A CASE STUDY OF THE PRODUCTION OF AN S-57 ENC WITH CARIS TOOLS

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April 1998

GEODESY AND GEOMATICS ENGINEERING
UNB

TECHNICAL REPORT
NO. 194

PREFACE

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A CASE STUDY OF THE PRODUCTION OF AN S-57 ENC WITH CARIS TOOLS

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May 1998

PREFACE

This technical report is an unedited reproduction of a report submitted in partial fulfillment of the requirements for the degree of Master of Engineering in the Department of Geodesy and Geomatics Engineering, July 1997. This work was supported by the Portuguese Hydrographic Institute and by Universal Systems Limited. The research was supervised by Drs. David Wells and David Coleman, and additional support was provided by the Natural Sciences and Engineering Research Council of Canada.

 The citation to this work should appear as follows:

Pais, L. M. (1998). *A Case Study of the Production of an S-57 ENC with CARIS Tools.* M.Eng. report, Department of Geodesy and Geomatics Engineering Technical Report No. 194, University of New Brunswick, Fredericton, New Brunswick, Canada, 144 pp.

ABSTRACT

The advent of the Electronic Chart Display and Information System (ECDIS) and the availability of an accurate positioning system, such as the Differential Global Positioning System (DGPS), were the driving technologies for a new digital hydrographic product.

The Electronic Navigational Chart (ENC) is a new hydrographic product, recognized by the international marine instances as the equivalent of the traditional paper chart. The production of ENCs is being supported by the use of Geographic Information System (GIS) tools to meet the requirements of the International Standard for the Exchange of Hydrographic Data, documented in the IHO special publication No 57 (S-57).

The S-57 document makes use of the *object-oriented* concept to model the real world into a computer-based format. The aim of this report is to study the production of an ENC with the tools from Universal Systems Limited (USL), *CARIS* and *OBMAN*, to make recommendations and suggestions not only for software enhancement but also to contribute to the optimization of procedures within an Hydrographic Office (HO)currently producing both paper and electronic charts.

This report is structured in seven chapters. The first two define the problem of building an ENC within an HO and introduce an historical background to support the discussion between raster and vector charts. The Object-Oriented (O-O) concept in general and its meaning for the S-57 standard, in particular, is described in chapter 3. The use of "dedicated methods" in O-O is particularly important within the S-57 ENC because it allows an object to be displayed with different geometries depending on the scale chosen. The S-57 standard is explained in detail in chapter 4, while chapter 5 introduces the *CARIS* tools used. Chapter 5 also compares two different ENC *viewers* (*ECVIEW* and *SeeMyENC!*). The steps followed by the author to build an S-57 ENC are described in chapter 6. Optimization of procedures, and suggestions for a software enhancement are also contained in this chapter. An example is the need for an appropriate layering of the data whenever a *CARIS* file is built for both paper and electronic chart production. The author also suggests a quality control tool to check for inconsistences and distortions on the shape of the feature objects after the filtering of the point data (S-57 standard).

Acknowledgments

I would like to thank my supervisors, Prof. Wells and Dr. Coleman for their support and friendship throughout the school years of 1995-1997.

I also would like to express my gratitude to USL for providing the software and their time to accomplish my research.

To Marta, a big thank you for answering all my questions and making my learning time shorter with *CARIS* for UNIX.

I also would like to thank the Portuguese Hydrographic Institute and in particular Cd. Pinto de Abreu for providing the *CARIS* data set used to convert to an ENC and the support during this Canadian experience.

Specially to my wife who gave up one year of her career and the home comfort to be nearby and to support me in every moment, thank you. Thank you for your love, patience and English corrections.

To my son and my Canadian born daughter Mafalda thank you for the psychological support of your presence.

And, last but not least a big thank you to my parents, in-laws, family and friends for their support and encouragement during the last two years.

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CHAPTER 1

INTRODUCTION

1.1 General

Cartography is one of the oldest disciplines in the world. As a means of expression, the map has survived through thousands of years of technological evolution. Since the advent of the digital computer, cartography has been in constant evolution, and cartographers have changed the way they see the mapmaking process. Digital products have replaced traditional paper charts, with all the advantages of the digital world in the storage, manipulation and retrieval of data. The computer has relieved the cartographer from tedious, time-consuming production tasks, allowing a greater focus on cartographic design. The computer also gave us new types of maps and new media for display such as the ones that can be walked around, manipulated, and seen as three dimensional objects. Interactive media, multimedia and animation are some of the new cartographic methods being used to show spatial representations over time and space.

Geographical Information Systems (GIS) allow the capture, storage, retrieval, analysis, and display of spatial data. These systems use geographic data extensively, and most of the queries made provide cartographic solutions. The latest developments have seen the introduction of *object-based* or *feature-based* programming for storing geographic information. In this new approach geographic features are stored in a database as units or objects .

Data collection is a high-cost, labor-intensive component in the overall production of a nautical chart, and converting data from another system is not always a straightforward procedure. The need for the exchange of data between the legal producers of nautical data, i.e., the Hydrographic Offices, was the starting point for the gathering of efforts between the IHO, IMO and ECDIS manufacturers in order to reach a standard format for the exchange of data. The Edition 3.0 of the Special Publication S-57 "IHO Transfer Standard for Digital Hydrographic Data"of the IHO contains a Data Model, Exchange Standard, Object Based Catalogue and an Electronic Nautical Chart Product Specification as the result of almost nine years of evolution and debate among the Marine Information Systems subject [IHO, 1996]. Not only the ECDIS manufacturers but also the GIS vendors have been involved in this technological process of standardizing procedures and products.

Among the GIS vendors, Universal Systems Limited (US) a Fredericton based company, has made an effort to provide its clients in the hydrographic community with the tools to produce nautical charts compliant with the IHO standards. The *CARIS* Object Manager (*OBMAN*) and *ECVIEW* software tools allow the cartographer not only to produce and control the quality of a paper nautical chart but also to perform the translation from a paper chart (*CARIS* format) to an Electronic Nautical Chart (ENC) product.

1.2 The Problem

The purpose of this report is to evaluate a case study of a production of an ENC with the tools made available by US. The report is organized in seven chapters .

The first chapter, contains an introduction to the problem of producing an ENC with an explanation of the computer-based and GIS technology techniques now available to the cartographer nowadays. In this chapter, a description of how the problem will be addressed is given to the reader.

In chapter 2, a brief historical background covers the evolution of cartography in a hydrographic office from a traditional manual-based technique through computer-assisted cartography for the production of paper and electronic charts . Raster and vectors charts products and their differences are also outlined in this chapter. The need for standards and an introduction to the S-57 standards themselves with a time line information concludes the chapter.

The design of the S-57 standard for the exchange of hydrographic data is Object-Oriented based. Chapter 3 addresses the concept of Object-Oriented Programming. In this chapter, the reader is given detailed information about the Object-Oriented concept and the advantages of using this approach for the design of a database and for the purpose of building and update an hydrographic chart product.

Chapter 4 gives a detailed explanation about the S-57 standard. The object data model and data structure are outlined in order to introduce the first product 'profile' developed from this document. This 'profile' is the Electronic Navigational Chart (ENC) Product Specification, or the first hydrographic product being produced under the specifications contained in the S-57 document.

Chapter 5 introduces the *CARIS* tools (software) that will be used by the author in the production of an ENC from a feature-based *CARIS* file to an object-based ENC. All the steps in the pre-processing of a *CARIS* file for the creation of objects will be described in detail.

Chapter 6 describes the methodology followed by the author to produce an ENC from a *CARIS* file of a paper chart - *Carta 115 Ilha das Flores e Corvo*. Suggestions and recommendations are outlined in this chapter, and procedures to improve the cartographic production process of building an ENC.

Chapter 7 contains conclusions and recommendations and a summary of the case study in this report.

CHAPTER 2

HISTORICAL BACKGROUND

Traditional cartography has been associated with printing techniques since the Middle Ages. Before the advent of the digital world, nautical cartography was the sum of error-prone and time--consuming manual processes. It would take several months, sometimes years, to move from fieldwork to the final paper product, involving subjective and painstaking processes.

Today in most of the Hydrographic Offices around the world, traditional cartography (in the sense of manual non-digital techniques) coexists with computer-based processes to provide different kinds of products to the client. This is a transition period, towards a future hydrographic office, based entirely on digital processes.

When survey work is assigned that results in a new nautical chart, the hydrographer is responsible for providing the field sheets with all the bathymetric and surrounding topographic information at a scale specified by the International Hydrographic Organization. In the digital world, the bathymetric information will be collected with a single or multibeam sounding system in digital format, after which the data will be cleaned of blunders before being delivered to the cartographic services.

Two different computer-based products are described in detail in this chapter :

(1) The Paper Nautical Chart; and

(2) The Electronic Chart.

For the purposes of this report, "Traditional Cartography" will be defined as the manual techniques used for the production of a paper chart, before the advent of computer based cartographic systems and digital hydrographic products.

2.1 Traditional Cartography

The aim of this section is to provide the reader with a description of the traditional cartographic work, based on colour separation and manual processes, as opposed to the digital hydrographic office (computer based) and in particular the production of Electronic Charts. In most hydrographic offices both techniques either co-exist, or the traditional approach as been replaced by a fully digital collection, processing, edition and printing of data.

Upon receiving the field sheets at the scale(s) surveyed, *compilation* work must be done to select the information required for the new edition of the nautical chart. The cartographer assembles new bathymetric information, updated topographic information, all previous data contained in the old chart edition (if such exists), and remote sensing (photogrammetric data) for comparison and selection purposes. Using photographic techniques, the selected information is reduced or enlarged to the new nautical chart scale.

Once all the desired information to be included in the nautical chart is gathered by the cartographer, several techniques can be used to achieve the final product. The process of producing hard copy nautical chart can be split into five components, as discussed in [Curran, 1988]:

(1) Image generation;

(2) Image registration;

(3) Contact copying at scale;

(4) Image separation / combination; and

(5) Printing.

Image generation is the process of assigning symbol type, shape and structure to features on a map. Who can have a basic geometric plan provided by the absolute location of each item in the map, or may need to modify or generalize this geometry to a greater or lesser degree. In traditional cartography all these images may be created manually.

Image registration is the technique to ensure that individual colour components precisely fit each other in the map. To achieve this purpose, there are several overlay registration systems and the selection is determined by the production requirements.

Contact copying at scale is the operation used to produce same-size line, half-tone and continuous-tone positives and negatives by a direct contact process. The most common is the lithographic printing which is a metal that has been chemically cleaned and coated with a light-sensitive emulsion.

Image separation comprises the techniques used to produce multicolor maps by the sequential overprinting of a number of separate color components. In most Hydrographic Offices

/ Cartographic Organizations, various line components and color masks used in the production of a map are produced separately in order to facilitate production and maintenance of the chart. This separation of colors can be done by either manually opaquing or photographically separating the various color components of a chart.

For ease of production and to facilitate future updating of chart information, the colour components are originally divided into a number of separate elements (layers) which, when **combined**, form a single image to be printed in a specific color. As an example, we may say that the blue printing image may be made up of separate elements such as shorelines, bathymetric contours and lakes.

The process of producing multiple copies or reproductions is associated with the **printing press** but also with the reprographic or electrostatic systems which are both capable of producing duplicates from an original. The most common is the planographic or offset lithographic process in which the image and non-image areas are on the same plane [Curran, 1988].

2.2 Computer Assisted Cartography

GISs are automated systems for the capture, storage, retrieval, analysis and display of spatial data. Within these systems, final maps reflect an emphasis on query and response rather than display [Clarke, 1995]. On the other end, Computer Assisted Cartography is a broader designation that means the ability of using computer based techniques (digital storage, automated procedures, interactive processing of data) to produce maps with specific cartographic purposes.

We can not dissociate the advent of Geographic Information Systems (GIS) from the field of the Computer Assisted Cartography (CAC). The use of the computer introduced new cartographic methods and techniques. GISs are usually supplied with an interface to a cartographic display system or can contain their own systems, they are available to assist data managers in the planning and decision making [Clarke, 1995]. In a GIS, the generation of charts provides the user with either an intermediate or a partial solution to a problem or query and so it may not contain other information rather than a figure and a geo referenced system reflecting an answer to the query made.

Although the goals of a GIS and of computer cartography are similar, they are not the same. Usually, GIS is the visible face to which people are first introduced in the CAC world, the computer has relieved the cartographer from tedious tasks such as the plotting and image generation, allowing interactive modifications to the product during the work flow process. The computer introduced several major features: the ability to manipulate colour and other display parameters (perspective, scale, etc...), giving new types of maps and new media display. Interactive multimedia and animation are some of the new cartographic display capabilities.

A new vocabulary was introduced in cartography with the advent of the digital world and GISs as a support tool for the production of nautical charts. Words like "workstation", "digitizers", "plotters", "topology", "raster/vector" and "objects"are now heard around the world where charts are produced supported by a computer system in accordance with the international standards. *Workstations* with fast processors, using GIS software, provide a powerful tool to run complex multi-function programs .

In most of the Hydrographic Offices (HOs) these workstations are inter-connected in a network where each client CPU is connected to the others using a network software that handles the movement of data and manages the individual systems, providing interconectivity and workgroup task sharing in a multi-user environment. As in the Canadian Hydrographic Office (CHS), networks can be extended through the telephone line and other utilities to link the branches around the country.

Input devices, such as light-pens, joysticks, keyboards, track balls or touch screens provide digital data capture from legacy documents. *Digitizing or Scanning* data is a key operation in loading a database, from existing information, to produce a nautical chart. *Digitizing* is the procedure of extracting georeferenced features in digital form from an existing chart. Cursors moving on top of the chart data generate an electric signal each time a button is pressed converting an electric signal into a pair of x and y values and any attributes entered that are sent down a cable to the workstation. Automatic Digitizers include *Scanners* and *Line Followers* which are very high resolution digital devices that capture gray tone or the intensity of a certain light frequency. Georeferencing is established using reference or control points.

A GIS system allows the manipulation and separation of colors miming what was previously done manually in the traditional cartography. At this point in time we can choose to produce a paper chart using lithographic techniques or using a "print-on-demand" approach using a plotter. Although the printing quality of a lithographic technique is superior when compared with computer output devices, the latest developments in technologies are turning such systems as the Electrostatic, Bubble-jet, Ink-jet or Laser-jet printers into attractive ones for cartographic purposes offering low cost and flexible printing options.

2.3 Traffic and Economic Reasons

Marine safety and economics are the two main reasons for development of an automated navigation system.

On March 24, 1989, while heading out from the port of Valdez, the EXXON Valdez left the channel and struck Bligh Reef, spilling 11 million gallons of crude oil into Prince William Sound. Although maritime accidents are not as frequent as road accidents their damages are substantial including loss of lives and cargo, damage to ecosystems, shutdowns of ports and increasing insurance premiums. Table 2.1 outlines some of the latest maritime accidents and their financial consequences (vessel damages). Damages caused to the environment are not included in the final costs.

After the EXXON Valdez accident, it was found out that human failure was the main cause for the catastrophe. Reports indicated that the officer of the watch was not only inexperienced but also suffering from a work overload. In fact, almost 80% of the maritime accidents are caused by human error [Pace, 1996] . Therefore, a U.S. government decision was made to reduce further accidents by identifying a new navigational aid that could ease and speed the task of officer of the watch to know the ship's position. A joint U.S.-Canadian study of the West Coast shipping

Table 2.1

Example of groundings and losses [NOAA, 1995].

SHIP	DATE	LOCATION	DAMAGES
Q.E.II	1992	Vineyard Sound, MA	$45 million
American Trader	1990	Huntington Beach, CA	$30 million
Glacier Bay	1987	Cook Inlet, AK	$50 million
Hyundai 12	1991	Twelve Fathom Straits, AK	$994,000
EXXON Valdez	1989	Valdez, AK	$3 billion *

*Only clean-up estimated cost

completed in July 1990 [NOAA, 1995] found out that a new electronic navigation system could reduce the total number of accidents by 15-19 percent. Recent studies done by the Woods Hole Center, MA, estimated that the use of the same system could avert an average of $3 million a day [Kite-Powell et al., 1996]. Although the increase of safety in navigation is the main impetus behind this new trend, the commercial benefits cannot be disregarded. In fact, the Association of Maryland Pilots recently increased Baltimore's maximum permissible vessel draft from 39.5 feet to 41 feet [NOAA, 1995] which was a direct result of the pilot's use of real-time water-level data from NOAA gauges and the degree of confidence provided by the use of an Electronic Chart Display and Information System (ECDIS). Estimated revenue increases from $36,000 US to a maximum of $288,000 US for each additional foot of draft for large bulk and container ships [NOAA, 1995]. In Portugal the volume of ocean foreign trade as increased over the past five years. Between 1993 and

1994 the traffic of tank ships in the port of Sines increased by fifteen percent and the cargo volume by twenty five per cent (see figure 2.1) . If an investment for a safer navigation (Vessel Traffic Systems and Electronic Chart Display Systems) is not considered, than an increase accident risk may occur.

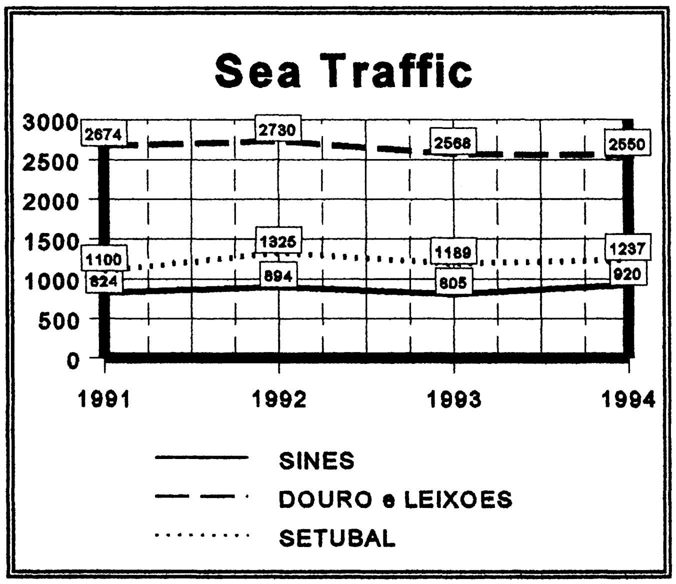

Figure 2.1

Sea Traffic in three of the largest Portuguese ports (after [DGPNTM, 1996]).

2.4 The Meaning of the Global Positioning System (GPS) for ENC

The emerging standard marine navigation system (Electronic Chart System / Electronic Chart Display and Information System) automates some of the human tasks, reducing time to plot the ship's position. Positioning is integrated through the use of an accurate positioning system. The global 24-hour availability of the GPS constellation alone allows a 100 metre accuracy, insufficient for some of the purposes of an ECDIS (docking with low visibility, navigation on large scales charts). The development of both GPS technology, allowing meter accuracies through the use of differential corrections (DGPS), and ECDIS/ECS has been a synergistic relationship. This relationship has led to the widespread availability of DGPS signals (U.S. and Canadian Coast Guard projects) which are at the same time needed to make ECDIS/ECS a worthwhile system [Casey et al., 1996].

2.5 Electronic Charts - Raster vs. Vector Charts

The ENC itself is a digital product with paper chart look-like appearance and "intelligent" capabilities such as danger warnings to the navigator, "embedded" in layers of information. All the information is displayed in a computer based system (keyboard, mouse and monitor) or on a Liquid Crystal Display (LCD) for the most simple systems.

The Electronic Chart System (ECS) is one of the visible faces of this new technology that will radically change the face of maritime navigation. ECS' available in the market run from systems using a simple optically scanned raster charts and systems as the ones running Admiralty Raster Chart System (ARCS) charts, to vector based systems.

On a top level, the Electronic Chart Display and Information Systems (ECDIS) using IHO-approved ENCs, accurately display a vessel's real-time location, automatically update that information every one or two seconds, and distinguish among floating aids to navigation, vessels and points of land. It also allows the superimposing of RADAR images [Krakiwsky and Bullock, 1995].

Although an ECDIS system offers a complete set of tools to the navigator similar to those offered by a GIS, some ECSs are now being developed with an increased complexity of features which will certainly change this hierarchic classification in the future.

2.5.1 Raster Charts

Between 1970 and 1993, the number of recreational boats owned by the Americans nearly doubled from 8.8 million to 16.5 million [NOAA, 1995]. Because recreational boaters have limited storage space and their demands for navigational aids in terms of complexity and costs must be very different from a commercial ship, a simple and low cost type of electronic chart has been offered for the last few years from private vendors. Since products developed by the U.S. government are not copyrighted, several private companies offer a raster product (produced form NOAA paper charts) to this share of the market. A "raster chart" is a bit-map image of a paper chart. Since the paper charts are simply scanned, the chart software has no knowledge of whether a feature within that image is a navigational aid or a navigational hazard. A chart, and a grid of latitude and longitude is mapped with the image where a RADAR image can also be superimposed on.

The United Kingdom Hydrographic Office (UKHO) recognized the long time frame that would take to develop a world wide vector S-57 ENC [Halls, 1996] and developed their own raster format, the Admiralty Raster Chart System (ARCS), in order to provide a faster worldwide charting coverage. The UKHO production of raster charts is intended to complement the ENC S-57 production. Both products are based on Object-Oriented technology supported by Laser-Scan software [Laser-Scan, 1997].The UKHO planned to have the complete folio of 2500 raster charts completed by December 1996 (see figure 2.2).

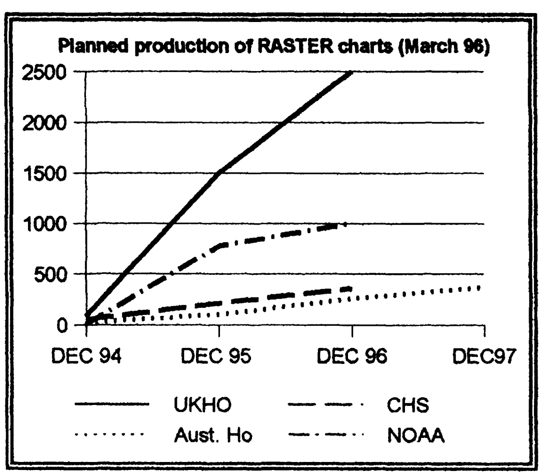

Figure 2.2
Planned production of Raster charts in four of the major HOs.

Raster Charts are being produced by the British Admiralty (ARCS), and private companies like NAVIONICS, C-MAP and MAPTECH. Raster Charts require large amount of storage space (10MB) and are usually delivered on CD-ROM. They are similar to paper charts, but no selective display can be performed. Within this product, zooming results only in the enlargement of the features in the display . The updating of a Raster Chart is done by the replacement of the complete chart by a similarly-scanned version of the new one.

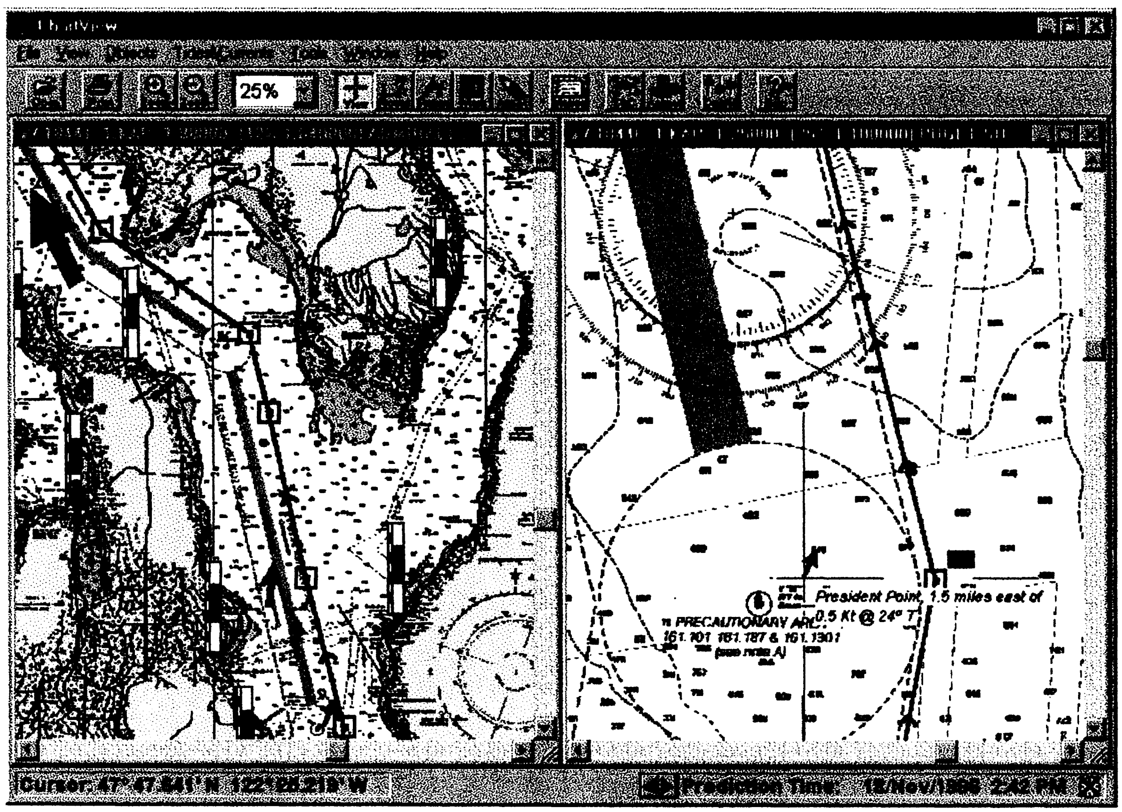

Figure 2.3

A Nautical Software Inc. viewer of a Raster Chart

(from Nautical Software [1997]).

2.5.2 Vector Charts

Vector Electronic Navigational Chart was adopted by the IHO/IMO to become the legal equivalent to a paper chart when displayed on an ECDIS. Vector Charts (or VC's) were developed to be a medium/long term solution to the demand for digital chart information [MacDougall, 1994]. Vector Chart data are capable of being structured topologically, which means that the chart structure has inherent intelligence, built to be recognized by a Geographic Information System. This intelligence means that selective display of the information is available and, when displayed at large scales, and will also show what was not visible in a small scale. The navigational situation can be automatically interpreted using GIS operations, e.g., recognizing course changes or giving alarms when appropriate. It requires less storage space than a vector chart because only the end-points of the lines defining objects are stored. Vector Charts are labor intensive and more expensive to product than a Raster chart [Krakiwsky and Bullock, 1995]. Table 2.2 summarizes some key characteristics of both raster and vector charts.

The IHO Special Publication for the Exchange of Data [IHO, 1996] commonly known as S-57, specifies an exchange format for the hydrographic information shared by HO's. In this standard, spatial objects must be of the vector type and the theoretical data model is implemented on a chain-node topology (see chapter 4 for details). Vector Charts are released in standard floppy disks or other digital storage medium. The updating of a Vector Chart is done by replacing a cell of that chart instead of the entire chart, as in the raster version.

Table 2.2

Raster Charts vs. Vector Charts.

	RASTER CHARTS	VECTOR CHARTS
STORAGE	-Large storage requirements (10MB) -Released on a CD-ROM	-Less than 10% of the required by a Raster Chart -Released on a common floppy disk
ZOOMING	-Enlargement of all the features in the display	-Selectively enlargement -Information is stored in layers
UPDATING	-Is done by the replacement of the all chart	-Only the cell of information is required to be updated
DATA COSTS	-Few hundreds of dollars ($100)	-Thousands of dollars ($10000)

2.6 The Need for Standards

Standards are "documented agreements containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics, to ensure that materials, products, processes and services are fit for their purpose" [ISO, 1996].

Standardization is a condition that exists within a particular commercial or industrial sector when the large majority of products and services conform to the same design and / or quality. Standards usually result from consensus-based agreements between economic players and often governments [ISO, 1996].

The aim of standards is to facilitate trade, exchange and transfer technology through [ISO , 1996]:

(1) Greater compatibility and interoperability of goods and services;

(2) Simplification for improved usability;

(3) Reduction in the number of models, and thus reduction in costs; and

(4) Increased distribution efficiency, and easier maintenance.

The existence of non-harmonized standards for similar technologies in different countries or regions can contribute to the so-called "technical barriers to trade " [ISO, 1996].The International Organization for Standardization (ISO) is a non-governmental organization of national standards bodies from some 100 countries with the mission to promote the development of standardization in order to facilitate the international exchange of goods and services. ISO / IEC 8211 describes an international standard for encapsulating digital data for information exchange. It comprises specifications covering both the transfer and the organization of the data.

From the "supplier side " of hydrographic data, the need for standards comes from the fact that the increasing costs in the collection of data requires the exchange of information to avoid duplication of efforts and costs. Collecting hydrographic information entails hundreds of hours of field work, thousands of dollars a day, and manual time consuming work of cleaning data and quality control procedures for cartographic purposes. In this context it is absolutely necessary to exchange data between HOs and governmental departments and agencies in order to reduce costs, avoid redundancy and duplication of the existing information and to maintain the latest version of the information on all HO products.

From the "demand side", navigators (unlike the land map user) need a worldwide uniformity, due to the fact that they sail the oceans and visit a multitude of coast lines, thus requiring standard horizontal and vertical datums.

2.7 S-57 Development History

The urgent need to exchange data between hydrographic offices in a computer based world, with so many protocols, required a study to be done by the appropriate commissions at the IHO and IMO. Digital data was being produced by HO's around the world demanding that duplication of efforts should be avoided.

The first step to achieve this objective was the establishment of a Committee on the Exchange of Digital Data (CEDD) to study the problem and define a document to be presented at the XIIIth International Hydrographic Conference, 1987. The draft of the standard was approved at this same event.

Soon after this first document was released, the advent of an Electronic Chart System with GIS capabilities, such as the Offshore Systems Limited (O.S.L) ECPINS [OSL, 1997] , pressed for a change in order to include topological relations and to develop an improved object code [Roberts et al, 1994]. This new document included a new exchange format, DX-90, and a detailed Object Code combined with digitizing conventions. The former standard was known as "IHO Digital Data

Transfer Standard" commonly known as Special Publication number 57 or S-57.

After receiving the comments from ECDIS manufacturers and HOs, some amendments were introduced. A data model was included in the document, and version 2 was released in March 1994 [Kerr, 1994]. Soon after the publication of version 2.0 it became evident that a Product Specification (PS) for Electronic Navigational Charts (ENC) was urgently required. Data produced in the S-57 format varied between Hydrographic Offices, due to the variety of possible interpretations of the standard.

The Product Specification requirements were established at the 6th Meeting of the Committee on Electronic Data (CoE) in November 1994. The preliminary work was followed by a workshop in February 1995 with the participation of ECDIS manufacturers, HOs and regulatory authorities in order to reach an agreement for the ENC Product Specification document content.

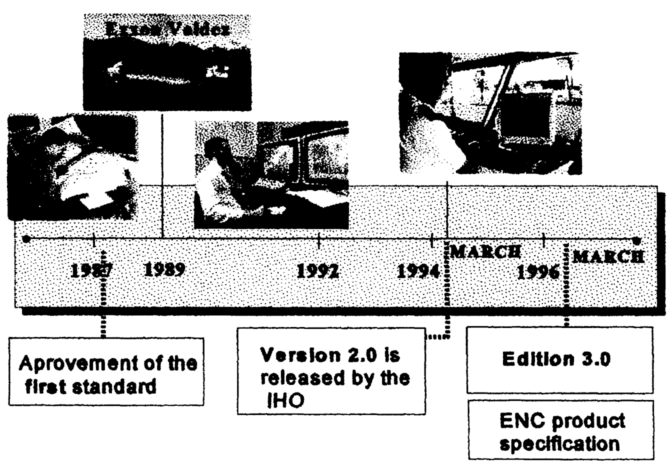

Figure 2.4
S-57 time line.

The Data Base Working Group (DBWG) of the CoE undertook the preparation of both the future Edition 3.0 and the ENC PS. Changes from the previous edition included:

(1) A new cell structure concept;

(2) A new updating mechanism;

(3) A binary implementation of the format in addition to the ASCII;

(4) Inclusion of time varying in the Object Catalogue objects; and

(5) A description of four levels of topology for vector data.

The edition 3.0 of the IHO Transfer Standard for Digital Data, publication S-57, was released in March 1996. Following this, a six-month period allowed ECDIS manufacturers and HO's to develop new software to import and export data, after which the commission met again to consider minor necessary changes. The changes were made and in November 1996, the final Edition 3.0 was released and will remain frozen (except the object catalogue)for at least four years (see figure 2.4) [IHO, 1996].

CHAPTER 3

OBJECT ORIENTED CONCEPT

The S-57 standard design is object-oriented based. A primary reason is the inherent ease of updating in comparison with more traditional approaches

GIS vendors like USL [Rawlence and Peyton, 1996] and LaserScan use the Object Oriented approach to develop Hydrographic applications [Peyton et al., 1996] because this new concept optimizes the manipulation and maintains the integrity of large databases. This Chapter will explain the Object-Oriented theory applied to GIS in general and, its relevance for hydrography (S-57 standard) in particular.

3.1 Relational vs. Object Oriented Databases

The object oriented concept has been developed in the world of programming languages for the last eight years. The Object Oriented (O-O) concept allowed users to better describe real-world concepts and relationships within the constraints of computer programming languages. Even a user with no background in programming easily understands this concept because modeling is closer to the real world features.

Although largely unknown a few years ago in the GIS world, an increasing number of vendors now offer Object-Oriented software solutions to some GIS problems. The Laser-Scan Automated Map Production System 2 (LAMPS2) software from Laser-Scan Inc. holds an object-oriented database [Laser-Scan, 1996]. This concept overcomes the difficulties of handling data and provides, to each user, in a multi-user environment its own view of the data.

It is generally agreed that conventional relational databases are inadequate for modeling complex spatial data in a GIS [Crosbie, 1993]. One of the possible solutions is to extended the capabilities of a relational database and another one is the use of O-O concepts.

Maintenance of attribute data occurs in a relational database management system (RDBMS) but the geometric data is organized and manipulated using conventional file architectures [Crosbie, 1993]. These conventional database systems were meant to handle large amounts of well structured data and to work with very short transactions, and sometimes failed when applied to data with more complex structures designed for spatial applications. Although this can be the most important factor to look for different approaches when handling with spatial data, some authors refer five main disadvantages of using relational architecture with GIS data [Joseph et al., 1991],[Maguire et al.,1990]:

(1) Lack of expressive modeling power;

(2) Lack of support for recursive routines;

(3) Lack of support for complex objects, data must be decomposed;

(4) Impossible to store geographical data in a natural manner; and

(5) Lack of mechanisms for supporting schema evolution.

Object-Oriented technology offers significant possibilities to GIS applications because it is independent of the complexity or structure to be represented. The structure can be represented by just one object without requiring decomposition into smaller parts as in the relational theory.

3.2 Interface and Implementation

It is the task of a programming language to facilitate the process of inventing programs. The language should make the ideas concrete in the instructions we write by encoding the abstractions that reveal the way things work. As the mechanism of a watch is hidden from the user, all programming languages provide a degree of abstraction by grouping implementation details, covering and hiding them giving a common interface (see figure 3.1).

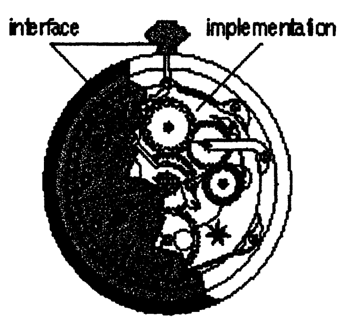

Figure 3.1
Implementation and interface (from NEXT Software [1996])
Like a watch, all programming languages provide an interface to the user to hide implementation complexities.

The user in both cases is only concerned with the final result: either to know what time it is, or to find out the result of a computer instruction.

Modeling in engineering requires the sum of Data, Structure and Algorithm brought together in the right proportions and relationships. The difference between relational and object-oriented technology is the fact that while the first supports a model with data and structure , leaving the algorithm outside at the application level, the second brings the algorithm into the model and groups them together as an object [Woodsford, 1996] (see figure 3.2). An object can be described as a "black box" [Montlick, 1995] and the user should never need to look inside.

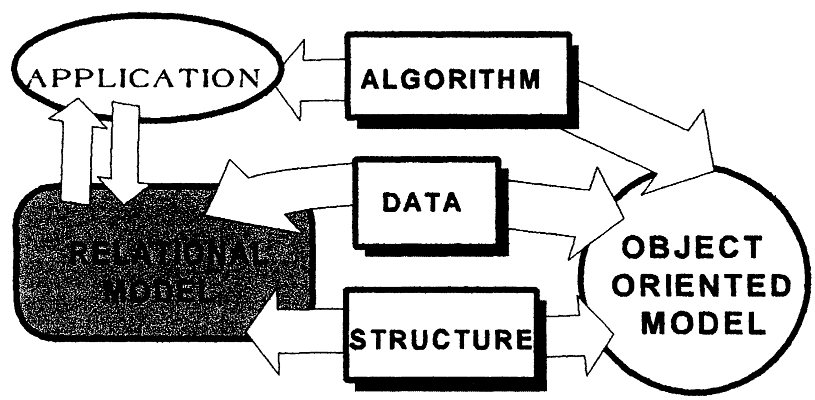

Figure 3.2
Differences between Relational and Object-Oriented Model.
The Object-Oriented Model brings the algorithm component into the model.

All the communication is done through *messages* that define the *interface* to the object. Providing access to an object only through its messages and keeping details apart is called *encapsulation* (see figure 3.3).

3.3 Object Model

In the Object Model theory of programming, an object is a group of related functions and a data structure that is used by those functions. The functions are known as the object's *methods* and the fields of its data structure are the *instance variables.*

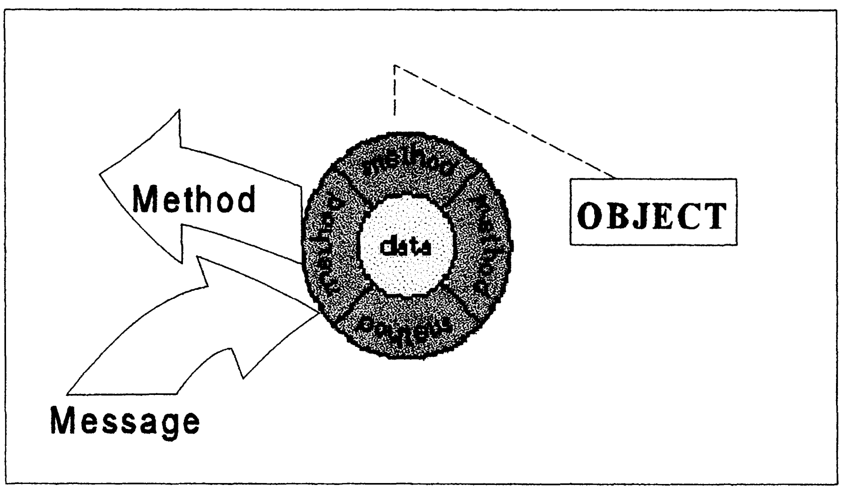

Figure 3.3
Objects are a group of *methods* and *data*.
***Methods* wrap around the data and hide it**
from the rest of the program.

Computation is done by a request being made to a specific object [Budd, 1991] , a message, and the object will exhibit its behavior (operation) by invoking a method in response to the message.

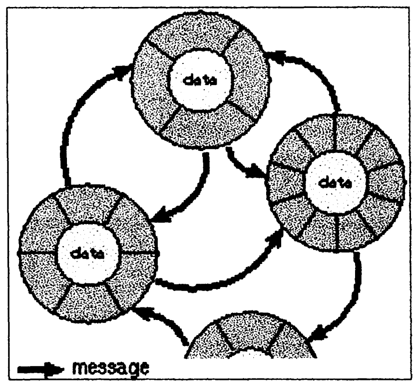

Figure 3.4
Objects communicating through messages.

A program consists of a network of interconnected objects that communicate with each other through messages to solve a problem (see figure 3.4).

3.4 Classes

Objects are defined by its instances of a class. The method invoked by an object in response to a message is determined by the class of the receiver. For instance, we can create an object called SPOT from the class *dog*. This class defines everything about what a *dog* object is, such as the messages that the *dog* objects understand [Montlick, 1995] . "Bark", "Fetch" or "Roll-Over" are just a few of the messages that an object of the class *dog* may understand.

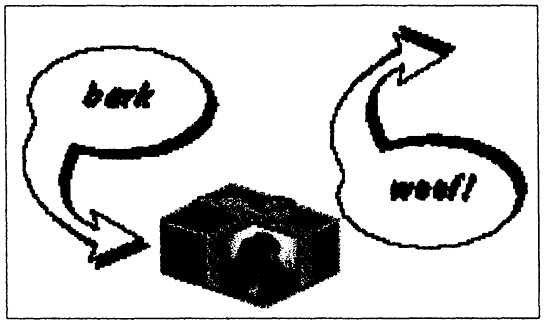

Figure 3.5
Object class *dog* (after [Montlik, 1995]).
To the message "bark" it behaves with a "woof".

Although there are similarities between a class definition and a traditional structure declaration, such as the fact that both lay out an arrangement of data elements (instance variables) they differ in the fact that a class also includes methods that specify the behavior of class members. Two objects with equivalent data structures but different methods would not belong to the same class.

3.5 Mechanisms of Abstraction

There are two important mechanisms that support the fact that an object can be seen as an high-level abstraction and coherent player in an application:

(1) Encapsulation; and

(2) Polymorphism.

Encapsulation, or *Information Hiding* as it is sometimes called, is the characteristic of the O-O technology to encapsulate or hide the details of implementation. Method implementations and instance variables are hidden inside the object.

Polymorphism is the ability of different objects to respond, each in its own way, to identical messages. When a message is sent to different objects, those objects may answer in different ways even if their methods have the same name. The advantage of this fact is that it simplifies the programming interface because we can reuse conventions in several classes. These abstract behaviors that build the programming interface are apart from the classes that implement them.

In a mapping program we could exemplify this concept by saying that a "road" object may answer to the "display" method by drawing a red line while a "river" may draw a blue line [Woodsford, 1996].

3.6 Inheritance

Inheritance is a mechanism that is needed to organize and simplify the definition of object.

This means that we can define a new class in terms of an existing class resulting in class of hierarchies. For example, the *hospital* class can be defined from the existing class *building* with the addition of values and attributes such as "number of beds". Object libraries involving both geographic base data (S-57 library) and specific applications (ENC production) can be set-up and reused with customization to a particular situation. For some authors [Woodsford, 1996] there is the belief that "the greatest benefits to the use of O-O lie in the long term maintenance and extensibility of object-oriented databases.

3.7 The Meaning of O-O for GIS

An Electronic Chart Display and Information System (ECDIS) is a computer based system developed from the GIS technology. Performance Standards for ECDIS were formally adopted by the International Maritime Organization (IMO) in December 1995 and it permited the National Maritime Safety Administrations to consider ECDIS as the legal equivalent to the charts [Alexander, 1996]. The S-57 standard specifies that data to be exchanged between Hydrographic Offices must be modeled according with the Object-Oriented concept. The ENC running in an ECDIS is a sub-product of the S-57 standard.

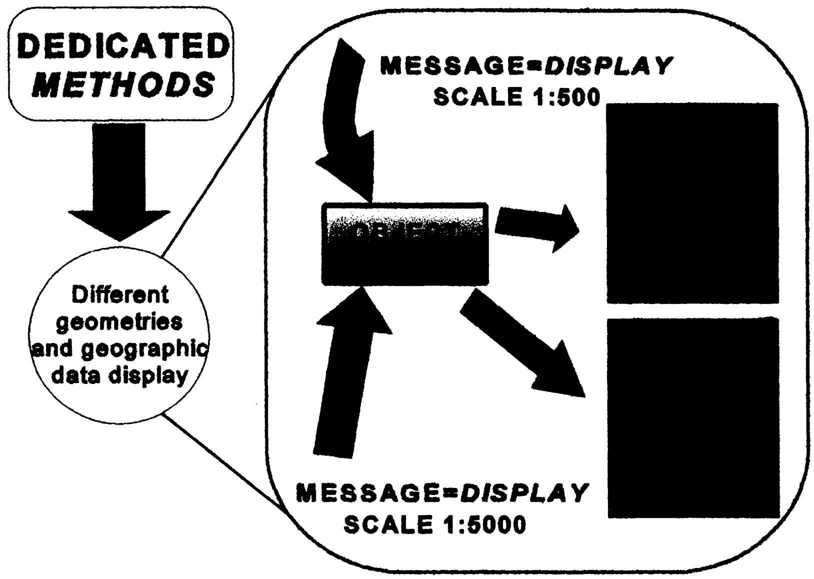

Figure 3.6
In O-O the same "method", depending on the scale allows an object to be displayed with different geometries.

Although most of the advantages that come with the O-O technology in a GIS world are relevant to the system developer, the user benefits from more powerful engines. But as it is generally agreed, the great advantage is the fact that data modeling in O-O matches closely the way people ordinarily think. Modeling with Object-Oriented technology in the hydrographic world allows an easy raster-vector integration since an object can hold different and multiple geometries.

In fact, within this new concept, there is no distinction between geometric and other traditional attribute data. Modeling is object-centered and not geometry-centered [Woodsford, 1996]. An example of the O-O modeling benefits for an ENC is the fact that for the same "message"

- *display* - several geometries or "behaviors" can be performed by an object. As shown in figure 3.6 an object "river", depending on the scale selected by the user, can be displayed as a line or an area.

This chapter introduced the object-oriented concept and described some of its properties that make it ideal for a ENC application. An example is the use of "dedicated methods" that allows an object to be displayed with different geometries. Chapter 4 describes in detail an object-oriented application, the S-57 Standard for the Exchange of Data.

CHAPTER 4

S-57 IN DETAIL

In the previous chapter was discussed the Object Oriented concept. In this chapter it will be described an O-O application, the S-57 standard, that uses an object hydrographic library. This standard defines objects to be used in the exchange of hydrographic data. It also defines specific objects, relations and constraints among them in a product specification: The production of the Electronic Navigational Chart (ENC).

As described in the IHO Transfer Standard for Digital Hydrographic Data, Edition 3.0, "...the S-57 standard is designed to permit the transfer of data describing the real world...". In order to simplify this world in a complete and highly-specific description we must model the reality, i.e., find a way to represent objects and features in a way that a computer based system may understand it. The S-57 standard concerns those entities in the real world that are related with hydrography.

4.1 Modeling the Real World

The task of modeling or schema design has to be considered in three levels [Laurini and Thompson,1992]:

(1) **Conceptual,** is the conceptual schema divorced from the descriptive limitations of the database implementation. It contains entities taken from the real world;

(2) **Logical,** where the conceptual schema is implemented into a set of constructs supported by the database, e.g., tables for a relational database and classes and values for an object database. It is the first in computer implementation. This level constitutes a mathematical basis or a set of mathematical concepts and corresponds to the transformation (mapping) of the conceptual model with the tools offered by the logical modeling, i.e., we have a transfer between the conceptual model and the Physical level, which is computer oriented. Different structures can be used in the logical level:

(i) Hierarchical Model;

(ii) Relational Model;

(iii) Network Model; and

(iv) Object Oriented Model.

The O-O model is the focus of this study since is the one which the S-57 document is based on; and

(3) **Physical,** where we are more concerned with the 'byte' level or how the logical schema is implemented. We deal at this level with storage devices, file structures and locations of data.

The O-O approach reduces the gap between the conceptual and the logical level. The physical level is completely hidden from the user (see figure 4.1).

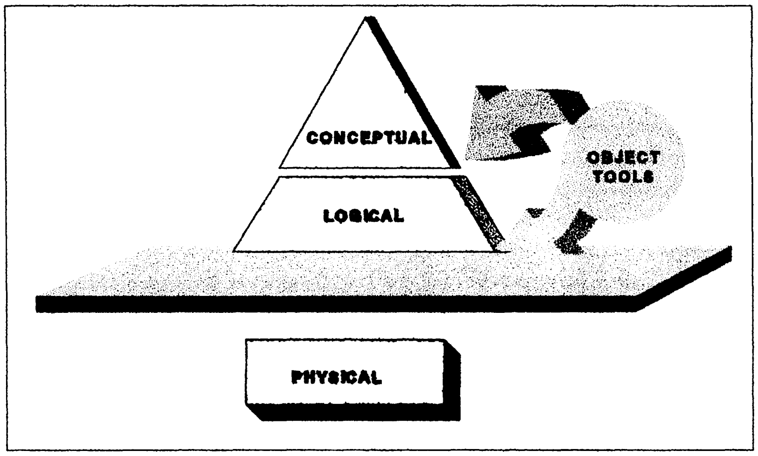

Figure 4.1
Modeling with object tools.
Object tools approach the Conceptual and the Logical level.

"Object-Oriented" is a description that can be interpreted or approached in any of several different ways depending on the needs of the user:

(1) To use an O-O programming language for system development and implementation;

(2) O-O as a language to replace the conventional 'macro' language; and

(3) To use an O-O database engine with GIS functionality.

S-57 standard is an O-O based document which stimulates the HOs to built an O-O database in order to store all the hydrographic data. The advantage is to later pick up the data that you need for different kind of products or for 'print-on-demand' purposes.

4.2 S-57 Data Model

An object in S-57 is a representation of a real world entity like a buoy, a pier or a coastline. Objects can also describe meta information about other objects or can simply represent a collection of multiple objects which share a relationship.

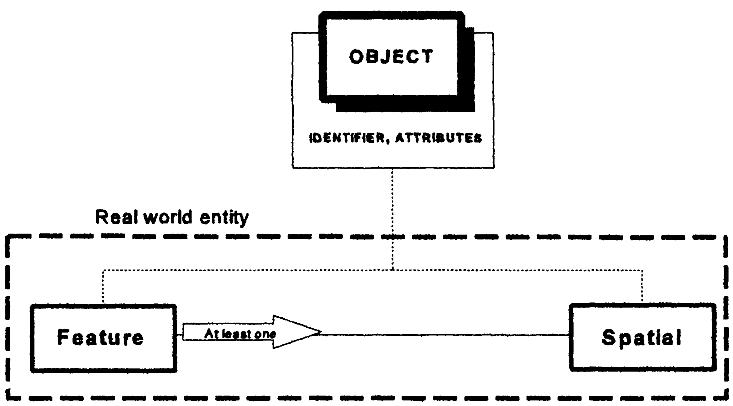

Figure 4.2
Object data model (after [IHO, 1996]).

4.2.1 Feature Object

A "feature object" and "spatial object" can be of the type 0-1-or 2-dimension, using the following terminology:

FEATURE OBJECTS	SPATIAL OBJECTS
point	entity point
line	node
area	edge
	face

4.2.1.1 Feature Object Class

The S-57 model encodes objects according to their real-world meaning as instances of object classes. For example, the acronym ACHARE defines an anchorage area of the object class "Anchorage Area" and BOYCAR is the object name for a cardinal buoy belonging to the object class "Buoy, Cardinal". To facilitate the efficient exchange of the non-locational description of the real world entities, the theoretical model defines four types of feature objects:

(1) **Meta** objects contain information about other objects including, for example, the accuracy of the data and compilation scale;

(2) **Cartographic** objects contain information about the cartographic representation (e.g. a compass on a paper chart);

(3) **Geo** objects carry the descriptive characteristics of a real world entity. Classes and acronyms of Geo Objects are for example BOYLAT (Buoy, lateral), COALNE (Coastline); and

(4) **Collection** describes the relationship between other objects.

There are three types of collection objects:

(i) Aggregation, where various objects of different geometric type are grouped to form a new collection object. An example of this is the collection of points , line and area objects that form a traffic separation scheme;

(ii) Association, is, for example, a buoy marking a wreck, i.e., they contain an interdependence for their existence. In this case the buoy and the wreck are two different objects but they are interdependent because, without a wreck, there would be no need for the buoy; and

(iii) Stacked On / Stacked Under, is the case where a physical dependance is the reason for collection. A good example is a bridge over a road.

4.2.2 Spatial Object

A **Spatial Object** contains the geometry used by the feature objects and must be of the vector type. Matrix and Raster representation are opened to be included in the future. Due to the existence of a worldwide folio of Raster charts made available by the ARCS project of the British Admiralty, it can be predictable that this encoding format will be included in the S-57 document in the future.

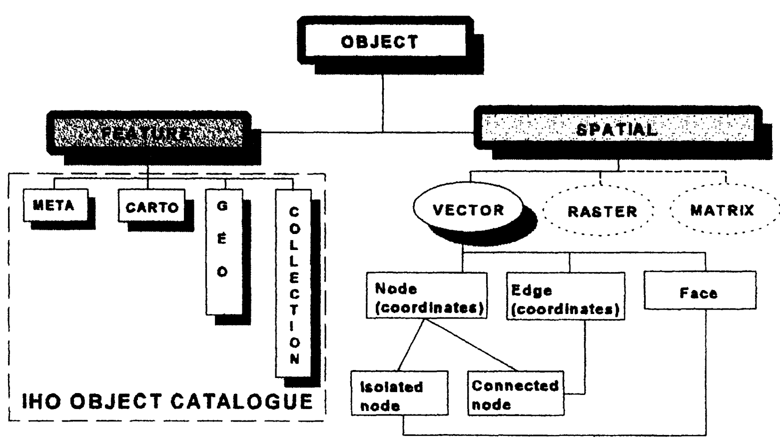

Figure 4.3
S-57 theoretical data model.

4.2.2.1 Vector model

Spatial objects expressed in a vector model can have zero, one or two dimensions implemented as nodes, edges and faces while the third dimension is represented as an attribute of an object. The relations between them can be used in four different levels of topology: **Cartographic Spaghetti, Chain Node, Planar Graph** and **Full Topology** [IHO, 1996].

Cartographic Spaghetti is a set of isolated nodes and edges. In this vector representation points and lines are coded respectively as isolated nodes and a series of connected edges while area is coded as closing loops of edges. Feature objects must not share spatial objects and, if logical consistency is required, coincident edges must contain identical geometry.

Chain Node, is the representation used in the ENC product specification. It is represented by a series of nodes and edges. Point representations are coded as nodes (isolated or connected) while lines are defined as series of edges and connected nodes. In the sequence of this logical representation, areas are coded as closing loops of edges forming their common boundary. Coincident geometry is prohibited, which means that features with common edges must be separated in different layers.

Planar Graph, is defined by a set of nodes and edges where edges must not cross and may touch only at connected nodes. Restrictions are that touching edges always share connected nodes such as the areas always share the edges forming their common boundary.

Full Topology, is a set of nodes, edges and faces. Point and line representations are respectively represented as nodes and series of edges and connected nodes while areas are coded as faces. It is a planar graph with defined faces.

4.3 Data Structure

In the Fall of 1971 the Committee on Computer and Information Processing (X3) of the American National Standards Institute (ANSI) formed a special group to determine the aspects of the database suitable for the development of standards [Chen, 1977]. The three level structure (external / conceptual / internal) was then defined. The goals of this architecture were to reduce the number of mappings between the external and the internal schemas and to be the basis of the modelling process.

After the theoretical model has been defined, an easy way to translate the resulting model into a data structure is for example to consider an entity-relationship (E-R) approach. This diagram structure allows the independence of the platform which means that we can translate our model into an easy understandable group of flow charts and diagrams that can be used by any different data structure to be considered.

The S-57 standard specifies how the translation between the data model and the data structure must be made, i.e., the linkage between logical and physical constructs. We can say that data structure is the first non-abstract level in the conception of a data exchange format or in any database building. Every object is structured into a record while an exchange is a set of one or more records. Records are grouped into files for exchange purposes and records are in their turn an aggregation of fields and subfields.

We can split the S-57 data structure implementation in two separate definitions:

(1) The **General** structure of data, independent of specification and common to all exchange

sets; and

(2) The **Product Specification** exchange format which at the moment only the ENC product specification is considered.

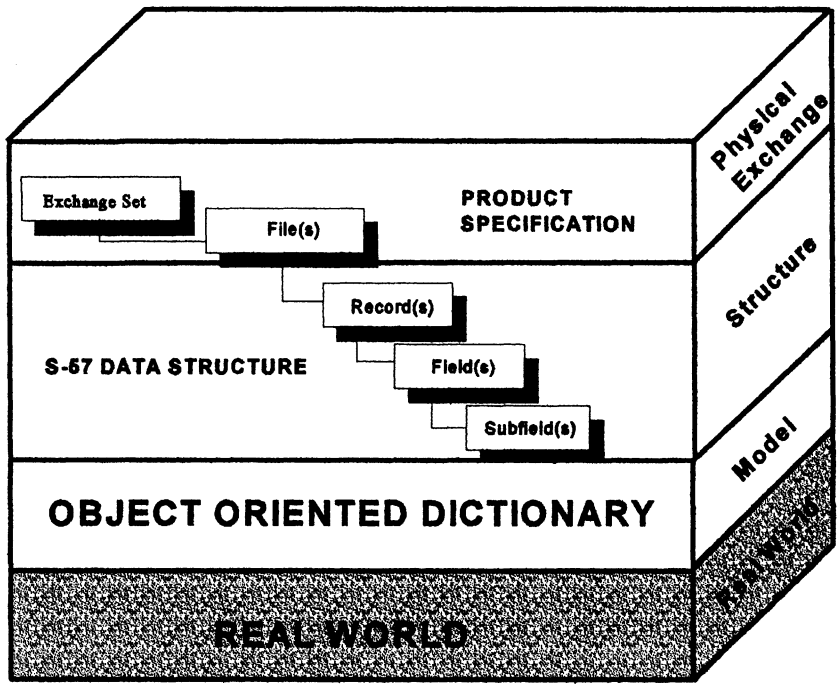

Figure 4.4
S-57 Data Structure.

4.4 ENC Product Specification

The rules established for the production of ENC are not part of the S-57 Standard. They apply only for the production of the Electronic Navigational Chart.

The ENC is recognized as the equivalent of a paper chart when produced by an HO and running in a GIS like system (ECDIS). It is topologically structured, employing a chain-node model as specified in the document.

The S-57 document was written with the objective in mind of minimizing storage requirements while permitting quick retrieval and fast drawing time in an ECDIS. To achieve this objective, some of the requirements are:

(1) No file may contain more than 5 Megabytes of data;

(2) The point density in lines must not be greater than 0.3 mm;

(3) The existence of master / slave relationships between structure and objects is mandatory;

(4) A layer of information called 'skin of the earth' must contain the objects considered absolutely necessary to be always displayed to the navigator. For the safety of information, they must cover the entire data cell without overlap;

(5) The official language is English; and

(6) To allow an integration with GPS positional information, the horizontal datum must be WGS 84. Units of position are decimal latitude and longitude and units of depth are metres with a decimetre resolution.

4.4.1 Files

ENC data is usually taken from the original paper chart file. The compilation scale of each paper chart also separates the ENC in several navigational purposes. These navigational purposes in S-57 are divided in:

(1) Overview;

(2) General;

(3) Coastal;

(4) Approach; and

(5) Harbour / Berthing.

For a faster processing and retrieving of the information from an ECDIS, all the geographic coverage of a certain usage must be separated into cells. The data producer must be aware that the Product Specification does not allow files that contain more than 5 Megabytes of data. These cells must be rectangular and bounded by two meridians and parallels. Within the cells' building constraints there are some specific rules such as the one that cells of same navigational purpose may overlap but not duplicate data in the overlap area (see figure 4.5).

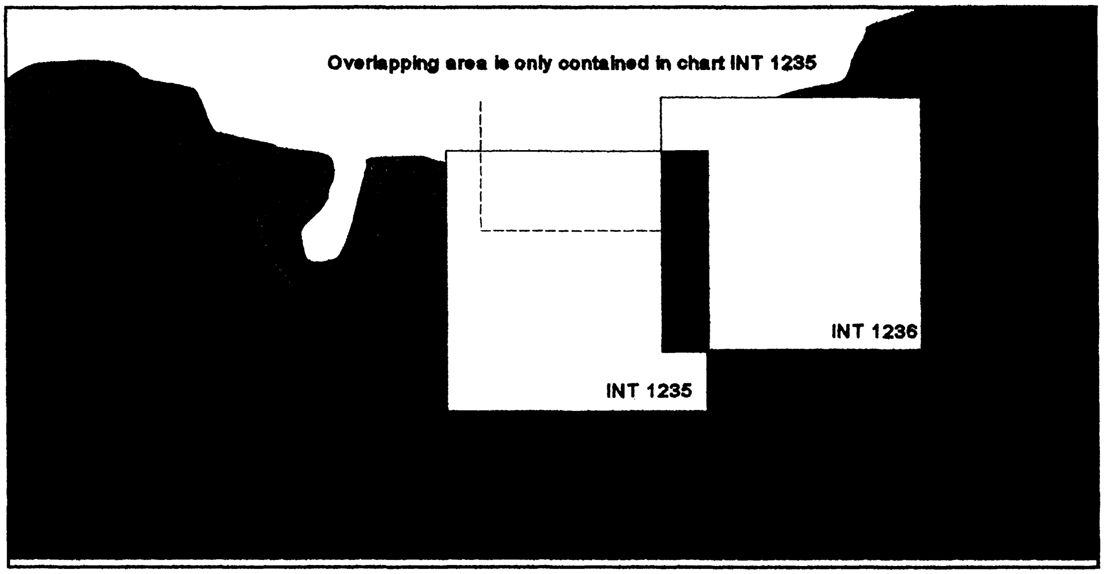

Figure 4.5
Overlapping areas in a ENC. Only one of the charts can contain hydrographic information on the overlapping area.

Objects on border of adjoining cells must reside in only one cell and objects crossing cells or usages must have same ID with full attribute description in all cells. Files in a ENC are binary and the exchange set is a catalogue file or table of contents and at least one data set file, these may include readme, ASCII text and TIFF picture files. The data sets may be classified as:

(1) **New**, when a ENC is released for the first time;

(2) **Update**, when the purpose is to change some information in an existing data set;

(3) **Re-issue**, when in a data set all the updates applied to the original data set are included up to the date of re-issue; and

(4) **New Edition**, a data set that includes new information which has not been previously distributed by updates.

The data set files are named, according to the specifications, CCPXXXXX.EEE, where CC stands for the producer code, P is the navigation usage, XXXXX represents the individual cell code and EEE the update number. This kind of representation on this format has several similarities with a DOS format.

4.4.1.1 Data Structure

In a ENC the topology must be chain node. The same principle is used by *the CARIS* files while the objects ID must be unique world-wide except where object crosses cells or usages

4.4.1.2 Data Storage

Edges in a ENC must be encoded using SG2D subfields , which means that linear data is comprised of repeating coordinate pairs and is transparent to the user. The point density in lines must not be great than 0.3 mm. This density is achieved when performing a transformation between a CARIS file and a S-57 compliant file using filter algorithm, at the compilation scale of the data

It is mandatory to have master / slave relationships between structure and objects, e.g., if a buoy has a light or a RADAR reflector on the top, they are two different objects where the buoy is the structure and the light is the equipment. This relation is only valid if the two objects are located at the same geographical place. All feature objects are located in two different groups: 1 and 2 (layers) (see table 4.1).

Table 4.1
Skin of the Earth contents

SKIN OF THE EARTH (GROUP 1)	
DEPARE	Depth Area
DRGARE	Dredged Area
FLODOC	Floating Dock
HULKES	Permanently moored ship
LNDARE	Land Area
PONTON	Pontoon
UNSARE	Unsurveyed Area

All features in group 1 must be area type objects and the above listed objects must be in group 1. These objects were selected as being absolutely necessary for the safety of the navigation. This set of area objects cover the entire data cell without overlap and it is the main component of the Display Base in the ECDIS that must always be visible to the mariner.

4.4.1.3 Object Catalogue Usage

In the S-57 Appendix A mandatory, prohibited and conditional GEO, META and COLLECTION objects are defined and also the attributes for those objects. In this product specification the CARTOGRAPHIC objects such as the magnetic declination or the compass rose are prohibited. An unknown attribute is defined by an attribute without value. For example even when a category of a coast line is not known it is mandatory to use an attribute with the unknown value. Meta data hierarchy is defined and prohibits attribute use where META object already applies and META object use where data set sub field exists.

4.4.1.4 Coordinates

In an ENC the horizontal datum must be WGS84 to allow the display of GPS data which is related with the same datum. The units of position are decimal latitude and longitude converted to integers with no map projection to be used. Units of depth are metres and the resolution is 1 decimetre. Units of height are metres and distances are represented in nautical miles and decimal miles or metres depending upon the attribute definition.

4.5 Object Class Catalogue

The Object Class Catalogue is a specification of the ENC Product Specification. It determines which objects can be used within an ENC and what geometric primitives are used with each of them (point, line and area). For some objects, more than one geometric primitive is allowed depending on the compilation scale of the chart. A navigable lake can be a point in a large scale chart and an area in a small scale chart.

4.6 Exchange File Format

The S-57 standard adopted the ISO/IEC 8211:1994 format for exchange of data between computer systems. No matter what tool is used to perform the encapsulation of the S-57 files, it must change the *Records / Fields / Sub fields* of the S-57 file structure into a *Logical Record* in the Exchange File Format. The *Logical Record* contains two types of files, the *Data Descriptive Record* and the *Data Record Files*, whose purposes are, respectively, to describe the logical structure of the data in the file and to store the actual data to be exchanged.

4.6.1 General Description

The S-57 standards were based on several ISO formats that were already established for other applications. The S-57 uses the ISO/IEC 8211:1994 encapsulation that specifies an interchange format for the exchange of data between computer systems. After a S-57 file is produced it must be encapsulated for transmission which with CARIS tools is done with a command called *writeS57*. This command runs a program that gathers several disperse information sets within the S-57 file format and puts them all together in an exchange format. As was stated before, the file structure is made up of Records / Fields / Subfields. In the Encapsulation format these constructs correspond to Logical Records (LR) containing a group of fields / Fields / Subfields.

4.6.1.1 Logical Records

The basic component of ISO/IEC 8211 is a logical record. The first LR of a file is called the Data Descriptive Record (DDR) containing the description and logical structure of the data in the file. The Data Record files (DR) contain the actual data to be exchanged (see figure 4.6)

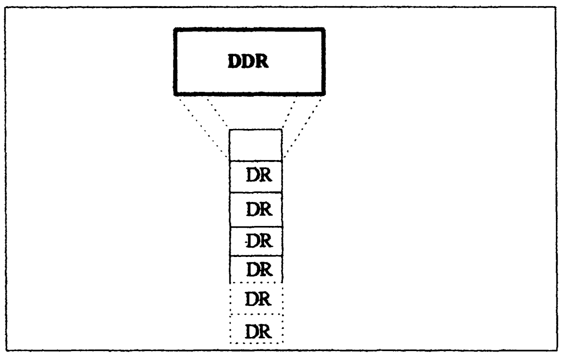

Figure 4.6
Logical Records in ISO 8211.

In each logical record, both DDR and DR are formed by three basic elements called; the **header** which contains the parameters needed to read the records and a few data descriptive parameters applicable to the entire file, the **directory** that has the parameters necessary to identify and locate each field in the field area, and the **field area**. The field area in the DDR contains the information necessary to decode the user data in the field area of the DRs . The field area in the DR contains the actual data to be transferred. The fact that the description of the data is included in the exchange file allows the exchange of data without any data description. If the Product Specification also requires an external data description, the data descriptive fields in the encapsulation cannot be omitted since they are part of an ISO/IEC 8211 conforming file.

Released in November 1996 the S-57 document provides the producers of hydrographic data and, ENC in particular, the set of rules for the encoding and exchange of information. Although the S-57 standard will be frozen for four years the object based dictionary for feature objects classes and attributes will remain opened for changes. GIS and ECDIS companies worldwide such as USL and Offshore Systems Limited (OSL) are developing software and hardware to provide HOs and marine users with the tools to build and display data accordingly with the international standard.

Chapter 5 introduces the tools available by USL used in the case study contained in this document.

CHAPTER 5

CARIS TOOLS

CARIS is a GIS software developed by Universal Systems Limited (USL), a Fredericton based company. Although the *CARIS* software was initially designed for geographic applications, one of its largest uses is in the field of Marine Information Systems (MIS). MIS is the name used to define GIS technology when applied to the production of Navigational Charts of either paper or electronic charts.

5.1 Object Creation from *CARIS* Features

Two different approaches can be followed in the flow chart of the production of an S-57 chart: either an HO is populating its database for the first time or is reclassifying previous digital files into the S-57 format.

The goal of this project is to perform a transformation of a *CARIS* file (paper chart) into an S-57 Electronic Chart using the *CARIS* tools. *CARIS* features will be changed into feature objects according to the S-57 dictionary.

The object creation process is achieved by running a program in a batch process called *fea2obj* or interactively with the *obman* program. *Fea2obj* runs without interaction, and matches *CARIS* features with S-57 objects.

The user can check the correct creation of the objects using the *obman* program. The *obman* program allows the user to edit and create feature objects and attributes.

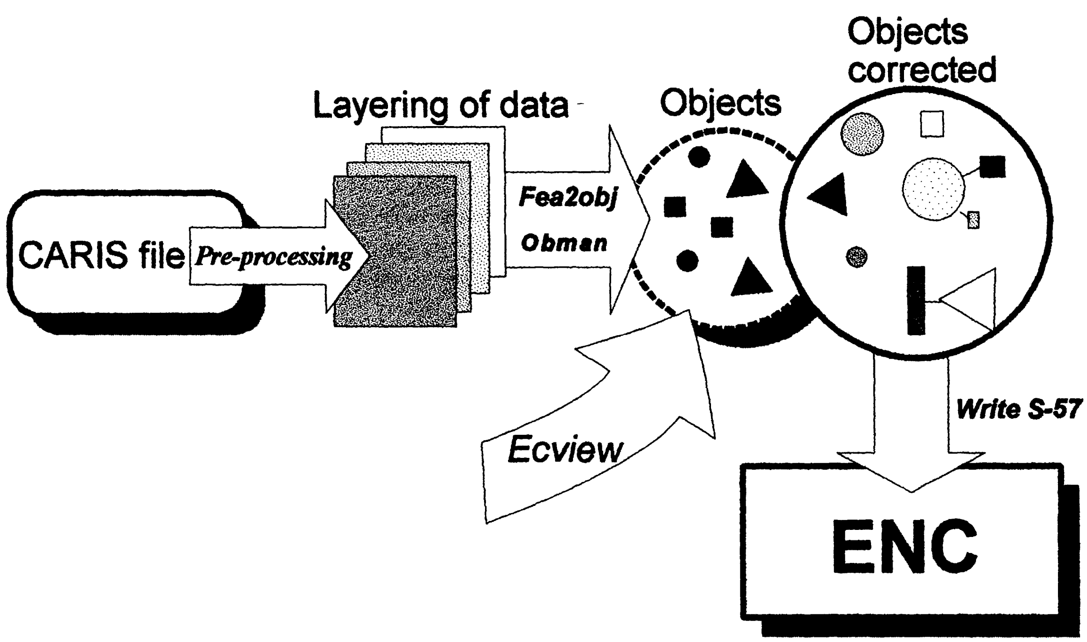

Figure 5.1
The process of building an ENC. From a CARIS file to the final product.

5.1.1 Preparing a CARIS File for Conversion

Assuming that a *CARIS* file is going to be used as the input data conversion to an ENC the following steps must be followed (see figure 5.2):

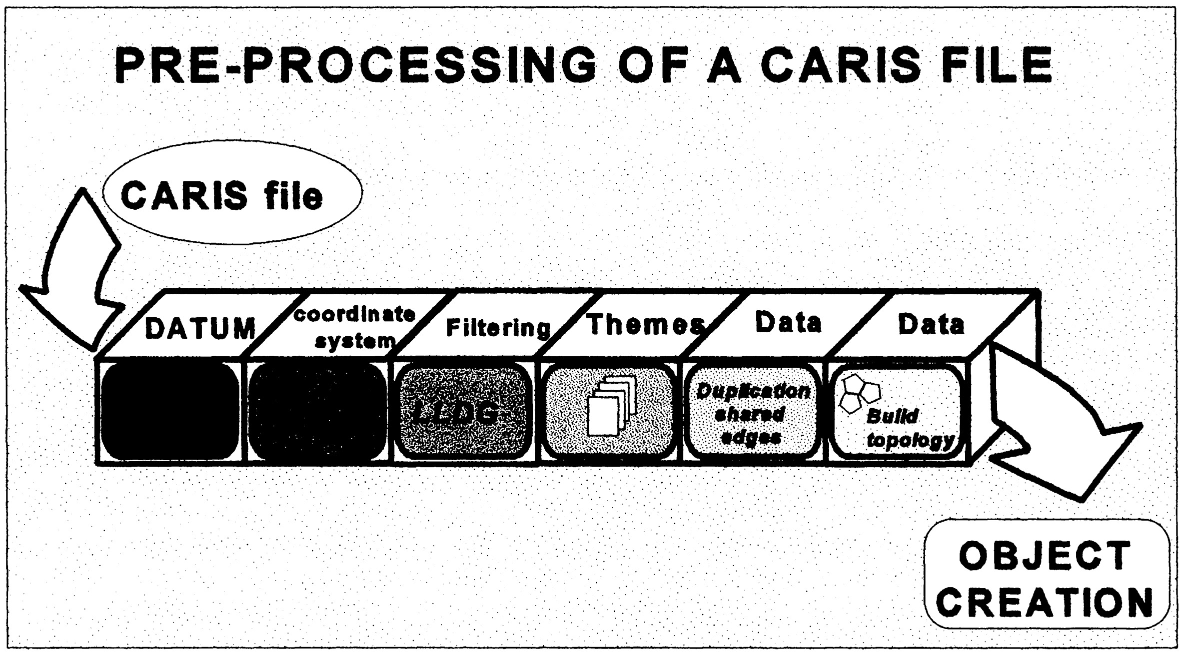

Figure 5.2
Pre-processing of a *CARIS* file.

1) Requirements: The first step should be to examine the file content (important when the converter was not the original producer) and check for *CARIS* file problems (topology, header information).

Procedures: *%disphead -file = 'file_name'* command to check datum, projection.

%Checedit -file = 'file_name' command to check for errors in the file.

2) Requirements: Change the original datum into WGS 84. Chances are that the *CARIS* file is built upon one of the 64 different datums known to be used in the Admiralty Charts [Gooding, 1996].

Procedures: The datum change is done through the use of the *MOSAIC* program which allows to edit and change the datum in the NTX original file. The new datum (WGS 84) must be typed in the appropriate command with the two letter acronym, *WG84*.

3) Requirements: Filter the point distance in the *CARIS* file into the mandatory 0.3 mm in "ENC Product Specification". The need for filtering comes from the fact that in S-57 the cell file should not be larger than 5 Megabytes. By reducing the density of the points stored in the file, we are deleting the numbers of spatial objects that need to be stored.

Procedures: The *CARIS* software runs an algorithm to remove the "extra" points in the file. The Douglas-Peucker [Douglas and Peucker, 1973] algorithm is a cartographic one.

The *CARIS* command to be used reformats the file filtering the original NTX file:

%refontx 'file_name' -filter = 0.3 (the default units are mm)

4) Requirements: The fourth step is to change the coordinate system from *CHMR* (CHS origin. It is a local coordinate system used for digitizing conventions) or *NEMR* (North Easting coordinates) to *LLDG* (Latitude and Longitude in decimal degrees). In S-57 it is mandatory that the ENC file is in Latitude / Longitude, decimal degrees. This step can be performed at any time of the work, but it is advised that it should be done before the object creation.

Procedures: To build (edit) an empty *CARIS* file with the same header as the original file with the exception that the coordinate system must be changed to *LLDG*. With the *tran* command in *CARIS* (batch process) we will merge the new header with the original file. The file will be changed to the new coordinate system:

%tran 'file_name' -head = 'new_header' -output = 'new_file'

It is suggested to assign always a new output file different from the original one.

5) Requirements: At this point the producer has finished three of the steps in the Pre-Processing work (see figure 5.2). The next step is to layer the data in two different groups. The S-57 objects are named with a six letter acronym and will be stored using a dual structure:

(1) The *CARIS* file is used to store spatial objects; and

(2) The feature object information is stored in an additional structure which is either a set of relational database management system (DBMS) tables or a *HOB* (Hydrographic Object Manager) file. For the purpose of this project, feature object information will be stored in a *HOB* file.

S-57 standard determines the existence of a *GROUP 1* category of objects (*GEO* Area objects) that must completely cover the dataset with no overlap, to form the 'Display Base'. These features will reside on a single topological theme in *CARIS*, to be used for building the *GROUP 1* or 'Skin of the Earth' topology. The *GROUP 2* area objects will sit on top of *GROUP 1* and are formed by all the other objects not belonging to *GROUP 1*.

Mandatory objects in *GROUP 1* are:

DEPARE = depth area

DRGARE = dredged area

FLODOC = floating docs

HULKES = permanently moored ships

LNDARE = land area

PONTON = pontoons

UNSARE = unsurveyed area

A layering separation by numbers is suggested by USL [USL, 1996] . It is suggested that each Hydrographic Office should build their own table in accordance with their own data specification.

Procedures: There are two distinct but equally effective ways of changing features into layers accordingly with S-57 standard:

(1) In a semi-automatic batch process with the command;

display parameters (*CARED>dp*) to select the features to be changed.

%makedisp 'file_name' makes a display (store) of the selected features.

%renu -file = 'file_name' -scope = display -theme='new_theme' -user_number = 'new_user_number' , renumbers the previous selected features into a new chosen theme and user number.

(2) Interactive with *CARED* lasso commands;

CARED> lapt , to create a lasso and surround the features to be changed.

CARED> laun , to change user number (does not change theme number. Only useful for non-topology building layers).

CARED> lade , to delete unauthorized features in S-57.

When using a lasso command (*laun or lade*) the information in all displayed layers will be affected.

6) Requirements: There are Area, Line and Point objects in S-57. Many area objects in S-57 will be built from line objects, assigning a label to a polygon before building polygon topology.The most common procedure is to assign a label "between" two depth contour features to later build a depth area object, DEPARE (see figure 5.3 -(6)).

Area objects can reside both in *GROUP 1* (if they belong to one of the seven mandatory objects) or *GROUP 2*. If a *GROUP 2* feature (OBSTRN -obstruction) lies on top of a *GROUP 1* object (LNDARE - land area), (see figure 5.3) and one of the edges is common to both objects, than this common edge must be duplicated to reside both in *GROUP 1* and *GROUP 2* layers.

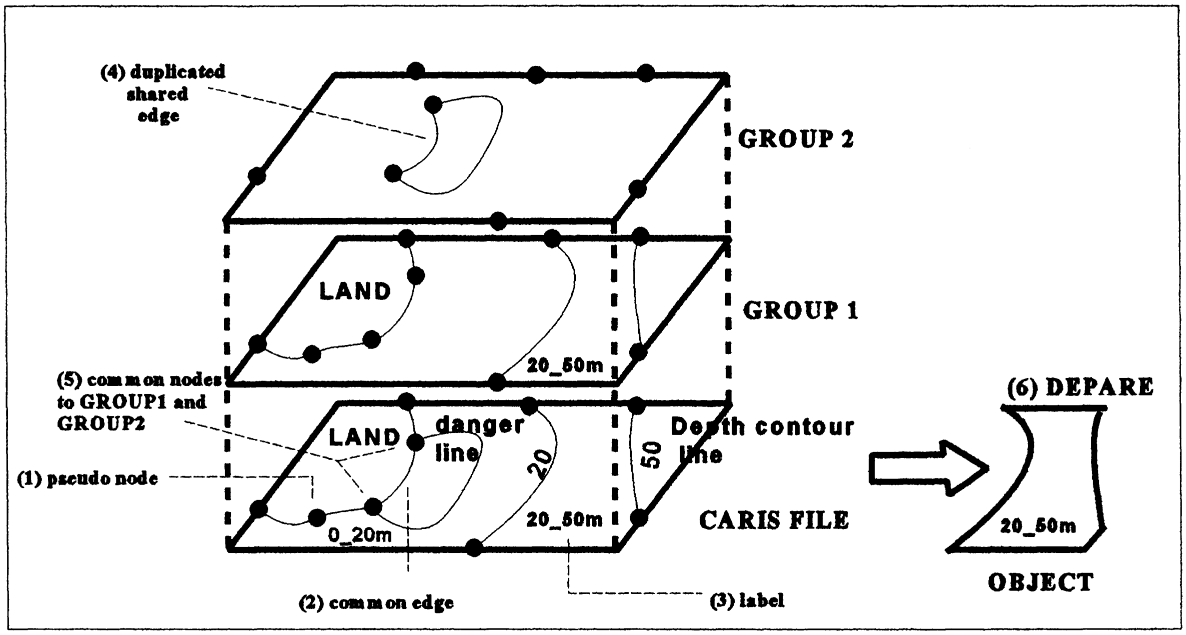

Figure 5.3
Layering information in CARIS.

Prohibited coincident linear geometry referenced in S-57 is part of this model but it will be eliminated during the *WRITES57* building of the exchange file.

Procedures: The *CARIS* command to be used is:

%optoon, turns the topology on for everything to be displayed in the CARIS window

%opun'theme_number', sets the theme number for all the features to be created or moved within the *CARIS* window.

CARED> lidu, duplicates the line to be chosen.

(1) 'Pick _the _line', graphicaly; and

(2) 'Assign_a_new_feature_code or keep_the_same'.

Remove the pseudo nodes in *GROUP 1* which are not needed, i.e., are not going to reference a spatial object (see figure 5.4) :

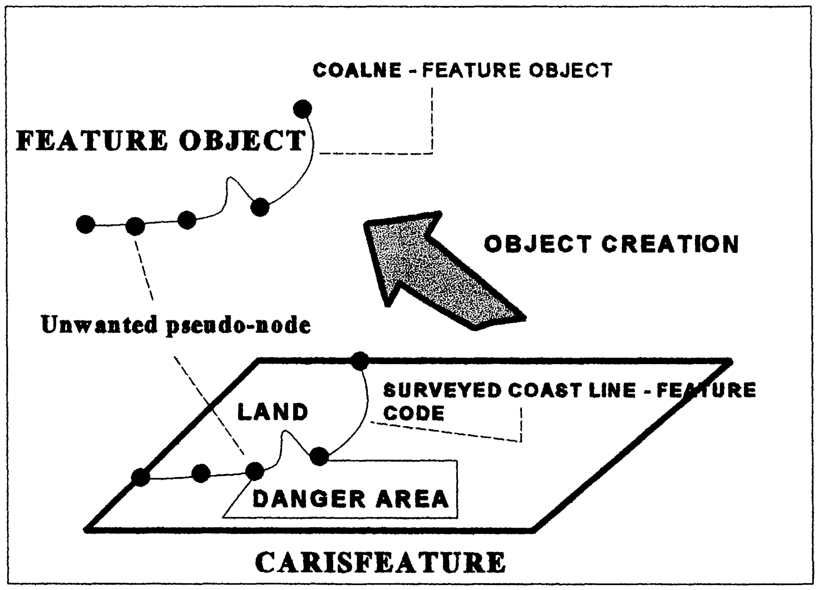

Figure 5.4
The representation of an unwanted node.

%remopseu -file = 'file_name' -theme = 'theme_number'

Do not remove "common" pseudo nodes to both *GROUP 1* and *GROUP 2* features (see figure 5.3 (5)).

7) Requirements: Build network topology for features on *GROUP 1*. Build polygon topology for *GROUP 1* features. Build network and polygon topology for all the area features on *GROUP 2*.

Procedures: The *CARIS* command to be used is :

%makearc file = 'file_name' -theme = 'theme_number', convert lines into arcs.

%builnetw file = 'file_name' -theme = 'theme_number', build network topology.

%builpoly file = 'file_name' -theme = 'theme_number', with this command arcs are assembled.

8) Requirements: Assign *CARIS* keys for all the features in the file except polygons (the *CARIS* software takes the polygon label by default as the key. If we have several polygons with the same label, e.g., LAND, we would have several polygons with the same key, i.e.,several feature objects pointing to the same spatial object) .

Procedures: Use the command:

%makeinde file = 'file_name' -lines -symbols -override, assign different keys to all lines and symbol features.

5.1.2 The "Object Look-Up Table"

The "object look-up table" is a text file that relates feature codes with feature objects. This table must be built following the constraints and format of the hydrographic object manager. *OBMAN* and *fea2obj* programs access this file to populate the *HOB* file with objects.

Mandatory fields in the table are :

(1) Object Code Information, the six character acronym contained in the S-57 dictionary; and

(2) Feature Code Information, the *CARIS* feature code.

Optional fields are:

(1) Object Class, as the name says it contains the name of the object class;

(2) Feature Type, assigns a constriction of a specific data type to the object to be created (Name NA, Polygon PO, Curved Line CL etc...);

(3) Feature Description, explanation about the feature;

(4) Attribute, will be used by the *fea2obj* program to assign attributes to an object;

(5) Attribute Script, names the script command to be run and assigns values to the attributes; and

(6) Comments, it is a non-executable entrance. Allows the user to comment on a certain procedure.

Example of a "look-up-table" for the creation of a depth contour (DEPCNT) and a radio mast (LNDMRK) objects is:

```
OBJECT CLASS: Depth contour
OBJECT CODE: DEPCNT
FEATURE CODE: CODTMR*
FEATURE TYPE:AL
ATTRIBUTE SCRIPT:assign_z VALDCO CARIS_Z
FEATURE DESCRIPTION: contour,depth, meters

OBJECT CLASS:Landmark
OBJECT CODE: LNDMRK
FEATURE CODE: ALRM7%
FEATURE TYPE: SY
FEATURE DESCRIPTION: Radio Mast
ATTRIBUTE: CONVIS 1
ATTRIBUTE: FUNCTN 31
ATTRIBUTE: CATLMK 7
```

5.1.3 The *fea2obj* Program

The *fea2obj* program runs without user interaction. It creates and stores feature objects in a *HOB* file or a relational data base, by default with the same name as the *CARIS* file (see figure 5.5).

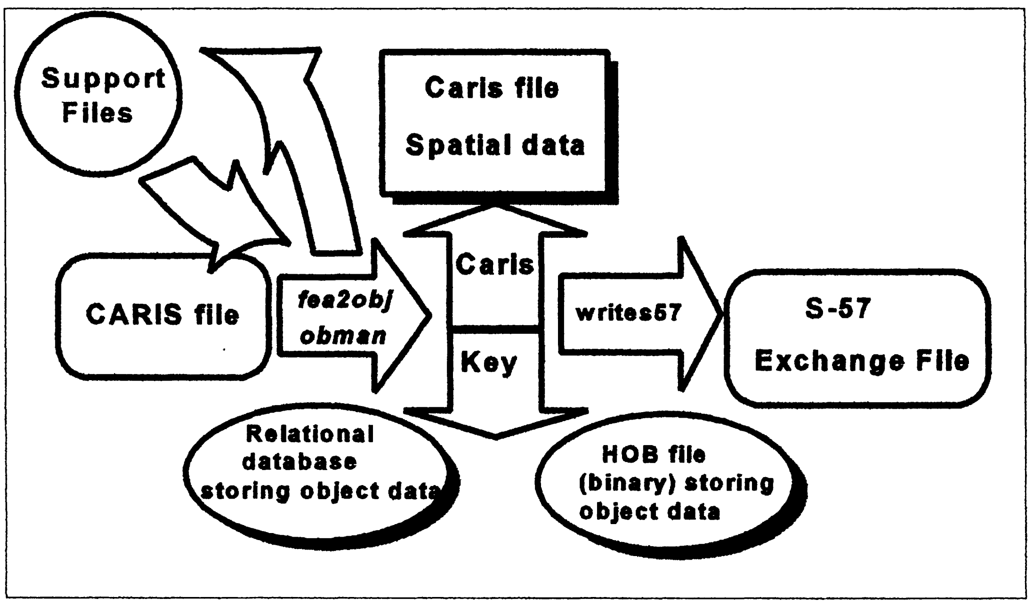

Figure 5.5
Creation of objects and exchange file with the Hydrographic Object Manager.

Fea2obj takes the *CARIS* feature-object relations contained in the "look-up table"and validates that information with the Object Dictionary (S-57) stored in the program. The Attribute Management File overrides the default attribute values retrieved by the Object Dictionary with the values assigned by an internal / external script (see figure 5.5 "Support Files").

5.1.4 *OBMAN*

OBMAN is the core program of the object creation within the Hydrographic Object Manager developed by USL.

It is a menu-based program that allows the user to build feature objects interactively. *OBMAN* runs applying the command *obman*. The qualifiers provide the ability to (among several features) :

(1) **-hob**, keep a dual data set both in a *HOB* file or a relational database;

(2) **-nodbase**, prevents the use of a data base, creating a *HOB* file when it does not exist.

5.1.4.1 Main Features

The *OBMAN* program simplifies the task of building objects through a graphically usage mode. This means that a *CARIS* file is loaded and displayed in a window, from where *CARIS* features can be picked up into a dialogue box. At the same time the dialogue box acts interactively with the object dictionary (classes and attributes) allowing the selection of objects in accordance with the S-57 standard. The main features of this program are:

(1) Graphical selection of features from the *CARIS* display file with the use of a three button mouse;

(2) Query of an Object and Attribute Dictionary;

(3) Creation of feature, Relationship and Collection Objects;

(4) Creation of objects on a semi-automatic mode, invoking a "look-up table";

(5) Editing of either previously created feature objects or *CARIS* features without the correspondent object, both graphically and in a query mode;

(6) Digitize point and line *CARIS* features to be added to the object file; and

(7) Delete and modify *CARIS* features from the original *CARIS* file.

5.2 Quality Control Procedures

There are two programs in the market being used for quality control of the ENC final product. Both of them allow the user to check for inconsistences of the objects and their attributes. Colors can also be checked, in accordance with the IHO S-52 standard [IHO, 1993].These programs simulate the ECDIS environment on a user's desktop computer, and they are:

- The *ECVIEW* from USL Ltd.
- The *SeeMyENC!* from SevenCs.

5.2.1 The *ECVIEW*

USL's *ECVIEW* or Electronic Chart Viewer is a 'motif' application that provides a friendly user environment hiding the complexities of the *ECMAN* program.

The input data comes from an *HOB* file for feature objects and the equivalent *CARIS* file for spatial objects. The graphic display offers four distinct 'button' functions and an interactive graphic window:

(1) Input / Output information . Allows the user either to import an S-57 file and generate an *HOB* file or to load an existent *HOB* file;

(2) Display information . *Pan* is available through the use of four different arrow buttons. The user can Zoom in, Zoom out, Overview and Redraw the screen around a point location defined by the use of a mouse;

(3) Settings .Setting the information to be displayed is available through a dialogue box window [USL, 1996b]. The user can restrict the data to be displayed by the use of three setting buttons:

(i) *Displaybase*, displays the mandatory minimum information that is shown in an ECDIS all the times;

(ii) *Standard*, is the equivalent information shown when the power is turned on in an ECDIS; and

(iii) *Other*, anything but the two above.

Latitude and Longitude information of the cursor position can be checked in a box; and

(4) Query . Query of an object and attribute is available through the click of a button that pops up a query window [USL 1996b].

5.2.2 The *SeeMyENC!*

The SevenCs software is free to be downloaded from the Internet and it allows the user to import and show ENC's (S-57) files. It is a windows NT based program and allows zooming, pan and error reports of values of object attributes. SeeMyENC is the version 1.0.0.4 released on February 1997. The first window to be displayed after opening the program comprises three different menus (see figure 5.6). This same window displays a Zoom in image of the opened ENC cell as the position of the cursor on the main file:

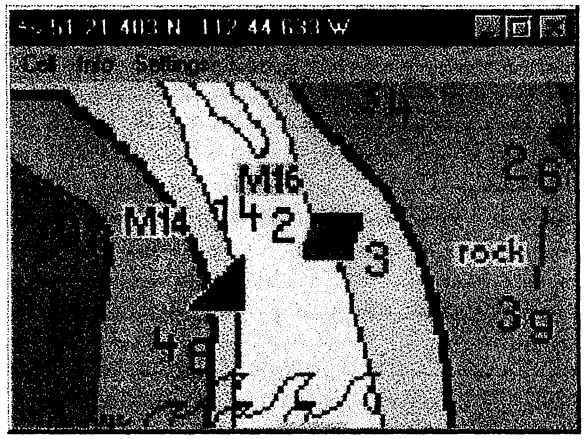

Figure 5.6
The "Cell" window in the SevenCs software [SevenCs, 1997].

(1) Settings:

(i) <u>Browser</u> .Allows the user to choose the browser to be connected with the 'trigger' attribute. The 'trigger' attribute can be in the attribute list of an object each time the user queries an object (see figure 5.7).

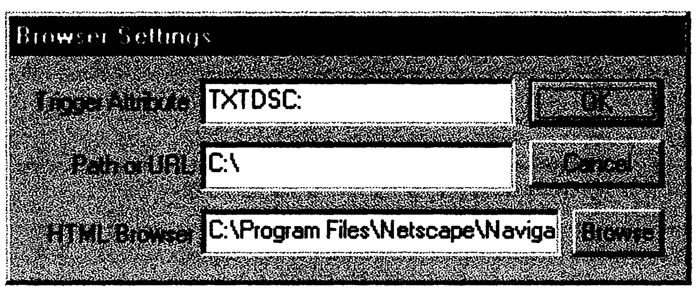

Figure 5.7
Browser settings window [SevenCs, 1997].

(ii) Save Settings . Saves the setting chosen, updating it each time a new setting is selected.

(2) Info: Provides help on-line.

(3) Cell:

(i) Display . Opens the window menu with the files available at the mother directory. Clicking twice on the file name opens the main display window.

(ii) Import . Imports an S-57 file from a different directory.

The second window to be displayed is the general ENC information about the loaded data set, and has the following menus:

(1) View:

(i) Show Overview . Shows all the content of the cell.

(ii) Show Error Log . Lists in a window outside the viewer the import error report of the cell displayed (see figure 5.8).

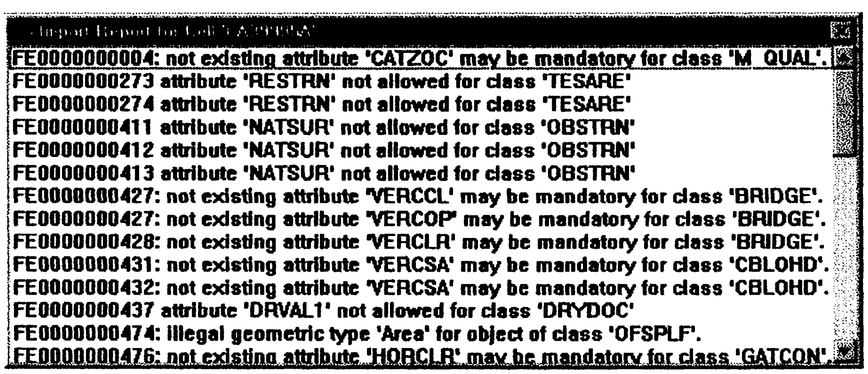
FE0000000004: not existing attribute 'CATZOC' may be mandatory for class 'M_QUAL'.
FE0000000273 attribute 'RESTRN' not allowed for class 'TESARE'
FE0000000274 attribute 'RESTRN' not allowed for class 'TESARE'
FE0000000411 attribute 'NATSUR' not allowed for class 'OBSTRN'
FE0000000412 attribute 'NATSUR' not allowed for class 'OBSTRN'
FE0000000413 attribute 'NATSUR' not allowed for class 'OBSTRN'
FE0000000427: not existing attribute 'VERCCL' may be mandatory for class 'BRIDGE'.
FE0000000427: not existing attribute 'VERCOP' may be mandatory for class 'BRIDGE'.
FE0000000428: not existing attribute 'VERCLR' may be mandatory for class 'BRIDGE'.
FE0000000431: not existing attribute 'VERCSA' may be mandatory for class 'CBLOHD'.
FE0000000432: not existing attribute 'VERCSA' may be mandatory for class 'CBLOHD'.
FE0000000437 attribute 'DRVAL1' not allowed for class 'DRYDOC'
FE0000000474: illegal geometric type 'Area' for object of class 'OFSPLF'.
FE0000000476: not existing attribute 'HORCLR' may be mandatory for class 'GATCON'.

Figure 5.8
The error log [Sevencs, 1997].

Double clicking on a message highlights the error in red on the display window.

(iii) Zoom In / Zoom Out, increases or decreases the display scale by 100 per cent.

(iv) Rotate Left / Right . Rotates the data set by 10 degrees but keeps the symbols and text horizontally.

(v) North Up

(vi) Copy to Clipboard . Allows the user to copy the displayed image to the clipboard (.CLP) which means that later on it can be changed to some other appropriate format.

(2) Presentation:

(i) Displaybase . Displays colors, safety contours, buoys (INT1) and traffic separation schemes.

(ii) Standard . Includes text, name of buoys, anchorage areas and pilot symbols.

(iii) Other. Displays every feature in the data set.

(iv) Traditional. Same as above.

(v) Simplified. Shapes of buoys become triangles (port side) or squares (starboard side).

Boxes to check:

-Lights, displays lights (symbols and sectors).

-Text, all the text is removed or included.

-SCAMIN, when checked filters the information to be displayed depending on the scale.

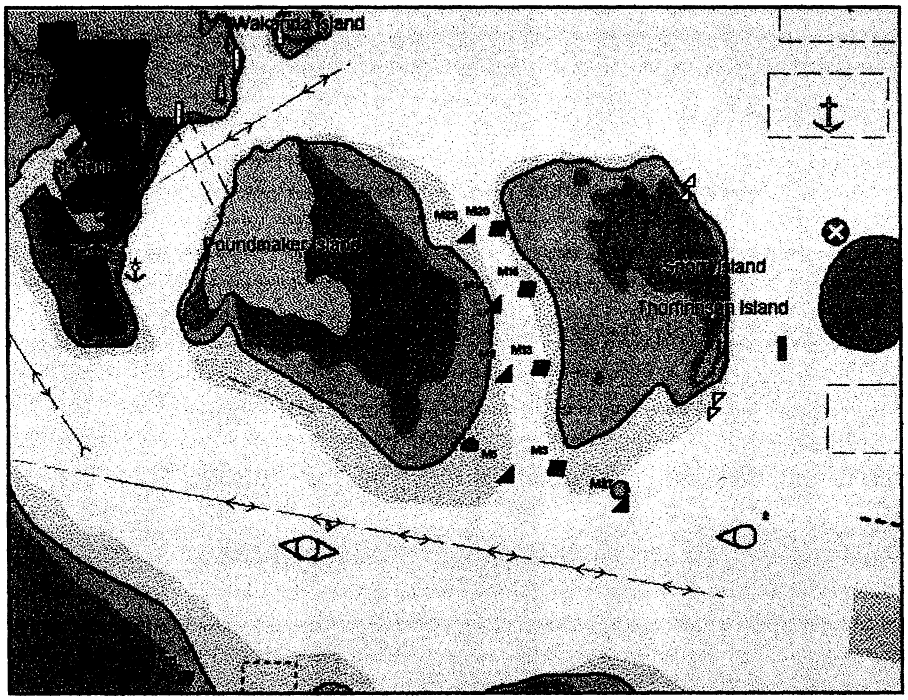

Figure 5.9
Example of a 'Simplified' display of the CHS test data set [Sevencs, 1997].

(4) Colors: displays different colors in accordance with the S-52 standard [IHO, 1993].

(i) Bright Day

(ii) Dark Day

(iii) Bright Night

(iv) Dark Night

(5) Mouse:

(i) Pan. With the right button centers the display in the mouse cross.

(ii) Zoom In. With the left button opens an area to be displayed.

(iii) Zoom Out. The middle button zooms out by 100 per cent of the previous scale.

(iv) Query. The left button clicked twice on an object in the display window opens a list of object description and attributes.

5.2.3 Evaluation Between *ECVIEW* and *SeeMyENC!*

From the evaluation made between these two viewers available in the market a few facts arise:

(1) The two viewers are meant for different purposes. While the USL program was mainly designed to check the quality of an ENC produced from a *CARIS* file, the SevenCs software is a more general one. In fact, *ECVIEW* loads both *HOB* (Hydrographic Object Manager) and S-57 files and also creates an *HOB* file from an S-57. *SeeMyENC!* displays and imports S-57 cells;

(2) *ECVIEW* runs in a UNIX environment and *SeeMyENC!* in a Windows NT OS. While the first provides a very good integration with the USL programs package (*OBMAN, CARIS* editor) since both work in the same environment, the second one offers a user friendly windows menu just like any common Windows application;

(3) The graphic display of *SeeMyENC!* is an easily readable one since it provides a dual display with Zoom "on-line" corresponding to the the place of the cursor. Another advantage is also the fact that all the menus are hidden instead of *ECVIEW* where all the buttons are always displayed;

(4) *Panning* and *Zooming* is easier in the USL software since it is done through the simple

use of the mouse;

(5) *SeeMyENC!* has more presentation possibilities than *ECVIEW* such as the Lights checking box;

(6) The great advantage in quality control procedures goes to the USL software. It allows the use of a "Dialogue box" where objects and attributes can be selectively displayed. This feature is of the utmost importance due to the fact that it can restrict the information to be displayed to the errors flagged. The object attribute allows 16 different combinations using four operators;

(7) A disadvantage in the SevenCs software is the fact that the query object window display is kept inside the window display of the data set, which sometimes prevents a total view of the file; and

(8) Because the *SeeMyENC!* program allows the user to copy the file to a clip board quite easily it can latter be changed to an appropriate format. Using *ECVIEW* we can only plot the file either in HPGL or Postscript.

5.2.4 Conclusions

As a quality control tool the choice should be *ECVIEW*. Although it is "*CARIS* user oriented" it provides a number of settings that offers its user a different combination of objects display. The disadvantage is the fact that it runs on a UNIX environment requiring a specific machine and OS instead of the more general used Windows environment. It is the perfect tool for a *CARIS* user and specially if the aim is to convert a *CARIS* file of paper chart to an S-57 ENC since it allows a quality control procedure in an intermediate step before the conversion to S-57.

The availability of *SeeMyENC!*,i.e., free to be downloaded from the Internet, makes it attractive to end users. It runs on a Windows environment and connections to information posted in the Internet makes this software not only user friendly but also a step ahead in technological features. An application running outside the viewer (netscape) with textual information is both useful for the navigator and saves storage space in the database allowing a faster change of image scale.

The suggestion would be to combine the quality control features of *ECVIEW* with a Windows environment of *SeeMyENC!* .

A raster image of the original paper chart file as a background to the ENC would help the user to check for inconsistences in object creation and misplacement of features.

In terms of a non-*CARIS* user, it would be useful to include or integrate an ENC editor to correct object / attribute creation errors at the same time that the error log window displays and highlights it in the SevenCs software.

5.3 *Writes57*

5.3.1 General

Writes57 is a line command used to populate a **data set file** from an *HOB* and a *CARIS* file.

For more details about this program see manual [USL, 1996b].

5.3.2 Command Execution

The format for the execution of *Writes57* is to be done from a ENC _ROOT directory in accordance with the standard, with the following structure:

%writes57 -file = 'file_name' *-output* = 'file_name' *-usage* = 'navigational_purpose'

The navigational purpose is the number to be chosen from the six different options available in accordance with the compilation scale of the chart and follows the numeration (see S-57 manual) [USL, 1996b].

Chapter 5 introduced the USL's tools available to build and control quality of an S-57 compliant ENC. Chapter 6 will describe the procedures followed by the author to build an ENC from a *CARIS* file of a paper chart. Suggestions and recommendations to improve both the software used and the flow chart of the procedures implemented in a HO will be mentioned.

CHAPTER 6

BUILDING AN S-57 COMPLIANT CHART

The aim of this Chapter is to explain the steps followed by the author in order to build an S-57 ENC using *CARIS* tools. In this Chapter, the author will include the description of the problems faced, solutions implemented and recommendations for future enhancement of the software.

6.1 The *CARIS* File - Chart 115

The original data set was a *CARIS* file used to produce the first Navigational Chart Assisted by Computer, of the Portuguese Hydrographic Office. The chart number 115 - "Arquipelago dos Acores Ilha das Flores e Ilha do Corvo" (Azores Archipelago Flores and Corvo Islands) - was released in July 1996. The data set was originally stored in a DAT (Digital Audio Tape) and later loaded to the UNB (Ocean Mapping Group) UNIX network. The work was achieved using a SUN workstation with 64 Mb of RAM, remotely logged to the HELAVA workstation, at the Geodesy and Geomatics Engineering Department (GGE), host of the *CARIS* and *OBMAN* programs.

The *CARIS* file was compiled to a scale of 1:100000 and comprises a rectangular area of the Atlantic Ocean bounded by the parallels 39^0 12' N and 39^0 51' N and the meridians 30^0 49' W and

31^0 31' W. It is a coastal Chart (navigational purpose) referenced to European Datum 50 (ED50) using a Mercator Projection. The Chart contains a legend on its North West boundary with the inclusion of a tide table (maximum, minimum and medium values) for the Port of Sta. Cruz das Flores.

A compilation diagram is included on the North East corner. Units of spot heights and soundings are in meters. Soundings are referred to the Hydrographic Zero, Lowest Astronomical Tide.

The file had two headers corresponding to the chart itself and to the compilation diagram. This fact was responsible for the problems that arose during the pre-processing work which are later explained in detail in this Chapter. As far as this data set is concerned , it should be pointed out that there is a large number of underwater / awashed rocks and small islands surrounding the mainland areas due to the Volcanic Origin of the mapped islands. This fact increased the amount of storage space necessary to record the large number of spatial features. The data set contained all the cartographic, text, neatline and grid not allowed in a ENC, and used to produce a paper chart at an HO.

6.2 Chart Flow of the Process

The next diagram explains the workflow followed, from the existing *CARIS* file of Chart 115 to the S-57 edition 3.0 compliant ENC. Details of the pre-processing general work and programs

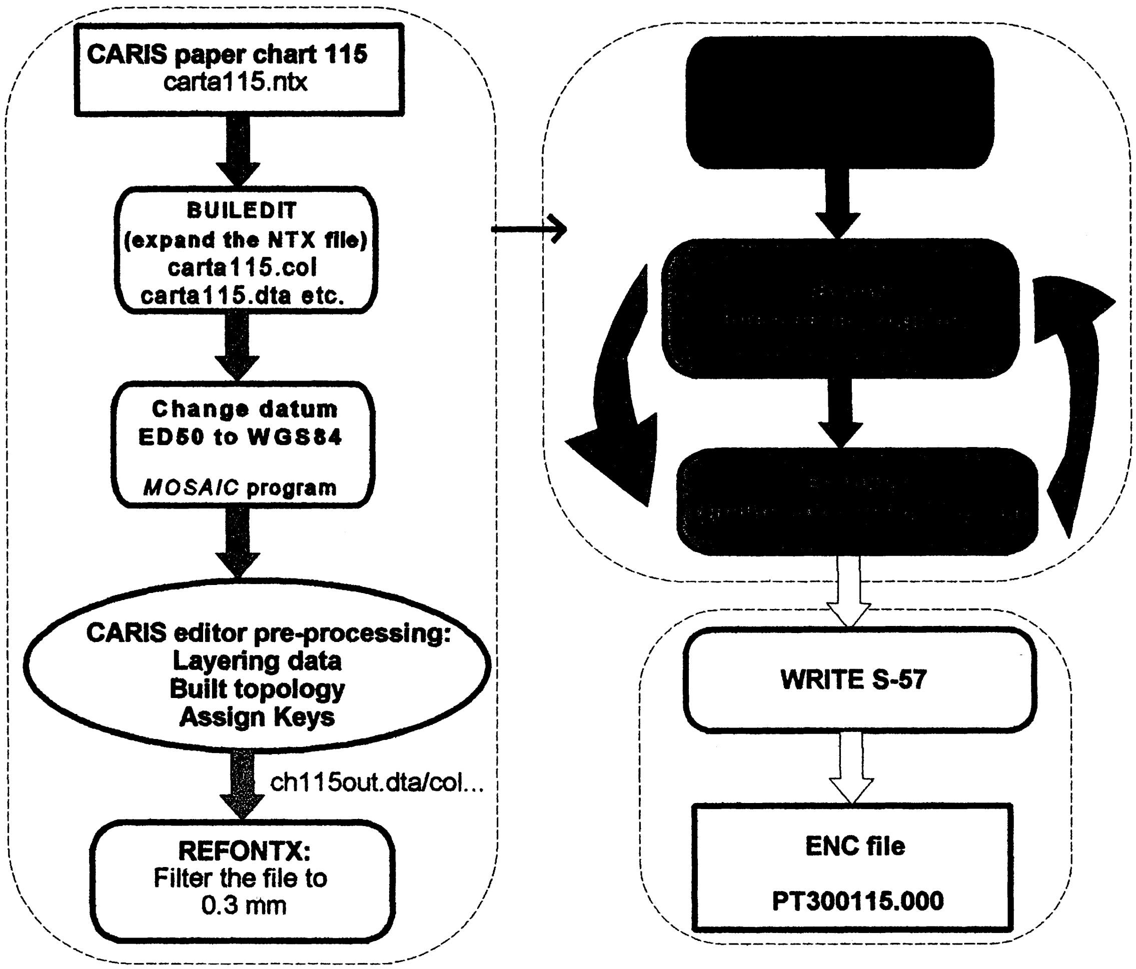

Figure 6.1
Workflow followed by the author to build an ENC: from a CARIS file to an S-57 ENC.

used are contained in Chapter 5. Yellow boxes are referred to pre-processing with *CARIS* software. The red boxes describe the intermediate step used to built feature objects from *CARIS* features. Blue boxes are referred to Quality Control procedures and Object Checking. The white boxes describe the Exchange Data Set creation (see figure 6.1).

6.3 Pre-Processing

Chart 115 file was designed based on the color separation by layers for the production of a paper chart. One of the problems the author had to face was his lack of familiarity with the file content. This kind of situation does not constitute a problem to an HO, since the production of a ENC is usually an in-house project. The first step was to check the features contained in each layer so that a selection of those allowed in ENC Product Specification could be made later.

6.3.1 Checking the CARIS File

After the *CARIS* file was loaded in the Ocean Mapping Group (OMG) UNIX system the first step was to expand it to several different files using the command:

%builedit carta115

The *CARIS* file was built in six theme layers (see table 6.1):

Table 6.1
Carta 115 file design.
The arcs and lines content by layer.

THEME	LINES	ARCS
0	343	45
1	81	0
10	273	273
11	1558	0
20	4	4
200	3	0

The feature content of each layer was the following one:

(1) **THEME ZERO**

(i)	LT3SHAD	Shade
(ii)	TEXT	Text
(iii)	CODTMR	Depth Contour
(iii)	CLSL	Surveyed Coastline
(iv)	BO_NEATLINE	Neatline
(v)	COIK	Approximate Depth Contour
(vi)	BO_( )	Border Features

(2) **THEME 1**

(i)	NFCFR(L)TSM	Steep Coast Line
(ii)	AWDMRT	Dam
(iii)	NFCFRTME	Steep Coast Medium
(iv)	NALTSLARC	Sector Lines
(v)	NALTSL	Sector Lines
(vi)	ALCN1	Purple Cartographic Text
(vi)	NFCFLT	Steep Coast

(vii)	CODTMR	Depth Contour
(viii)	*VARIOUS*	All the symbols

(3) **THEME 10**

(i)	CLSL	Surveyed Coast Line
(ii)	DLLD2	Danger Area
(iii)	CODTMR	Depth Contour
(iv)	CLICK	Unsurveyed Coast Line
(v)	CLLR	Lake
(vi)	LABEL	Label
(vii)	DLLD	Danger Area
(viii)	CODTMR	Depth Contour

(4) **THEME 11**

(i)	CODTMR	Topographic Contour (50 to 800 m, 50 m apart)
(ii)	CLRI	River / Stream
(iii)	ALRODL	Hard Surface Road

(5) **THEME 20**

(i)	DLLD	Danger Area

(6) **THEME 200**

(i)	DLLD	Danger Area
(ii)	CLSL	Surveyed Coast Line

A check of the file and examination of the content of the layers indicated that the concerns of the original producer were mainly related with color separation. The consequence of this was that the author had to move features from layer to layer. Layer numbers were changed in accordance with the ENC Product Specifications (Layer 0 cannot be specified, since it is mainly used for system storage of information).

Recommendation 1: When designing a *CARIS* file to be used both for the production of a paper chart and an ENC the producer must keep in mind the layering of data requirements contained in a ENC. Due to this fact, an appropriate labeling and layer designation should be designed according to the "Skin of the Earth" (*GROUP 1*) and *GROUP 2* themes. This avoids the complexity of changing data between layers, an error-prone process since both features and their corresponding polygon labels must both be changed.

Recommendation 2: Every Hydrographic Office or Data Producer should have their own ENC production manual. This standardized manual is intended to be followed by each individual in the work flow of digital data production and should contain layer designation to be used and the feature objects allowed in each layer.

6.3.2 Change of Datum

The original *CARIS* file Chart 115 was built using the European Datum 50 (ED50) one among several datums contained in the Portuguese folio of Charts. It was necessary to change the file to WGS 84 datum, which in *CARIS* is designated by the acronym WG84.

The *CARIS* program *MOSAIC* allows the changing of datum in a NTX file. The system did not recognize the parameters of ED50 because it was stored under a different name. The problem arose due to the fact that the environment variables set up in the HO in Lisbon were not the same that the author had in UNB. The ED50 datum parameters were stored in the system file *carisXsys/datum.dat* under the name ER50 . The parameters were copied into the new datum ED50, the same designation displayed in the chart header. The command typed was:

> *%mosaic*
>
> *MOSAIC> ellipsoid WG84*
>
> *MOSAIC> process carta115*

The program automatically looks for the corresponding NTX file. A different approach could be the use of CARIS *tran* command to merge the file with a new header in which the parameter datum would be changed to WGS84.This same process will be later used to change the coordinate system form *CHMR* to *LLDG*.

6.3.3 Erasing Unauthorized Features

After a visual check, the author concluded that cartographic features not allowed in the ENC Specification should be erased. This process was achieved by using the *lasso* commands in *CARED* (see Chapter 5 para. 5.1.1 number 5). The *CARIS* features deleted were:

Table 6.2
CARIS features erased and their description.

CARIS FEATURE	DESCRIPTION
BO_DICING	Border Dicing (shade)
LT5SHAD	Shade of depth Contour
BO_HALF_TICK	Border Half Tick
BO_FULL_TICK	Border Full Ticks
BO_NL_FRAME2	2nd Border Line
BO_PICTURE	Border Picture Frame
BO_EXTN_TICK	Border Extended Tick
BO_NL_FRAME1	1st Border Line
BO_LABEL_MIN	Border Label (Minutes)
BO_LABEL_DEG	Border Label (Degrees)
BO_PICT_TICK	Border Picture Frame Ticks
BO_LABEL_INT	Border Label (Corner Coord.)
TEXT	Chart Number 115 (Corners) Size of Chart(6018X721)mm

Recommendation 3: Features not allowed in an ENC Product Specification but used for Paper Chart Production (Grids and Cartographic Features among the most common ones) should be isolated in different layer(s) and not mixed up with other features. The result is an easy deletion of a single theme number and its contents instead of picking up features spread among several different layers.

The first deletion of unauthorized features was completed. Several more features will be deleted in the following pre-processing steps.

6.3.4 Layering of Data

For the purpose of this project the author separated the information in seven layers as follows:

Table 6.3
Layering of data for an ENC.

LAYER NUMBER	CONTENT
1000	"SKIN OF THE EARTH" or GROUP 1 features
2000	AREA FEATURES
2100	LINE FEATURES
2200	NEATLINE
9000	SYMBOLS
9100	SOUNDINGS

In the original paper chart, the Northwest corner displayed the legend. According with the information contained in the *CARIS* features parameters, some of the data contained in this chart came from the rasterization of a previous paper chart (1967), and through the use of *SAMI* converted to vector information. Due to this fact there was no sounding information "under" the displayed legend in the digital file. Because S-57 does not allow the existence of holes in the primary layer (all the *GROUP 1* data must be area objects and cover all the cell) and the cell must rectangular in shape, it was necessary to digitize an area on the place where data was missing (see figure 6.2) . Later, this area will be covered by a meta object M_COVER and assign an attribute describing an area without information.

Recommendation 4: When building a *CARIS* file for the purpose of producing a paper chart, all the information compiled that will be covered by other meta information or cartographic features should also be included in the file. The ***mask*** option should be used to hide this information allowing to later recovering for ENC or other cartographic production purposes.

To digitize a new rectangle in the file, the original NEATLINE feature was isolated with the display parameters. The *CARIS* command used was:

CARED>liap , at a convenient scale. Using the mouse, three points were digitized.

With the appropriate *CARIS* commands, intersections were computed creating the correspondent files. The last step was to cut the lines in the nodes and later to delete the extra lines.

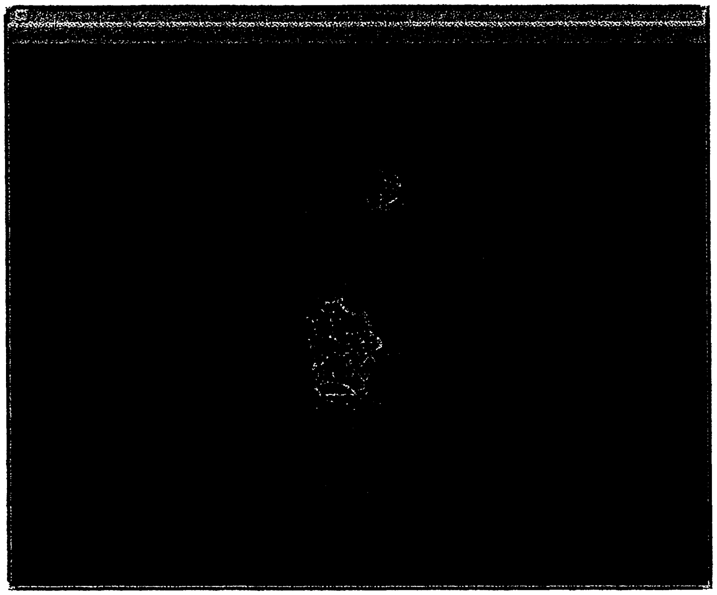

Figure 6.2
Digitizing extra polygons on the CARIS file
Although initially three polygons were digitized, the author found out that sounding information was only contained within the two most easterly polygons. The 'dangling" arcs were deleted.

Layer 1000 contains all the *CARIS* features that will be changed into feature area objects belonging to "Skin of the Earth" (see Annex A figure A.1). They are:

(1) CODTMR	Depth Contour	→	DEPARE Object;
(2) COIK	Approx. Depth Contours	→	DEPARE Object;
(3) CLSL	Surveyed Coast Line	→	LNDARE Object;
(4) CLICK	Unserveyed Coast Line	→	LNDARE Object;and
(5) LABEL	Label of polygons	→	Will be used to build areas.

Layer 2000 contains the area features that are not part of layer 1000 (see figure 6.3 and Annex A figure A.2):

(1) CLLR	Lake	➔	LAKARE Object;
(2) DLLD/DLLD2	Danger Area	➔	OBSTRN Object; and
(3) LABEL	Labels	➔	Used to build areas objects.

Layer 2100 contains all the line features that will later be line objects (see Annex A figure A.3):

(1) CLRI	River	➔	RIVERS Objects;
(2) ALRODL	Road	➔	ROADWY Objects; and
(3) COTPMR	Topographic Contours	➔	LNDELV Objects.

Layer 2200 contains the neatline used to create meta coverage mandatory objects (see Annex A figure A.4). Layer 9000 contains all the symbol features (see Annex A figure A.5):

(1) DLRA	Underwater Rock	➔	UWTROC Object;
(2) ALCHLH	Church	➔	BUISGL Object;
(3) ALRM7%/NALTQ%	Landmark	➔	LNDMRK Object;
(4) DLAN	Anchorage Area	➔	ACHARE Object;
(5) NPL1	Lights	➔	LIGHTS Object; and
(6) ALAIPLJ	Airport	➔	AIRARE Object.

Layer 9100 contains the sounding features (see Annex A figure A.6):

(1) SGUR Soundings ➔ SOUNDG Object.

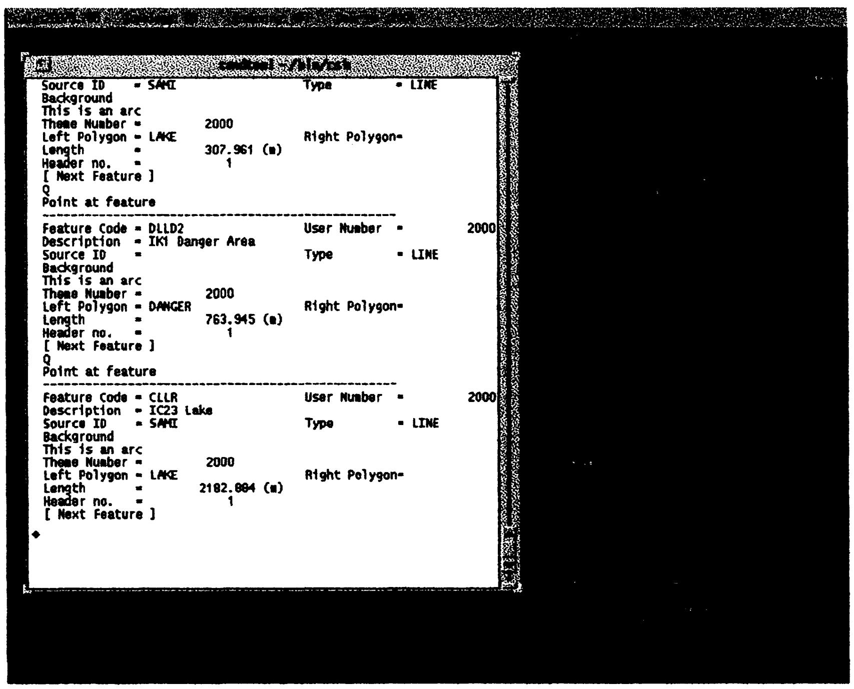

Figure 6.3
Window of CARED displaying theme 2000.
Inserted is a description of several features contained in this theme.

Some problems arose after all the features were stored. Not only did two features in the same theme possessed coincident edges (see figure 6.4), but also depth contours originally masked to design the paper chart, when unmasked revealed that they were crossing future Land Area features (see figure 6.6). In the first case, there was the need to intersect lines, cut the intersections and delete common edges (see figure 6.5). What was at first an island so close to land that they had common edges turned to be one feature that would later became a LNDARE - Land Area.

Figure 6.4
Coincident geometry in CARIS file.

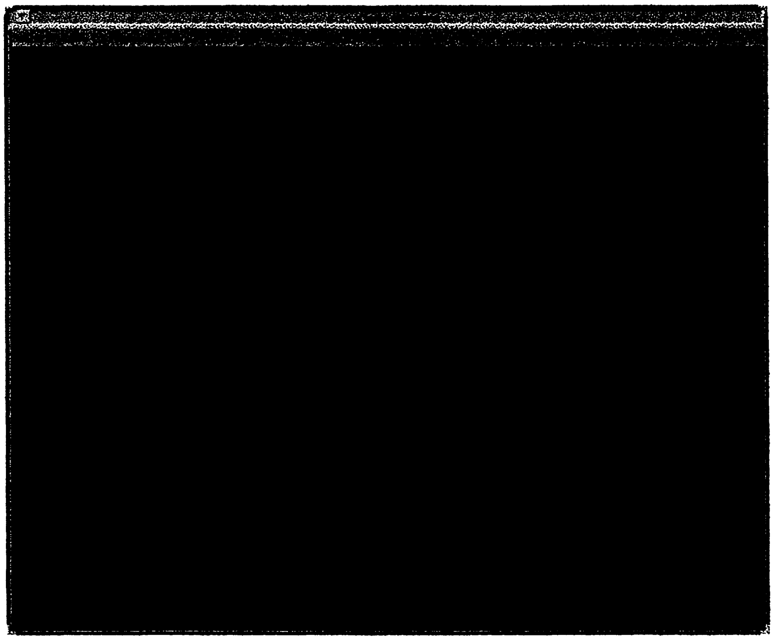

Figure 6.5
Coincident geometry is solved.

In order to build polygon objects from non-existent features (e.g. create objects DEPARE from depth contours) it was necessary to assign labels to each intermediate depth areas (see figure 6.6). These labels will be later retrieved by the *fea2obj* to create objects and assign attributes to the same object. An example is a label of the type 20_50M that will become an attribute DRVAL1=20M DRVAL2=50M for the object DEPARE.

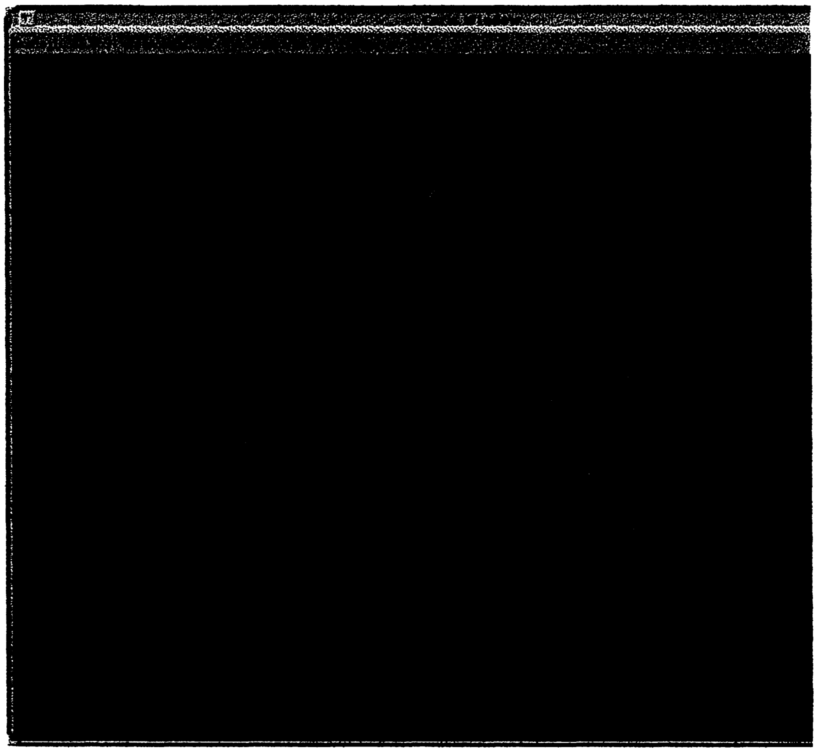

Figure 6.6
Labels 20_50M were assigned with the command *%naad* where they did not exist.

Recommendation 5: The data producer, when in the process of digitizing or converting features from Raster to Vector, must be aware that no overlap or intersection should exist between line or area features not belonging to the same GROUP in a ENC. Intersection between features means assigning a node or creating another spatial object. We should always bear in mind that the number of spatial features should be reduced to the minimum in order to increase draw speed in

ECDIS.

Recommendation 6: The cartographer when producing a *CARIS* file should, when convenient, assign Labels to area features in accordance with the mandatory format for *OBMAN* use.

An interesting problem that the author came across was the existence of Land features inside a Lake feature. Recalling that Land Areas must reside in layer 1000 ('Skin of the Earth') and Lake Areas reside in layer 2000 (Area Objects) it was necessary to (see figure 6.7):

(1) Move the CARIS feature CLLR, corresponding to the island, to layer 2000;

(2) Assign to this feature the same feature as in CLLR; and

(3) Label this "donut" shape feature as "LAKE".

The aim of the changes was to create a "donut" shaped lake to be displayed on top of the LAND area residing on layer 1000 (see figure 6.7).

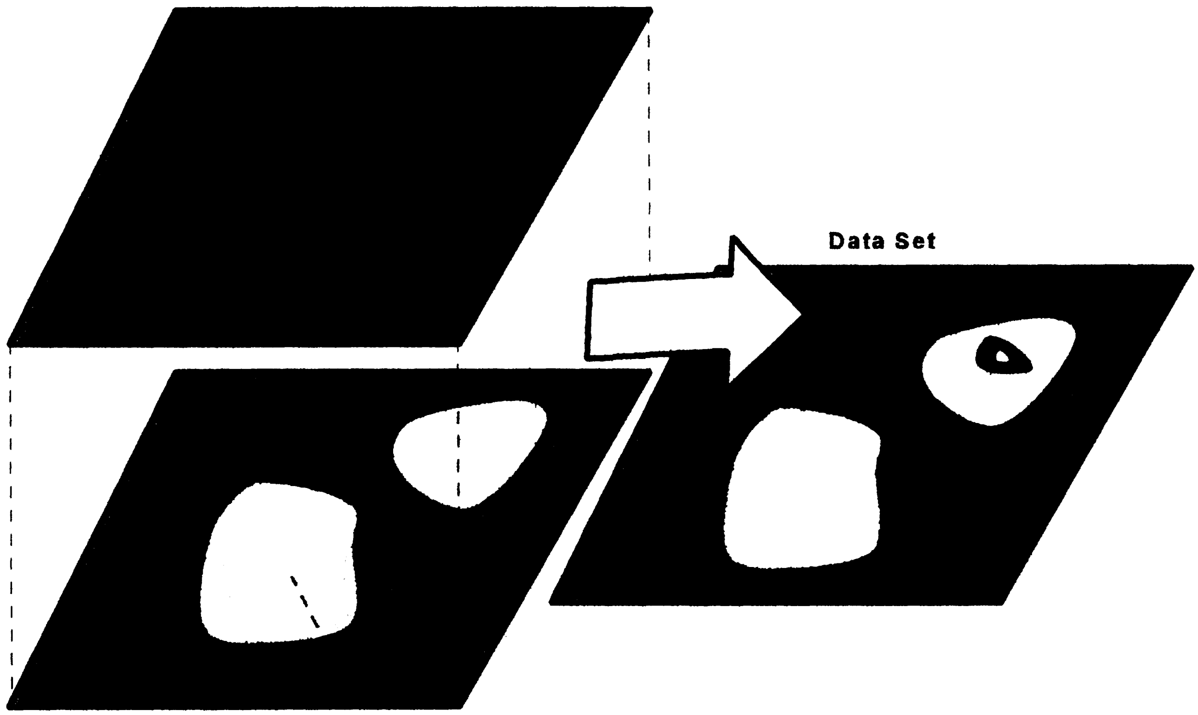

Figure 6.7
An Island inside a Lake. How to solve an uncommon problem.

6.3.5 Filtering the File

In accordance with the S-57 standard, the density of points in a data set must be not less than 0.3 mm apart. Filtering the file can be done at any time during the pre-processing but it is advised to filter it before rebuilding the network / polygon topology. The *CARIS* command (*refontx,* see Chapter 5 paragraph 5.1.1) must be used with the ntx file which means no topology available. Using the referred command the file was filtered to 0.3 mm. The *CARIS* software runs a cartographic algorithm to reduce the point density [Douglas and Peucker, 1973]. This algorithm tends to keep more points in corners or sharp lines deleting points on straight lines where they are not needed to define the shape of the line. After the filtering was achieved the author noted that several features were distorted (an example was that islands were changed into lines and boundaries were crossing each other). It looked like the file had its appearance completely distorted which meant a Nautical Chart completely different from the original (see figures 6.8 and 6.9).

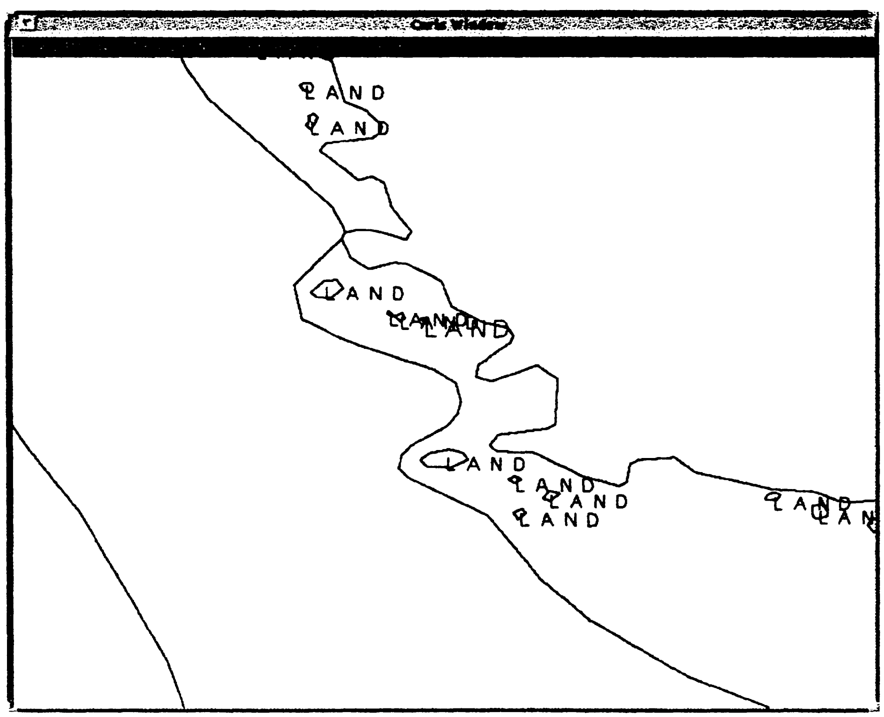

Figure 6.8
Zoom-in (1:10000) image of layer 1000 before filtering, corresponding to land area and small islands around the main island.

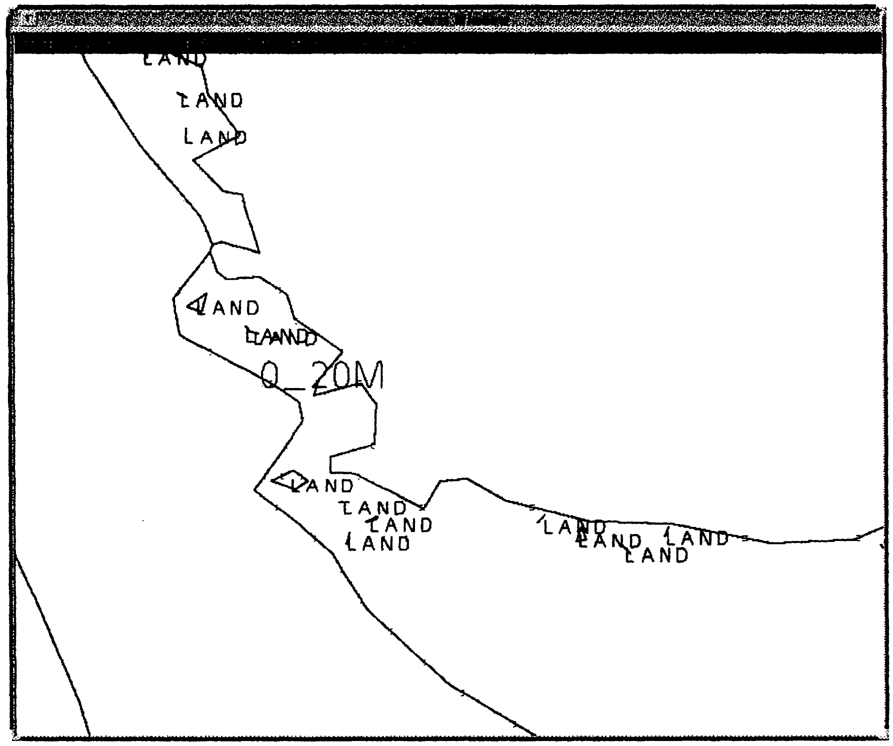

Figure 6.9
Zoom-in (1:10000) image of layer 1000 after filtering, corresponding to land area and small islands around the main island.
Some features changed shape.
Some islands (polygons) became lines.

The distortion of the features seemed unacceptable to the author, not only at this scale but also at the original scale (1:100000). For the accuracy of the work and safety for the navigation, it was necessary to restart the pre-processing work and to try different filter values that would reduce the size of the file but at the same time wouldn't change the cartographic representation.

The experiences were achieved extruding small pieces of data, reformatting with the new filtering and compared with the original file. Filtering was tried with 0.1 mm and 0.05 mm values. As shown in Annex B filtering with 0.1 mm did not make considerable changes in the shape of the features on a visual check but introduced several topological errors due to transformations in the position of some features (see Annex B).

With a 0.05 mm filtering the author was not following the S-57 standard, but it seemed like it was the only way to reduce the size of the file to 1/10 of the original size keeping the truthfulness of the information. Displaying the data at the original scale (1:100000), before and after filtering, there are no visual differences neither topological error massages.

Recommendation 7: Although the S-57 standard states that the point filtering of the data should not be less than 0.3 mm, the producer on an S-57 compliant ENC must maintain the truthfulness of the information. Before filtering the entire file content (due to the fact that a *undo* command is not available) it is advisable to try several other values using a portion of the data file checking for the change of feature shapes.

Recommendation 8: A suggested enhancement to this software would be a quality control tool that would flag the producer of data for the change of the shape of the features after a filtering command. This tool could check the original data selected by the user against the filtered one displaying the shape differences.

6.3.6 Change of Coordinate System

The next step in the pre-processing was to change from coordinate system, i.e., NEMR to LLDG or Latitude and Longitude in decimal degrees.

It was followed the procedure described in Chapter 5 , 5.1.1 number 4, using the *tran* command. After a visual check of the output file it seemed as if a line feature or a polygon edge was moved several degrees in longitude and latitude from its original position.

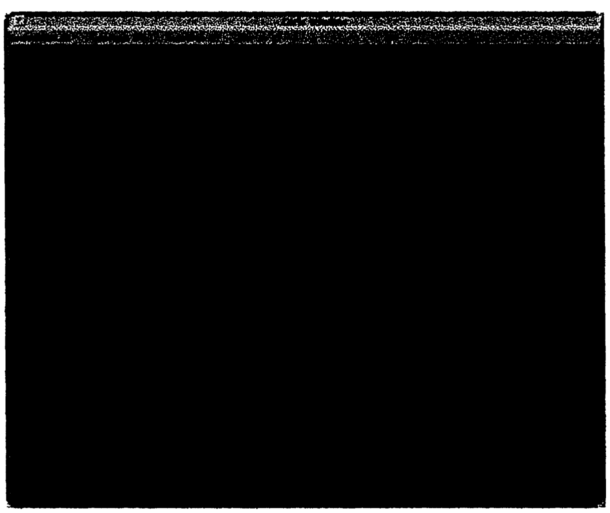

Figure 6.10
Zoom-in of the layer 1000 before changing coordinate system.

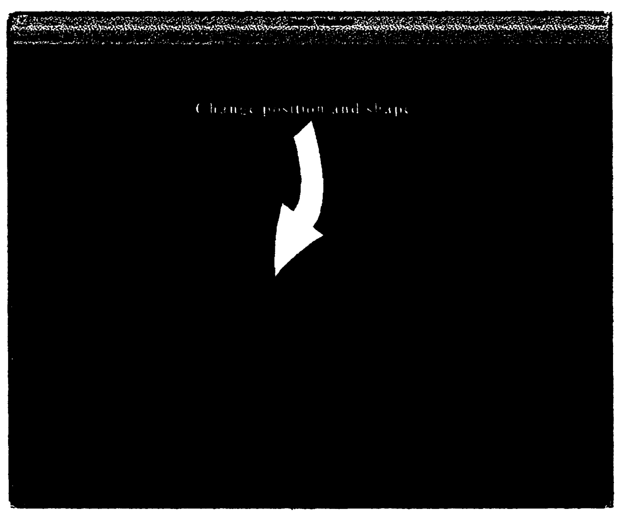

Figure 6.11
Zoom-in of the layer 1000 after the attempt to reposition the changed line.

After an attempt to reposition this feature (see figures 6.10 and 6.11) the author found out that deleting the header number two of the original (correspondent to the compilation chart information and not in use in a ENC) and re-computing the *tran* command the problem seemed to be solved and the feature appeared to be on its correct position. The are no logical reasons why only that small line changed position.

6.3.7 Rebuild Topology

To rebuild topology the author followed the procedures described on Chapter 5. 5.1.1 number 7. Some topological errors like the existence of dangling arcs were flagged and corrected. Digitizing new lines to close polygons was also performed.

6.3.8 Assign Keys

The linkage of a feature object and its geometry is done through the use of the *CARIS* key. During the process of splitting and duplicating lines for layering the data we ended with different lines with same keys. Since keys must be unique so that an object must reference a unique geometrical entity there is the need to reassign new keys to *CARIS* features making sure that objects have unique keys. The procedure followed was described on Chapter 5, 5.1.1 number 8.

Sounding objects are a special case in S-57. If all the sounding attributes are the same and if the sounding keys are the same, *fea2obj* will create a single object. This will reduce the number of spatial objects and consequently the length of the data set. Grouping all the soundings under the same key requires a more involved procedure:

(1) Isolate the features (soundings) to process them;

(2) Assign system keys with ***makeinde -scope=display*** command;

(3) Generate a list of keys creating an output textfile with the command ***dispsoun -format=key -scope=display -noheading -output='texfile_name'***; and

(4) Change the keys into a new unique key with the command ***chankeys -file='file_name' -keylist=texfile -newkey=NEWKEY***.

Recommendation 9: An enhancement to *CARIS* that would ease the task of the S-57 ENC producer would be to provide a command to summarize the four steps needed to assign a unique key to a group of features.

6.4 The Creation of Objects

After the data set was ready for object conversion, the author had the chance to build object features, either using a "Look-up table" and creating objects on a batch mode or / and interactively with the *obman* software. For the purposes of training and to cover the different ways available for creating objects, it seemed like the use of both the batch and interactive mode was the appropriate one.

6.4.1 The "Look-Up Table"

The "Look-up table", as described early, is a text file created in the same directory as the data set. The table contains twenty three (23) entries covering the individual object classes to be created when running *fea2obj* and covers all of the *CARIS* features within the file (see Annex C). Within the table we can find the mandatory fields *object code* and *feature code* and the optional fields *object class*, *feature type*, *attribute* and *feature description*. For Depth Contour objects (DEPCNT), the author has chosen to use an internal script available in *fea2obj* program. This script automatically assigns Z values contained in the *CARIS* feature to an attribute of the feature object, in this case the bathymetric value of the *CARIS* feature depth contour will become the VALDCO attribute value of the DEPCNT feature object. The format used in the table was:

ATTRIBUTE SCRIPT: assign_Z VALDCO CARIS_Z

where "assign_Z" corresponds to the script name, VALDCO is the name of the feature object attribute to be populated and CARIS_Z determines that it is the Z value of a *CARIS* feature that will be retrieved.

An external script was used for DEPARE (Depth Area) objects. This external script is a UNIX shell script and returns a string of the form <attribute><value>![<attribute><value>!... that was used to automatically populate the mandatory attributes DRVAL1 and DRVAL2 for DEPARE (Minimum and maximum depths of a depth area). Any polygon with the label of the type 10_20M where 10 is the minimum depth of 10 metres and 20 the maximum depth of 20 metres will trigger the use of *depthdepare* script. Consequently this will generate area objects of the type DEPARE and populate the attributes DRVAL1 and DRVAL2 automatically.

All the object classes and attributes contained in the table are in accordance with those allowed in the S-57 dictionary.

The objects left out for latter creation with *obman* were the mandatory meta objects M_COVER (describes the coverage and extend of a spatial object), N_SYS (describes the navigational system of marks used) and M_QUAL (quality of the data). Master/slave relations were also created interactively with *obman*.

6.4.2 *Fea2obj* - Batch Command

The batch command *fea2obj* was run and some error messages were flagged. Some of these messages corresponded to features not contained in the "Look-up table". Features without keys were also flagged.

The problems were corrected and the file was first viewed with the *ECVIEW* program for a visual check for inconsistences. The first problem to arise was that due to the fact that no object was built on the NW corner of the file (polygon containing no bathymetric information) the data set did not meet the S-57 requirements to be a rectangle in shape. It was therefore necessary to build an object with *obman* at the same spot. A Depth Area object (DEPARE) was built with no sounding attributes (containing no sounding information).

6.4.3 *OBMAN* - Interactive Object Creation

OBMAN was used to:

(1) Build Mandatory Meta objects referenced in 6.4.1 (see figure 6.12);

(2) Complete all lighthouses attributes (height and name - text);

(3) Complete light attributes (colour, period, type and range); and

(4) Include toponymic information (text).

All the objects were either built from scratch or edited and corrected interactively. This meant that every time it was necessary to check for the quality of the data with *ECVIEW*, *obman* had to be closed. Only after closing *obman* were all the edited objects stored in the *HOB* file, in this case *ch115out.hob.*

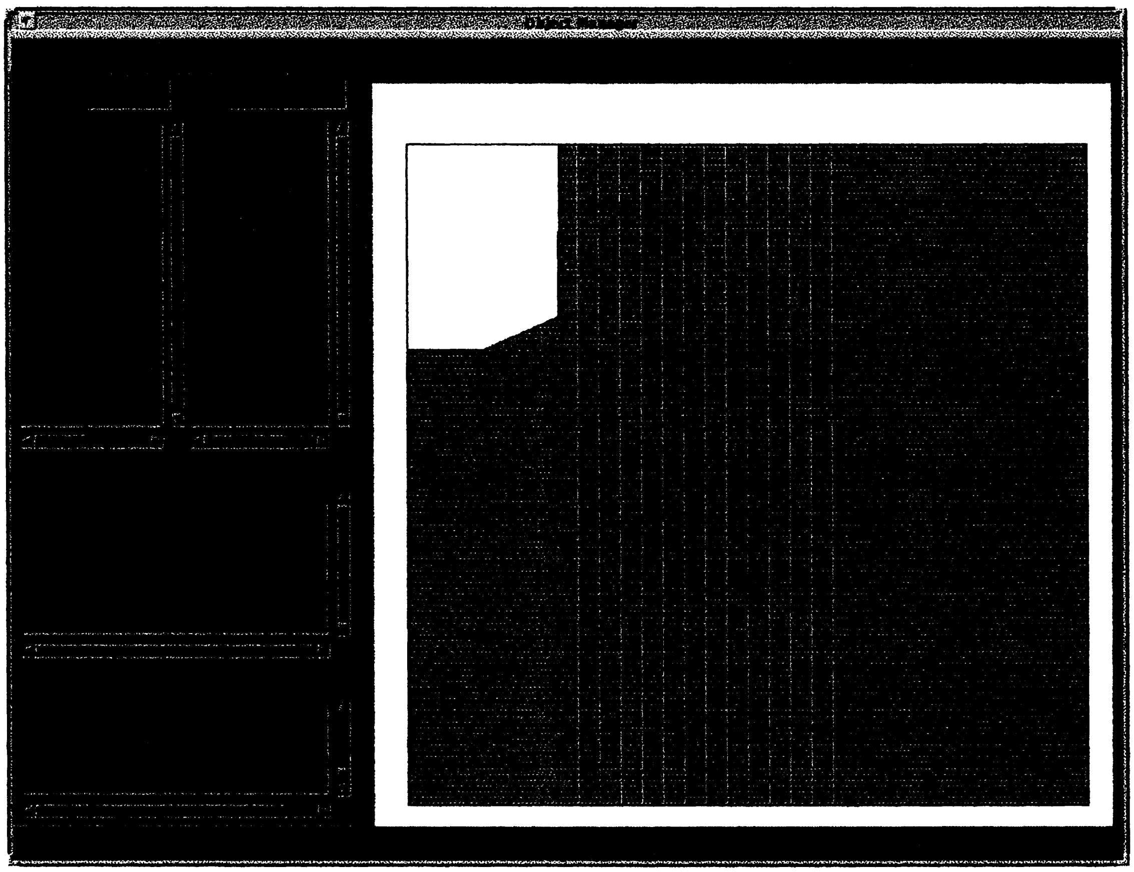

Figure 6.12
The use of *obman* to build the Meta Object M_COVER.
The NW polygon is covered with the CATCOV attribute 2 (no data).
The polygon in bold is covered with the CATCOV attribute 1 (data included).

6.5 Writes57 - The Exchange File

In accordance with the S-57 standard the Data Set must be stored in a ENC_ROOT directory. The first step before running *Writes57* was to create that same directory containing the correspondent *CARIS* files.

Writes57 created a Data Set in accordance with the ISO8211 standard, from the file *ch115out.hob* and the correspondent *CARIS* file.

The command used was:

%writes57 -file=ch115out -output=PT00115.000 -usage=3

The qualifier output specifies the name of the ENC (PT for Portugal, 115 for the ENC number and extension 000 for the first edition) and usage 3 creates a navigational purpose *coastal*. Pictures of the ENC are contained in Annex D.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

Released last November, version 3.0 the S-57 standard is officially frozen for 4 years to allow not only the implementation of methodologies in the HOs but also a consistent development of software for the production of ENCs . The Hydrographic Offices that have embraced the digital technology for chart production in general and the production of S-57 Charts in particular, are now in the process of releasing their first ENCs S-57 compliant. It is predictable that with the increase of ECDIS installations the demand for ENCs will soon require an adequate answer from the HOs.

The aim of this report was to build an S-57 compliant ENC (the first ENC built with Portuguese hydrographic data), evaluate the software used (USL's *CARIS* and Hydrographic Object Manager) and, when appropriate, to make recommendations for future enhancement of the software.

After the work was conducted, several implementation procedures were suggested to be used within an hydrographic office to optimize the production of both paper charts and S-57 ENCs from a *CARIS* file. Examples are, the need of an adequate layering of information in a *CARIS* file that fits both the paper chart production needs (color separation) and S-57 ENC requirements ("Skin of the earth" and thematic *GROUP 1* and *2* topology building) also to filter a subset of the file to the mandatory 0.3 mm and compare with the correspondent original subset to check for distortions on the data.

The USL's Hydrographic Object Manager (HOM) was used to convert a *CARIS* file into an ENC. For a non-*CARIS* user this means that he must purchase a *CARIS* GIS package to build *CARIS* features, after which they must be converted into feature objects (S-57 architecture) using the HOM.

Although this architecture optimizes and fits a *CARIS* client that needs to convert previous *CARIS* files to the new format, it requires an additional step in the workflow. In order for a first time ENC producer to avoid this step, the *OBMAN* software package should be re-designed in order to increase its functionality.

A proposed solution is to make the Hydrographic Object Manager object-oriented in design, thus avoiding the unnecessary step of converting modeling design as discussed in chapter 6. Most of the Hydrographic Offices will certainly continue to produce paper charts and ENCs. USL's Object-Manager should include digitizing tools that would create objects. These objects would be created from scratch and stored in a O-O data base.

Before such a profound change (one which would certainly require a new software design) takes place, a proposed solution to ease the work of the producer should be to create an intermediate step in the form of a new program aggregating the pre-processing *CARIS* steps (discussed in chapter 5 section 5.1.1).

This new program could be Windows-based and it would include filtering button (0.3 mm), datum conversion (reads the original file datum and converts to WGS84) and coordinate system conversion (reads the coordinate system from the header of the file and converts to LLDG) on its menus. Some of the complexity of the work done in layering the data according with the standard requirements would therefore be hidden to the user though providing a user friendly interface.

In a more ambitious step, the software proposed on the previous paragraph could be combined with the functionalities of *OBMAN* and *ECVIEW* in a unique Hydrographic / Mapping Software package to create, edit objects and do quality control of the data. This would end the need to close a editing program (*Obman*) to open another one (*ECVIEW*) to check for data inconsistencies.

The Canadian Hydrographic Service (CHS), a leading organization in Electronic Charting has just released its first six S-57 ENCs in the market. This fact means that the process of changing work methods and re-engineering in an digital hydrographic office, has taken place.

Within the CHS, the experience of the last two years on building and converting *CARIS* files into ENCs and lately to the S-57 compliant ENC format has shown the need for optimizing procedures and software enhancements.

Although this report has certainly not found the solution for every problem now facing an HO when producing S-57 ENCs, the author contributed with his recommendations and suggestions to ease the work of the cartographer / hydrographer who has embraced this new technological challenge.

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ANNEX A

Plotted images of the CARIS file into layers

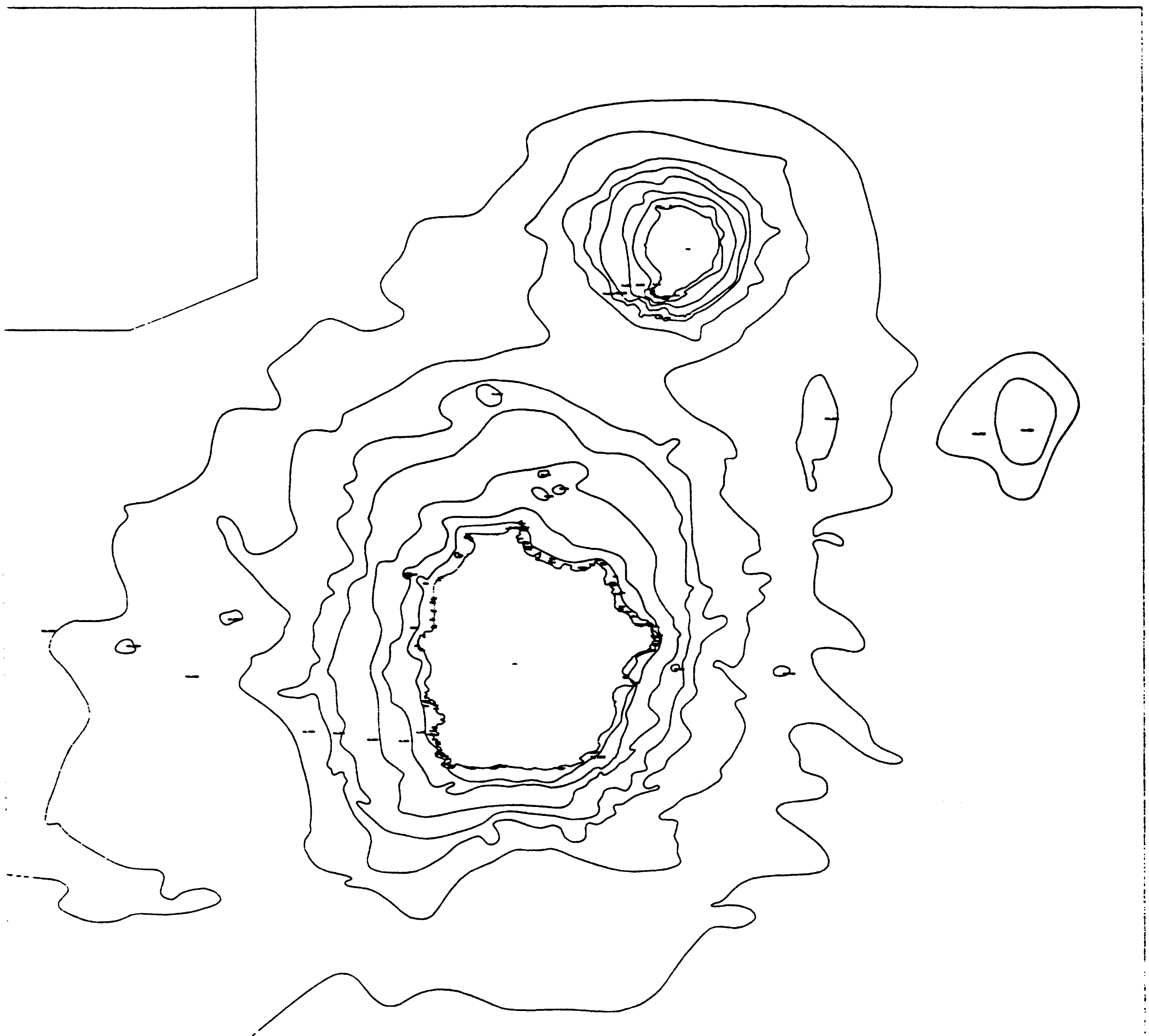

Figure A.1
A plot of ch115.out file. Layer 1000.

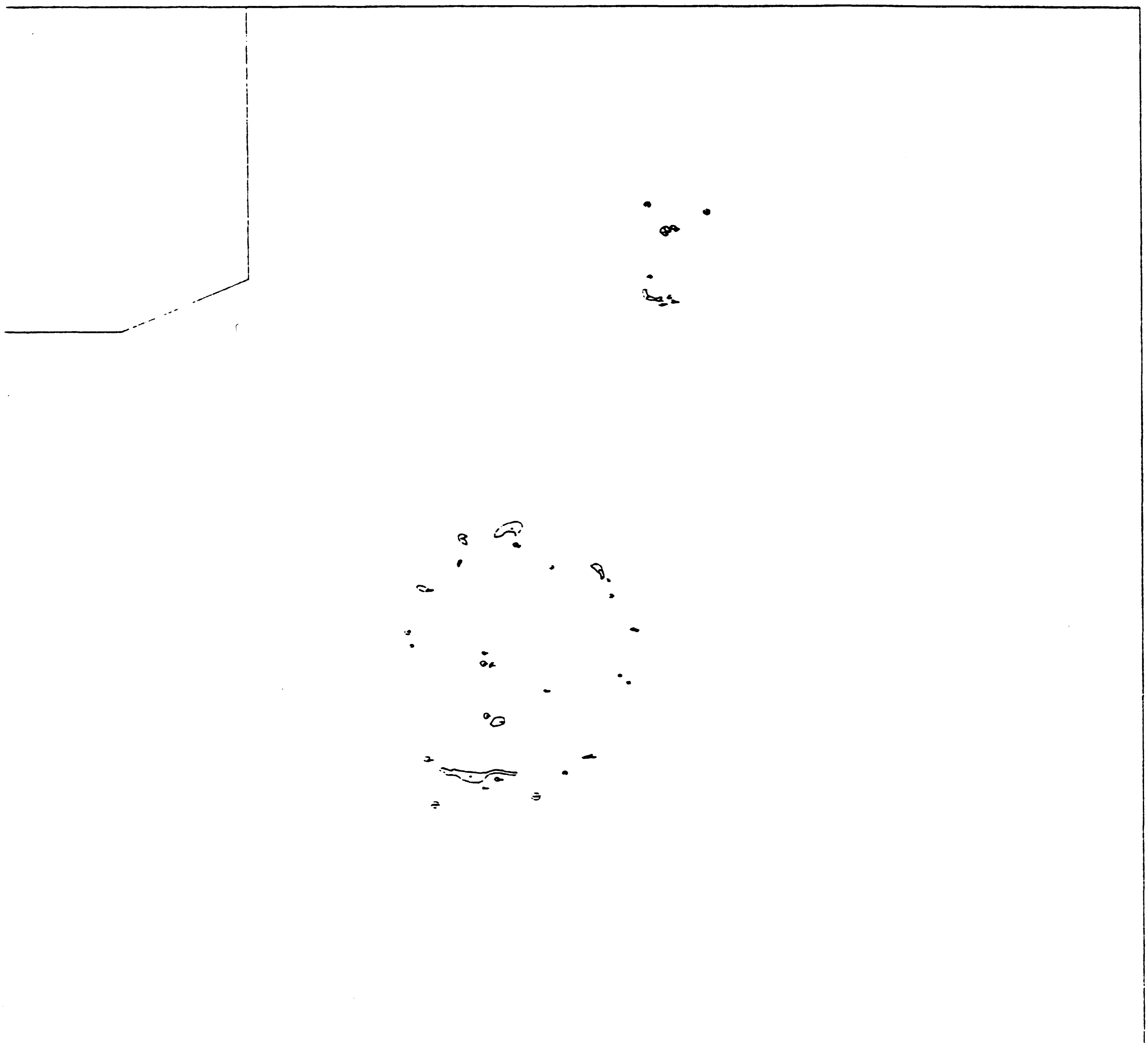

Figure A.2
A plot of ch115.out file. Layer 2000.

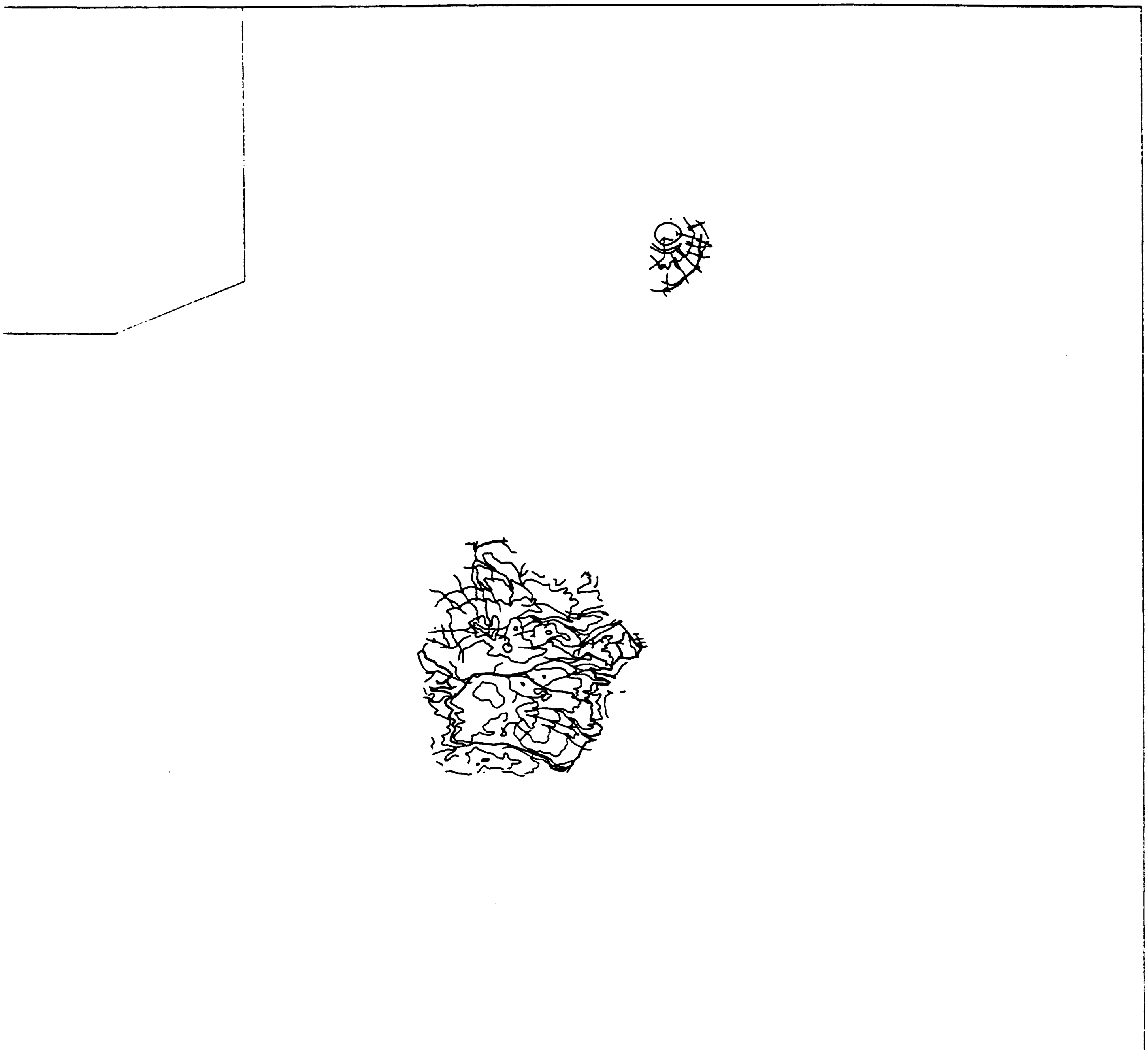

Figure A.3
A plot of ch115.out file. Layer 2100.

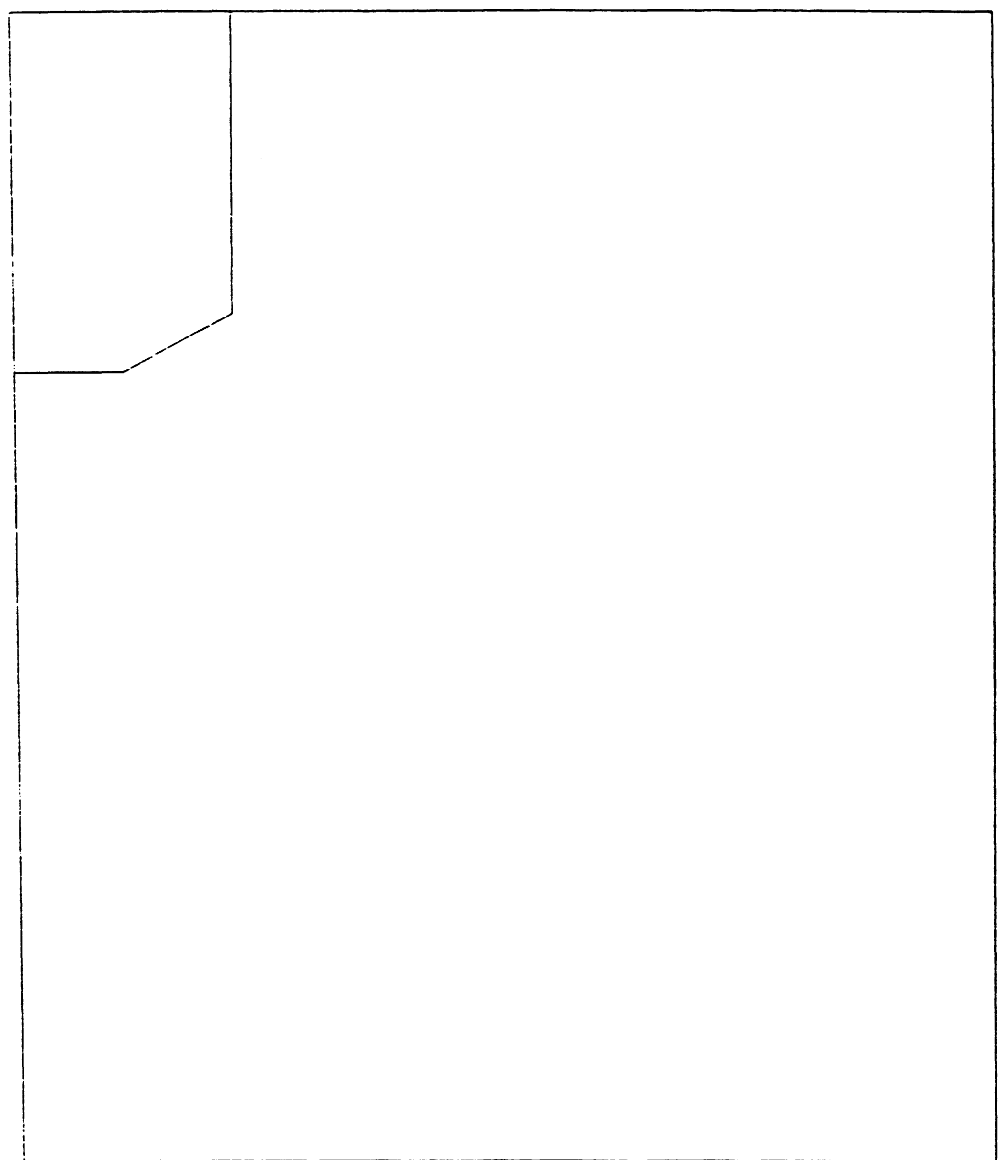

Figure A.4
A plot of ch115.out file. Layer 2200.

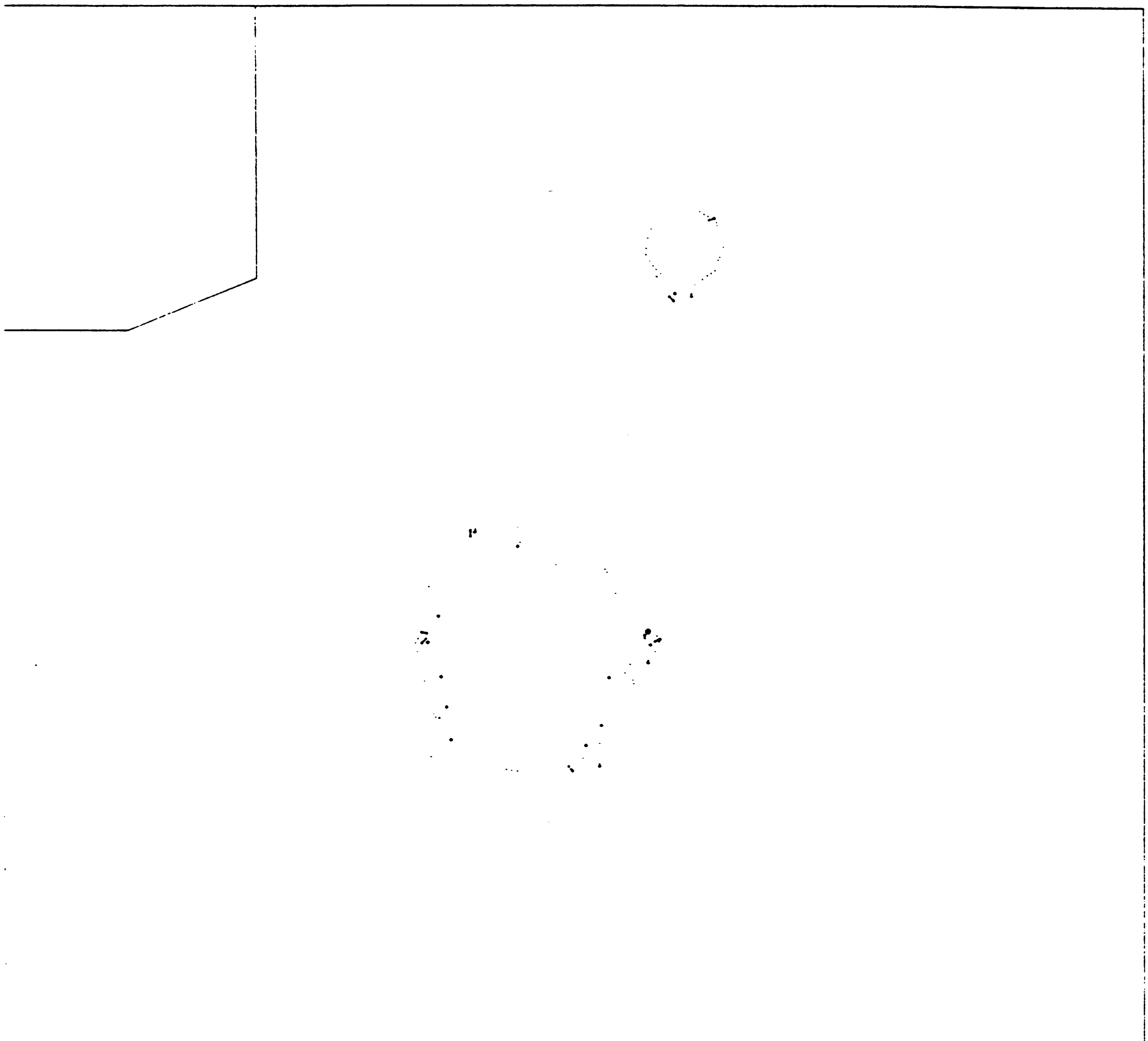

Figure A.5
A plot of ch115.out. Layer 9000.

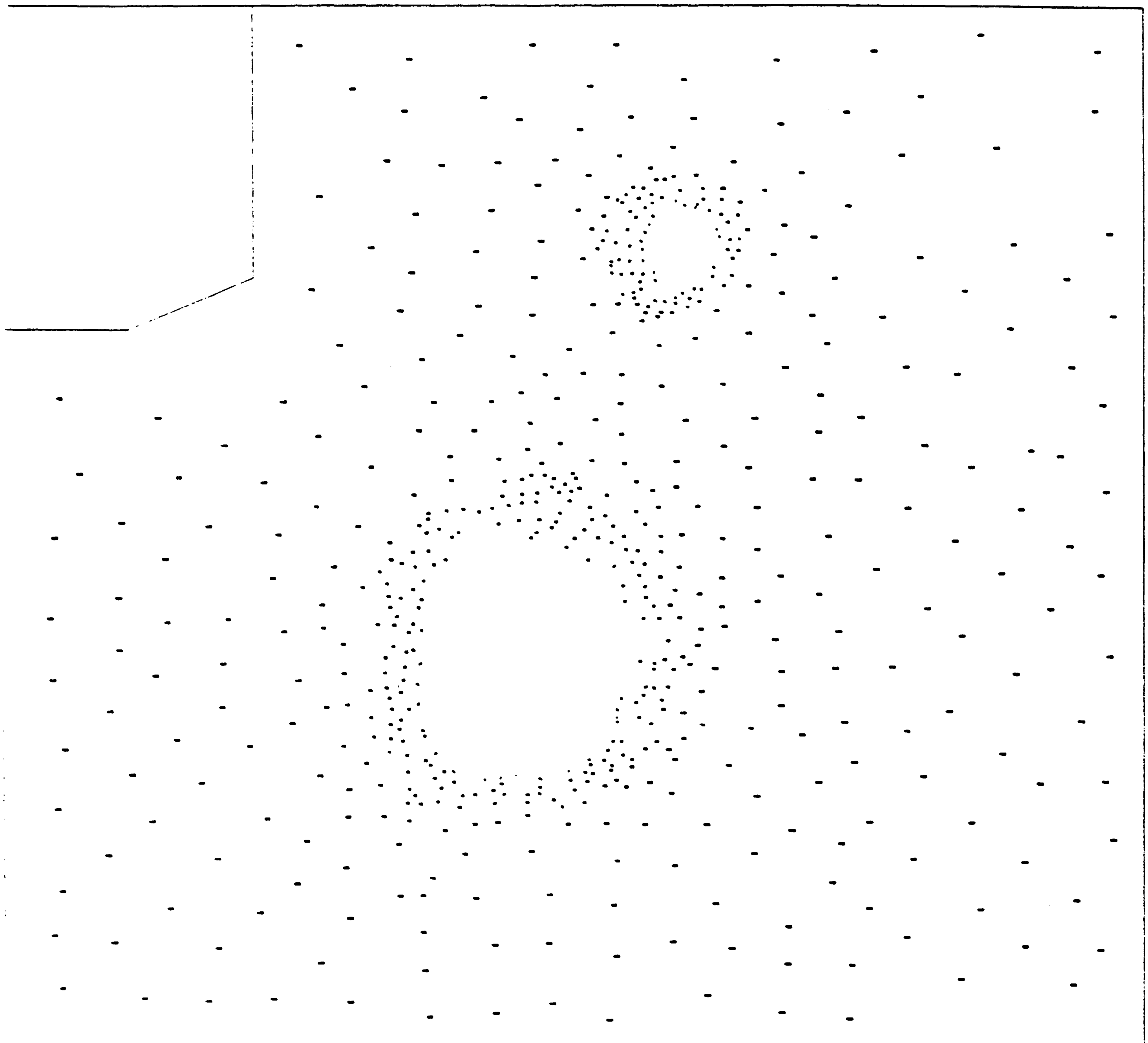

Figure A.6
A plot of ch115.out. Layer 9100.

ANNEX B

Reported messages by CARIS

(1) Filtering the file with 0.05 mm.
(2) Filtering the file with 0.1 mm.

```
helava.gge.unb.ca{lpais.42}%refontx -file=ch115out -convert -filter=500d
 All data

Working ...
    6000  descriptors remaining at 11:04:36 for header      1
    5500  descriptors remaining at 11:04:44 for header      1
    5000  descriptors remaining at 11:04:56 for header      1
    4500  descriptors remaining at 11:05:07 for header      1
    4000  descriptors remaining at 11:05:18 for header      1
    3500  descriptors remaining at 11:05:25 for header      1
    3000  descriptors remaining at 11:05:37 for header      1
    2500  descriptors remaining at 11:05:47 for header      1
    2000  descriptors remaining at 11:05:58 for header      1
    1500  descriptors remaining at 11:06:07 for header      1
    1000  descriptors remaining at 11:06:17 for header      1
     500  descriptors remaining at 11:06:26 for header      1
       0  descriptors remaining at 11:06:28 for header      1

 Header#        1
 ----------------------------------------
 Number of output features:      6577
 Number of output descriptors:    7174
 Number of output notes:          0
 ========================================

     7174 descriptors written
 Reformat completed
helava.gge.unb.ca{lpais.43}%ls -l
total 8457
-rw-r--r--  1 lpais     173228 Jun 24 11:00 ch115out.cel
-rw-r--r--  1 lpais       3431 Jun 24 11:00 ch115out.col
-rw-r--r--  1 lpais       3431 Jun 24 11:00 ch115out.col%
-rw-r--r--  1 lpais       1484 Jun 24 11:00 ch115out.d_89
-rw-r--r--  1 lpais     669036 Jun 24 11:00 ch115out.des
-rw-r--r--  1 lpais    5981192 Jun 24 11:01 ch115out.dta
-rw-r--r--  1 lpais        260 Jun 24 11:01 ch115out.err
-rw-r--r--  1 lpais     542573 Jun 24 11:01 ch115out.hob
-rw-r--r--  1 lpais      94208 Jun 24 11:01 ch115out.idx
-rw-r--r--  1 lpais      53248 Jun 24 11:01 ch115out.ix
-rw-r--r--  1 lpais     176640 Jun 24 11:01 ch115out.lin
-rw-r--r--  1 lpais       1536 Jun 24 11:01 ch115out.nol
-rw-r--r--  1 lpais          0 Jun 24 11:01 ch115out.not
-rw-r--r--  1 lpais       4098 Jun 24 11:01 ch115out.ntb
-rw-r--r--  1 lpais     752328 Jun 24 11:05 ch115out.ntx
-rw-r--r--  1 lpais       1316 Jun 24 11:02 ch115out.plb
-rw-r--r--  1 lpais      57856 Jun 24 11:02 ch115out.pol
-rw-r--r--  1 lpais       1024 Jun 24 11:02 ch115out.ras
-rw-r--r--  1 lpais      58693 Jun 24 11:05 ch115out.rec
-rw-r--r--  1 lpais        210 May 29 13:05 programa
helava.gge.unb.ca{lpais.44}%source programa

 Creating CARIS file ...

  Created: /export/home/omg3/lpais/test/ch115out.des
  Created: /export/home/omg3/lpais/test/ch115out.dta
  Created: /export/home/omg3/lpais/test/ch115out.cel
  Created: /export/home/omg3/lpais/test/ch115out.lin
  Created: /export/home/omg3/lpais/test/ch115out.nol
  Created: /export/home/omg3/lpais/test/ch115out.pol
  Created: /export/home/omg3/lpais/test/ch115out.ras
  Created: /export/home/omg3/lpais/test/ch115out.idx
  Created: /export/home/omg3/lpais/test/ch115out.not

        500 descriptors output at 11:07:23
       1000 descriptors output at 11:07:25
```

```
     1500 descriptors output at 11:07:28
     2000 descriptors output at 11:07:32
     2500 descriptors output at 11:07:34
     3000 descriptors output at 11:07:36
     3500 descriptors output at 11:07:38
     4000 descriptors output at 11:07:39
     4500 descriptors output at 11:07:40
     5000 descriptors output at 11:07:42
     5500 descriptors output at 11:07:43
     6000 descriptors output at 11:07:46

Build completed

Building network topology ...

Theme is       1000

Locating end points ...

Sorting the end points ...

Recording nodal groups ...

      588  matched arc ends and/or explicit nodes
        0 floating arc ends and/or explicit nodes
-- 237 nodes left at 11:07:54 with message count =      25
-- 187 nodes left at 11:07:55 with message count =      40
-- 137 nodes left at 11:07:56 with message count =      55
--  87 nodes left at 11:07:57 with message count =      82
--  37 nodes left at 11:07:57 with message count =     102

Inclusive message number(s):
  All

BUILD NETWORK statistics :
------------------------------------------------

Number of arc ends linked is ---------       588
Number of explicit nodes is ----------        0
Number of implied/floating nodes is --        287
Number of short arcs deleted is ------        0

Reported message statistics:

Count for message no.       127 is       130

Total of 130 messages reported (plus 0 hidden ones)

Log file is ch115out.NTB

Build complete
Theme is       1000

Building polygon topology ...


Walking polygons ...
      200 polygons built at 11:08:06 with message count =        0

Processing islands ...

       10 islands processed at 11:08:07 with message count =      0
       20 islands processed at 11:08:08 with message count =      0
       30 islands processed at 11:08:08 with message count =      0
       40 islands processed at 11:08:09 with message count =      0
```

50 islands processed at 11:08:10 with message count = 0
60 islands processed at 11:08:10 with message count = 0
70 islands processed at 11:08:11 with message count = 0
80 islands processed at 11:08:12 with message count = 0
90 islands processed at 11:08:13 with message count = 0
100 islands processed at 11:08:13 with message count = 0
110 islands processed at 11:08:14 with message count = 0
120 islands processed at 11:08:14 with message count = 0
130 islands processed at 11:08:15 with message count = 0
140 islands processed at 11:08:16 with message count = 0
150 islands processed at 11:08:17 with message count = 0
160 islands processed at 11:08:17 with message count = 0

Processing trapped islands ...

Labelling polygons ...

10 labels processed at 11:08:18 with message count = 0
20 labels processed at 11:08:19 with message count = 0
30 labels processed at 11:08:20 with message count = 0
40 labels processed at 11:08:20 with message count = 0
50 labels processed at 11:08:21 with message count = 0
60 labels processed at 11:08:22 with message count = 0
70 labels processed at 11:08:23 with message count = 0
80 labels processed at 11:08:24 with message count = 0
90 labels processed at 11:08:25 with message count = 0
100 labels processed at 11:08:26 with message count = 0
110 labels processed at 11:08:27 with message count = 0
120 labels processed at 11:08:29 with message count = 0
130 labels processed at 11:08:30 with message count = 0
140 labels processed at 11:08:32 with message count = 0
150 labels processed at 11:08:33 with message count = 0
160 labels processed at 11:08:35 with message count = 0

Inclusive message numbers:
All

BUILD POLYGON statistics :

Number of polygons processed ----------- 170
Number of labels processed ------------- 169

Log file is ch115out.PLB

Reported message statistics:

Count for message no. 95 is 1

Total of 1 messages reported (plus 0 hidden ones)

Build completed
Theme is 2000

Locating end points ...

Sorting the end points ...

Recording nodal groups ...

110 matched arc ends and/or explicit nodes
0 floating arc ends and/or explicit nodes
-- 4 nodes left at 11:09:11 with message count = 24

Inclusive message number(s):
All

BUILD NETWORK statistics :

Number of arc ends linked is --------- 110
Number of explicit nodes is ---------- 0
Number of implied/floating nodes is -- 54
Number of short arcs deleted is ------ 0

Reported message statistics:

Count for message no. 127 is 26

Total of 26 messages reported (plus 0 hidden ones)

Log file is ch115out.NTB

Build complete
Theme is 2000

Building polygon topology ...

Walking polygons ...

Processing islands ...

10 islands processed at 11:09:17 with message count = 0
20 islands processed at 11:09:20 with message count = 0
30 islands processed at 11:09:21 with message count = 0

Processing trapped islands ...

Labelling polygons ...

10 labels processed at 11:09:24 with message count = 0
20 labels processed at 11:09:24 with message count = 0
30 labels processed at 11:09:25 with message count = 0

Inclusive message numbers:
All

BUILD POLYGON statistics :

Number of polygons processed ------------ 41
Number of labels processed -------------- 37

Log file is ch115out.PLB
Reported message statistics:

Count for message no. 95 is 4

Total of 4 messages reported (plus 0 hidden ones)

Build completed

Building network topology ...

Theme is 2100

Locating end points ...
500 lines read at 11:09:33

Sorting the end points ...

Recording nodal groups ...

```
     962  matched arc ends and/or explicit nodes
     208  floating arc ends and/or explicit nodes
-- 436 nodes left at 11:09:37 with message count =      0
-- 386 nodes left at 11:09:38 with message count =      0
-- 336 nodes left at 11:09:39 with message count =      0
-- 286 nodes left at 11:09:40 with message count =      0
-- 236 nodes left at 11:09:41 with message count =      0
-- 186 nodes left at 11:09:43 with message count =      0
-- 136 nodes left at 11:09:45 with message count =      0
--  86 nodes left at 11:09:45 with message count =      0
--  36 nodes left at 11:09:46 with message count =      0
```

Exclusive message number(s):
All

BUILD NETWORK statistics :

```
Number of arc ends linked is ---------        1170
Number of explicit nodes is ----------          0
Number of implied/floating nodes is --         486
Number of short arcs deleted is ------          0
```

Total of 0 messages reported (plus 249 hidden ones)

Log file is ch115out.NTB

Build complete

ERRORS WITH FILTERING 0.1MM:

@error topic? 75

75

CAUSE:

Two arcs are very close to each other within the orientation tolerance of the builnetw command. If two arcs lie within one disk unit of each other, they may be given the same coordinates in the CARIS file, causing them to overlap. Since CARIS can not determine which node comes first when cycling nodes, this error is generated.

REMEDY:

First use the remo duplicate command to rebuild the network. This should eliminate most of the errors, leaving a few to be located interactively using the graphics editor ersc command, and then edited. If there are too many errors remaining to edit interactively, then their numbers may be reduced by using the builnetw command with a slightly larger -orientation value. Consult An Introduction to Topological Processing for details about the

Hit return to continue

orientation tolerance.

@error topic? 127

127

CAUSE:

Only two arcs meet at this node. It may occur if you:

1. Forgot to include an arc in your network

2. Deleted one or more lines leading into a node, leaving only two lines entering the node.

REMEDY:

If only two arcs meets at a node, it is called a pseudo_node. Pseudo_nodes are perfectly valid. They are flagged merely to indicate that another problem may be evident in the vicinity (e.g. missing arcs).

The remopseu command can be used to eliminate nodes which are not

Hit return to continue

valid errors.

Alternatively, the checmess message=127 command can be used to remove pseudo_nodes which meet certain selection criteria.

@error topic? 81

81

CAUSE:

This polygon is extremely small. This may result from line consisting of only one point.

REMEDY:

Use the graphics ERSC command to highlight the error. If you cannot see anything, try increasing the magnification using the MA command and try ERSC again. If you still cannot see anything, the small polygon is probably meaningless.

To remedy the situation, use the selepoly command with the -smaller_than qualifier to create a selection file of polygons smaller than a given area. Then use the remofeat scope.selection_file command to delete the selected polygons.

@error topic? 89

89

CAUSE

There are two or more unidentical display labels within the same polygon. Multiple display labels are permitted in a polygon only if they are all identical.

REMEDY

You should first confirm that there are no missing arcs. If the arcs are correct, you should change the display labels to make them all identical within the polygon concerned.

@error topic? 95

95

CAUSE

No display label can be found within a polygon.

REMEDY

If you do not explicitly override polygon labelling using the -nolabel qualifier, an attempt will be made to associate each polygon with a display label. The need for display labels depends on the operating procedures being used at your installation. Typically, display labels ARE used, and each polygon is expected to have one.

Confirm that all display labels have been digitized. All names digitized with the topology switch on are considered to be labels.

If names were digitized with the topology switch OFF, you can use the makelabe command to declare that they are labels, and then run

Hit return to continue 1

builpoly again.
@error topic? 113

113

CAUSE:

Adjacent polygons have the same key. This may mean that an incorrect key has been assigned to one of the polygons or that the two polygons need to be merged into one. In some cases this may not even be a problem.

REMEDY:

If a polygon has been assigned the wrong key, the key may be changed by using the CARIS chankeys command or the cared deky (data edit keys) command. If the polygon key is also the display label of the polygon, you may use one of the following commands to change the key and update the display label:

. CARIS chankeys -display_label_update command

. cared deky command

Hit return to continue

. cared nach (name change) command

If adjacent polygons need to be merged into one, the line separating the polygons may be removed by using the cared lide (line delete) command. Alternatively, the CARIS dissarcs -same_key command may be used to merge adjacent polygons with the same key; this solution is the most practical if more than a few polygons are involved.

@error topic? 130

CAUSE:

Duplicate polygon label. The same label occurs more than once in the same polygon. This will not prevent the polygon from being built; however, it is recommended to remove one of the labels.

REMEDY:

Remove one of the duplicate polygon labels using the cared NADE (name delete) command and rebuild the polygon topology.

MESSAGES FOR FILTERING 0.1MM:

```
helava.gge.unb.ca{lpais.28}%refontx -file=ch115out -convert -filter=1000d
 All data

 Working ...
    6000 descriptors remaining at 10:32:35 for header       1
    5500 descriptors remaining at 10:32:43 for header       1
    5000 descriptors remaining at 10:32:54 for header       1
    4500 descriptors remaining at 10:33:06 for header       1
    4000 descriptors remaining at 10:33:16 for header       1
    3500 descriptors remaining at 10:33:24 for header       1
    3000 descriptors remaining at 10:33:36 for header       1
    2500 descriptors remaining at 10:33:45 for header       1
    2000 descriptors remaining at 10:33:56 for header       1
    1500 descriptors remaining at 10:34:05 for header       1
    1000 descriptors remaining at 10:34:14 for header       1
     500 descriptors remaining at 10:34:22 for header       1
       0 descriptors remaining at 10:34:24 for header       1

 Header#        1
 -------------------------------------
 Number of output features:      6577
 Number of output descriptors:   7174
 Number of output notes:         0
 =========================================

     7174 descriptors written
 Reformat completed
helava.gge.unb.ca{lpais.29}%source programa

 Creating CARIS file ...

 Created: /export/home/omg3/lpais/test/ch115out.des
 Created: /export/home/omg3/lpais/test/ch115out.dta
 Created: /export/home/omg3/lpais/test/ch115out.cel
 Created: /export/home/omg3/lpais/test/ch115out.lin
 Created: /export/home/omg3/lpais/test/ch115out.nol
 Created: /export/home/omg3/lpais/test/ch115out.pol
 Created: /export/home/omg3/lpais/test/ch115out.ras
 Created: /export/home/omg3/lpais/test/ch115out.idx
 Created: /export/home/omg3/lpais/test/ch115out.not

       500 descriptors output at 10:35:06
      1000 descriptors output at 10:35:08
      1500 descriptors output at 10:35:11
      2000 descriptors output at 10:35:15
      2500 descriptors output at 10:35:17
      3000 descriptors output at 10:35:19
      3500 descriptors output at 10:35:21
      4000 descriptors output at 10:35:22
```

```
     4500 descriptors output at 10:35:23
     5000 descriptors output at 10:35:25
     5500 descriptors output at 10:35:26
     6000 descriptors output at 10:35:27

Build completed

Building network topology ...

Theme is       1000

Locating end points ...

Sorting the end points ...

Recording nodal groups ...588  matched arc ends and/or explicit nodes
        0 floating arc ends and/or explicit nodes
-- 237 nodes left at 10:35:39 with message count =       25
-- 187 nodes left at 10:35:39 with message count =       40
-- 137 nodes left at 10:35:40 with message count =       55
--  87 nodes left at 10:35:41 with message count =       82
--  37 nodes left at 10:35:42 with message count =      103

Inclusive message number(s):
  All

BUILD NETWORK statistics :
-------------------------------------------------

Number of arc ends linked is --------        588
Number of explicit nodes is ---------          0
Number of implied/floating nodes is --       287
Number of short arcs deleted is ------         0

Reported message statistics:

Count for message no.      75 is       2
Count for message no.     127 is     130

Total of 132 messages reported (plus 0 hidden ones)

Log file is ch115out.NTB

Build complete
Theme is       1000

Building polygon topology ...


Walking polygons ...
      200 polygons built at 10:35:52 with message count =        4

Processing islands ...

        10 islands processed at 10:35:53 with message count =        4
        20 islands processed at 10:35:54 with message count =        4
        30 islands processed at 10:35:54 with message count =        4
        40 islands processed at 10:35:55 with message count =        4
        50 islands processed at 10:35:55 with message count =        4
        60 islands processed at 10:35:56 with message count =        4
        70 islands processed at 10:35:57 with message count =        4
        80 islands processed at 10:35:58 with message count =        4
        90 islands processed at 10:35:58 with message count =        4
       100 islands processed at 10:35:59 with message count =        4
       110 islands processed at 10:36:00 with message count =        4
```

ANNEX C

The Object Look-Up-Table

OBJECT CLASS: Depth area
OBJECT CODE: DEPARE
FEATURE CODE: "%[-0-9]_%[-0-9]%s"
FEATURE TYPE: PO
ATTRIBUTE SCRIPT: depthdepare CARIS_FCODE

OBJECT CLASS: Depth contour
OBJECT CODE: DEPCNT
FEATURE CODE: CODTMR*
FEATURE TYPE:AL
ATTRIBUTE SCRIPT:assign_z VALDCO CARIS_Z
FEATURE DESCRIPTION: contour,depth, meters

OBJECT CLASS: Depth Contour
OBJECT CODE: DEPCNT
FEATURE CODE:COIK
FEATURE TYPE: AL
ATTRIBUTE: QUAPOS 4

OBJECT CLASS:Land area
OBJECT CODE: LNDARE
FEATURE CODE: LAND
FEATURE TYPE:PO
FEATURE DESCRIPTION: Land Area

OBJECT CLASS: Coastline
OBJECT CODE: COALNE
FEATURE CODE: CLSL
FEATURE TYPE: AL

OBJECT CLASS: Coastline
OBJECT CODE: COALNE
FEATURE CODE: CLIK
FEATURE TYPE: AL
ATTRIBUTE: QUAPOS 2

OBJECT CLASS:Lake
OBJECT CODE:LAKARE
FEATURE CODE:LAKE
FEATURE TYPE:PO
FEATURE DESCRIPTION: lake area

OBJECT CLASS:River
OBJECT CODE:RIVERS
FEATURE CODE:CLRI
FEATURE DESCRIPTION:River, Stream -Single line

OBJECT CLASS: Underwater/awash rock
OBJECT CODE: UWTROC
FEATURE CODE: DLRA
FEATURE TYPE: SY
FEATURE DESCRIPTION:Rock:Awash
ATTRIBUTE: WATLEV 5

OBJECT CLASS: Obstruction
OBJECT CODE: OBSTRN
FEATURE CODE:0M
FEATURE TYPE: PO
FEATURE DESCRIPTION: Danger line limiting area or point
ATTRIBUTE: EXPSOU 2
ATTRIBUTE: QUASOU 6
ATTRIBUTE: WATLEV 3
ATTRIBUTE: VALSOU 0

OBJECT CLASS: Obstruction
OBJECT CODE: OBSTRN
FEATURE CODE: danger
FEATURE TYPE: PO
FEATURE DESCRIPTION: Danger line limiting area or point
ATTRIBUTE: EXPSOU 2
ATTRIBUTE: QUASOU 6
ATTRIBUTE: WATLEV 3

OBJECT CLASS: Obstruction
OBJECT CODE: OBSTRN
FEATURE CODE:DANGER
FEATURE TYPE: PO
FEATURE DESCRIPTION: Danger line limiting area or point
ATTRIBUTE: EXPSOU 2
ATTRIBUTE: QUASOU 6
ATTRIBUTE: WATLEV 3

OBJECT CLASS: Underwater/awash rock
OBJECT CODE: UWTROC
FEATURE CODE: DLRK
FEATURE TYPE: SY
FEATURE DESCRIPTION: Rock
ATTRIBUTE: WATLEV 3
ATTRIBUTE: QUASOU 2

OBJECT CLASS: Sounding
OBJECT CODE: SOUNDG
FEATURE CODE: SGSL
FEATURE TYPE:SO
FEATURE DESCRIPTION: Soundings, sloped
ATTRIBUTE:QUASOU 1

OBJECT CLASS: Land Elevation
OBJECT CODE: LNDELV
FEATURE CODE: COTPMR
FEATURE TYPE: AL
FEATURE DESCRIPTION: Height contours
ATTRIBUTE: CONVIS 1

OBJECT CLASS: Road
OBJECT CODE: ROADWY
FEATURE CODE: ALRODL
FEATURE DESCRIPTION: Road
ATTRIBUTE: CATROD 3

OBJECT CLASS: Building, single
OBJECT CODE: BUISGL
FEATURE CODE: ALCHLH
FEATURE TYPE: SY
FEATURE DESCRIPTION: Church
ATTRIBUTE: CONVIS 1
ATTRIBUTE: FUNCTN 20

OBJECT CLASS: Landmark
OBJECT CODE: LNDMRK
FEATURE CODE: ALRM7%
FEATURE TYPE: SY
FEATURE DESCRIPTION: Radio Mast
ATTRIBUTE: CONVIS 1
ATTRIBUTE: FUNCTN 31
ATTRIBUTE: CATLMK 7

OBJECT CLASS: Anchorage area

OBJECT CODE: ACHARE
FEATURE CODE: DLAN
FEATURE TYPE: SY
FEATURE DESCRIPTION: Anchorage area
ATTRIBUTE: CATACH 1
ATTRIBUTE: STATUS 3

OBJECT CLASS: Light
OBJECT CODE: LIGHTS
FEATURE CODE:NPL1
FEATURE TYPE: SY
FEATURE DESCRIPTION: Lighthouse Light

OBJECT CLASS:Landmark
OBJECT CODE: LNDMRK
FEATURE CODE: NALTQ%
FEATURE TYPE: SY
FEATURE DESCRIPTION: Lighthouse
ATTRIBUTE:FUNCTN 33
ATTRIBUTE: CATLMK 17

OBJECT CLASS:Airport/airfield
OBJECT CODE: AIRARE
FEATURE CODE: ALAIPLJ
FEATURE TYPE: SY
FEATURE DESCRIPTION: Airport

OBJECT CLASS: Sounding
OBJECT CODE: SOUNDG
FEATURE CODE: SGUR
FEATURE TYPE: SO
FEATURE DESCRIPTION: Sounding GEBCO94
ATTRIBUTE: SORIND AA,AA,graph,GEBCO94

ANNEX D

ECVIEW images of the final Data Set

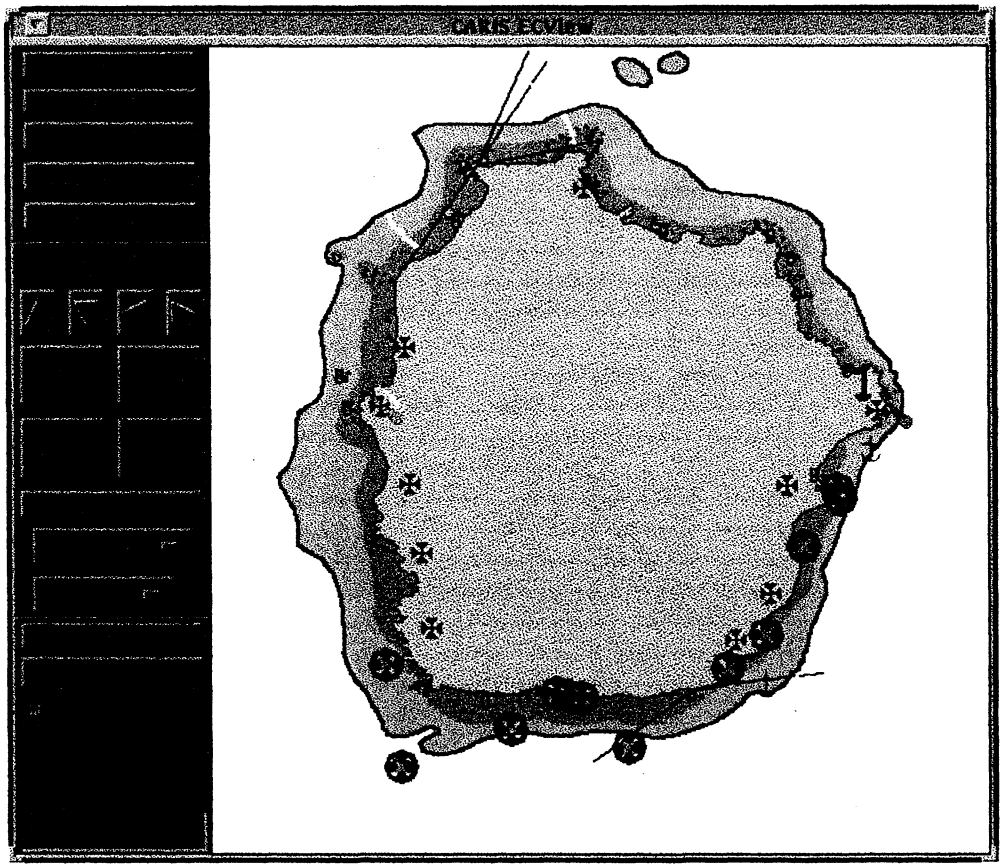

Figure D.1
The *ECVIEW* display of Ilha das Flores.
The features displayed belong to the *standard* classification.
No soundings are available in this content level

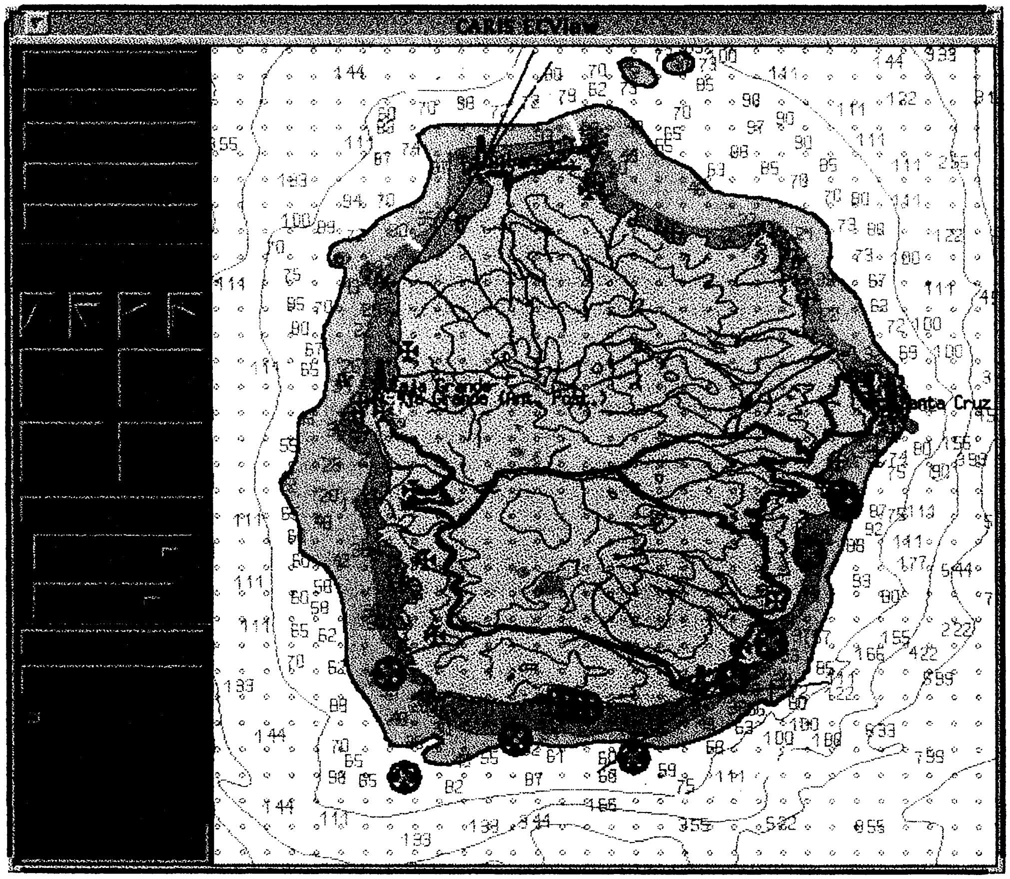

Figure D.2
The Standard + Other content level of information.
Includes text, soundings, depth contours and *full* representation of features.

VITA

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