically, what areas of the ocean could a LCS go where current deeper draft ships cannot? The request was based on the Navy's proposed new LCS that is to be optimized for operations in the littoral regions of the world. NRL's Mapping, Charting and Geodesy Branch was asked to address the request based on in-house expertise and data capabilities.

The LCS will be part of the Navy's new Surface Combatant Family of Ships. The ships will be optimized to fight in the littorals. They will be fast, maneuverable and able to operate in shallow waters. LCS ships will be able to counter asymmetric threats including mines, small boats and submarines. The LCS ships will have innovative hull designs, propulsion systems and use open system architecture for modular mission payloads fully "netted" within the battle force[1].

Specifications for the shallow safe operating depths were provided. In this report 50 feet (15.24 meters) is used for the LCS and 100 feet (30.48 meters) is used for the larger vessels. Calculations were performed globally using hypsometry information, and for thirteen specific geographic regions using the Digital Bathymetric Database Variable Resolution (DBDBV). Results are depicted graphically and numerically in terms of square miles (kilometers) and percent of area.

2. Global Calculations Using Hypsometry Curves

Approximately .91% of the world's ocean area lies between the 50-foot and 100-foot depth contours, or 1.27×10^6 square miles (3.29×10^6 sq km). This estimate is based on interpolation of values from the hypsometric curve of all ocean basins. Figures 1 and 2 are typical hypsometric curves showing cumulative area in square kilometers and in cumulative percent respectively[2&3]. Table 1 provides higher resolution data for the Coastal Water Depth Distribution of the World's Oceans[4].

Manuscript approved January 21, 2003.

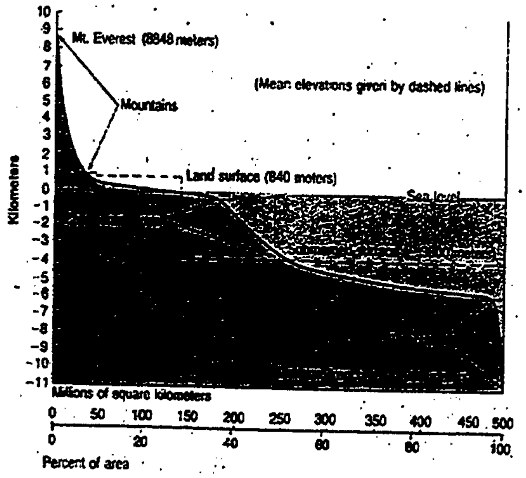


Fig. 1 --- Hypsometry of all Ocean Basins

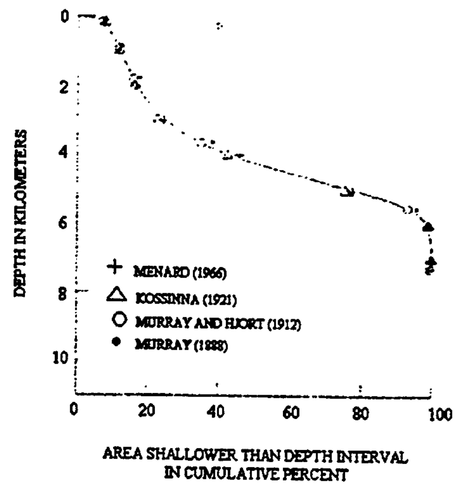


Fig. 2 --- Hypsometry of the Earth

Table 1 --- Coastal Water Depth Distribution of World's Oceans

Water Depth (Meters)	Ocean Area $Km^2 \times 10^6$	Percent of Total Ocean
0-20	6.23	1.75
0-40	9.69	2.73
0-60	14.22	4.01

Hypsometry is the study of the elevation and depth distribution on the continents and oceans. Sir John Murray made the first systematic measurements of the depth distribution and mean ocean depths, which were published in 1912. There have been many additional measurements and studies since then; however, they have caused little change in the hypsometric curve[3]. Harrison[5] provides theory on the shape of the hypsometric curve.

3. Selected Geographic Regions

NRL was also requested to analyze the hypsometry of thirteen selected areas with the purpose of determining what portions of these areas have depths between the 50 and 100-foot contours. The following geographic regions were analyzed:

1. Persian Gulf
2. Taiwan Strait
3. Yellow sea
4. Sea of Japan
5. Red Sea
6. Gulf of Aqaba

7. Gulf of Sidra
8. Gibraltar
9. Aegean Sea
10. Sea of Marmara
11. Coastline from Turkey to Egypt
12. Ionian Sea
13. Malacca Strait

4. Area Computation Methodology

The Digital Bathymetric Data Base – Variable Resolution (DBDB-V)[6&7] was used to determine what portions of the selected geographic regions were within the defined depth ranges. DBDB-V provides worldwide bathymetry data points in varying resolutions restricted by classification and survey quality. This study used the highest available resolution that provided adequate coverage of a given area. Appendix A gives a brief description of the DBDB-V data used in this study.

Bathymetry points were extracted from DBDB-V for each geographic region selected. Appendix B lists the coordinates used to form bounding areas for each region. Areas in square miles were calculated for each region based on the spatial resolution of the region's bathymetry points. Data were grouped by depth value and summed. Three groups were used. The first group had depth values from 0 to 50 feet, the second from 50 to 100 feet, and last group was 100 feet and deeper.

Results were formatted and provided as input to NRL's Geospatial Information Data Base (GIDB)[8&9]. Appendix C provides a brief description of the GIDB. The figures used in this report were produced from the GIDB.

5. Results

Results from this study are presented in Table 2. Calculations performed could benefit from higher resolution classified datasets, particularly in smaller areas such as the Strait of Gibraltar and the Gulf of Aqaba.

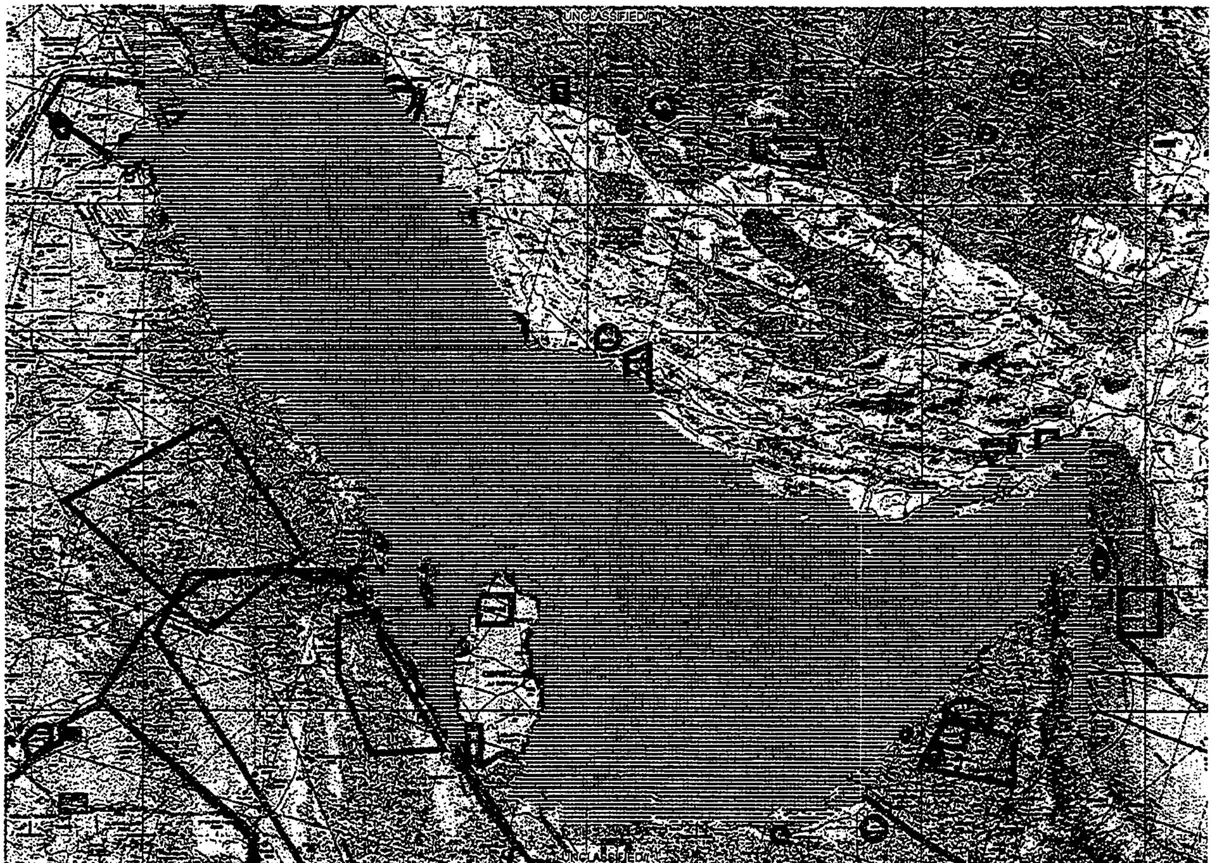
Note Figure 8 contains examples of the difference between 5 minute and 1 minute resolution gridded bathymetry data in the Gulf of Aqaba region. The coarseness of the data presents difficulty in accurately determining various depth categories. Contrast this with Figure 5 that represents the region of the Yellow Sea. This area is of sufficient size to give a thorough sampling of the data and accordingly accurate proportions. An investigation into higher resolution data is suggested for further study.

Table 2 --- Area Calculations by Geographic Region

	Resolution (Minutes)	*Total Area (Sq.Miles)*	*Area 0 to 50 feet*	*Area 50 to 100 Feet*	*Area Greater Than 100 Feet*	*Percent in 50 to 100 Range*	*Percent Increase in Accessible Area*
1. Persian Gulf	5	91,060.3	25,772.6	23,455.4	41,832.4	25.75%	**56.07%**
2. Taiwan Strait	5	32,313.3	3,480.5	3,903.3	24,929.5	12.08%	**15.68%**
3. Yellow sea	5	127,764.2	42,956.6	22,745.9	62,061.7	17.80%	**36.65%**
4. Sea of Japan	5	339,113.0	5,682.3	3,811.5	329,619.2	1.12%	**1.16%**
5. Red Sea	1	176,007.9	24,225.6	15,344.4	136,437.8	8.71%	**11.25%**
6. Gulf of Aqaba	5	1,307.5	87.7	116.5	1,103.3	8.91%	**10.56%**
7. Gulf of Sidra	1	28,380.7	1,090.7	1,095.7	26,194.4	3.86%	**4.18%**
8. Strait of Gibraltar	1	799.9	42.9	36.5	720.5	4.56%	**5.06%**
9. Aegean Sea	1	27,004.9	2,762.3	1,100.6	23,142.1	4.08%	**4.76%**
10. Sea of Marmara	1	4,241.1	609.7	359.5	3,272.0	8.48%	**10.99%**
11. Coastline from Turkey to Egypt	1	14,606.4	412.1	458.5	13,735.8	3.19%	**3.34%**
12. Ionian Sea	1	24,766.8	382.0	269.6	24,115.3	1.09%	**1.18%**
13. Malacca Strait	5	42,218.5	10,654.9	5,473.1	26,090.5	12.96%	**20.98%**

6. Figures

The following figures represent the 13 areas chosen for consideration. For background, NIMA CADRG maps were chosen. Overlaid on each CADRG are colored regions representing the 3 groups of points. Regions are colored for all areas that contain relevant data points. Red areas represent depths in the range from 50 to 100 feet. Blue areas represent depths greater than 100 feet, and green areas represent depths less than 50 feet.

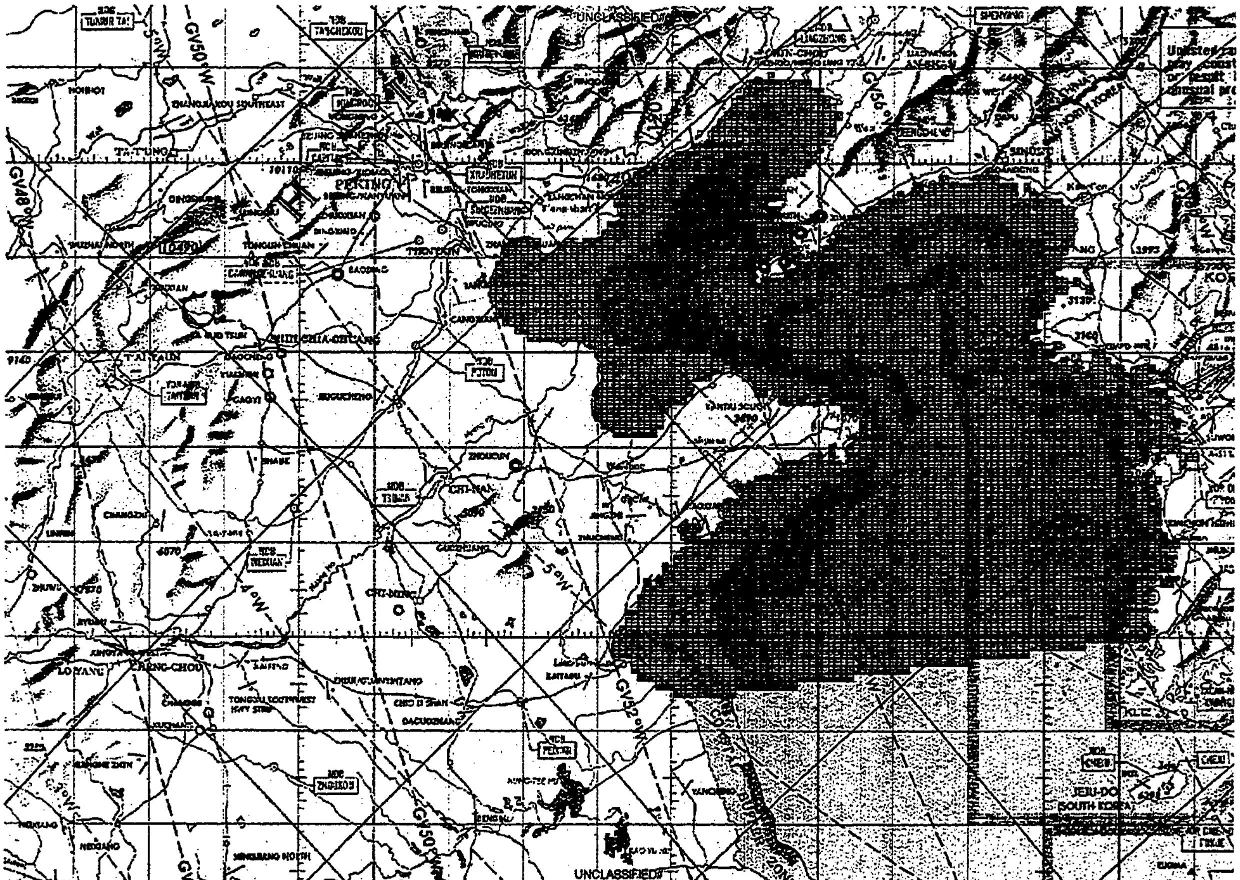


Green: 0-50 Feet
Red: 50-100 Feet
Blue: 100 and Greater

Fig. 3 --- Persian Gulf

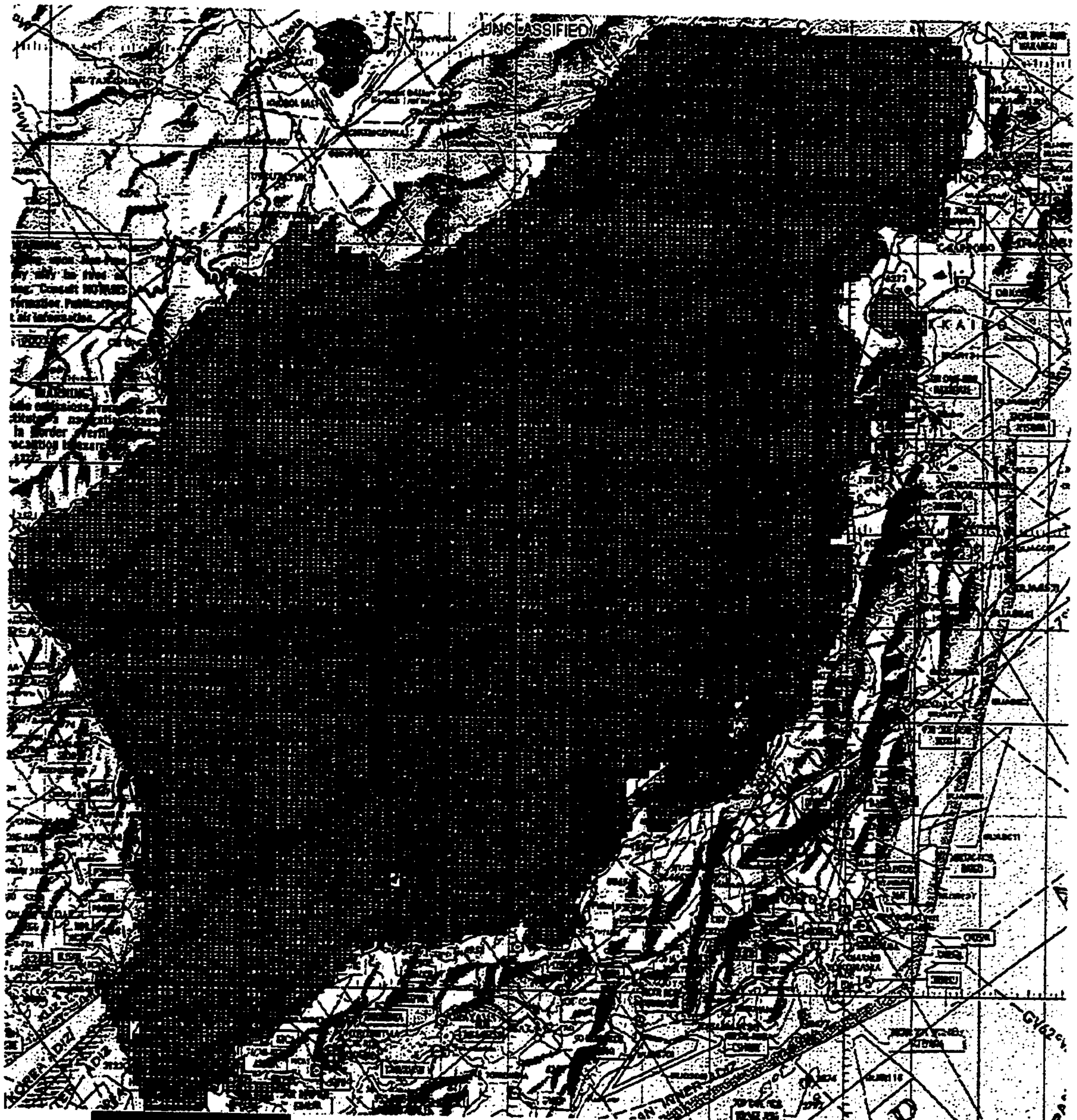
Red: 50-100 Feet
Blue: 100 and Greater

Fig. 4 --- Taiwan Strait



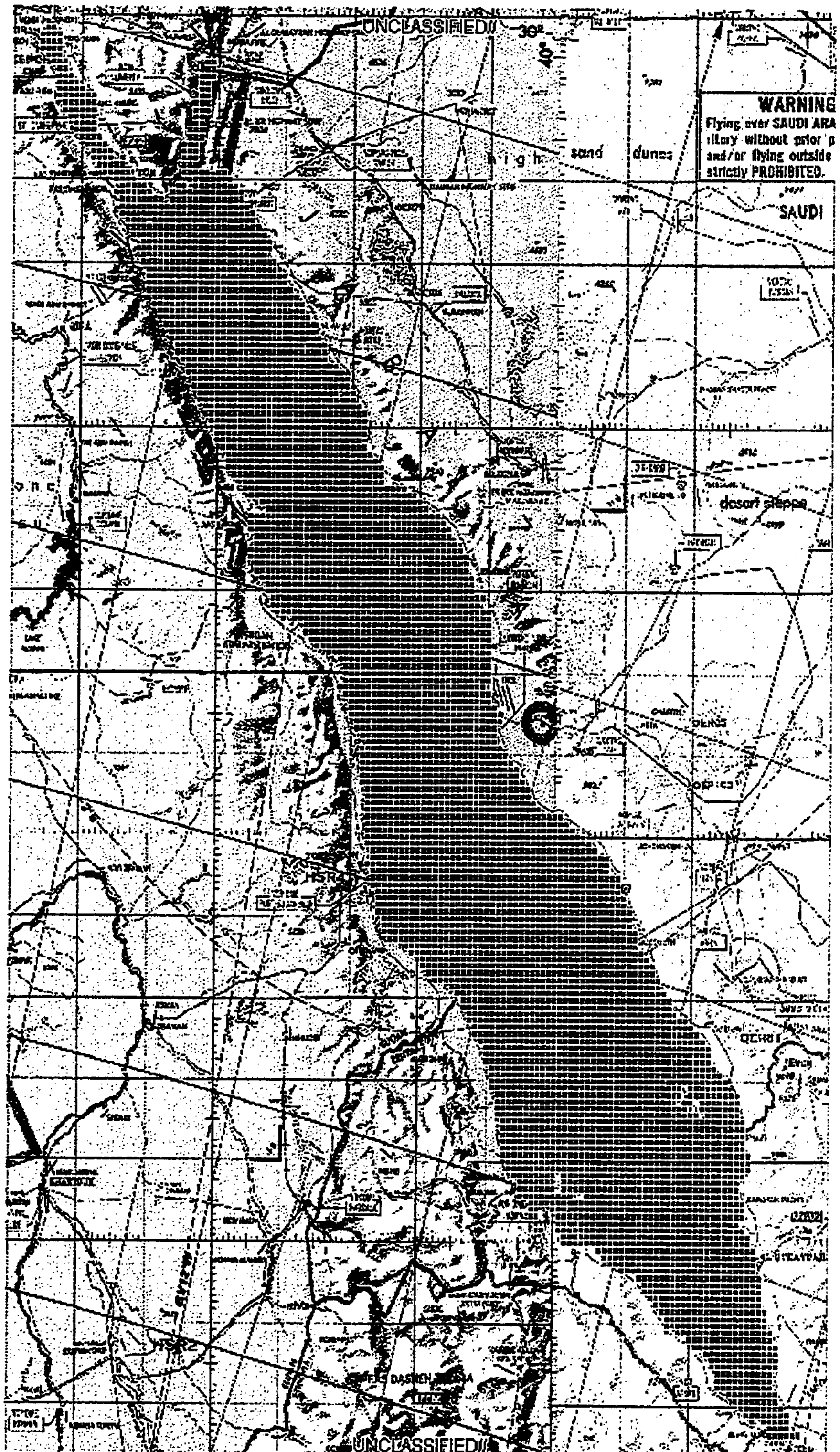
Red: 50-100 Feet
Blue: 100 and Greater

Fig. 5 --- Yellow sea



Red: 50-100 Feet
Blue: 100 and Greater

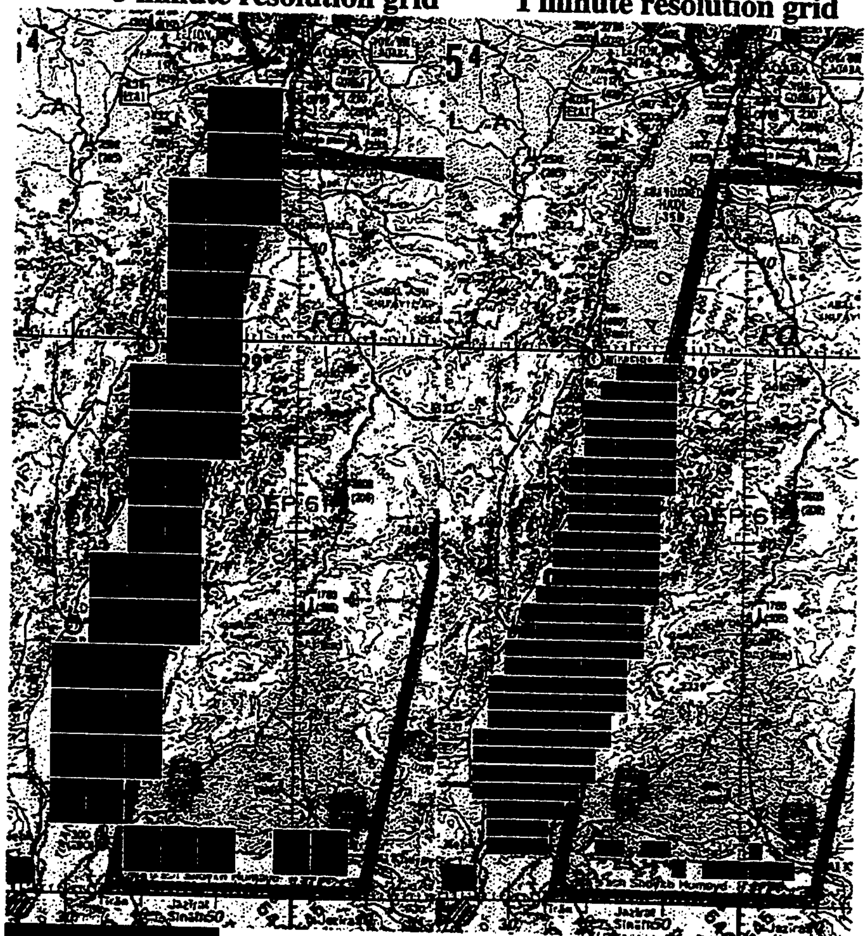
Fig. 6 --- Sea of Japan



Red: 50-100 Feet
Blue: 100 and Greater

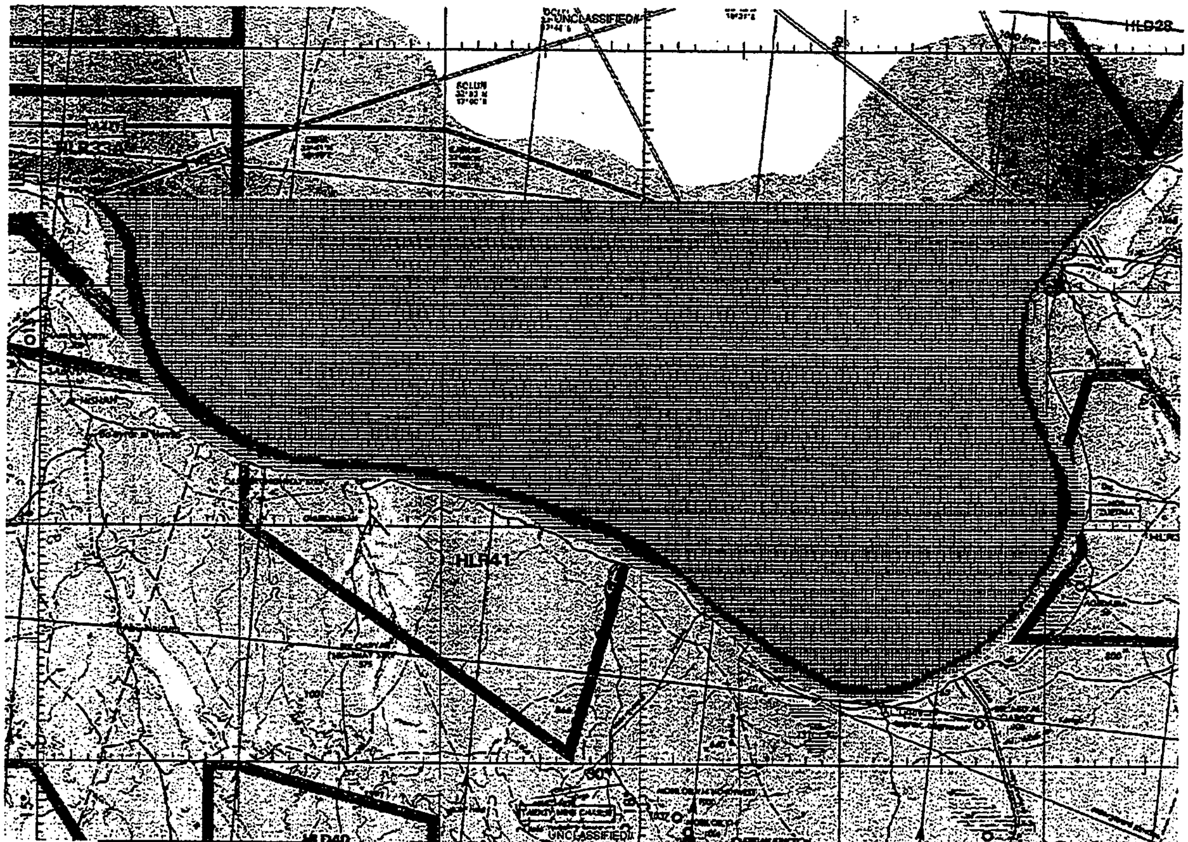
Fig. 7 --- Red Sea

5 minute resolution grid **1 minute resolution grid**



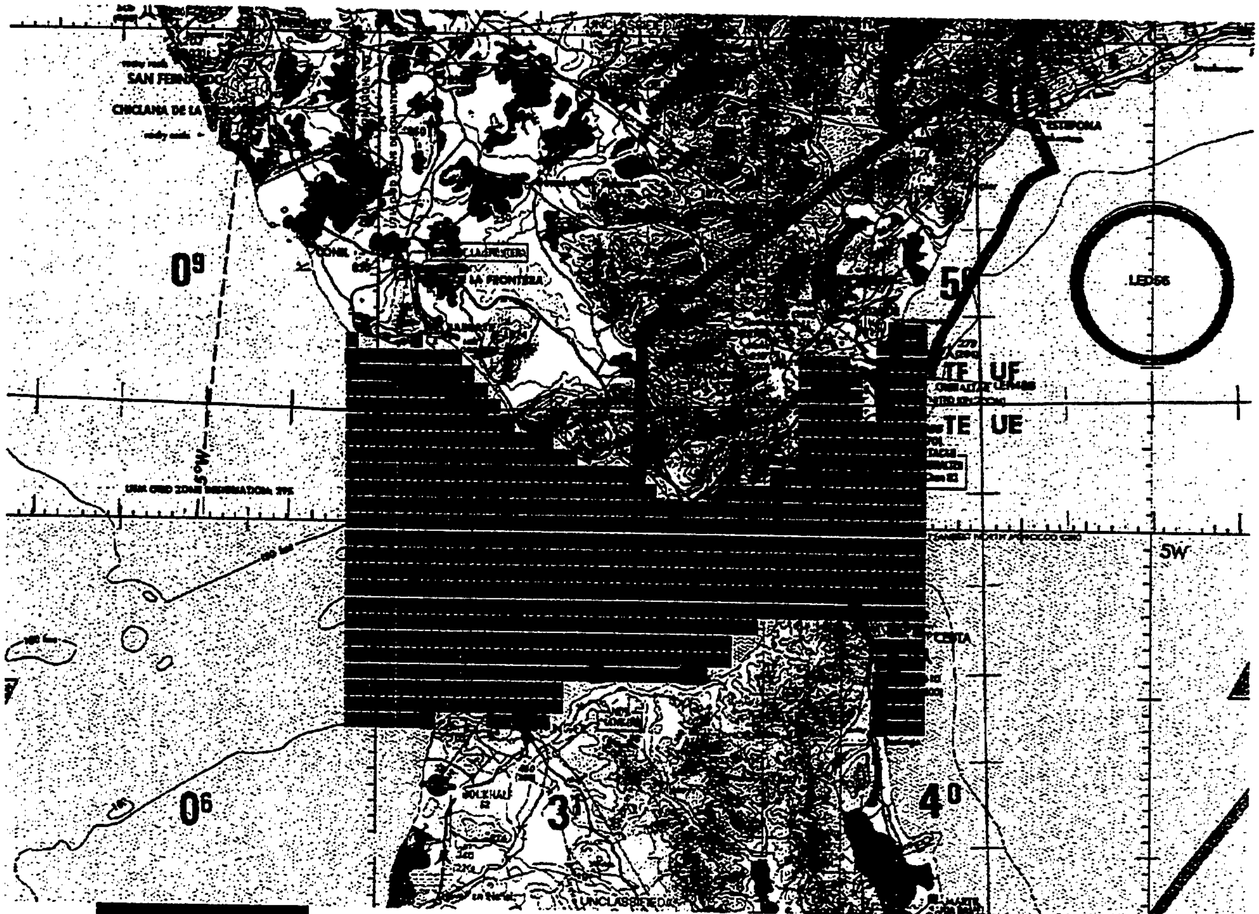
Red: 50-100 Feet
Blue: 100 and Greater

Fig. 8 --- Gulf of Aqaba



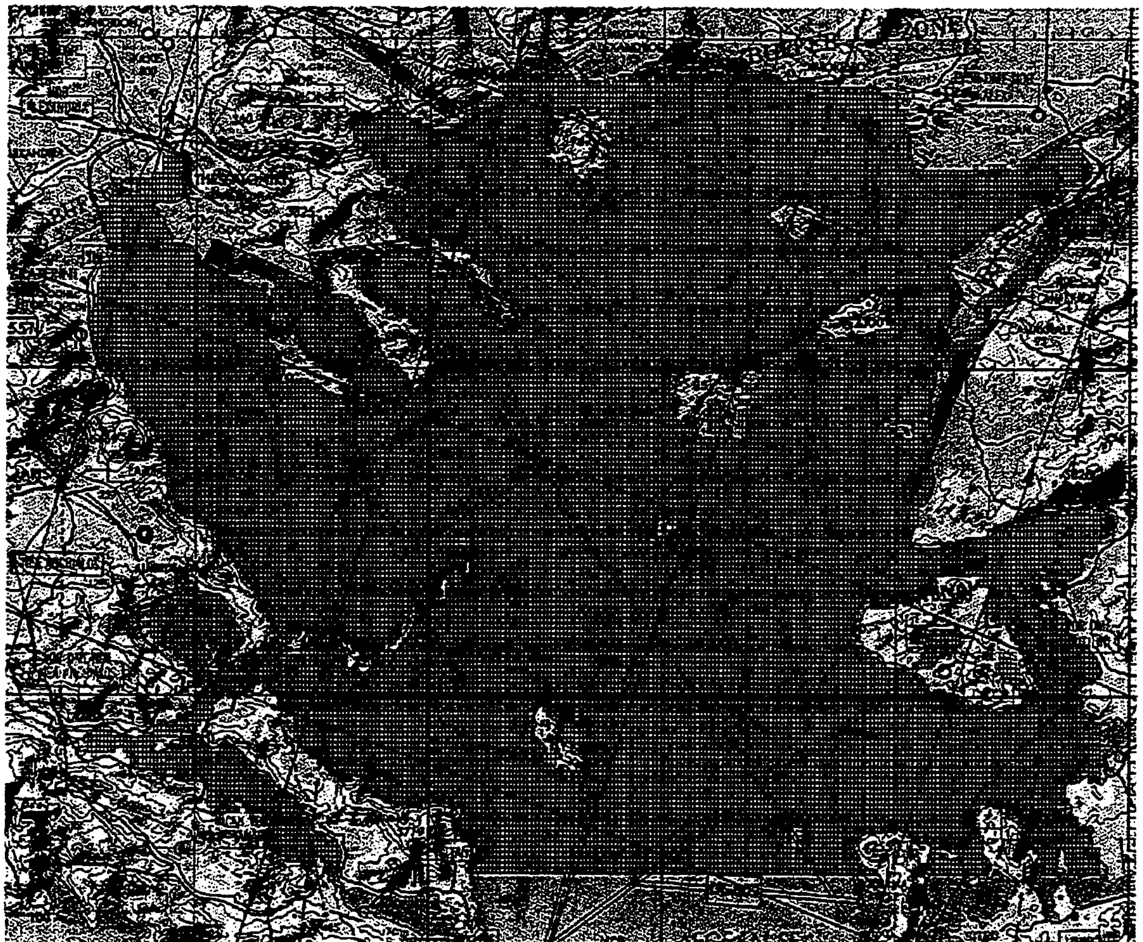
Red: 50-100 Feet
Blue: 100 and Greater

Fig. 9 --- Gulf of Sidra



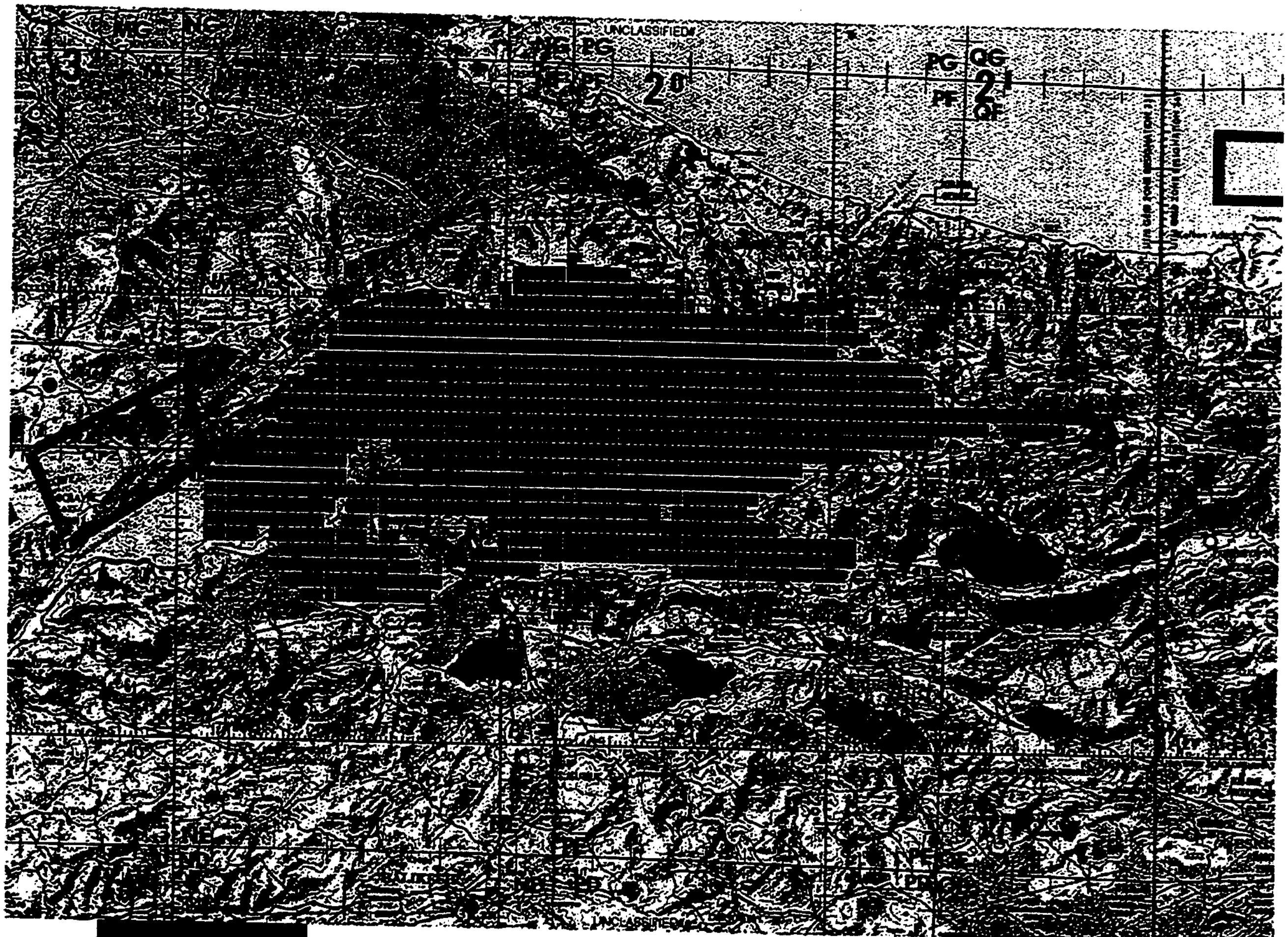
Red: 50-100 Feet
Blue: 100 and Greater

Fig. 10 --- Strait of Gibraltar



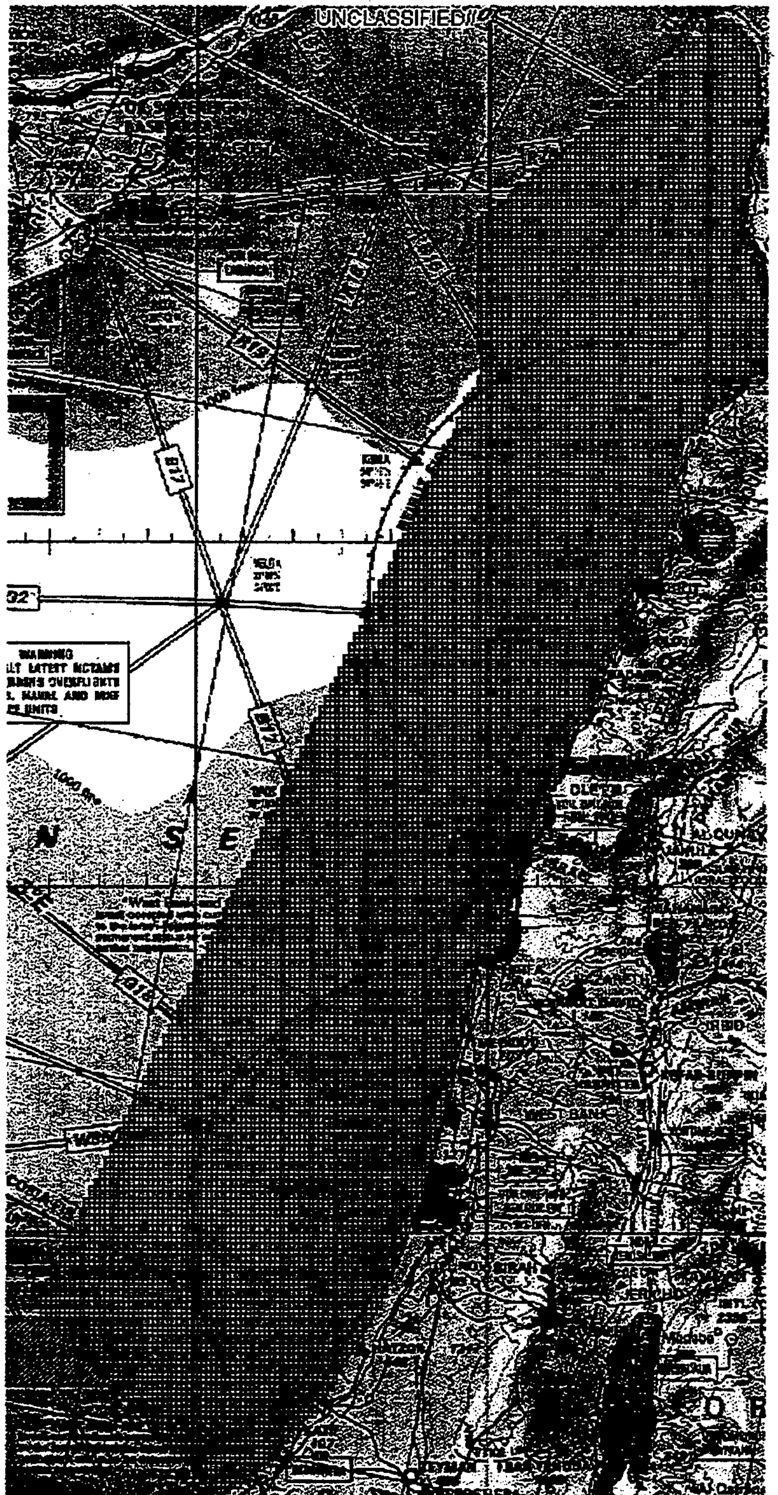
Red: 50-100 Feet
Blue: 100 and Greater

Fig. 11 --- Aegean Sea



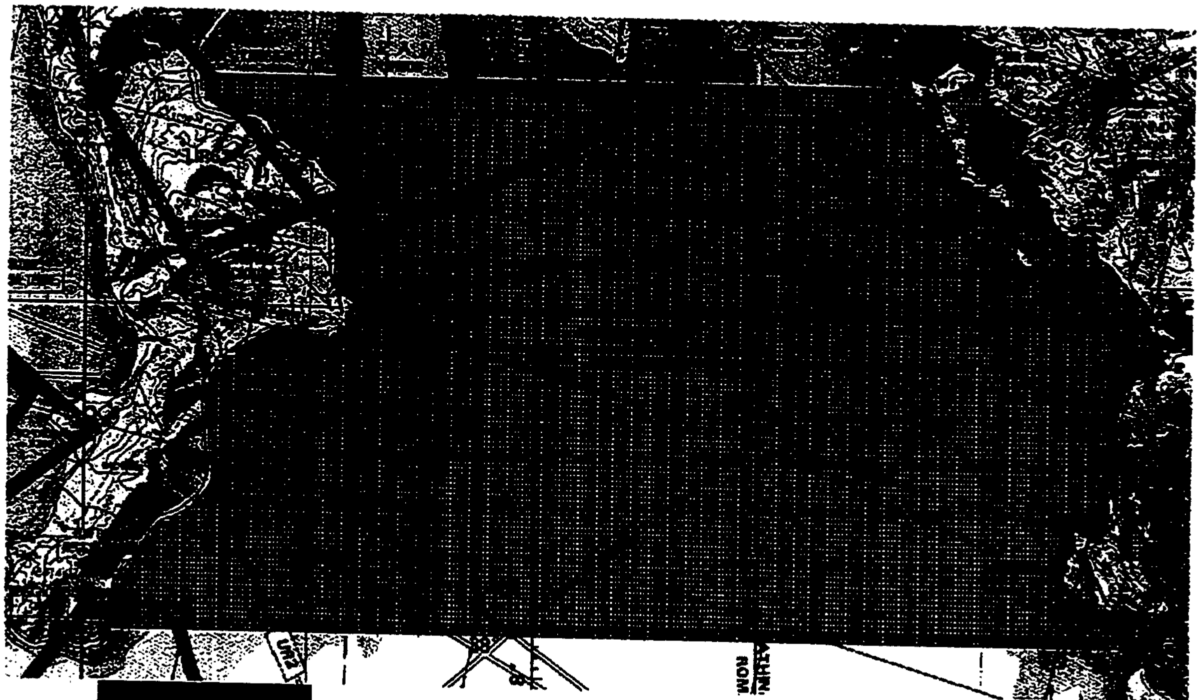
Red: 50-100 Feet
Blue: 100 and Greater

Fig. 12 --- Sea of Marmara



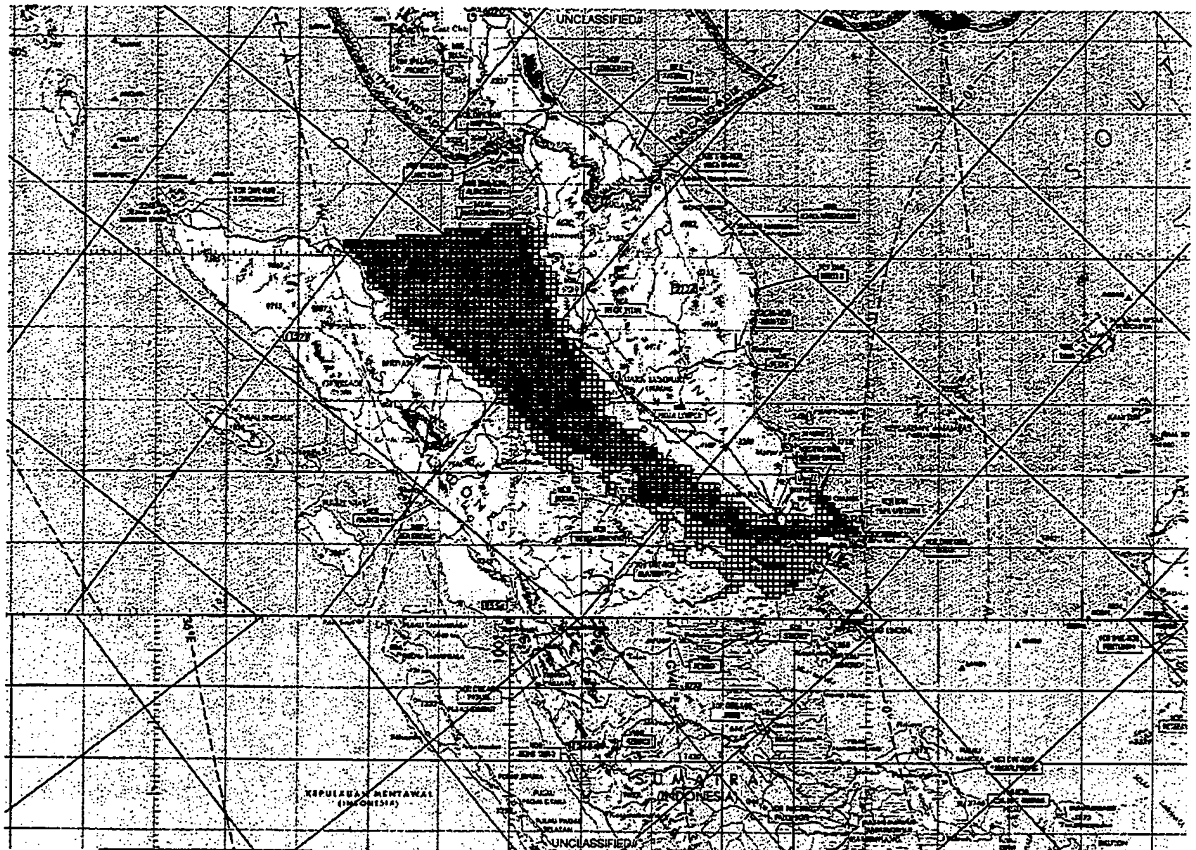
Red: 50-100 Feet
Blue: 100 and Greater

Fig. 13 --- Coastline from Turkey to Egypt



Red: 50-100 Feet
Blue: 100 and Greater

Fig. 14 --- Ionian Sea



Red: 50-100 Feet
Blue: 100 and Greater

Fig. 15 --- Malacca Strait

7. Summary and Conclusions

Approximately one percent (0.91%) of the world ocean area lies between the 50 and 100-foot contours. For the thirteen small areas listed in section III, the percent within this depth range varies from of a low of 1.09% for the Ionian Sea to a high of 25.75% for the Persian Gulf. Of those 13 strategic areas, 6 have less than 5% of their area within the depth range, and 4 have more than 12% of their area within the depth range. Thus the additional area that a shallow draft Littoral Combat Ship would be able to safely operate over that of a conventional deeper draft combat ship is provided by the percent area identified. The Persian Gulf and the Yellow Sea have the largest percent increase in accessible area for a shallow draft vessel, 56.01% and 36.65% respectively.

8. Future Work

In addition to the analysis presented in this report, there are several other issues that could be addressed to further refine the results. Those issues are:

1. Use higher resolution data from classified sources to improve result quality.
2. Calculate average distance to shore for each depth contour in a selected geographic area to determine ship effectiveness.
3. Use more sophisticated algorithms to calculate area with higher resolution data to improve result quality.
4: Further refine selected geographic regions and/or include additional regions.
5: Perform statistical analysis on the data and its potential error for each region.

9. Acknowledgements

This work was sponsored under Program Element 0603704N by the Oceanographer of the Navy via SPAWAR PMW 155, Captain Bob Clark, Program Manager. The authors also acknowledge Captain Samuel Perez of the Navy's future ship requirement branch (N763F) and Mr. Dick Martino from NIMA for their efforts in defining the problem and requesting NRL's assistance.

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Appendix A: Digital Bathymetric Data Base – Variable Resolution

The Digital Bathymetric Data Base – Variable Resolution (DBDB-V) data product is maintained and distributed by the Naval Oceanographic Office (NAVOCEANO) through the Oceanographic and Atmospheric Master Library (OAML). DBDB-V Version 4.1, Level 0 consists of a 5-minute grid of ocean floor depths with global coverage and 2, 1, and 0.5-minute grids at various locations of the earth's oceans (see Figure 1).

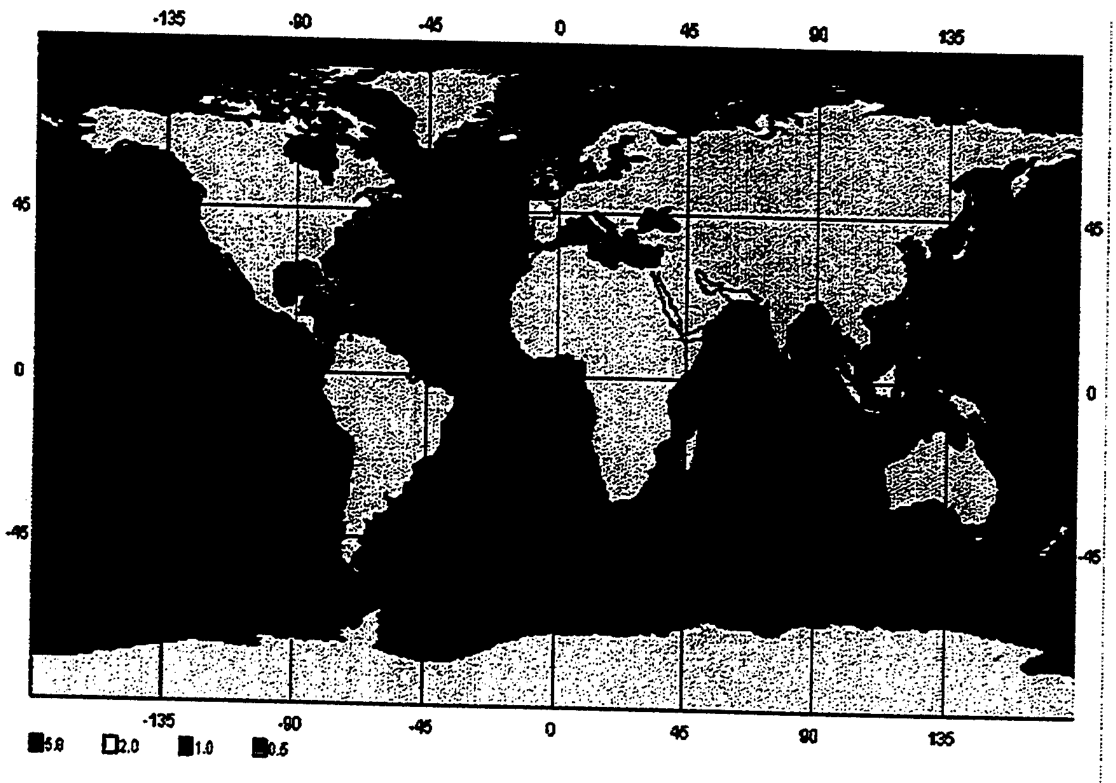

Figure 1 DBDB-V Version 4.1 Level 0 Grid Coverage

DBDB-V is a collection of individual grids of differing aerial extent and grid resolution. These grids have been developed independently over a long period of time and consequently may be based on input data of significantly varying quantity and quality. For the most part, the grid resolutions chosen reflect the maximum resolution obtainable based on the input data available and hence, reasonably reflect the spatial frequency content of the underlying survey data. More recent grids are generally of higher resolution reflecting superior input data coverage and quality. Quality differences arise from improvements in such areas as navigation accuracy, sonar systems and data processing techniques.

With the next release of DBDB-V, Version 5, the product will include support for the storage of bathymetry collected by the Precision Underwater MApping System (PUMA). The OAML approved, historical DBDB-V will accept data upgrades from the PUMA system on a global level at NAVOCEANO, and on a local/regional level via the Tactical Environment Data Server (TEDS). To support the high resolution PUMA datasets, this release of DBDB-V will include a flat earth coordinate system based on the Universal Transverse Mercator and Universal Polar Stereographic projections. This new coordinate system will be offered in conjunction with the traditional DBDB-V round earth coordinate system that is based on Geographic and Polar Stereographic projections.

The OAML distribution of DBDB-V includes an Application Programmer's Interface (API) written in the C programming language. In addition to the API and database, command line utilities, a GUI data extraction tool, and a Java Internet interface are included in the OAML DBDB-V package. The underlying file format for DBDB-V is the Hierarchical Data Format version 5 (HDF5) developed and maintained by the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign.

Appendix B: Coordinates for Geographic Areas

Listed coordinates form bounding regions for selected geographic areas.

1. Persian Gulf

Longitude	Latitude
46.2614	30.0856
56.4999	30.0856
56.4999	24.1285
46.2614	24.1285

2. Taiwan Strait

Longitude	Latitude
119.1918	25.7537
121.4877	25.1934
120.7419	22.0057
116.6326	23.3658

3. Yellow sea

Longitude	Latitude
117.0	41.02
127.0	41.02
128.3395	35.2118
117.0	34.0

4. Sea of Japan

Longitude	Latitude
135.7104	45.4638
141.9527	45.2315
139.5	36.4808
129.7923	33.2758
125.928	40.1194

5. Red Sea

Longitude	Latitude
43.6219	30.034
43.6219	12.6333
32.3439	12.6333
32.3439	30.034

6. Gulf of Aqaba

Longitude	Latitude
34.0076	29.6534
35.2815	29.5828
35.1905	28.0427
34.201	28.1123

7. Gulf of Sidra

Longitude	Latitude
15.1437	32.3775
20.1881	32.3775
20.1881	30.2865
15.1437	30.2865

8. Strait of Gibraltar

Longitude	Latitude
-6.045	35.7837
-6.045	36.2038
-5.2958	36.2038
-5.2958	35.7837

9. Aegean Sea

Longitude	Latitude
22.5422	38.4505
22.5422	40.8934
26.8794	40.8934
26.8794	38.4505

10. Sea of Marmara

Longitude	Latitude
27.0999	40.3148
27.0999	41.15
29.7976	41.15
29.7976	40.3148

11. Coastline from Turkey to Egypt

Longitude	Latitude
36.3799	35.9141
36.4257	34.6272
34.301	31.0654
33.4585	31.7931
34.9696	34.4817
34.9512	34.9141

12. Ionian Sea

Longitude	Latitude
16.0	37.979
16.5	39.7255
20.7749	39.7255
20.7749	37.979

13. Malacca Strait

Longitude	Latitude
96.0	4.9666
100.6637	5.527
104.8427	1.2533
103.4677	0.0203

Appendix C: Geospatial Information Data Base (GIDB)

NRL's Geospatial Information Data Base (GIDB) offers a fully Object Oriented (OO) database approach to managing the input, storage, retrieval, and presentation of geospatial data in relation to a specific user defined area of interest (AOI). It utilizes both public domain and commercial OO database management systems (OO-DBMS) technology to store and retrieve the data and can present this information in both 2D and 3D perspective views. It also offers the flexibility to query spatial data with reference to time and space.

The GIDB utilizes the Java™ programming environment and the Oracle® OO-DBMS as the primary data storage mechanism for all types of vector, raster and image-based spatial information. The primary goal of GIDB is to foster the advancement of Geospatial Information Technology (GIT) by encouraging the use of advanced OO data basing techniques for spatial data storage, retrieval and presentation. GIDB constitutes a more integrated approach to spatial data architectures and encourages the development of new and improved techniques for defining both spatial and temporal relationships among real world data entities. For more information on GIDB see: http://postoffice.nrlssc.navy.mil/dmap/gidb.html