MARINE TRAFFIC VISUALIZATION

CANADA'S WEST COAST

ETH
Eidgenössische Technische Hochschule Zürich
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GEOIDE

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DEPARTMENT OF GEOGRAPHY
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Diplomarbeit

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PREFACE I

This thesis is the result of a sixteen week study on the commercial shipping database provided by the Marine Communication and Vessel Services (MCST) Division of the Canadian Coast Guard (CCG) Pacific Region. The author is a Geomatics Engineering Student at the Department of Civil, Environmental and Geomatics Engineering of the Swiss Federal Institute of Technology (ETH) in Zurich, in her last term. The so-called "Diplomarbeit" (diploma thesis) completes the ten semester program and has to be released to officially obtain the title "Dipl. Geomatik-Ing ETH". The diploma thesis was written between April and August 2003 in the Spatial Science Laboratories at the Department of Geography at the University of Victoria (UVic) on Vancouver Island, British Columbia, Canada, in cooperation with the CCG.
Professor Dr. Lorenz Hurni, Head of the Institute of Cartography at ETH, is the professor in charge of approving this thesis in order to obtain the diploma in Geomatics Engineering. Professor Dr. Peter Keller from the Department of Geography at UVic led the project work on site and is responsible for scientific concerns.

I would like to take the opportunity to express my acknowledgment to people who made this thesis possible and successful. First of all I thank Dr. Keller for the invitation to fulfill my diploma thesis at UVic and for giving me the possibility to work on an unfamiliar but highly interesting topic within the Geomatics field. I am also indebted to Dr. Hurni for the offer to assume the organizational side of this project work abroad and his essential support in the preliminary tasks. Special thanks go to Cindy Marven, a UVic M. Sc. Candidate in Geography, who was supervising my work in a great manner – not only in a scientific sense but also with a lot of helpful assistance with administrative concerns and software support. And I also highly appreciate the endeavors of my roommate, Cecilia Frankhauser, to proofread this report. Last but not least I would like to express my gratitude to the Canadian Coast Guard that made this thesis possible by providing the needed information and to David Cake who assisted the programming side of this work.

The stay in Victoria was successful and satisfactory not only from the educational point of view but also for the amazing beauty of Vancouver Island and the City of Victoria and the friendliness of its residents.

ABSTRACT II

Vessel traffic in Canadian waters is monitored by Marine Communication and Traffic Services, a subdivision of the Canadian Coast Guard. The movements of each vessel larger than 20 meters – with a few exceptions - are controlled and recorded by a VTS (Vessel Traffic Service) system, operated by five different centers located on Canada's West Coast and one cooperative station in the American Puget Sound region. The traffic information that includes the vessel's position each six to seven minutes and further attribute fields is aggregated and stored as separate day tables in an overall database on the Pacific Region.

The purpose of this thesis is to prepare this data (available months include January, February, April, June, July and a part of August 2003) in order to visualize marine traffic. This task includes several work steps from understanding the data recording procedure to carrying out a user needs assessment concerning the content and design of the maps to be created. One single day file may contain up to 50'000 entries, therefore data processing has to be automated as far as possible. Applying different preliminary statistical and visual analysis approaches on selected data samples reveals various errors in the database. Data cleaning algorithms are defined in order to remove or correct inoperative records and are manually tested on a subset of the data; afterward they are implemented in a MS Access application by a computer science expert outside the project environment. Potential users of the visualized database are interviewed about their expectations and requirements on the displayed subjects and the graphical presentation of the maps. Their answers are combined with established traffic mapping approaches from other application fields to define possible marine traffic visualization strategies. An evaluation is made on the graphical capabilities of MARIS, an existing "Maritime Activity and Risk Investigation System" GIS software, to rate its suitability for mapping marine traffic. At last, eight charts presenting a subset of the proposed marine traffic topics are created using ArcMAP from ESRI and briefly described. Conclusions about the available data, the cooperation with the Canadian Coast Guard and the degree of meeting the user's needs are made in the end.

This research is part of the national "Marine Activity Geomatics and Risk Analysis in the Coastal Zone" project, founded by the Canadian Coast Guard and the GEOIDE (Geomatics for Informed Decisions) Network; researchers started investigations on that topic on Canada's East Coast in 1997. The University of Victoria, representing the West Coast in the project scope was involved in the year 2000.

ZUSAMMENFASSUNG II

Der Schiffsverkehr in kanadischen Gewaessern wird von „Marine Communications and Traffic Services (MCTS)", einer Abteilung der kanadischen Kuestenwache ueberwacht. Die Bewegungen von allen Schiffen, die laenger sind als 20 Meter, werden kontrolliert und von einem sogenannten „Vessel Traffic Service" (VTS) System aufgezeichnet, welches von fuenf verschiedenen Zentren an der kanadischen Westkueste und einer kooperativen Station in der amerikanischen Puget Sound Region betrieben wird. Die Positionen und weitere wichtige Angaben dieser Schiffe werden ca. zehnmal pro Stunde erfasst und in einer Datenbank ueber die ganze pazifische Region zusammengefasst. Daraus werden Tagestabellen erzeugt und gespeichert.

Das Hauptanliegen dieser Diplomarbeit besteht darin, die verfuegbaren Daten (Januar, Februar, April, Juni, Juli und erste Haelfte August 2003) fuer eine kartografische Visualisierung vorzubereiten. Um dieses Ziel zu erreichen sind verschiedene Arbeitsschritte notwendig: vom Verstehen der Datensammlungs-Methode bis hin zu einer Beurteilung der Beduerfnisse von potentiellen Benutzern der Karten. Da ein einziges Tages-File bis zu 50'000 Eintraege enthalten kann, sollte die Datenbearbeitung so weit als moeglich automatisiert werden. Eine erste Analyse an ausgewaehlten Beispieldaten mittels statistischen und graphischen Methoden deckt die unterschiedlichsten Fehler auf. Um diese Fehler zu entfernen oder zu korrigieren werden „Daten-Reinigungs-Algorithmen" definiert und manuell an einer Teilmenge getestet; die Implementierung in eine MS Access Anwendung erfolgt durch einen Programmierer ausserhalb der Projektumgebung. Potentielle Anwender der visualisierten Daten werden nach ihren Beduerfnissen und Anforderungen an den Inhalt und die graphische Darstellung gefragt. Ihre Antworten werden mit etablierten Ansaetzen zur Visualisierung von Verkehr kombiniert und in „Strategien zur kartographischen Darstellung von Meeresverkehr" festgehalten. Um ihre Eignung fuer die Kartierung zu pruefen werden die graphischen Moeglichkeiten der bestehenden „Maritime Activity and Risk Investigation System" (MARIS) GIS Software beurteilt. Schlussendlich werden in ArcMAP von ESRI acht Karten gezeichnet, die eine repraesentative Auswahl aus den definierten Ansaetzen praesentieren. Abschliessende Betrachtungen ueber den Zielerreichungsgrad und die ausgewerteten Daten runden diese Diplomarbeit ab.

Diese Untersuchung steht im Zusammenhang mit dem uebergeordneten "Marine Activity Geomatics and Risk Analysis in the Coastal Zone" Projekt, das 1997 an der Ostkueste von Kanada gestartet wurde und von der kanadischen Kuestenwache und dem GEOIDE (Geomatics for Informed Decisions) Netzwerk unterstuetzt wird.

TABLE OF CONTENTS III

TABLE OF FIGURES IV

PROJECT BACKGROUND 1

1.1 "Marine Activity Geomatics and Risk Analysis in the Coastal Zone"

In mid-summer 2000, the Canadian GEOIDE Network[1] approved the funding of a project to develop a software package that encompasses a comprehensive database of marine activities and can perform risk and incident analysis. Categories of activities include commercial fishing, recreational boating, commercial shipping, ferries, cruise lines, ecotourism, aquaculture and offshore exploration; potential causes of maritime SAR (Search and Rescue) incidents imply weather, geography, activity type, vessel characteristics, human factors and other variables. The research team consists of members from different Canadian institutions; project leadership is at Dalhousie University in Halifax, Nova Scotia (Dr. Ronald Pelot, Associate Professor at Department of Industrial Engineering). Other participants are the University of New Brunswick UNB (Dr. David J. Coleman, Professor at Department of Geodesy and Geomatics Engineering), the University of Victoria UVic, British Columbia (Prof. Carl Peter Keller, Geography Department) and the Canadian Coast Guard CCG as the project's major partner outside the educational environment.

First attempts at this topic were made by Dr. Ronald Pelot and others as early as in the year 1997 in order to support the Search and Rescue Services provided by the Canadian Coast Guards on Canada's East Coast [Pelot, Ronald et al., 1997/1998].

During the first phase under the support of GEOIDE (2000-2002) the main thrust of the research was to determine the best type of modeling to conduct risk and statistical analyses, including also the determination of the best exposure measures for each type of activity, the data availability and different approaches to spatially aggregate, consolidate and display the distribution of activities and incidents. Most of these tasks were conducted first at Dalhousie using data from Canada's East Coast, especially the maritime regions and the Bay of Fundy. Investigations at the Pacific Region started a bit later. The project efforts resulted in the development of SARMAP (Search and Rescue Marine Analysis Program) at Dalhousie using the MapBASIC programming language within MapInfo GIS software. The custom program provides for data manipulation and display, traffic simulation and risk calculation, in terms of the

[1] GEOIDE is a research network established in order to consolidate Canadian expertise in Geomatics. As a federally funded Network of Centers of Excellence, GEOIDE brings together many of the country's leading experts from academic, government and industrial institutions. GEOIDE stands for Geomatics For Informed Decisions.

principal objectives of the project. As new requirements and/or datasets are identified during the further project, new modules can be added to the framework to allow additional functionality.

As the funding from GEOIDE was extended to another 2 years the project is currently in its second phase (2002-2004) continuing with the described tasks and objectives, involving more and more investigators (mostly M.Sc. and Ph.D. Students) from the participating educational institutions. The main issues of the second phase were redefined according to the three GEOIDE's scientific themes:

(1) Data acquisition and data management

Intensify "data discovery" initiatives through improvements to better metadata documentation and on-line clearinghouses; conduct a thorough analysis of available, relevant databases; determine the best procedures for cleaning and integrating databases; develop and implement appropriate approaches to collecting and maintaining relevant data for selected activities with no suitable existing database (such as recreational boating); translate all of the data as required and integrate them into the developed GIS risk model; develop and test various display modes for different attributes; use new techniques and expert opinions to gather new data (most of these tasks are hosted by UVic and Dalhousie).

(2) Decision-making

Determine the best delineation rules for sub-zones; conduct spatial analyses to look for trends and clusters of activities and incidents; determine the best exposure measures; determine which factors are significant predictors of each class of incident for each type of activity; PFM (Preference Function Modeling), a new powerful procedure and tool, may be implemented as a decision tool for selecting amongst options (primarily conducted at Dalhousie and UVic).

The original software package SARMAP was replaced during the second phase with a newer program called MARIS (Maritime Activity & Risk Investigation System), also developed by Pelot et al. at Dalhousie University. Accomplishing the same tasks as the former software this version combines the original possibilities with a better usability and stability. A complete copy of MARIS will be delivered to the Canadian Coast Guard upon completion of this project; full documentation and training will also be provided as required. MARIS's final version is supposed to become one of the main tools for rationalization of Canadian Coast Guard Search and Rescue services.

1.2 The Scope of the Thesis in the Project Environment

The report on hand is one component of the above-described GEOIDE project "Marine Activity Geomatics and Risk Analysis in the Coastal Zone", Phase II, basic issue (1) – data acquisition and management. As described in the following chapter (2. Main Issues and Tasks) it deals mainly with aspects of data management (preparation and cleaning), analysis and visualization. The described research is based on a dataset about commercial shipping on Canada's West Coast; final task in terms of the superior project is the implementation of the data in MARIS in an adequate format. This procedure includes most of the steps described above (like metadata documentation, cleaning algorithms and translating). The other main issue besides the adaptation of the available data is to deliver a set of maps illustrating the marine traffic on Canada's West Coast. A more detailed description of the main issues and task of this diploma thesis can be found in the following chapter; this short overview should only give a notice about the thesis in the context of the overall project "Marine Activity Geomatics and Risk Analysis in the Coastal Zone", in the following referred to as "Marine Geomatics" project.

MAIN ISSUES AND TASKS 2

The following listing of the main aspects of this thesis dealing with commercial shipping data from Canada's West Coast is based on a meeting with Dr. Ronald Pelot, project leader of this GEOIDE project in phase II (see project description in the previous chapter). The meeting was related to the Annual Scientific Conference of the GEOIDE Network in Victoria and took place Friday, May 23, 2003 at University of Victoria involving different participants of the above-mentioned project. The tasks refer to the requirements of the diploma thesis for the author, as well as to general purposes of the project.
Therefore the three main issues of the analysis of the commercial shipping database from the Canadian West Coast are defined as:

- **Data cleaning an preparation**
- **Data visualization**
- **Data conversion for usage in MARIS software**

Each aspect consists of different tasks and implies several steps as described in the following section and discussed in the project team.

2.1 Data Cleaning and Preparation

The process of data cleaning and preparation includes every step that has to be undertaken to use the data for visualization or integration in MARIS. First task is to describe the database and the enclosed attributes as well as deriving and recording the metadata. This assignment should be made in cooperation with the Canadian Coast Guards of the Pacific Region, which are responsible for collecting the data and storing it in the MCTS Database (namely Mr. Grant McGowan from the Vancouver MCTS center). Second problem is to detect the errors in the database and to "fix" or remove them. Preliminary known difficulties are multiple records and duplicated tracking, wrong positions, non explicit identification and false time recording. Several approaches to these discrepancies are possible, e.g. cross-referencing with other databases (like the Llyods shipping register) to find the inconsistencies in the vessel identification or the detection of large deviations between adjacent points to locate wrong position recordings. All these processes should be automated as far as possible because of the large data volume. The conception to discover the errors is defined by the author at the University of Victoria; a computer science expert supports the programming and implementation of the algorithms. Third task of data preparation is the generation of well-identified unique trip routes out of the points. This step may also include thinning out the data in order to reduce data volume and ensure an efficient use in MARIS and other supporting software. In case the track generation from the recorded position points only results in an insufficient accuracy, this part of the work would also mean the application of different algorithms, developed by the project participants on the East coast, like "land avoidance" and/or "shipping lanes". Another important part of the first main issue is to maintain an exchange of experience about using the MCTS database with the participants on the East Coast and the Canadian Coast Guard for the purpose of future data collecting, storing and using concerns.

2.2 Data Visualization

This second issue is a required part of the thesis written on the commercial shipping data from the Canadian West Coast. The graphical implementation is necessary and helpful in order to make the data coherent to different users such as the researchers, the software developers but also the Coast Guard Planning officers or the "laities". The visualization efforts should be based on two basic approaches: first on a user need assessment that shows the expectations for all kind of supposable applications and secondly on an evaluation (SWAT analysis) of the graphic possibilities provided by the existing MARIS software. Therefore this task not only includes the visual presentation of the database in different scales, cutouts and cartographic variations, but also a set of different visualization strategies like color spectrum, hot spots and particularly possibilities of showing the traffic changes in time. Promising approaches to the latter problem could be potential extension to be implemented in a later version of MARIS software.

2.4 Data Conversion for Usage in MARIS Software

The last, but regardless important issue for the further project development is the data conversion into a format that can be read by the MARIS software. This step includes also the generation and completion of the requested attributes and their classification (age, type of commodity, size/GRT, flag and distance traveled in Canadian waters). The software developers at Dalhousie give the defaults and guidelines for the format.

VESSEL TRAFFIC SERVICES AND MARINE COMMUNICATIONS IN CANADA 3

3.1 Introduction to Vessel Traffic Systems

Vessel Traffic Systems (VTSs) are land-based marine vessel surveillance systems usually operated by government authorities or government approved agencies. Their main objective is to enhance safe navigation in restricted shipping areas, such as coastal waters, heavy traffic areas, and areas of dangerous or difficult navigation. Secondary objectives include port operations management, security, control of trade and commerce, shipping information exchange, Search and Rescue (SAR) coordination, and environmental protection. Usually, VTSs are operated in an advisory capacity only, and provide coordination and dispatch of pilotage and tug services in and out of controlled waters.

There are over 2000 ports, worldwide, that handle varying amounts and types of commercial shipping. VTSs supporting these ports are implemented through various means of technology ranging from navigation aids (buoys, leading lights, traffic separation zones, etc.), to radio communications advisories, and radar and transponder supported surveillance.

The purpose of Vessel Traffic Services, as stated above, is to enhance safe navigation. As such, all VTSs perform two major tasks: long-term strategic traffic planning, and short-term tactical advisory and regulation. The first task is accomplished by providing a clear and concise overview of operating conditions within the Vessel Traffic Service operating area. This overview includes weather, traffic, and other hazards, along with ship transit scheduling information provided from various sources. The second task is accomplished by providing navigational advisories during inclement weather, pilotage scheduling (if required), approach and departure support, and other ship arrival and departure services.

These tasks are common to all VTSs, and apply equally to both small and large ports. The extent to which these basic tasks are performed tends to be related to the port size and the costs of providing these services. As such, extensive VTSs are not generally found in smaller ports. In addition, the basic tasks described above are not inclusive of all tasks performed by different ports, which may include pilotage control, SAR, environmental protection, regulation, and others.

However, in VTS systems that are in place, a generally common configuration for performing these tasks includes the following features:

- Equipment for the location of all objects in critical areas (Radar, Closed Circuit TV (CCTV), Radio Direction Finders (RDF), Global Positioning Systems (GPS), transponders, miscellaneous visual aids, etc.).
- Navigational aids (buoys, leading lights, horns, lighthouses, etc.) and environmental sensors (wind, tide, current, wave, etc.).
- Communications equipment (VHF, UHF, HF, MF, Cellular Telephone, etc.).
- Processing equipment for the display, evaluation, presentation, and recording of information (Control center display and data processing equipment, etc.).

Not all these features may be present within a VTS, or for that matter, under the control of the Vessel Traffic Service provider. The application and use of the features described are dependent on both the geographical requirements and the organizational nature of the maritime authority in any particular region or country.

Canada's Vessel Traffic System is operated by highly trained, certified Marine Communication and Traffic Officers (MCTSOs), who monitor the movement of vessels using VHF radio and direction finding equipment, tracking computers, and, in areas of high traffic density, surveillance radar. A more detailed description on the VTS and its components used on Canada's Pacific Coast is part of the following chapters.

3.2 Marine Communication and Traffic Services

To achieve greater service efficiency, the Canadian Coast Guard integrated its 15 Vessel Traffic Services and 29 Canadian Coast Guard Radio Stations (CGRS) programs into a new 23-centre organization called the Marine Communications and Traffic Services (MCTS). This process was spread over four years, and started in 1995/96 for completion by the end of 1998/99.

The main task of the MCTS – a subdivision of the Canadian Coast Guard (CCG) – is providing communications and traffic services for the marine community and for the benefit of the public at large to ensure safety of life at sea in response to international agreements; the protection of the environment through traffic management; the efficient movement of shipping and the information for business and the national interest.

In order to meet the above mentioned objectives, MCTS offers marine safety communications co-ordination with rescue resources; vessel traffic services (VTS) and waterway management, broadcast weather and safety information; sail plan services in addition to support other government and marine agencies. Within the Coast Guard, MCTS provides also the initial response to ships in a distress situation, reduces the probability of ships being involved in collisions, groundings and striking, and is a cornerstone in the marine information collection and dissemination infrastructure. In addition to ensuring safe marine navigation, Marine Communications and Traffic Services supports economic activities by optimizing traffic movement and facilitating industry ship/shore communications. All of these functions are derived from a regulatory framework based primarily on the Canada Shipping Act (CSA) and the Safety of Life at Sea Convention (SOLAS).

Marine Communications and Traffic Services Officers (MCTSO's) are skilled in a variety of disciplines that includes transportation systems, marine safety and public communications, and shore-based radar surveillance traffic regulating. MCTSO's are designated Marine Traffic Regulators (MTRs) by the Commissioner of the Canadian Coast Guard through a Certification Training Program that can take upwards of fourteen months to complete.

3.3 VTS Zones and MCTS Centers

In the Pacific Region of Canada, the five Canadian MCTS centers are located in Vancouver, Victoria, Prince Rupert, Comox and Tofino. Additionally there is a cooperative Vessel Traffic Agreement (CVTS) between Canada and the United States on the segmentation of the Pacific Coast. The United States Coast Guards, Seattle Traffic therefore operates the Puget Sound VTS System, providing VTS for both the Canadian and US waters of Juan de Fuca Strait.

On a typical voyage from Japan to Vancouver, a freighter will be provided with many VTS services. It will obtain a clearance from "CVTS Offshore". When the freighter arrives within 50 nautical miles of Vancouver Island, Tofino Traffic will communicate with the ship using one of several remote VHF sites and track the vessel on radar into the Juan de Fuca Strait. Seattle Traffic will monitor the ship's movement from four remote radars as it passes through the Juan de Fuca Strait. The last six hours of its trip will be monitored by Victoria and Vancouver Traffic using five remote radar/VHF sites.

Each zone is described in more detail and illustrated with a map in the following sections; the information is taken from the Coast Guard's MCTS Pacific Region homepage [www.pacific.ccg-gcc.gc.ca/mcts-sctm/index_e.htm].

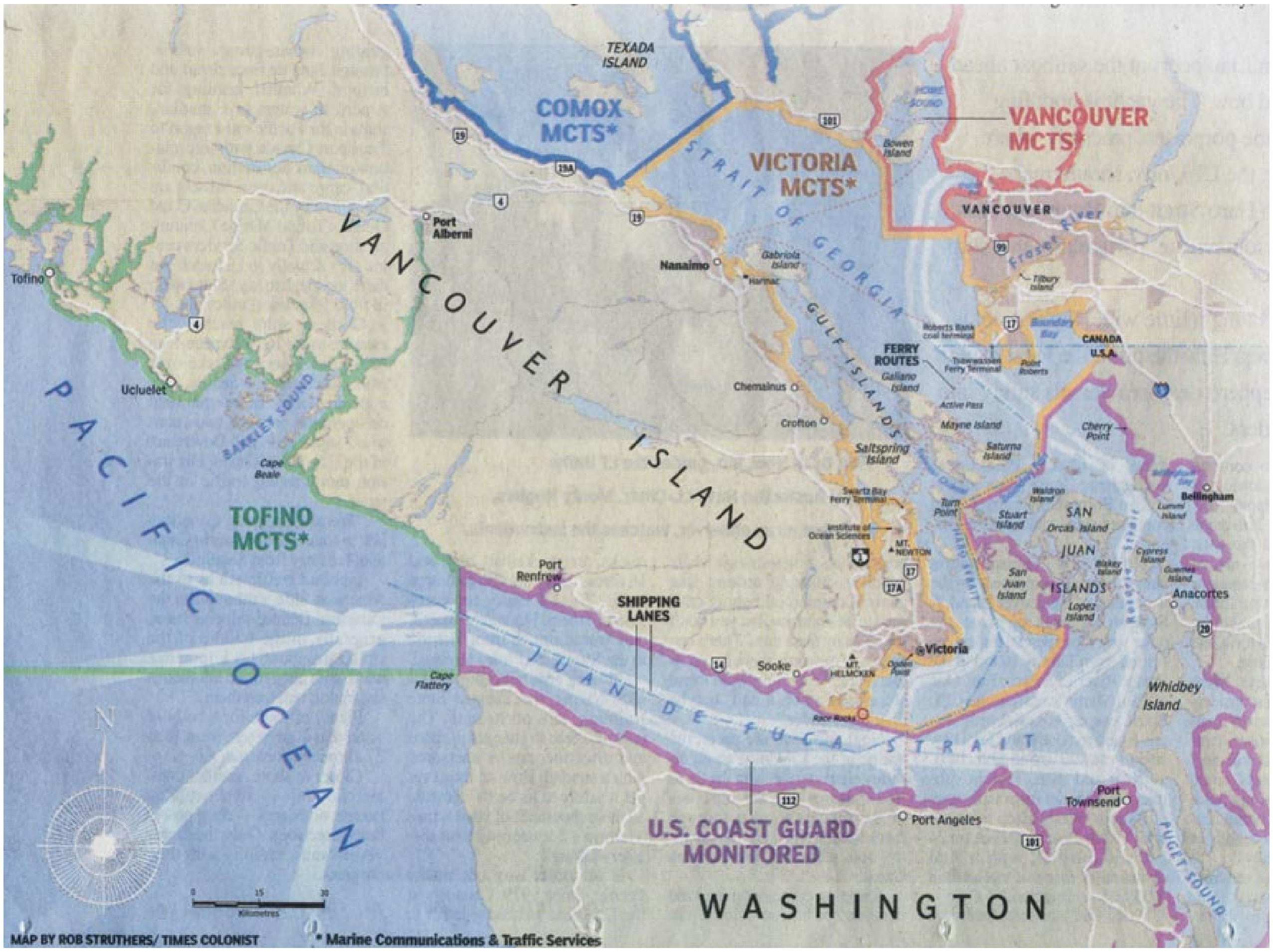


Figure 3.1: The five southern VTS zones (source: Times Colonist, May 25th 2003)

3.3.1 Vancouver

Vancouver Traffic was the first Traffic Regulating Zone in the Pacific Region and was formerly known as Vessel Traffic Management (VTM). Vessel Traffic Management then became Vessel Traffic Services and now the combined services (Coast Guard Radio and VTS) known as MCTS. There is one traffic position, one safety position and one supervisory position. Co-located with Vancouver MCTS is the RMIC (Regional Marine Information Center, see the following chapter 3.4) that provides shipping information, message distribution services, notice to shipping creation/distribution and pollution reporting services. The communication sites are located in Vancouver itself and on Watts Point in Howe Sound.

During the studies on this database the MCTS/RMIC center in Vancouver was visited in the middle of July (Thursday July 17, 2003) for a better understanding of the ongoing processes. At the same time it was also possible to have a look at the control office and to talk to the persons who developed the supporting software tool (see section 3.5) and are responsible for the database.

Figure 3.2: Vancouver VTS Zone and communication sites

Figure 3.3: Vancouver MCTS Center, 23rd floor of the Harbour Center

3.3.2 Victoria

As Canada's newest MCTS center, established by agreement in 1997 and inaugurated on December 15th, 1999, this station has no immediate history; however, because it is an offshoot from the division of MCTS Vancouver, it's lore and history can be taken from there. Located at the Fisheries & Oceans Science and Maintenance facility, called the Institute of Ocean Sciences at Patricia Bay on Vancouver Island, MCTS Victoria provides Coast Guard Radio and Vessel Traffic coverage to British Columbia's southern inside waters; specifically all waters between Juan de Fuca Strait to the south, and Ballenas Island to the north.

VHF coverage in this zone is complete. As well, radar coverage is complete on all major waterways. However, due to geographical topography, some areas of the waters of the inside Gulf Islands and the Fraser River are radar blind. All communications coverage is provided by five mountain top remote sites: specifically Bowen Island, Lulu Island, Mount Parke, Mount Newton and Mount Helmcken. The radar coverage is accomplished through 4 remote sites co-located with the communication sites at Bowen, Parke, Newton and Helmcken.

Figure 3.4: Victoria VTS Zone and communication sites

Being situated between British Columbia's lower mainland shoreline and Vancouver Island, the Victoria zone has one of Canada's highest concentrations of small pleasure craft, and hence the largest share of Search & Rescue (SAR) operations on their behalf. From a VTS perspective, all deep draught vessels inbound and outbound from Vancouver, all of the tugs with tows and coastal freighters involved in the Washington and Alaska state trade must pass though those waters regulated by the officers at MCTS Victoria. All this combined with the local commercial trade make this center one of this country's busiest MCTS Areas of Responsibility.

The Victoria MCTS center at the Institute of Ocean Science was also visited during this work by the end of July (Thursday July 31, 2003) in order to interview a Coast Guard officer about their visualization needs (compare chapter 5.3). On the basis of a short guided tour through the traffic control headquarters the differences to the Vancouver station were obvious: Victoria MCTS is mainly working with a radar based computer tool, applying the later described VTOSS only as a backup system, while all other stations main instrument is still the VTOSS. The Coast Guard in Victoria is also following an advanced approach in the cooperation of its different divisions; for a few years the SAR (Search and Rescue) and MCTS officers are working in the same control office back-to-back in order to profit from and to support each other. Expectations so far are mainly positive, although they are still using different computer systems and map displays.

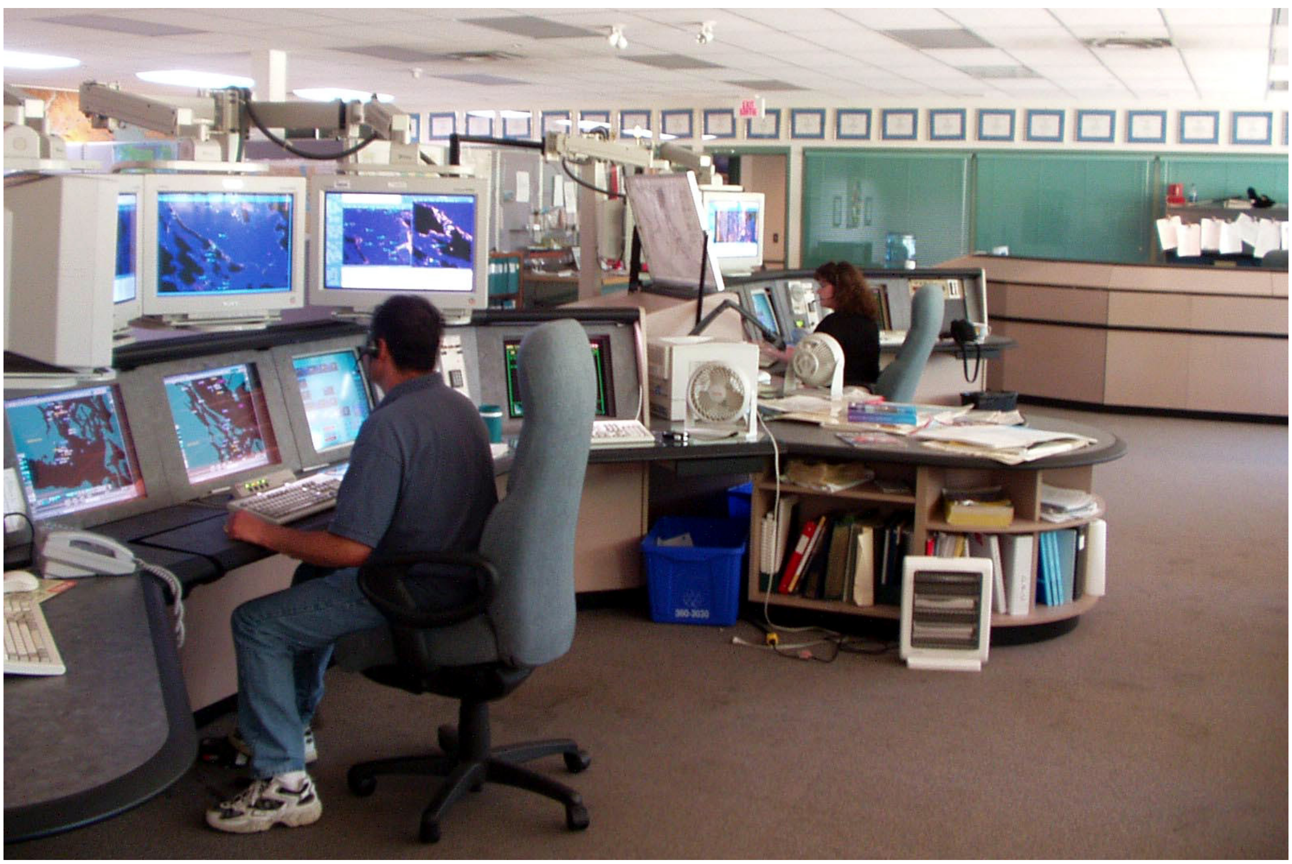


Figure 3.5: Victoria MCTS Center, Institute of Ocean Science (above: Radar System, below: VTOSS)

3.3.3 Prince Rupert

Prince Rupert Radio opened in 1911. The cable to the mainland was laid and a landline was built along the Grand Trunk poles to the city of Prince Rupert. The opening of the Prince Rupert station marked the completion of a chain of communication extending from Vancouver to northern British Columbia providing the province full coverage of its coast. The chain of stations provided the only means of communication with the Queen Charlotte Islands, plus offering communications services to commercial stations installed by owners, canneries, and paper mills. The station covered the entrance to Prince Rupert Harbour as well as the surrounding waters of Digby Island. On January 8, 1924, a portion of the quarantine wharf collapsed during a heavy gale, thus severing the telegraph cable to Prince Rupert. The cable was beyond repair. Temporary wireless communications were established with Prince Rupert by installing small valve equipment in the Prince Rupert Post Office building in town.

Figure 3.6: Prince Rupert VTS Zone and communication sites

The station would remain at Digby Island, until 1967 when its services were combined with those of Prince Rupert aeradio. In 1981, marine communications were moved to Seal Cove. Like many other centers across Canada, the Prince Rupert MCTS saw integration of both radio and Vessel Traffic Services functions in 1996. New console configurations were drawn up and installed making multi-tasking Radio/VTS operations a reality. The Prince Rupert MCTS Center controls communications sites at Hunter Point, Barry Inlet, Rose Inlet, Cumshewa, Dundas Island, Kitimat, Klemtu, Mount Dent, Mount Gil, Mount Hays, Naden Harbour, Calvert Island, Digby Island and Van Inlet.

3.3.4 Comox

The original station opened in 1908 on a high sandstone bluff known as Cape Lazo. The original name of Lazo, or Cape Lazo Radio was later changed to Comox Radio and eventually Comox Coast Guard Radio. Contrary to most east coast and Great Lakes stations, the west coast service was not run by the Marconi Company but by Government employees from what was then called the Department of Marine and Fisheries. Initially, the station had a range of 150 miles. Not unlike most stations in the west coast network, a 5 horsepower gas engine generated the power supply for Cape Lazo. For nearly six decades the Cape Lazo Station provided mainly safety and weather broadcast service from its site on top of the bluff. In 1962 a new station was built in the civil air terminal building and operations continued from the airport until 1993, when a new facility was completed on the original site at Cape Lazo. In 1994, with the closure of Alert Bay CG Radio, Comox CG Radio's area of responsibility (AOR) and staff doubled, now encompassing all of Johnstone Strait, Queen Charlotte Strait and southern Queen Charlotte Sound. The integration of the Coast Guard Radio and Vessel Traffic Services functions allowed the alignment of the radio and traffic functions; this simplified the operation for the Center and its clients. Comox MCTS Center became a fully integrated MCTS Center on April 1, 1996.

Figure 3.7: Comox VTS Zone and communication sites

3.3.5 Tofino

The Amphitrite Point VTS Center was officially opened on January 2, 1978, and for the next two months, the staff were deeply involved in geography training and the development of local procedures. VTS watch keeping commenced on the 6th of March 1978. VHF radio transceivers were located at the chosen radar site atop Mt Ozzard, 3 miles north of and some 2500 ft above Amphitrite Point. Because the VTS Center would be dealing with mostly foreign vessels, it was decided that "Tofino Traffic" would be used as a voice call sign. It was considered that it would be easier to pronounce for the deck officers and Captains of foreign vessels instead of "Amphitrite Traffic" or "Ucluelet Traffic".

In July 1978 the radar arrived, and was transported to the site where it was installed high on Mount Ozzard. The 38-foot radar scanner is protected from the strong storm winds by a protective geodetic dome. On August 30, 1978, the radar signal was connected to the radar screens at Amphitrite Point. During the months that followed, the various systems and procedures were brought on line. On the 17th of November 1978, site acceptance testing began and by November 30th, the system was placed on operational testing. A "Notice to Shipping" was issued to this effect.

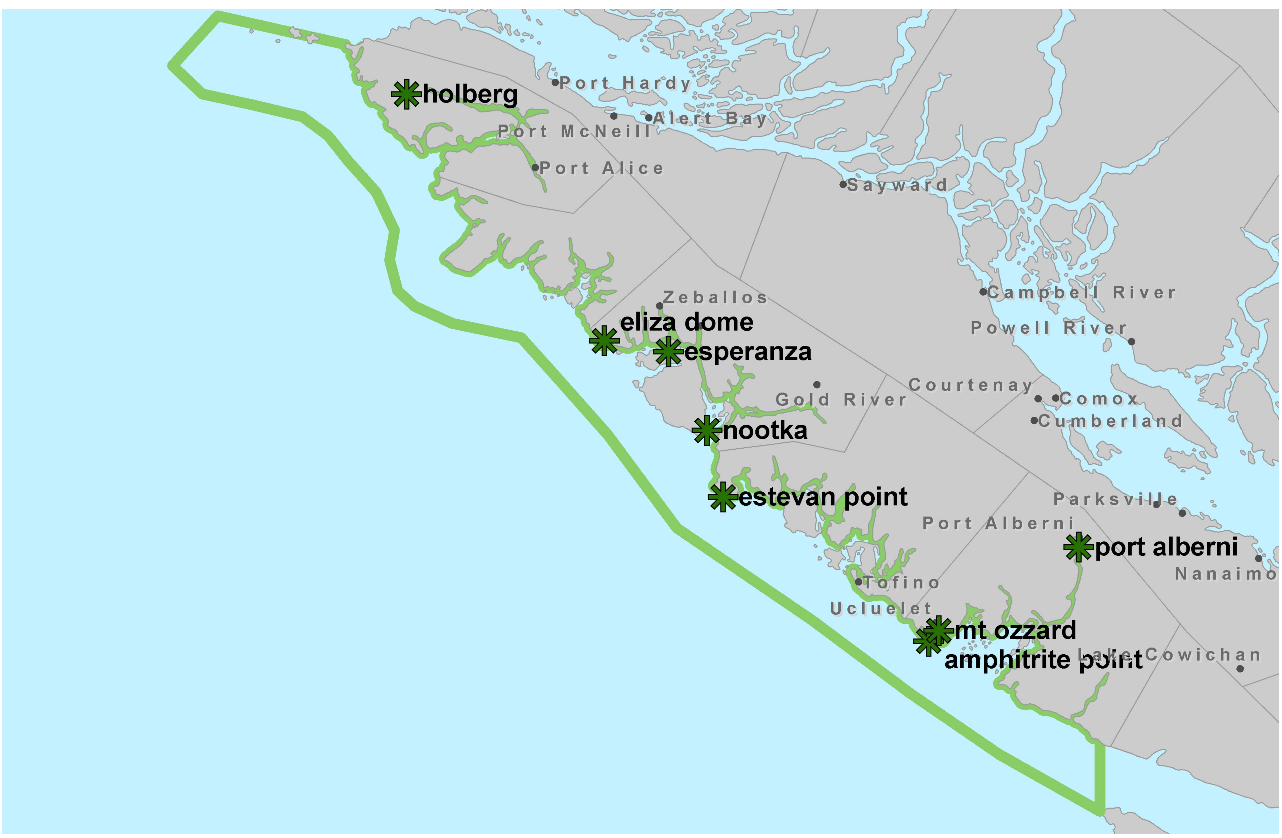


Figure 3.8: Tofino VTS Zone and communication sites

In April 1980, the Tofino Coast Guard Radio Station (marine), operating in conjunction with the CG Air Radio Services at Tofino Airport since 1956, relocated to the new MCTS (VTS) center. In addition to Mt Ozzard, the combined operation controls remote communications sites at Holberg (Quatsino Sound), Eliza Dome, Estevan Point, Esperanza, Nootka and Port Alberni. All peripheral sites are linked to the MCTS via a microwave system, with the exception of Holberg and Port Alberni, which are linked via leased telephone landlines. In order to facilitate service to remote sites, a helicopter pad was built at the center in 1979.
Although co-located at the center, the VTS and CG Radio Station worked as two independent operations until the amalgamation into MCTS began in April 1996.

3.3.6 Puget Sound

Figure 3.9: Puget Sound CVTS Zone (Communication Sites not available)

The United States Coast Guard operates the Puget Sound VTS system, Seattle Traffic, from Seattle, Washington. A cooperative Vessel Traffic Services Agreement (CVTS) exists between Canada and the US. As part of the Agreement, Tofino Traffic provides VTS for the offshore approaches to the Juan de Fuca Strait and along the Washington State coastline from 48 degrees north. Seattle Traffic provides VTS for both the Canadian and US waters of Juan de

Fuca Strait and Victoria Traffic provides VTS for both Canadian and US waters of Haro Strait, Boundary Passage, and the lower Georgia Straits.

In 1975, Puget Sound Vessel Traffic Service started using four radar sites to monitor the vessel traffic in the Strait of Juan de Fuca. By 1980 radar surveillance was expanded to ten sites. These radar sites covered the Strait of Juan de Fuca, the San Juan Archipelago and Puget Sound. Finally, in 1992, two more sites were added providing coverage to the Port of Tacoma. These twelve radar sites are actually providing the watch standers with a survey of vessel traffic from Cape Flattery in the west, all the way east to Elliott Bay, south to Tacoma and north into Canadian waterways, a radar coverage of approximately 2800 square miles.

3.4 Regional Marine Information Center

RMIC stands for Regional Marine Information Center and is the information clearinghouse for the Pacific Region of Canada located in Vancouver. Information handled ranges from pollution reports to shipping information to after hours call outs for other government agencies and Notices to Shipping. Generally the RMIC operations involve fielding calls from the general and maritime public for shipping information for the West Coast and the Port of Vancouver in particular, to report pollution and navigational hazards and also occasionally calls requesting tide and weather information. Some of the government agencies that the RMIC liaises with are the Port of Vancouver, Transport Canada Marine Branch, the Fisheries and Oceans Radio room, Environment Canada - Environmental Protection Branch and the Provincial Emergency Program, Canada Customs and Agriculture Canada, the US Coast Guard, VTS and various Canadian and US naval groups. When the RMIC was first started, it was specifically established to support the Marine Traffic Regulators in the radar operations room, but as time has passed the RMIC has developed and become a government agency with information for both government and the Maritime business community.

Figure 3.10: RMIC section of the Vancouver MCTS Center

3.5 Vessel Traffic Operations Support System

3.5.1 Description

The Vessel Traffic Operations Support System (VTOSS) is a set of software program modules developed by CCG employees in Vancouver (McGowan, G. et al., 2003), which assists the MCTS operators and the RMIC officer in their work. It is a tool developed for supporting the marine traffic regulation of various communities, harbours, and inlets, located on the Pacific Coast. The most important functions of the VTOSS include:

- Visual aid for traffic control and allocation of "vessel clearances"
- Generation of "electronic strips" data
- Storage of vessel data and activity (towards a database of vessel information)
- Preparation of "traffic lists" for public and private authorities
- Generation, posting and updating the "notices to shipping" (notships) for the marine community
- Handoff and integration of important vessel data to/from other international marine communities
- Provision of vessel information to specific clients (e.g. Department of National Defence and Port of Vancouver)

The VTOSS modules are designed to be able to interact with each other. There are a few modules that are crucial to the proper operation of VTOSS, while other parts are added on to increase functionality. This modularity of the system lends itself to a variety of configuration possibilities and provides a path for added functionality.

The various MCTS/RMIC regional centres communicate information with each other using a "Wide Area Network" (WAN) called VTOSSNet. Each participant is able to function independently on the VTOSS platform as a safeguard against any WAN anomalies. This leads to the ability of each LAN ("Local Area Network") to be configured to run VTOSS as a local system ("LAN Mode" of operation) as well as an expanded system ("WAN Mode"). Please see appendix A for the specific network architecture.

3.5.2 Primary operations

In the following section the primary operations of the VTOSS are described. A more detailed description on all implemented functions can be found in appendix B. The VTOSS functional overview diagram shows an overall depiction of the role of VTOSS in the functions of the MCTS/RMIC. The view also displays different forms of possible data flows at the top level of

VTOSS functionality. The added text refers to the indicated functionality groups and their modules.

MCTS operations are carried out by the plotter module (*plotter.exe*). The graphical user interface (GUI) of this module simulates a graphic representation of the physical areas that are in control of a particular site (each site has its own sector maps and there is also a master sector map that covers the entire area). The objects (vessels, calling-in-points, navaids, tracks, zones, boundaries, traffic lanes, etc.) are overlaid onto these maps. The physical operations being conducted by vessels in the real world are represented as "virtual objects" on the GUI. The plotter application operates in a continuous loop waiting for the operator to initiate keyboards or mouse events that are processed by so-called "event handlers" performing the appropriate action. Typical operations would be creating/identifying/removing a vessel; retrieving/entering/updating vessel information; simulating/tracking the movement of a vessel and every other action within the responsibility of the operator.

RMIC operations are processed by the RMIC module (*vtoss_r.exe*). This module manipulates RMIC generated information and incorporates it into the VTOSS database. The interface is composed of "Menu Screen Functions" for viewing, composing, and updating data. Data input happens manually and is joined to VTOSS tables using menus that call on internal functions to perform the various tasks of the RMIC. The common module functions all refer to data management and storing.

Other VTOSS operations include the manipulation of data from the VTOSS database to service specific clients needs. This would generally be achieved by the use of specific data extraction utilities like the "audit tool" to prepare data on specific vessels, ports or routes.

3.6 Outlook: Universal Automatic Identification System

3.6.1 Description

The Universal Automatic Identification System (UAIS or AIS) is a shipboard broadcast transponder system, operating in the VHF maritime band, that is capable of sending ship information such as a unique identification code (MMSI: Maritime Mobile Service Identities), position, heading, ship length, beam, type, and draught, hazardous cargo information, to other ships as well as to shore. It is capable of handling over 2,000 reports per minute and updates as often as every two seconds. It uses Self-Organizing Time Division Multiple Access (SOTDMA) technology to meet this high broadcast rate and ensure reliable ship-to-ship operation. The system is also compatible with digital selective calling systems.

Each UAIS system consists of one VHF transmitter, three VHF receivers, and a standard marine electronic communications link to shipboard display systems. Position and timing information is normally derived from an integral or external GPS receiver, normally including a medium frequency differential GPS receiver for precise position in coastal and inland waters. Other information, if available, is broadcast by the UAIS and is electronically obtained from shipboard equipment through standard marine data connections. Heading information is usually mandatory. The UAIS transponder normally works in an autonomous and continuous mode, regardless of whether it is operating in the open seas, coastal or inland areas. Although only one radio channel is necessary, each station transmits and receives over two radio channels to avoid interference problems, and to allow channels to be shifted without communications loss from other ships. The system provides for automatic contention resolution between itself and other stations, and communications integrity is maintained even in overload situations.

3.6.2 International advances

A variety of technical Commissions and Workgroups worldwide started in the year 1997 to develop performance, technical, operational and testing standards as well as carriage requirements for the UAIS. The International Conference on Maritime Security concluded on December 9 and 10, 2002 by adopting a number of revisions to the Safety of Life at Sea (SOLAS) Convention, including the status of the implementation dates for the UAIS. The conference moved the deadline for fitting of AIS on ships engaged in international voyages forward. Now all ships over 300 tons and not required to fit AIS at an earlier date, will have to fit AIS at the first safety equipment survey after 1 July 2004, but in any case, not later than 31 December 2004. Deadlines for these ships had been as late as 1 July 2007. The deadline for ships not engaged in international voyages remains at the first of July 2008, but national authorities can move this date forward in their own waters.

3.6.3 Implementation in Canada's Pacific Region

The Canadian Coast Guard MCTS Directorate has taken a proactive role in its commitment to support international efforts to complete Universal Shipborne AIS standards and institute carriage requirements for ships internationally. The MCTS Directorate chairs the National AIS Steering Committee (made up of Coast Guards and Industry representatives) that created an AIS Implementation Sub-committee to address the development of a national AIS implementation strategy given the evolving international standards.

The MCTS Centre in Vancouver plays the leading role in implementing the AIS in the Pacific Region. Operational tests started in British Columbia as early as 1999 involving the three Princess Cruise Ships. The objective of this evaluation project was to gain operational experience with AIS and to formulate recommendations on ways to integrate AIS into bridge team operations in British Columbian waters. AIS testing continued during the following years incorporating more vessels and the MCTS center in Comox. In the evaluation project 2002 the Bridge Teams of three modern cruise ships evaluated the current implementation of AIS during the summer of 2002 while cruising British Columbian and southeast Alaskan waters. Their evaluation resulted in findings and recommendations aimed at improving its value as a navigation aid. Bridge Teams formulated their recommendations so specifically that, in the process, they defined the meaning of 'AIS-Aided Navigation'. They developed detailed specifications of how AIS should aid navigation and what changes should be made both to the system and its environment to attain true 'AIS-aided navigation' as a state of the art in all of its aspects and dimensions. Testing procedures for the implementation phase are also taking place in the current summer of 2003. According to estimations of CCG officers the system should be ready to operate in approximately five years, but the biggest challenge in the implementation will be the international and inter-corporate standardization. At this time the vessels of a couple of shipping and ferry companies are already fully equipped with the requested transponder, but rather for internal use to ensure effective dispatching than for overall traffic control purposes. These consisting systems are not compatible yet and can therefore not be used for MCTS intentions.

On the technical side the Automatic Identification System has to be integrated in the existing VTOSS. The modifications to the existing VTOSSNet and its data flow are shown in appendix C. MCTS officers also emphasize not using the AIS in isolation but in connection with the established VTOSS and Radar System abilities to provide a consistent, accurate, always ready, and user-friendly marine traffic control tool.

THE MCTS DATABASE 4

4.1 Introduction

4.1.1 Background

Vessel traffic within Canadian (and a part of the U.S) waters is monitored by Marine Communications and Traffic Services Officers (MCTO's) ensuring safe and efficient shipping activities. As described in the previous chapter the VTS is a land-based surveillance system controlling vessel movements and recording specific information. Therefore the processed data are resulting from communication with the vessels complement; the input is done by the operator. One tool of the supporting software VTOSS *(exporter.exe)* is permanently collecting the data from each MCTS center of the Pacific Region, joining the tables together and storing the files for each day separately.

4.1.2 Participation requirements

Prior to beginning a voyage within Canadian waters or entering from seaward, ships are required to obtain a Vessel Traffic Service (VTS) clearance from a MCTO. All vessels accomplishing the following conditions have to participate in this MCTS program:

- every ship twenty (20) metres or more in length overall (LOA)
- every ship engaged in towing or pushing any vessel or object, other than fishing gear, where;
- the combined length of the ship and any vessel or object towed or pushed by the ship is forty five (45) metres or more in length; or
- the length of the vessel or object being towed or pushed by the ship is twenty (20) metres or more in length.

Exceptions:

- a ship towing or pushing inside a log booming ground
- a pleasure yacht less than thirty (30) metres in length
- a fishing vessel that is less than twenty-four (24) metres in length and not more than 150 tons gross.

4.1.3 Advanced report

In addition to the VTS clearance and as a means of enhancing public safety, security, and the uninterrupted flow of commerce, the Canadian and United States Coast Guard established an advance notification in reporting requirements for vessels entering Canadian/American waters. Until further notice, all vessels that are over 300 gross tonnage inbound to Canadian and US West Coast ports must file both a 96 and a 24 hour Co-operative Vessel Traffic Services (CVTS) Offshore Advance Report directly to the MCTS Regional Marine Information Centre (RMIC) in Vancouver via Internet/E-mail, Telex (Immarsat) or Fax. The required information to submit in this report includes details about the vessel (name, call sign, flag, Lloyds number, etc.), its cargo (dangerousness), current position, course and speed, departure and destination data (incl. estimated time of arrival). An entire description of the format can be found in appendix D. These specifications are with other information the basis for the generation of the "electronic strips" for incoming deep-sea vessels.

4.1.4 Time boundaries

Usually the information is recorded for one ship in the monitored region every six (sometimes seven) minutes during the whole day (midnight to midnight). Available data for this thesis starts at January 1st 2003 at 4.15 a.m. listed consecutively until up to date (middle of August, 2003) with the exception of the entire months of March and May 2003. For each day data are stored in a separate dbase-file named TKYYMMDD.dbf, accessible through a password-protected ftp-site. One day has 1440 possible point in time to record information (24hrs times 60min), but usually there is not a recording every minute. One of these so-called Day-Time-Groups (DTGs) can contain information about up to 100 different vessels. For that data volume, files can get really big (up to 60'000 records or 14 MB for one day).

4.1.5 Positioning modes

The designation of the vessel's actual geographical location can happen in different manners ranging from all manual to all automated and is dependent on the station's equipment and the practice of the proceeding officer. According to the VTOSS description [McGowan, G. and Athwal, R., 2003] each vessel can be tracked within the Canadian Pacific Region by one of the following methods:

Radar Tracking: This is real-time data being received from the radar systems; the data are typically updated every 2-3 minutes. Locations determined that way are highly accurate, but not every tracking station is equipped with a Radar System. Vessels cannot be identified by the operator, the visual detection of the calling vessel is based on the experience of the officer. Despites this fact the positioning method is very accurate because in 99% of the cases the operator is determining the correct vessel (according to information obtained from the Victoria MCTS center that is working mainly with the radar system).

AIS Tracking: This is the latest and most precise tracking method currently being developed for the Pacific Region. This procedure involves the placement of transponders on tracked vessels that transmit real-time information to onshore database collection sites including high-precision positions derived from GPS (further information on the AIS can be found in the previous chapter, section 3.6).

Dead Reckoning: The earlier described VTOSS plotter module handles this procedure. The vessel is tracked choosing a series of selectable waypoints and entering speed or ETA ("estimated time of arrival") date (time and position). The vessel then automatically follows the predetermined route. The software supports different kinds of Dead Reckoning (DR), like Advanced Report DR (initial vessel position is based on the mandatory Advanced Report for incoming deep-sea vessels), Offshore DR and Fixed Route DR (based on predefined popular routes). Dead Reckoning locations are usually fairly accurate, but the precision depends on the correctness of the starting points and therefore mainly on the information submitted by the vessels complement.

Manual Tracking: This positioning is accomplished by selecting the vessel and dragging it manually to its new assumed location; for that reason it is the least exact position source.

4.2 Database content

FIELD	DESCRIPTION	FORMAT
LAST_UDDTG	DTG (Day-Time-Group, i.e. Year, Month, Day and Time) of last system position report	YYYYMMDDTTTT
VSL_ID	Internal system identifier	Numbers and letters
NAME	Name of vessel	Character string
CALLSIGN	Vessel's radio call sign	Letters and numbers
LLOYDS_ID	Official Lloyds registry number	Letters and numbers
FLAG	Vessel's flag of registry (country)	Abbreviation of the country (2 letters)
SATCOMNUM	Satellite communication address	(Unknown)
TYPE_ENC	VTS type encode for this vessel	Letters or numbers
TYPE_DEC	Plain English vessel type	Character string
LOA	Length overall of the ship	Number (metres)
GRT	Gross registered tonnage	Number (tons)
TOW_ENC	Encode described a tugs tow if any	Letters and numbers
TOW_DEC	Plain English tow encode	Character string
IS_DC	Is dangerous cargo on board?	(Unknown)
IS_DD	Is vessel reporting defects or deficiencies in shipboard equipment?	(Unknown)
IS_SPI	Is vessel of special interest?	(Unknown)
POS_LAT	Current known, reported or observed latitude position	Number [XX.YYY]
POS_LONG	Current known, reported or observed longitude position	Number [XXX.YYY]
POS_RDRDTG	If Radar tracked, then time of radar plot	YYYYMMDDTTTT
POS_CIP	Place of last call of vessel at Calling-In-Point	(Unknown)
POS_CIPDTG	DTG above occurred	YYYYMMDDTTTT
POS_SRC	Position source	Three letters [XXX]
CVTS_ZONE	Cooperative Vessel Traffic Zone	Three letters [XXX]
FROM_AT	Where vessel departed or is currently at	Letters and numbers
NEXT_TO	Where vessels next intended destination or is en route to	Letters and numbers
SERVICE	Foreign going vessels requiring pilots or vessel engaged in coastal services	(Unknown)
COURSE	Current nautical course over ground	Three numbers [XXX]
SPEED	Current speed over ground	Number [knots]

Figure 4.1: Complete overview on MCTS database fields

Further Specification of the Fields:

LAST_UDDTG: Day-Time-Group of the last system position report for this vessel trip, written as a number string consisting of the Year [YYYY], Month [MM], Day [DD] and Time [TTTTT]. Because it is recorded as a number it can be assorted ascending or descending, even though the original field format is not integer.

VSL_ID: Automatically generated identification number for system tracking purposes when the vessel first contacts a VTS center. Usually starting with three or four letters and followed by a year [YYYY] and a continuous number (sometimes also beginning with the year right from the start without letters first). Starting letters refer either to the tracking station or the type of vessel (DEEP = deep-sea, CSTL = coastal); VSL_IDs generated by the Puget Sound Station start direct with numbers. Few records don't contain a vessel identification code at all.

NAME: Name of the vessel written as a character string. The operator enters the name in the database the first time the vessel gets in contact with the particular VTS zone. Almost every record contains a vessel name – but as it is manually acquired, typing errors are possible.

CALLSIGN: Radio call sign of the vessel, consisting of letters and numbers. Generally unique to a vessel, but some vessels don't have one recorded.

LLOYDS_ID: Official and unique Lloyds of London Registry number backed by the Lloyd's Register-Fairplay database containing over 140,000 ship and 154,000 ship owner and manager entries. This database, the world's principal source of maritime information, allows queries about ships, owners, companies and other features. Lloyds Numbers in the MCTS Database have their proper source in the mandatory Advanced Report for deep-sea vessels, but can be inconsistent for coastal vessels due to the missing of a standardized contact procedure.

FLAG: The flag, resp. the country under which the vessel is registered. Used is an international two letters abbreviation of the nation. For some vessel the flag is unknown. However, the flag is not very significant, because the vessel can be registered in a total different country than it is mainly sailing.

SATCOMNUM: Satellite communication address used for delivering messages to ships via Inmarsat. Field in all records is nearly empty.

TYPE_DEC/ENC: Plain English description (TYPE_DEC) and VTS type encode (TYPE_ENC) of the vessel, corresponding to the following list:

TYPE_ENC	TYPE_DEC	TYPE_ENC	TYPE_DEC
.	UNKNOWN	P	PASSENGER
1	COASTAL TANKER	PC	PLEASURE CRAFT
2	OCEAN OIL TANKER	PS	PASSENGER SHIP
3	VLCC	Q	FERRY
5	LPG	Q	REEFER
6	CHEMICAL TANKER	R	RAIL FERRY
7	VEG OIL/MOLASSES	R	RO-RO
8	COMBINATION CARRIER (OBO)	RC	RORO CARGO/CONT SHIP
		RE	RESEARCH SHIP
A	TUG	RO	RORO CARGO SHIP
BU	BULK CARRIER	S	RESEARCH (GOVERNMENT)
CC	CONTAINER SHIP	SC	OTHER SPECIAL CARGO
CG	US COAST GUARD	SP	OTHER SPECIFIC SERV
CH	CHEMICAL CARRIER	SU	SUPPLY (OFFSHORE)
CV	CHARTER VESSEL	T	GOVERNMENT VESSEL
DE	DECK SHIP CARGO	TG	TUG TOW BARGE
DR	DREDGE	US	NAVY VESSEL
FC	REFRIGERATED CARGO	V	HOVERCRAFT
FF	FISH(ING) FACTORY	V	VEHICLE CARRIER
FN	FERRY (NONLOCAL)	VC	VEHICLE CARRIER
FS	FISHING VESSEL	W	WARSHIP
FV		Y	PLEASURE CRAFT
FY	FERRY	YM	MOTOR YACHT
I	MISCELLANEOUS	YS	SAILING VESSEL
K	BULK CARRIER	YT	YACHT
L	GENERAL CARGO	Z	FISHING VESSEL
LC	LANDING CRAFT	ZC	CRABBER
LG	LIQ GAS CARRIER	ZD	TRAWLER
M	FISH PROCESSOR	ZF	FISH FACTORY
N	CONTAINER SHIP	ZL	LONGLINER
O	COASTAL FREIGHTER	ZP	FISH PACKER
OL	LOG CARRIER	ZP	FISH PROCESSOR
OT	OIL TANKER	ZS	SEINER

* Types derived from dBase April 2003, 1-22. May not be complete……………..

Figure 4.2: Overview on MCTS vessel types and codes for April 2003

LOA: Overall length of the vessel (LOA) in metres. Can range between 6 and 300 metres. Not every ship has an indicated length (then it's set to zero).

GRT: Gross registered tonnage of the vessel in tons. Range between 5 and 1E+05 tons, not indicated for each vessel (unless it's set to zero).

TOW_DEC/ENC: Plain English description (TOW_DEC) and encode (TOW_ENC) of the tow or load, corresponding to the following encoding:

[Number - type of barge – loaded or empty – further barges]

TYPE **B:** barge, **C:** chip barge, **D:** oil barge, **E:** log barge,
F: empty rail barge, **G:** section log tow, **H:** bulk barge,
J: chemical barge, **L:** general cargo, **X**: others

LOAD **E:** empty, **L:** loaded

SAMPLE **2CL1BE** means 2 loaded chip barges + 1 empty barge

IS_DC/DD/SPI: Fields containing information about dangerous cargo on board (IS_DC); reported defects or deficiencies in shipboard equipment (IS_DD) and special interests (IS_SPI); but the field is hardly ever filled out.

POS_LAT/LONG: Current known, reported or observed spherical position on the globe measured in latitude and longitude, each number specified to three decimal places. As one nautical mile is approximately defined as the distance subtending an angle of one minute of arc at the Earth's center, the accuracy of the indicated position lies in a hundredth of one nautical mile (which means app. 20 metres). Because the Canadian West Coast lies within the third quadrant of the coordinate system, the longitude needs to be multiplied by (-1) for use with some Geographic Information Systems (GIS).

POS_RDRDTG: Day-Time-Group of plotting the position given above if the vessel is radar tracked. In the majority of cases, this point in time corresponds with the DTG of the last system position report (LAST_UDDTG).

POS_CIP(DTG): Place of last call of vessel at Calling-In-Points (and Day-Time-Group of this record). Calling-In-Points are specific positions where the vessels have to report. Both of the described fields are always empty.

POS_SRC: Position source, corresponding to the codes listed in figure 4.3 on the following page. The mode of the positioning depends on the equipment of the tracking station and the preferences of the operator in charge. The different procedures are described in detail and rated for their accuracy in the previous chapter 4.1.5.

POS_SRC	MODE
ADR	Advance Report Dead Reckoning
AIS	Automatic Identification System
ANC	Anchored
DRP	Offshore Dead Reckoning
FDR	Fixed Route Dead Reckoning (Auto Route)
FIX	Fixed in position by operator
MAN	Manual Plot
MDR	Manual Route Dead Reckoning
RDR	Radar
SAT	Satellite Plot Extracted

Figure 4.3: Overview on position sources

CVTS_ZONE: Cooperative Vessel Traffic Center working the vessel. Canadian Coast Guard Pacific Region operates the three VTS Zones Vancouver, Tofino and Prince Rupert. The Vancouver Zone is divided up into three sub regions Vancouver, Comox and Victoria. The United States Coast Guards, Seattle Traffic operates the Puget Sound VTS System. From there vessels can be tracked by one of the following six MCTS centers:

CVTS_ZONE	NAME	RESPONSIBILITY
CMX	Comox	Canada
PUG	Puget Sound	USA
RUP	Prince Rupert	Canada
TOF	Tofino	Canada
VAN	Vancouver	Canada
VIC	Victoria	Canada

Figure 4.4: Overview on VTS zones

FROM_AT: Location where the vessel departed from or is currently at. (Non-official) abbreviation with up to five characters (letters and numbers possible). Not filled in for every record.

NEXT_TO: Location where vessels next intended destination or is en route to. (Non-official) abbreviation with up to five characters (letters and numbers possible). Not filled in for every record.

SERVICE: Foreign going vessels requiring pilots or vessels engaged in coastal service (not filled out).

COURSE: Current course "True North" over ground of vessel expressed in degrees of a 360° circle.

SPEED: Current speed over ground of vessel expressed in knots (NM per hour).

4.3 Preliminary Statistical Analyses and Data Sampling

In order to get a better overview of the database and its content at first, different data samples are examined. To identify the fields and the attributes described in the last preceding chapter a subset of the data from April 1st to 22nd 2003 was scanned. This amount of data is advisable because it is despite its size still manageable in MS Access and Excel and it provides a good overview of almost a whole month. The data are investigated in terms of vessel types, length over all and position source. Additionally several different days from the first third of the year 2003 are selected for the comparison of number of recorded different vessels and trips per day and the proportion between different length classes. For this statistical analysis an Excel worksheet is used. Results are presented in the following sections.

4.3.1 Vessel classification

In order to make the handling of the data more efficient for comparison and preliminary statistical analysis a classification scheme for the overall length of the vessel would be advantageous. Searching the Internet as well as looking for appropriate literature does not result in discovering a common system for the length classification of different vessels. For that purpose the decision is made to devise an own classification scheme for this thesis.

The jointed database for April 1-22, 2003 is used for the development. As a first step all 63'029 records without a proper length (LOA=0, mainly for tugs) are removed. Secondly a query is created to calculate the average length and its minimum and maximum value grouped for each type of vessel (TYPE_ENC/DEC). The standard deviation of the length is assessed to get an idea on the variations within one specific type. To get notice of the frequency of the types the number of involved vessels is also indicated. From all these values the classes are derived manually along reasonable boundaries that should be coherent and are showed below:

Class	from [m]	to [m]	Vessel types
1		20	Miscellaneous*
2	20	30	Tugs
3	30	50	Passenger Ships, Fishing and Charter Vessels
4	50	60	Coast Guards, Government Vessels
5	60	100	Freighters, Fishing Factory/Industry
6	100	120	Ferries
7	120		Cargo, Carrier and Container Ships, Tankers

* contains not all vessels <20m because not all of them need a traffic clearance from VTS centers and hence are not tracked (accordingly to the MCTS conditions).

Figure 4.5: Classification system based on overall length

The class limits are generated taking into consideration the higher occurrence of few vessel types like tugs, fishing and government vessels, ferries, bulk carrier and container ships (more than 20'000 correct records in the mentioned 22 days). Apparently it's not possible to draw the borders between the different lengths without compromises, but the developed scheme seems to fit the requirements for this specific thesis as good as possible. The BC Ferries fleet, which adds most of the ferry traffic on Canada's West Coast, consists of vessels between 13 and 167 metres LOA. Obviously all the small and large vessels of this fleet are assigned to the wrong category, but these failures can be removed manually without big effort considering the following table shown in figure 4.6 [source: www.bcferries.bc.ca/fleet/]. The four vessels connecting Victoria's Inner Harbor with Seattle are also shorter than their class [www.victoriaclipper.com/marketing/information_vessels.shtml]. Ferries from other companies serving the West Coast Region (like the Coho Ferry [www.cohoferry.com] and most of the Washington State Ferries [www.wsdot.wa.gov/ferries/]) are fitting adequately in the developed scheme.

NAME (BC Ferries)	LOA
Spirit of British Columbia	167.57 m
Spirit of Vancouver Island	167.57 m
Queen of Alberni	139.29 m
Queen of Coquitlam	139.29 m
Queen of Cowichan	139.29 m
Queen of Oak Bay	139.29 m
Queen of Surrey	139.29 m
Queen of Burnaby	129.97 m
Queen of Esquimalt	129.97 m
Queen of Nanaimo	129.97 m
Queen of Saanich	129.97 m
Queen of New Westminster	129.97 m
Queen of The North	125.00 m
Bowen Queen	84.96 m
Dogwood Princess II	12.80 m

NAME (BC Ferries)	LOA
Howe Sound Queen	73.64 m
Kahloke	54.75 m
Klitsa	47.46 m
Kwuna	71.64 m
Mayne Queen	84.96 m
Mill Bay	37.49 m
Nimpkish	33.93 m
North Island Princess	61.04 m
Powell River Queen	84.96 m
Quadra Queen II	49.64 m
Queen of Capilano	96.00 m
Queen of Cumberland	96.00 m
Quinitsa	74.52 m
Quinsam	86.85 m
Tenaka	47.09 m
Tachek	49.56 m

NAME (Victoria Clipper)	LOA
Victoria Clipper	40.42 m
Victoria Clipper III	26.00 m
Victoria Clipper IV	39.00 m
San Juan Explorer	24.00 m

Figure 4.6: Ferries exceeding the LOA classification scheme

4.3.2 Position source and vessel type

According to the description of the MCTS Database there are 10 different sources for the vessel position. An effort to state coherence between the vessel's type, resp. length overall is difficult because each vessel can change its positioning mode for each trip, even for each record. Although a preliminary survey of the April data shows that four different sources are favored: "Advance Report Dead Reckoning" [ADR], "Fixed Route Dead Reckoning (Auto Route)" [FDR], "Manual Plot" [MAN] and "Radar" [RDR]. The distribution between the different classes for the length of the vessel (LOA) looks like followed:

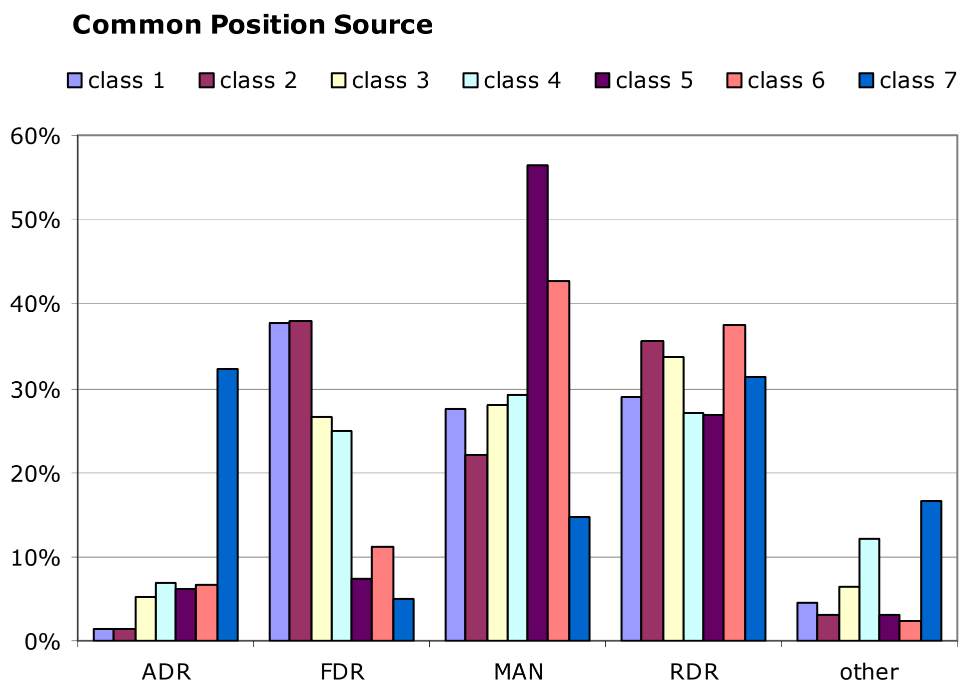


Figure 4.7: Histogram of vessel classes versus position source (April 2003)

It stands out that more than half of all vessels in class 5 (freighters and fishing Factory) are still positioned using a manual plot method, but only about 15 percent of the large cargo/container ships and tankers (class 7). Also remarkable is the fact that the positions of a third of all the large vessels (>120 metres, class 7) are recorded applying "Advance Report Dead Reckoning", whereas the small vessels (class 1 and 2, <30 metres) are mostly proceeded with "Fixed Route Dead Reckoning (Auto Route)". The application of the "Radar-Method" is distributed in each class roughly uniformly because this method depends rather on the geographical position than on the vessel type. The group "others" consists of other positioning procedures like "Offshore Dead Reckoning" [DRP], "Manual Route Dead Reckoning" [MDR] or "Anchored" [ANC]/"Fixed in Position by Operator" [FIX] which are used infrequent.

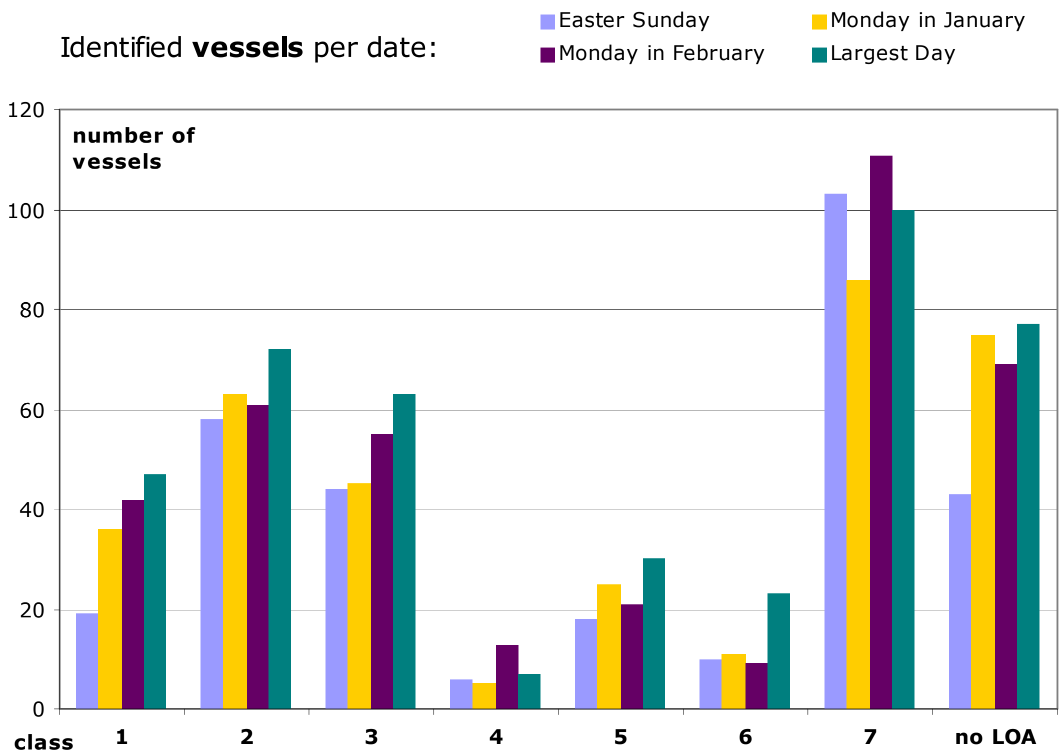
4.3.3 Comparison of different days

To detect traffic variations between different weekdays and seasons a few day samples are investigated primarily in terms to compare numbers of different vessels and trips per day and their affiliation to the seven length classes. Because this comparison is made in an early stage of this thesis not the complete dataset is available, but only data for the first three months (January, February and April). Out of it four different days are selected: Easter Sunday (April 20, 2003), a Monday in January (January 13, 2003) and one in February (February 10, 2003), and the day with the largest data volume in the period (Thursday April 3, 2003). These days are not selected randomly but with certain reason: Easter Sunday is supposed to imply more ferry and "tourist" traffic than any other day in this period, while weekdays are usually preferred by transportation shipping companies (because ports and transshipping agencies are working). April 3rd is selected because it has the largest data amount in the considered time frame. An overlook of the results of the comparison implemented in an Excel worksheet are presented in the following table and graphs. As it can be seen in the graphics there is not a conspicuous difference between the selected days. The contribution between the length classes stays almost the same between the different days. Remarkable are the numerous identification problems (up to 7% of the vessels and around 1% of all trips). This circumstance is described in the next section.

								Class of Length [%]							
Day	**Date**	Number of recorded different vessels:	Number of Vessel Identification Errors:		Number of recorded different trips:	Number of Trip Identification Errors:		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**no LOA**
Easter Sunday	20-Apr	**301**	19	6%				6.3	19.3	14.6	2.0	6.0	3.3	34.2	14.3
					607	5	1%	3.5	13.8	13.7	1.5	10.2	8.7	40.7	7.9
Monday in January	13-Jan	**346**	19	5%				10.4	18.2	13.0	1.4	7.2	3.2	24.9	21.7
					562	6	1%	7.3	15.8	14.1	0.9	15.5	5.0	27.4	14.1
Monday in February	10-Feb	**381**	23	6%				11.0	16.0	14.4	3.4	5.5	2.4	29.1	18.1
					681	8	1%	8.7	11.3	15.4	2.9	10.1	6.8	33.5	11.3
Largest Day	3-Apr	**419**	30	7%				11.2	17.2	15.0	1.7	7.2	5.5	23.9	18.4
					826	10	1%	8.0	18.9	17.4	1.3	9.8	7.0	27.2	10.3

Figure 4.8: Statistical comparison between different days

Figure 4.9: Absolute vessel traffic distribution (identified vessels and trips per date)



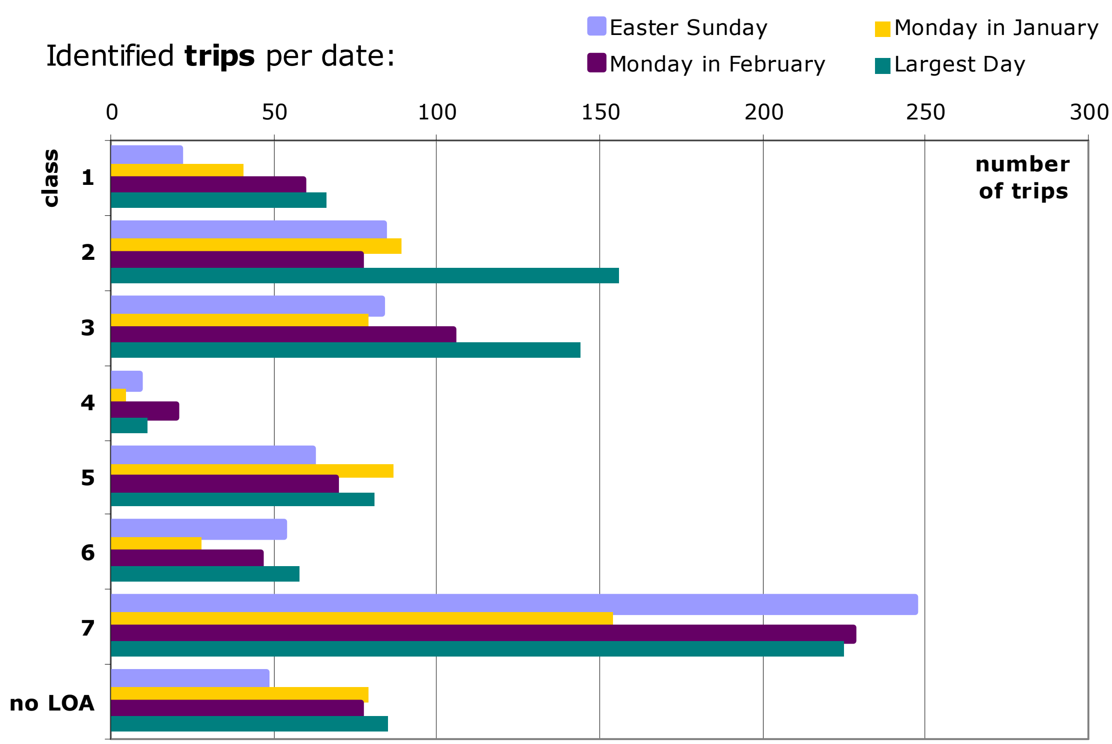
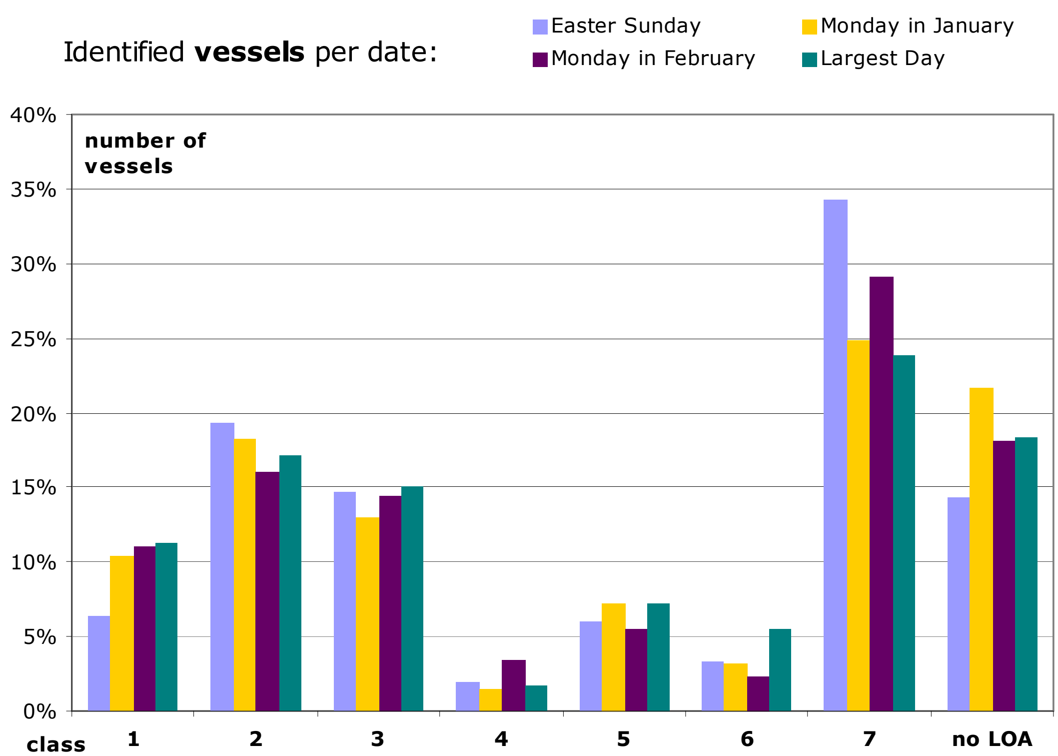
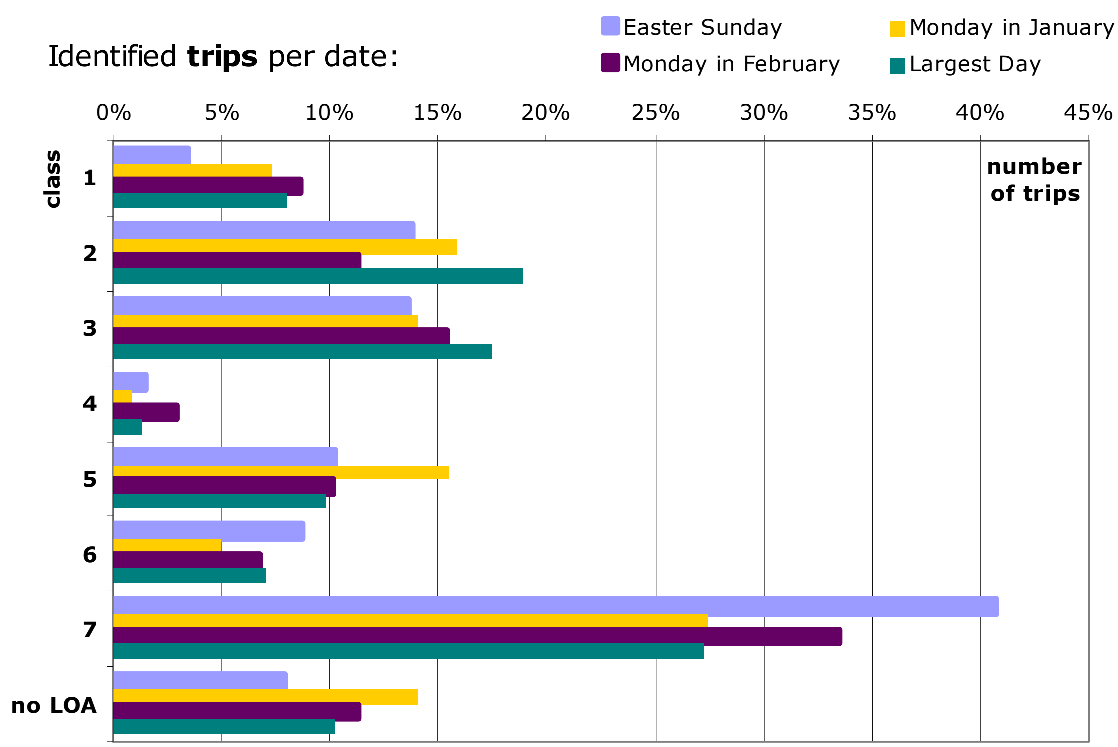


Figure 4.10: Percentage vessel traffic distribution (identified vessels and trips per date)





4.4 Difficulties and limitations of the data

4.4.1 Technical errors "at a first glance"

An advanced look at the MCTS database confirms some errors that were also uncovered during the preliminary analysis and data sampling described in the last chapter.

- In the beginning of each day file there is a multiple recording (up to 500 times the same position) of one specific vessel with an impossible DTG (false date or year).
- Some records are listed repeatedly for one vessel and one position.
- Some records contain neither a longitude nor latitude.
- Not every file starts exactly at midnight of the specific day, sometimes the first correct recording is from the day before (around 11pm) or a couple of hours after midnight.
- Not every file ends exactly at midnight of the specific day sometimes the last recording is an hour later during the next day, but indicated as same day with time exceeding midnight.
- The above-mentioned situation implements overlapping records in the database. As a sample there are different recordings for [200304012459] and [200304020059], which is in fact the same point in time (DTG of April 1st 24.59, resp. April 2nd 00.59].
- Some DTG's look impossible at a first glance [202003020309].
- Sometimes the name of one unique vessel (NAME) is written unequal for the same ship because of manual acquisition and the inconsistent use of abbreviations.

4.4.2 Spatial problems "at a first glance"

The first attempts to visualize parts of the MCTS database (data sample used for this chapter and displayed in the figures is from April, 3rd 2003) bring out a lot of difficulties and further errors as well, which could only be detected by having a look at the appearance of the data. First visualization approaches include the graphical display of point locations and first attempts to generate polylines for unique trips identified by the VSL_ID (detailed information on the import and visualization procedure in the used GIS software can be found in chapter 7).

- Some positions are obviously outside the area under investigation.
- Some polylines include either big time or space gaps.
- Sometimes a line cannot be drawn because all points of one VSL_ID are identical in position.
- Some vessels are doing more than one trip with the same VSL_ID (mainly ferries); inversely the same ship, resp. one unique trip can have different VSL_ID's.
- Vessels with no VSL_ID are treated and shown like one and the same trip.
- The Puget Sound VTS station had an obviously wrong time recording (mixing up the 12- and 24-hour system) for the first six months of the present year (January to June 2003).

– Changing the position source or changing the course in some positioning modes means often also a major shift in position (up to 300 kilometers in 5 minutes).

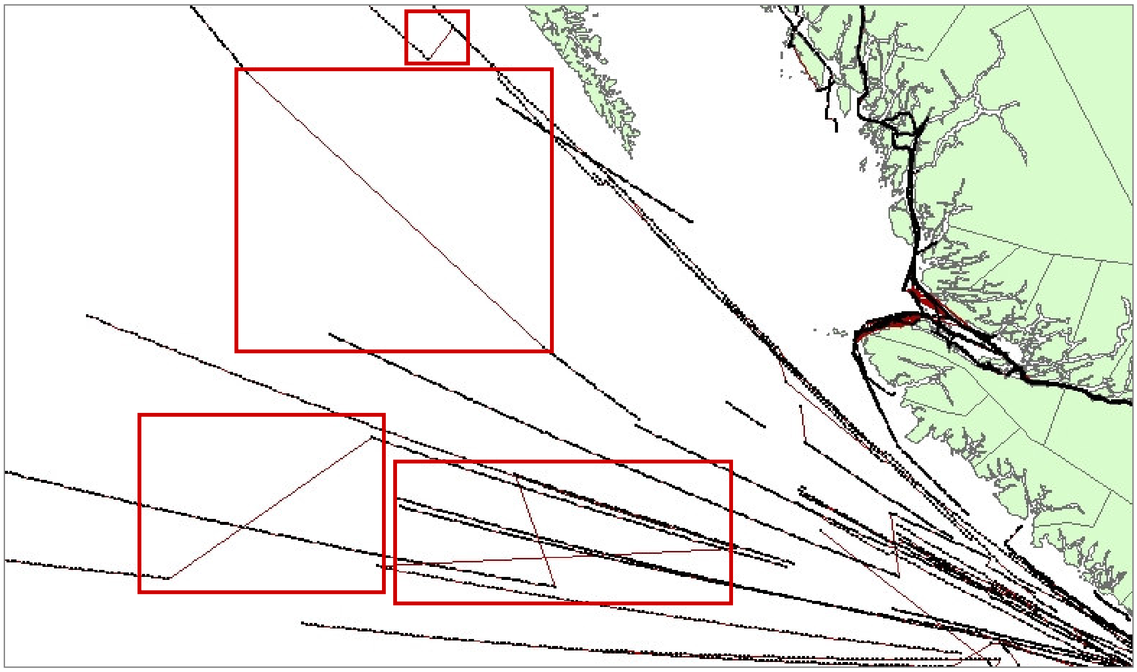


Figure 4.11: Shifting due to changing of position source (marked with red boxes)

– It's not apparent what order the GIS operation uses to connect the point to polylines, but since most of the built lines seem to be reasonable it is assumed that the tracks are generated following the original order of the data.

– Some frequent positions – mostly from a manual positioning source - recorded multiple times for lots of different vessels are evidently wrong.

Figure 4.12: Questionable MAN positions for different vessels (marked with a red box)

– Vessels changing the CVTS zone are sometimes provided with another VSL_ID from the new recording station and are even double tracked.

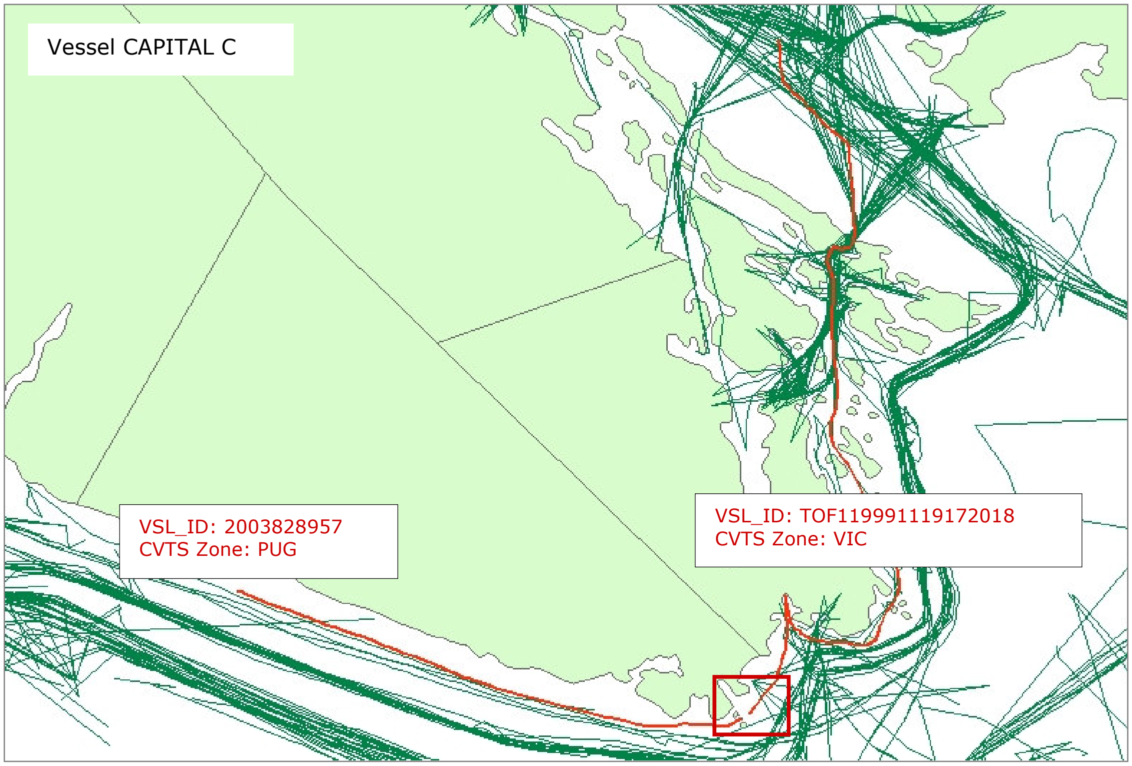


Figure 4.13: Changing CVTS zone and obtaining another VSL_ID (marked with a red box)

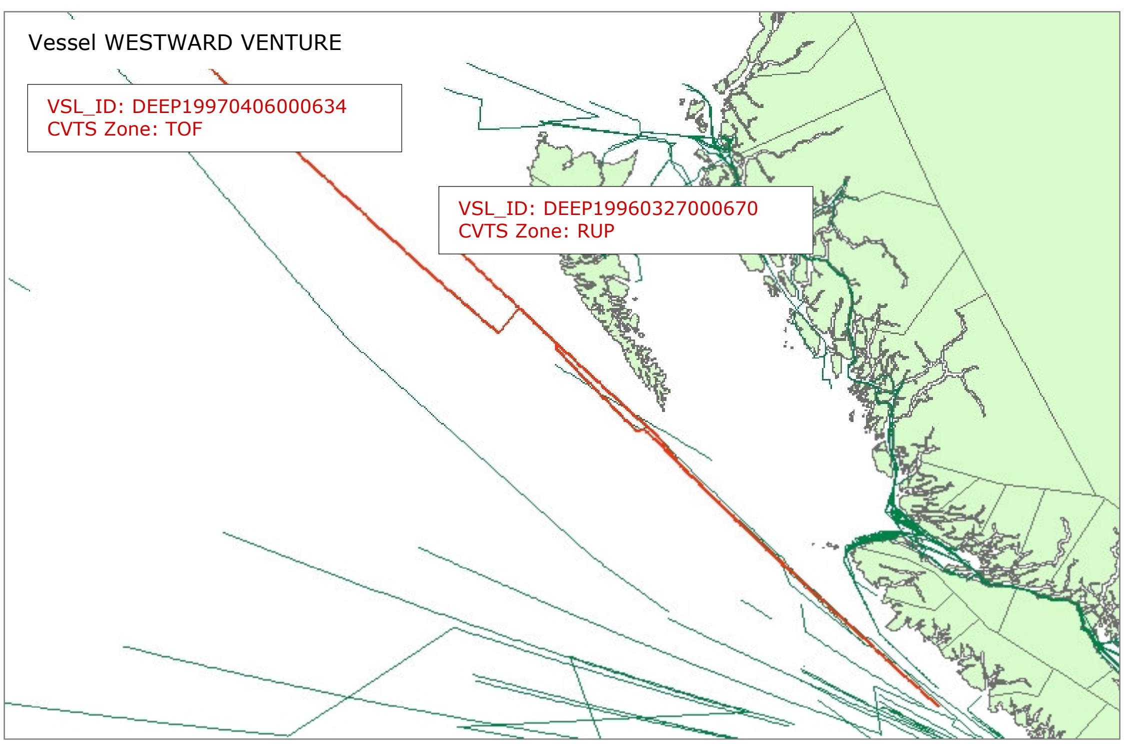


Figure 4.14: Double tracking through two different MCTS stations (Prince Rupert and Tofino)

– The allocation of the recordings to the five different CVTS Zones (Rupert, Comox, Victoria, Puget and Tofino - compare the description of the database in subchapter 4.2) seems quite reasonable, even though there are some overlaps, especially between Prince Rupert [RUP] and Tofino [TOF]; as well as between Puget Sound [PUG] and Victoria [VIC].

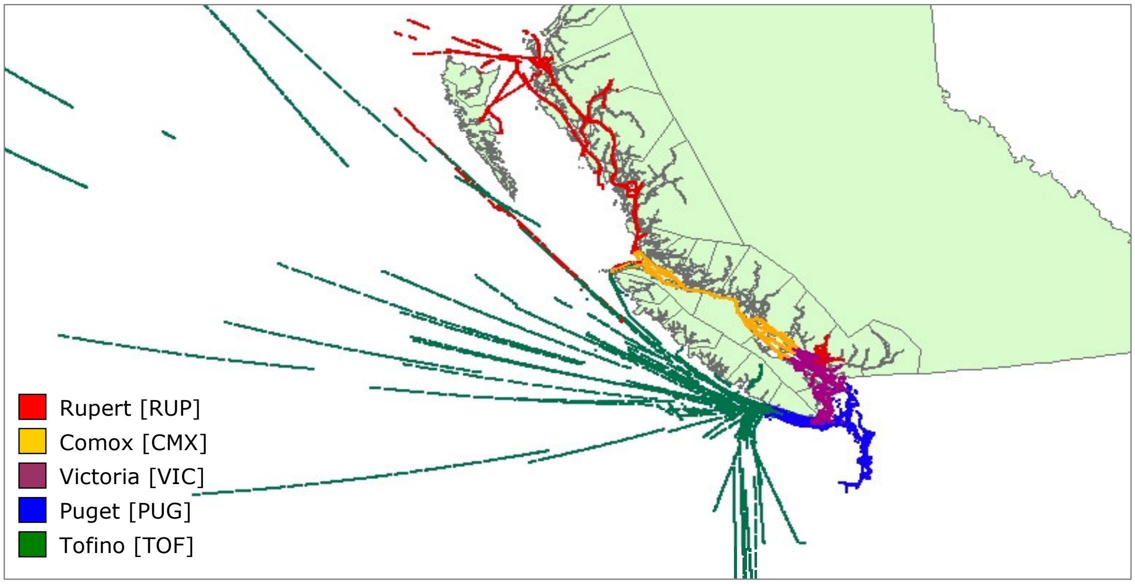


Figure 4.15: Allocation to the five different MCTS centers, resp. VTS zones

– Whereas the generation of the VSL_ID seems much more random and does not have an obvious geographically founded system, except the Puget Sound Region which is covered by the American CVTS Station.

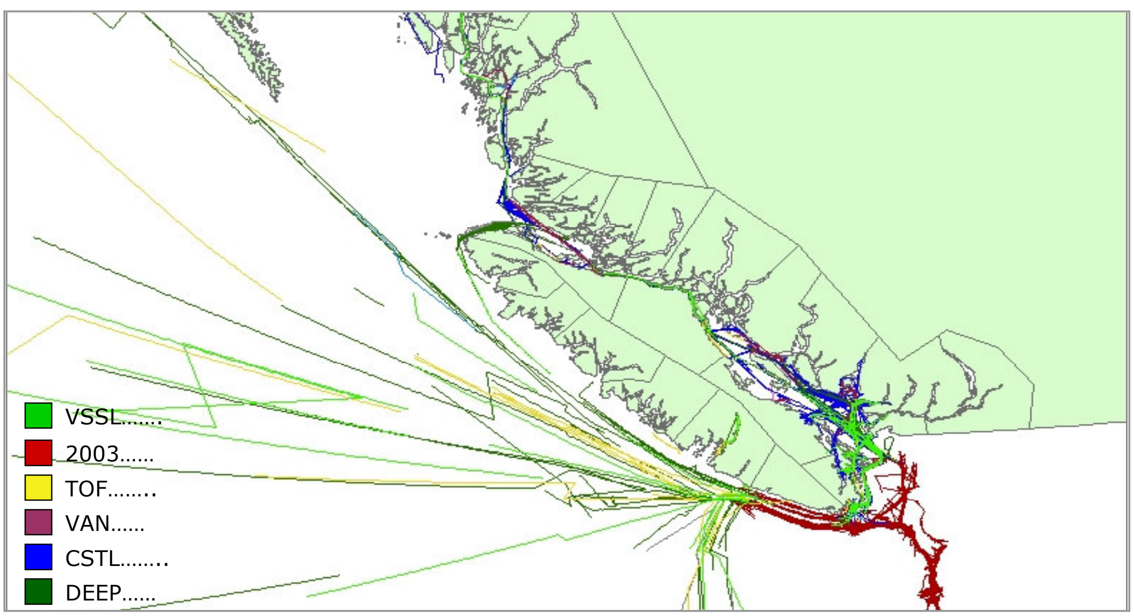


Figure 4.16: Spatial distribution of the VSL_ID

4.4.3 Problem of well-defined identification of the vessels

The MCTS Database contains four fields for the identification of a single vessel, which are: VSL_ID, NAME, CALLSIGN and LLOYDS_ID. The VSL_ID identification number is an internal system identifier, which is automatically generated on the first contact ever between the vessel and the VTS station. For this reason a single ship can usually get only one unique VSL_ID from the VTS station, except Puget Sound VTS that obviously assigns different VSL_IDs for the same vessel. But it is certain that each MCTS center issues its own VSL_ID and therefore the identification code of a single vessel depends on the geographical region it is in at the time. The vessel's NAME is entered manually from the operator; therefore it is a considerable source of errors in spelling and typing. The CALLSIGN is a unique code for each vessel (with few exceptions: obvious typing errors), means that there is only one eligible vessel for a call sign, but each vessel can have more than one call sign. Beside that there are vessels with no recorded call sign at all. The Lloyds number is reliable only for incoming deep-sea vessel because of the requirements of the mandatory advanced report. The same numbers for the coastal vessels are inconsistently recorded because of a minor priority for the actual use of the CCG. Browsing through the data of April 1-22, 2003 a remarkable number of problems with identifying a single ship appear because the different identification fields don't fit together. For examples see the following table:

Figure 4.17: Identification failures

NAME	LLOYDS_ID	CALLSIGN
PACIFIC CHALLENGER		
PACIFIC CHALLENGER	571631	WDA3588
PACIFIC CHALLENGER	7043221	WY5999
PACIFIC CHALLENGER	7509445	WDA3588
PACIFIC CHALLENGER	8805004	ELLE5
PACIFIC EXPLORER		WCZ9005
PACIFIC EXPLORER	7724617	ELKV4
PACIFIC EXPLORER	8103016	WBK6365
PACIFIC EXPLORER	8103016	WUT3635
PACIFIC EXPLORER	8412302	WCZ9005
BLACK HAWK	515015	WBN2081
BLACK HAWK	7021962	WBN2081
AMATULI		WY2117
AMATULI	7049079	WBQ2117
AMATULI	7049079	WY2117
AMATULI	7049079	WY2184
ARCTIC ENTERPRISE	248169	WCZ4167
ARCTIC ENTERPRISE	8835528	WCZ4167
CGC ORCAS	1327	WPB1327
ORCAS		WPB1327
CGC ORCAS	WPB1327	WPB1327

Especially the hand written name implies a specific number of possible errors like wrong spelling, incorrect spacing or the inconsistent use of abbreviations and digits. For this purpose it is not useful to identify the ship only by its plain written name - although it is the only field that is almost filled in completely. From there the approach to identify a single vessel (unlike one unique trip) has to be a combination of its call sign and its written name (for vessels with more than one or no call sign). To gain information about a single trip from a specific vessel the VSL_ID can be used (where available) in combination with the call sign. For an example see the table below:

Figure 4.18: Different trips (VSL_IDs) of one vessel

VSL_ID	NAME	CALLSIGN	Records	LAST_UDDTG
2003836825	FRISIA	3EAF4	123	200304200414
DEEP19960327001130	FRISIA	3EAF4	136	200304212108
2003837836	FRISIA	3EAF4	42	200304221624

(The above data means, that the vessel FRISIA did different trips in the time of April 1-22nd, 2003: The first trip started on April 20th at 4.14 a.m. The vessel was registered by the VTS center for this trip with the ID 200383625, tracked during ca. 12 hours (123 records). The second journey was on April 21st, beginning at 9.08 p.m. for about 13 hours and the third trip started on April 22nd at 4.24 p.m., tracked for about 4 hours.)

The examination of four different days in the first third of the year 2003 (January 13th, February 10th, April 3rd and April 20th, compare statistical analysis in chapter 4.3.3) shows that the number of identification difficulties lies within 5% to 7% of the total quantity of different vessel and around 1% of all the trips on the examined day. Therefore it seems to be less problematic to identify only single trips instead of unique vessels.

4.4.4 Length classification

The first attempts to visualize the existing database (all records from April 3, 2003) turn out that the developed classification as described above is not appropriate enough for the visualization. As shown in the following map (figure 4.19) the coherence between the location and the length is lower than expected. For that reason the classification scheme is redefined by using the vessel type instead of the length overall; the different classes are suggested by a Coast Guard officer at the Victoria MCTS Center. The resulting final classification looks as shown in figure 4.20.

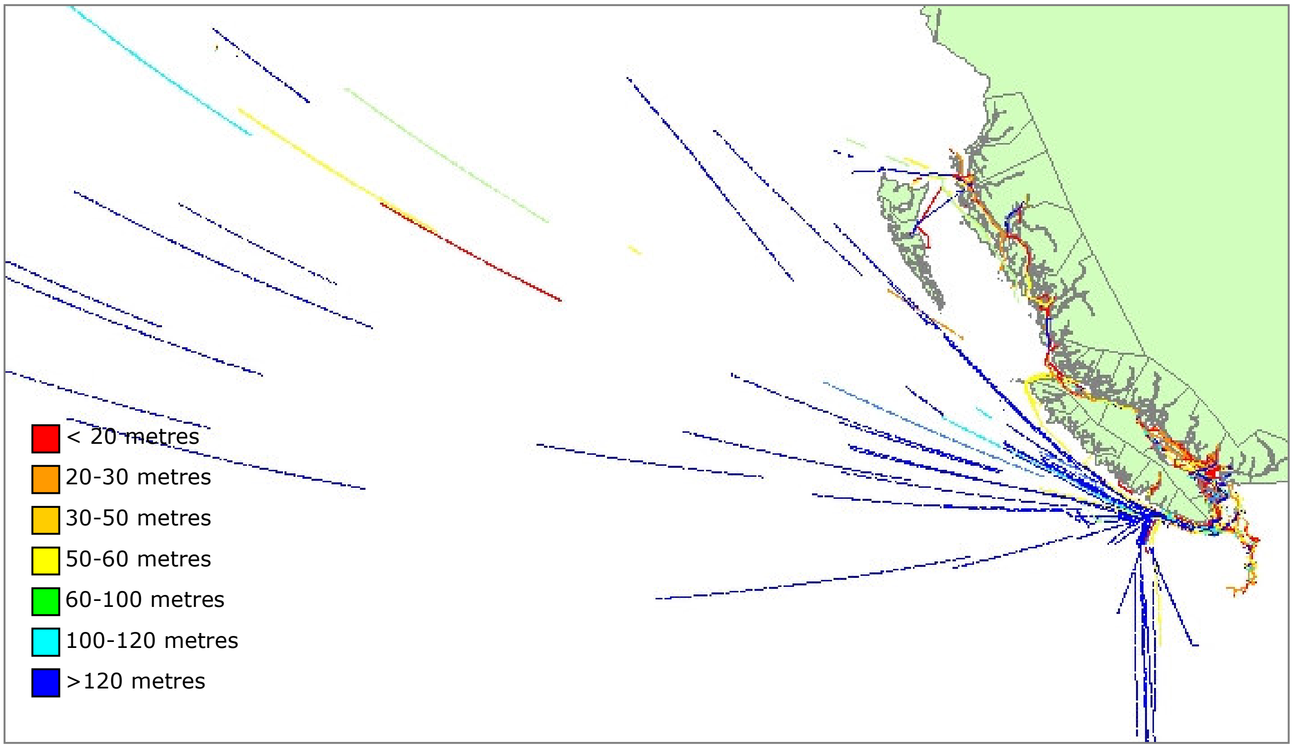


Figure 4.19: Spatial distribution of the defined length classes at first

Class	Kind of vessel	Types (encoded according to the description of MCTS data)
1	MISCELLANEOUS	CG, CV, I, RE, S, SP, SU, T, US, W
2	TUGS / BARGES	A, DR, LC, TG
3	FISHING VESSELS	FF, FS, M, Z, ZC, ZD, ZF, ZL, ZP, ZS
4	PLEASURE CRAFTS	PC, Y, YM, YS, YT
5	CRUISE SHIPS	P, PS
6	FERRIES	FN, FY, Q
7	RAIL FERRIES	R
8	FREIGHTERS	8, BU, CH, DE, FC, K, L, O, OL, SC, V
9	CONTAINERSHIPS	CC, N, RC, RO
10	TANKER	1, 2, 3, 5, 6, 7, LG, OT

Figure 4.20: Revised vessel classification system (based on MCTS needs)

Although this classification scheme based on vessel types looks more reasonable in undertaken visualization approaches, it is difficult to use it on a regularly and automated basis because the type encoding is applied inconsistently and has to be checked manually. Nevertheless it is tried to apply this classification scheme for this thesis, mainly for the mapping; possible ambiguities have to be treated (and are described) as the case arises.

4.4.5 Spatial analysis of the position source

If another subset of the MCTS database (June 1st, 2003) is visualized classified by the position source, a clear dependency between the positioning method and the geographical distribution can be detected, as the following map cutout is displaying:

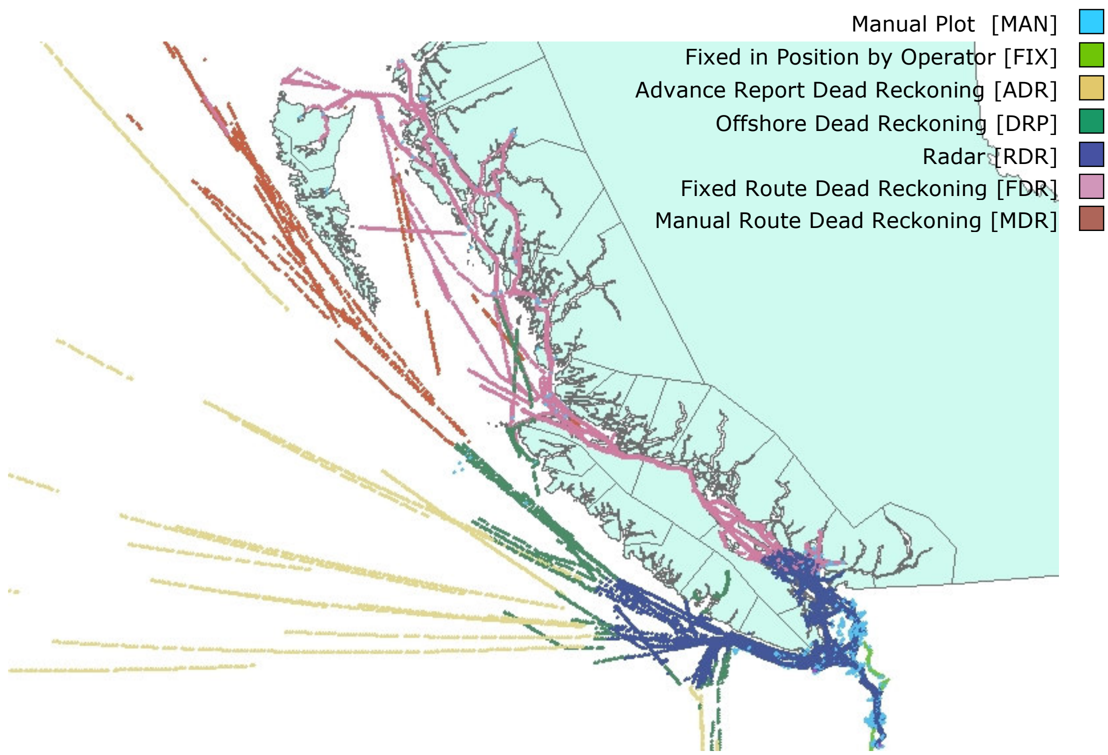


Figure 4.21: Spatial distribution of the positioning modes

As shown in the map above, vessels close to the northern mainland and around the northern gulf islands are usually recorded using "Fixed Route Dead Reckoning [FRD]" while vessel on the open sea are tracked mostly with "Advance Report Dead Reckoning [ADR]". Around the southern half of Vancouver Island most vessel are tracked by Radar [RDR] or further outwards to the west applying "Offshore Dead Reckoning [DRP]". Cases of "Manual Route Dead Reckoning [MDR]" and "Fixed in Position by Operator [FIX]" are infrequent. Most of the "Manual Plots [MAN]" appear in the American controlled Puget Sound Region, around Vancouver and a few further north around Prince Rupert. As a next step the position source is analyzed in connection to the boundaries of the VTS zones. Each of the five zones is apparently using different main positioning modes to track the vessels. A crosstab comparison between the six zones Comox [CMX], Puget Sound [PUG], Prince Rupert [RUP], Tofino [TOF], Vancouver [VAN], Victoria [VIC] and the ten possible position sources specifies a clear coherence, listed in the following table:

Figure 4.22: Cross tabulation between position source and VTS zone

POS_SRC		CMX	PUG	RUP	TOF	VAN	VIC
unknown		X		X			
ADR	Advance Report Dead Reckoning				**X**		
AIS	Automatic Identification System					**X**	
ANC	Anchored		**X**				
DRP	Offshore Dead Reckoning				**X**		
FDR	Fixed Route Dead Reckoning (Auto Route)	**X**		**X**		**X**	
FIX	Fixed in position by operator		**X**				
MAN	Manual Plot		**X**	**X**		**X**	
MDR	Manual Route Dead Reckoning			**X**		**X**	
RDR	Radar		**X**		**X**		**X**
SAT	Satellite Plot Extracted						

This table shows, for example, that all vessels in the VTS zone Victoria [VIC] and a part of in the Tofino and Prince Rupert zones [TOF, RUP] are radar tracked. Since the following subchapters will uncover that manual plots [MAN] are the most critical records, special attention must be paid to the VTS zones Puget Sound, Prince Rupert and Vancouver.

4.4.6 Inaccuracy of the "Manual Plot" positioning mode

"Manual Plot" positioning appears mostly in the VTS zone Puget Sound and also isolated in Prince Rupert and Vancouver, but never in Comox, Tofino or Victoria. Testing this characteristic on the April data similar values are found. About 25% of all the records have the [MAN] position source whereof again more than the half is situated in the Puget CVTS zone, the other half is divided into the Prince Rupert (28%) and Vancouver (16%) zones (see following graph from April, 3rd 2003 and the map cutout from June 1st, 2003).

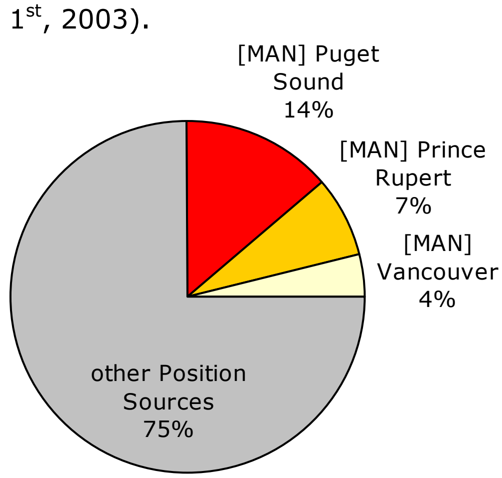
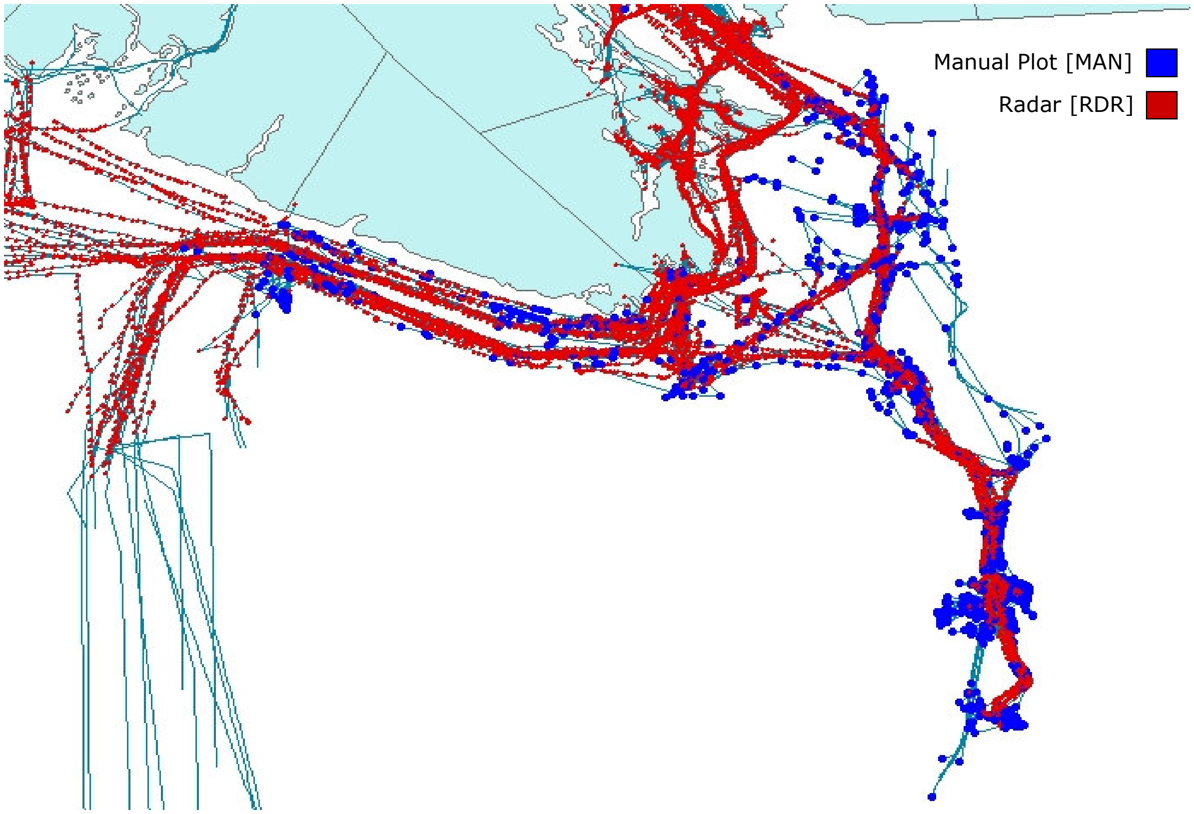


Figure 4.23: Fractions of MAN position sources in different VTS zones (April 3, 2003)

Figure 4.24: Fractions of manual and Radar position sources in Puget Sound (June 1, 2003)



A preliminary look on the displayed data shows divers difficulties with the manual positioned recordings. In the majority they are accountable for large shifting to the positions located by other procedures. It seems that the problems are founded in the lower precision of the positions recorded with "Manual Plots [MAN]" – when compared to Radar [RDR] or other positioning modes. Observing vessel trips, which are known - as for example the route of a ferry - can prove this statement. Regardless of that matter of fact the values for the latitude and longitude are shown as accurate as the other values (three decimal places) and are treated the same way. When creating lines from all points with the same VSL_ID the manual positions can frequently be found in the beginning or the end of a trip, particularly in that case the route shows an inconsistent course. One manual position often conduces as starting point for different trips and vessels. The same position is often also recorded for more than one point in time. [MAN] positions in the middle of a journey come mostly together with gaps in time and/or space. Inconsistent routes also are generated when different position source alternate; for example each second record is a "Manual Plot [MAN]" and the entries between are from a Radar [RDR] source. Trips consisting of manual located positions only are seldom and mostly small ferry routes; these connections are usually known and the exact positions can be derived from geographic information provided by the responsible agencies from both Canada and the United States.

The following map cutouts should illustrate the above described problems:

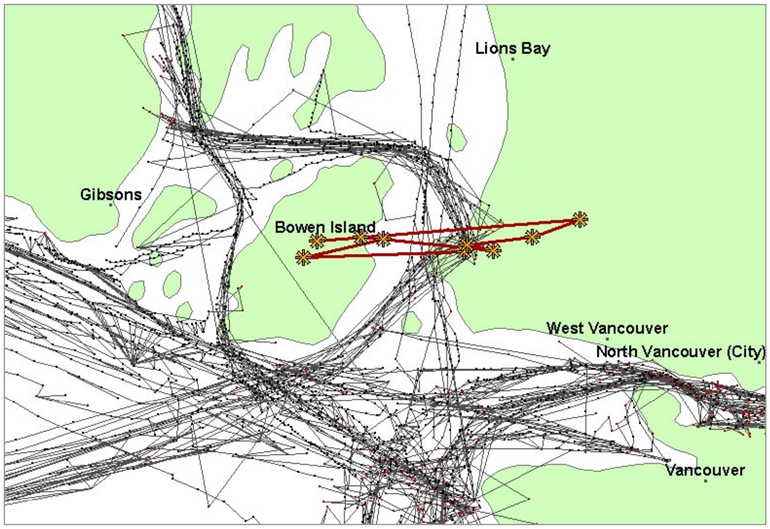


Figure 4.25

April 3, 2003

QUEEN OF CAPILANO
(*BCFerries*)

VSL_ID: CSTL19940124101700

Route:
Horseshoe Bay – Bowen Island and return *(known from the WWW www.bcferries.bc.ca)*

Problem:
only Manual Plots [MAN]
the inaccuracy is obvious!

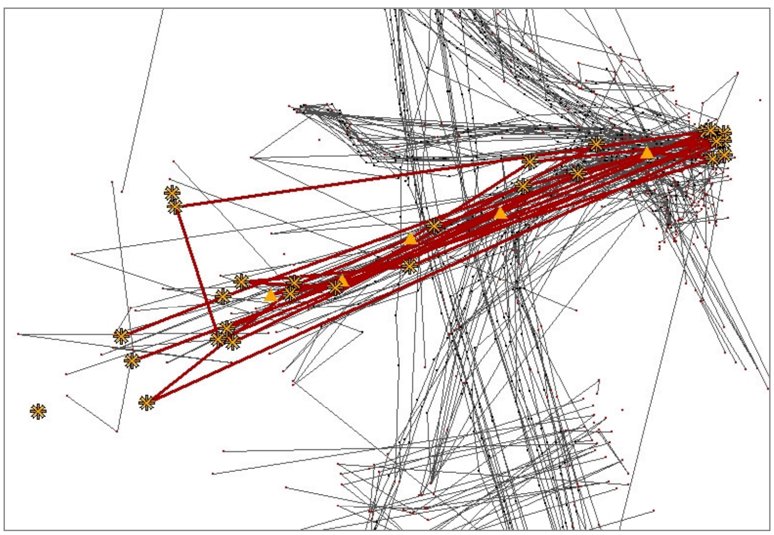
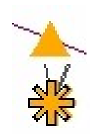


Figure 4.26

April 3, 2003

CHINOOK (*Ferry*)



non [MAN] Position

[MAN] Position

Route:
Unknown

Problem:
This vessel has more than 10 different VSL_ ID's and obvious strange positions!

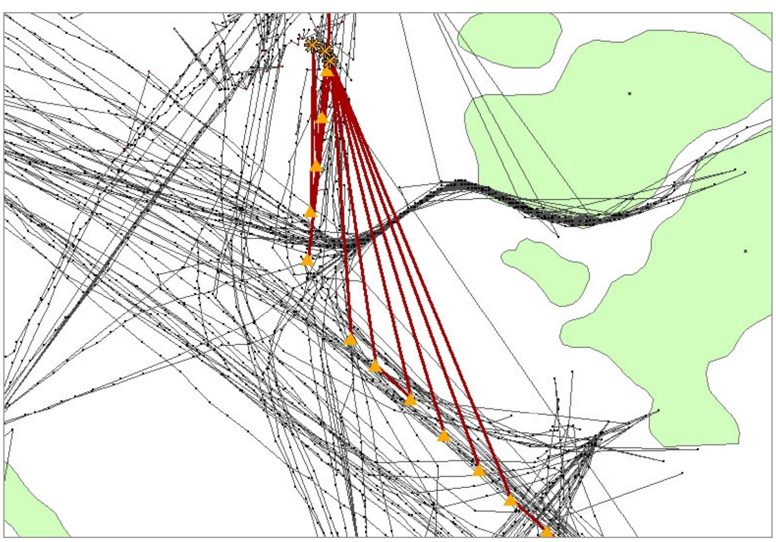
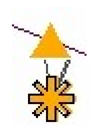


Figure 4.27

April 3, 2003

WESTWOOD ANETTE

VSL_ID: DEEP19960327001498

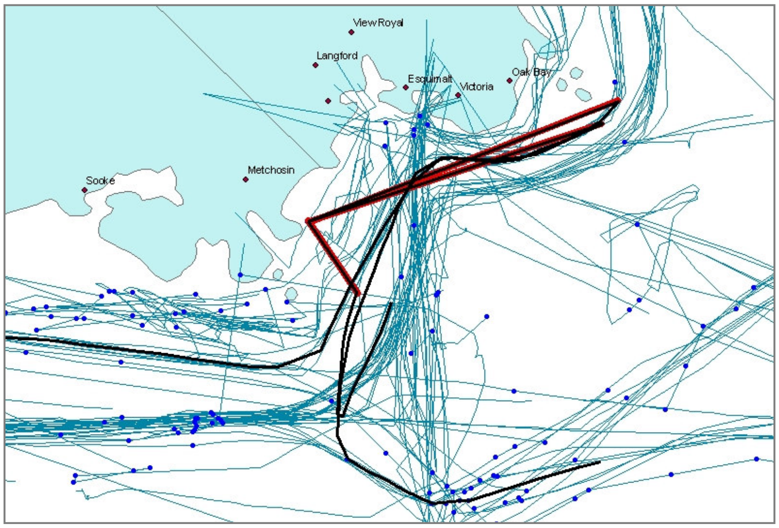


non [MAN] Position

[MAN] Position

Route:
Not important

Problem:
Alternating position source [MAN] and [RDR]



June 1, 2003

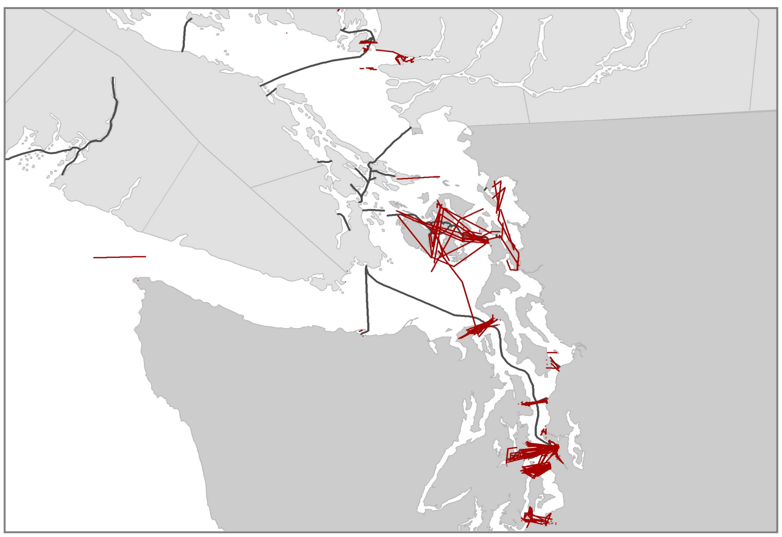
Different vessels and different trips

Manual Plot [MAN]
different trips
same MAN starting point

Different routes

<u>Problem:</u>
The same manual position conduces as starting point for different vessel trips

Figure 4.28



June 1, 2003

All "manual-only" vessel trips

known ferry connections
"manual plot" only routes

Correct ferry routes are known from different sources.

<u>Problem:</u>
"Confusing" vessel trips consisting exclusively from manual positions

Figure 4.29

4.4.7 Shifting observations between different positioning modes

If the positioning mode during a unique vessel trip is changed once or more, it comes mostly together with a shifting in the positions, the size depending on the type and the combination of the changing position sources. Analyses and maps in the following sections are based on the data from the first week of June in the year 2003 (June 1 – 7, 2003).

a) ADR / DRP

Between the positions tracked with "Advanced Report Dead Reckoning" and "Offshore Dead Reckoning" there usually exist a big shifting in space. The displacements appear mostly in the region about 130 km south of Nootka Island off the Westcoast of Vancouver Island (VTS Tofino Zone). They can be as large as 20 to 30 km and are pointing in different directions. Shifting in other areas (like about 80 km south of Bamfield) is lower (~10km) and more consistent in the direction.

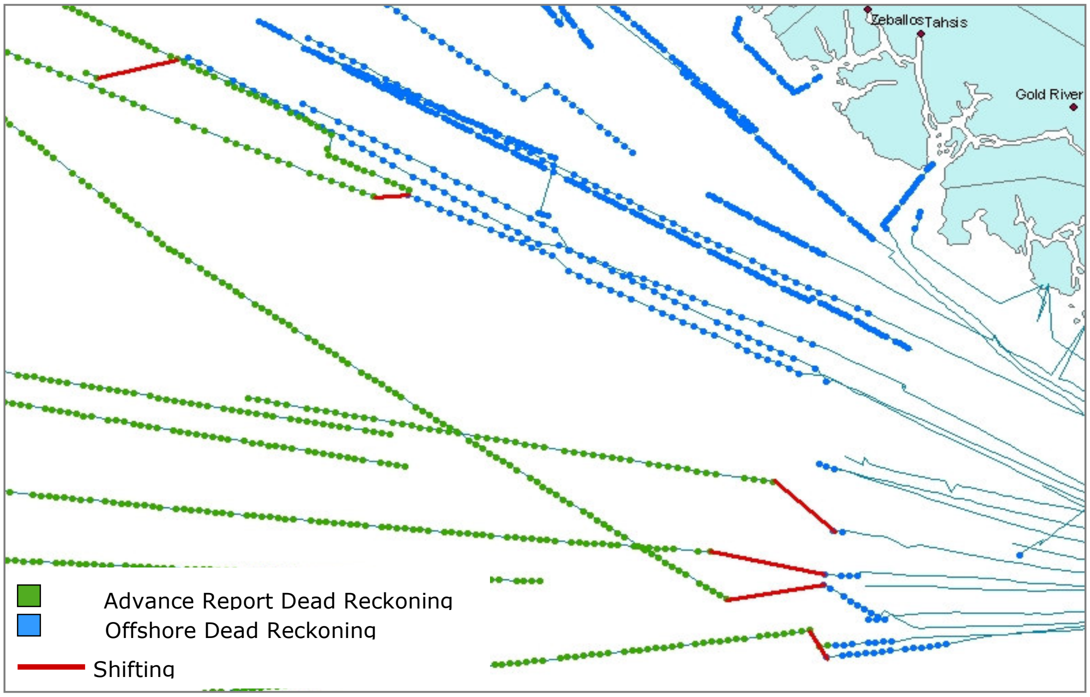


Figure 4.30: ADR->DRP changing

b) DRP / RDR:

between the different position source "Offshore Dead Reckoning" and "Radar" no large displacements appear. The changeover takes usually place in the same region south of Nootka Island as described above after a few points reported with DRP.

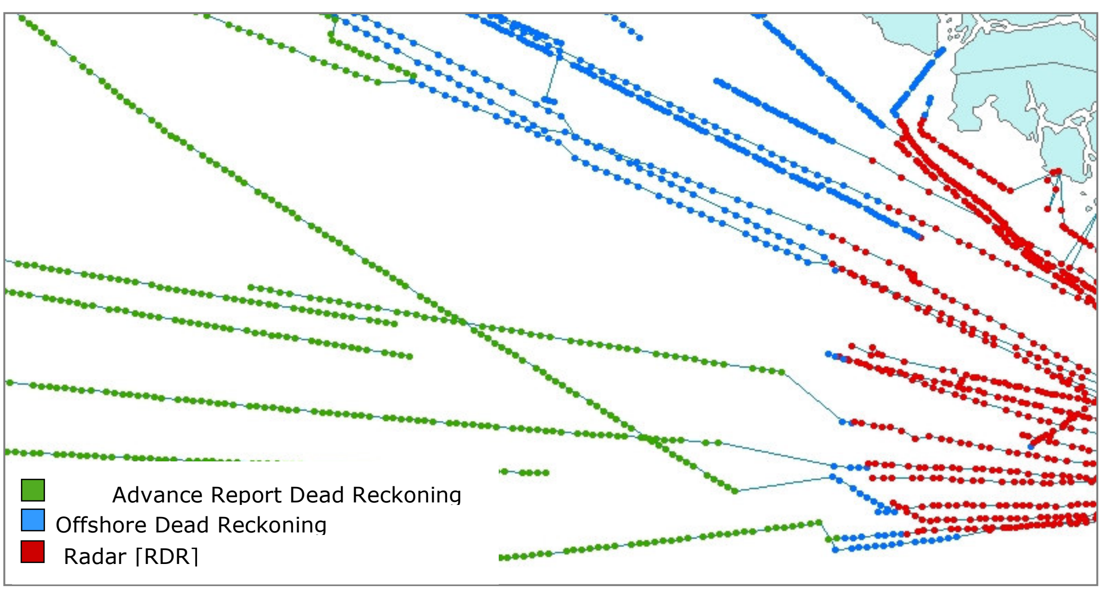
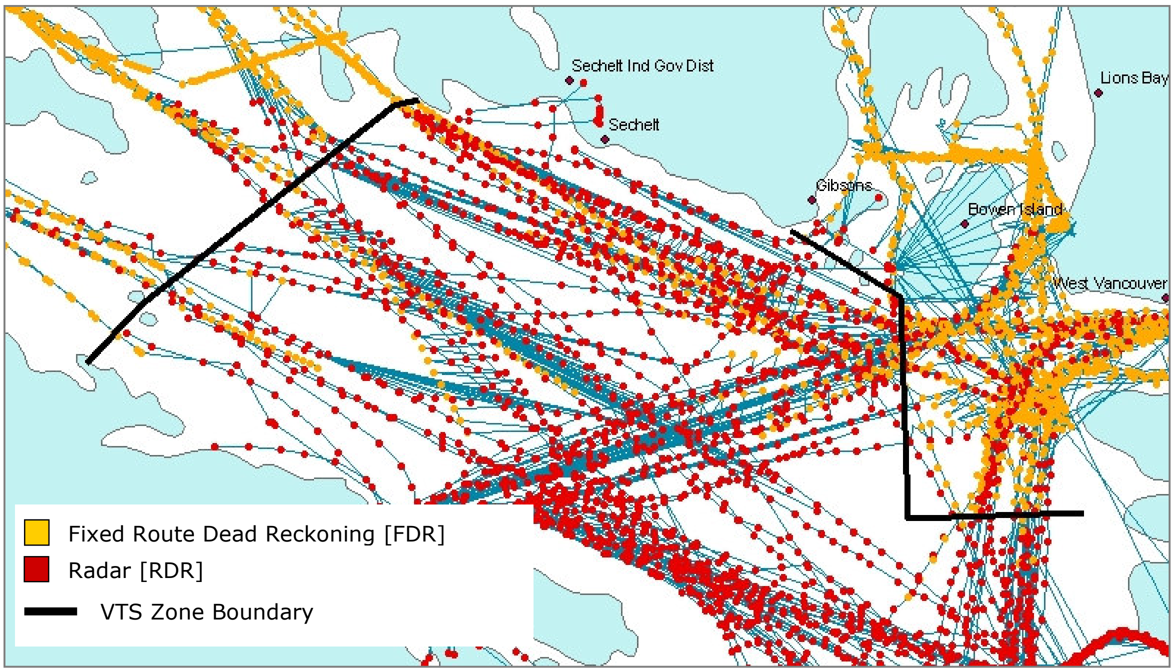


Figure 4.31: DRP->RDR changing

c) FDR / RDR:

The displacements between "Fixed Route Dead Reckoning" and Radar are obviously dependent on the zone they are tracked in. VTC zone Victoria is recording the locations only with the Radar mode, while the zones Prince Rupert and Vancouver are tracking without Radar but with other procedures (mainly FDR). That means that RDR located position outside and FDR points inside the Victoria zone are responsible for the displacement between connected points. Especially when the two position sources are alternating along the same trip the route shows a confusing picture.



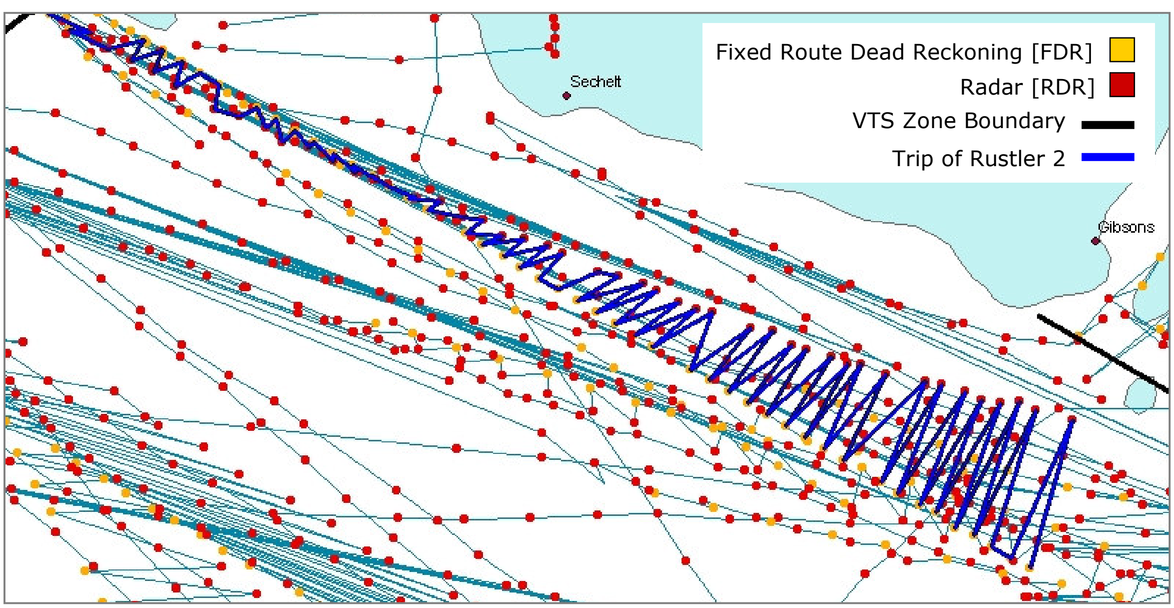


Figure 4.32 and 4.33: FDR->RDR changing

d) MDR / FDR:

"Manual Route Dead Reckoning" is used in Prince Rupert and Vancouver VTS zones only. Usually the positioning mode changes somewhere around of Queen Charlotte Island to "Fixed Route Dead Reckoning". Shifting between these two sources is not large and seems acceptable.

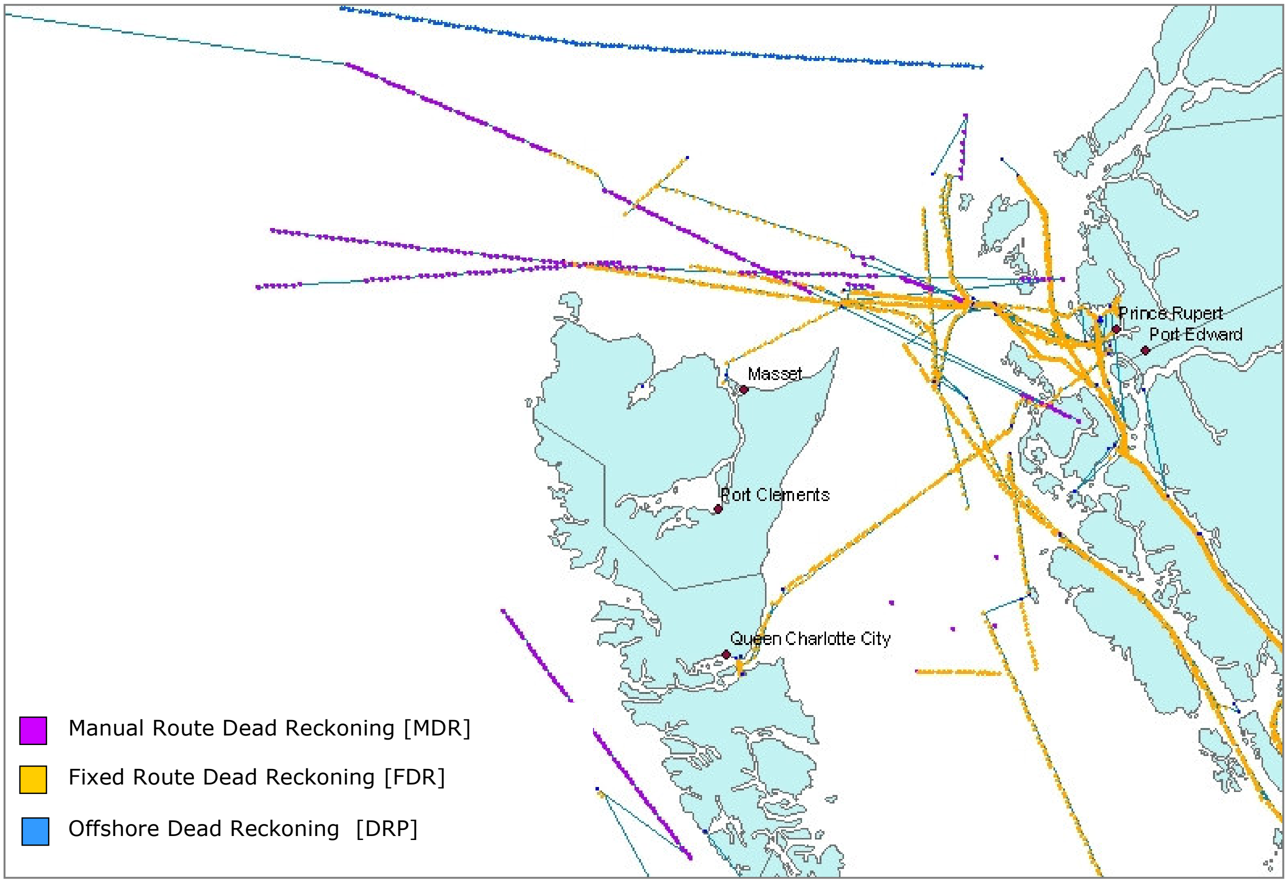


Figure 4.34: MDR->FDR changing

4.5 Data cleaning algorithms

In order to provide a clean database for further tasks, namely the visualization, the data need to be cleaned from the detected errors according to the main issues discussed with the project leaders (compare chapter 2). Different steps are necessary to spot and remove – or fix – the errors described in detail in the previous chapter 4.4. The work frame for the data cleaning is set to one day for efficiency and processing speed reasons (the name of the available day files is TKYYYYMMDD.dbf).

4.5.1 TASK 1: Detecting and removing absolutely wrong entries:

Recordings that are not provided with the proper date (that is the date of the file ± one day) should be erased from the database.

Algorithm: *LAST_UDDTG < YYYYMMD(D-1)0000* ***-> delete!***
LAST_UDDTG > YYYYMMD(D+1)0000 ***-> delete!***

4.5.2 TASK 2: Removing positions outside the considered perimeter:

Entries, which don't have a reasonable latitude and longitude for the area under investigation, should be deleted from the file (especially 0/0 positions).

Algorithm: *POS_LAT < 20 degrees North* ***-> delete!***
*POS_LAT > 65 degrees North****-> delete!***
POS_LONG < 100 degrees West ***-> delete!***
POS_LONG > 180 degrees West ***-> delete!***
(these boundaries include all tracked data)

Depending on the expectations of the user (mainly the Canadian Coast Guard) the cutout can be scaled down to a smaller area covering the northern part of the United States (Washington) and the whole west coast of British Columbia. In that case the boundaries would be the following:

Algorithm: *POS_LAT < 45 degrees North* ***-> delete!***
*POS_LAT > 55 degrees North****-> delete!***
POS_LONG < 120 degrees West ***-> delete!***
POS_LONG > 140 degrees West ***-> delete!***

4.5.3 **TASK 3**: Deleting multiple recordings:

If there is more than one record for the same day-time-group and the same vessel (Name and ID), all but one should be removed.

Algorithm: *Group by LAST_UDDTG and VSL_ID*

CountOfVSL_ID > 1 ***-> delete!***

4.5.4 **TASK 4:** Removing inaccurate positions:

4.1: Manual recorded positions

Due to the fact that all the points tracked with "Manual Plots" [POS_SRC=MAN] are highly inaccurate and responsible for confusing routes, they are entirely deleted from the database. Trips consisting of "Manual Plots" positions only are exempt from removing to secure the traffic information.

Algorithm:

A. Count how many different positions sources exist for each VSL_ID (cross tab query: CountOf[POS_SRC])
B. Write down all the VSL_IDs, where CountOf[ADR]=CountOf[AIS]=CountOf[ANC]=CountOf[DRP]= CountOf[FDR]=CountOf[FIX]=CountOf[MDR]=CountOf[RDR]= CountOf[SAT]**=0 and MAN > 0** [VSL_ID_MANonly]
C. *Where VSL_ID ≠ VSL_ID_MANonly:* *[POS_SRC] = MAN* ***-> delete!***

4.2: Impossible positions within a unique trip

For unknown reasons isolated vessel trips are recorded that obviously cannot be possible, because vessels change their positions for several hundred kilometers in just a few minutes. To secure an efficient data cleaning such evident positions should be removed from the database in an early stage. Vessels that "jump" for a big distance should therefore be recovered calculating the difference between sequent latitude and longitude positions within the same trip [VSL_ID]:

Algorithm: sort the database first by the Vessel ID **[VSL_ID]** and then by the recording time **[LAST_UDDTG]**;

calculate: **lat_dis** = abs($[POS\_LAT]_n$-$[POS\_LAT]_{n+1}$)

long_dis *= abs($[POS\_LONG]_n$-$[POS\_LONG]_{n+1}$)*

t_dif *= abs($[LAST\_UDDTG]_n$-$[LAST\_UDDTG]_{n+1}$)*

if ***lat_dis > 1*** *degree* ***or long_dis > 1*** *degree*

and ***t_dif < 60*** *min*

-> annotate VSL_ID and the relevant positions

If the positioning mode [POS_SRC] between the relevant points is alternating and each second record has the same position, it is a known "once in a while"-incident and the obvious wrong records can be deleted. If there is no evident regularity between the large "jumps", VSL_IDs should be annotated but the entries not deleted.

4.5.5 **TASK 5**: Repairing wrong time recording:

Vessels tracked by the American VCTS Station in Puget Sound (ID starting with 2003….) between 12 noon - 1 pm and 12 midnight – 1 am are provided with the wrong time (24.xx instead of 12.xx, resp. 12.zz instead of 00.zz).

Algorithm: *for all VSL_ID starting with* ***2003***
and *LAST_UDDTG YYYYMMDD**24**xx*
or *LAST_UDDTG YYYYMMDD**12**xx*
-> **LAST_UDDTG - 1200**

4.5.6 **TASK 6:** Detecting and fixing double tracking and trip overlaps:

Two different VCTS stations sometimes simultaneously track the same vessel. In order to have a useful database, trip overlays that are resulting in double-tracked positions must be erased. Different steps have to be undertaken to identify double-recorded positions:

A. Select the vessel by its written name
B. List all the different VSL_ID found for that vessel name and date
C. Find first and last recording for each trip (VSL_ID) and sort the beginning of the trips ascending
D. By calculating the time interval between two trips, overlaps can be found with negative time differences:
   $([MaxOfLAST\_UDDTG_{trip1}] - [MinOfLAST\_UDDTG_{trip2}]) < 0$ ***-> overlap!***
E. Marking overlaps and calculating their duration
F. Check if it concerns the same vessel, because sometimes vessel names are not unique. For that reason the temporal closest record from the second trip to the last entry in the first trip has to be found ("closeness in minutes"):
   Minimize $(abs([LAST\_UDDTG_{trip2}]-[MaxOfLAST\_UDDTG_{trip1}]))$
   Calculate, resp. approximate* the distance between these two points by using the flat distance formula from Pythagoras:

Y = *([POS_LAT$_{trip2}$]-[POS_LAT$_{trip1}$]) x 111km***

X = *([POS_LONG$_{trip2}$]-[POS_LONG$_{trip1}$]) x (71.7km+1.37 x (50-([POS_LAT$_{trip2}$]+[POS_LAT$_{trip1}$])/2)****

Distance (app.) = *sqrt(x^2+y^2)*

---

* Approximation is good enough (~20m) for distances < 20km and latitude less than 50 degrees
** 111km is roughly the equivalent to 1 degree of latitude anywhere between the equator and the poles
*** 71.7km is the equivalent to 1 degree of longitude at latitude 50 degrees and 1.37km is the increase for one degree in latitude between 40 and 50 degrees latitude.

Check if the calculated distance is possible, means that it is not longer than a fast vessel (~60ktns) can do in the time between the two positions ("closeness in minutes"): maximum 1.852 km per minute.

Possible distance = [closeness (min)] x 1.852 km

[possible distance] – [calculated distance] < 0 ***-> not the same vessel!***

G. Priority rules to remove one set of positions (same VSL_ID) from the database (if the points concern the same vessel):

-> removing points from a trip with ***no VSL_ID***

-> removing positions with ***always the same position***

-> removing positions from the ***temporal second trip***

4.5.7 **TASK 7**: Removing shifting between different position sources and VTS zones

7.1: ADR / DRP

If there is a change between the ADR and the DRP positioning mode within one trip, the locations usually shift over a large distance (up to 30 km). To eliminate these displacements, the points of the "older" source are shifted to connect well with the later positions:

Algorithm:

A. Find all VSL_ID's that have **ADR and DRP** position sources
B. Find the **minimal** and **maximal** [LAST_UDDTG] for each section with the same position source (attention: sometimes the position source can change more than once between ADR and DRP in during the same trip!).
C. Compare changing locations, calculate the time difference and find the **newer**, resp. "**younger**" record:

time_diff = FirstOf[LAST_UDDTG]$_{section2}$ - LastOf[LAST_UDDTG]$_{section1}$ ***> 0***

D. Calculate the direction between the first two points of the newer section:

dlat = $POS\_LAT(FirstOf[LAST\_UDDTG]_{section2}) - POS\_LAT(SecondOf[LAST\_UDDTG]_{section2})$

dlong = $POS\_LONG(FirstOf[LAST\_UDDTG]_{section2}) - POS\_LONG(SecondOf[LAST\_UDDTG]_{section2})$

alfa = *atan(dlong/dlat)*

E. Suppose that the "younger" recordings are more accurate and move the last location of the older section into a reasonable **distance** (time difference times speed) and **direction** (contrary to the course from the new section) to the first point of the newer section:

dist = *time_diff [min] * [SPEED]/60*

dist_Y [miles] = *distance*cos(alfa)*

dist_X [miles] = *distance*sin(alfa)*

dist_lat [degrees] = *(distance*cos(alfa))/70*

dist_long [degrees] = *(distance*sin(alfa))/45*

New location of LastOf[LAST_UDDTG]$_{section1}$:

if dlat > 0:

$POS\_LAT\_new = POS\_LAT(LastOF[LAST\_UDDTG]_{section1}) + dist\_lat$

$POS\_LONG\_new = POS\_LONG(LastOF[LAST\_UDDTG]_{section1}) + dist\_long$

if dlat < 0:

$POS\_LAT\_new = POS\_LAT(LastOF[LAST\_UDDTG]_{section1}) - dist\_lat$

$POS\_LONG\_new = POS\_LONG(LastOF[LAST\_UDDTG]_{section1}) - dist\_long$

F. Suppose that the new location of the last position of the older section is correct and shift **all the points from the previous section** for the deviation [ΔPOS_LAT] and [ΔPOS_LONG] between the new and the old location of the last point from the previous section:

$\mathbf{\Delta POS\_LAT} = POS\_LAT\_new(LastOf[LAST\_UDDTG]_{section1}) - POS\_LAT(LastOf[LAST\_UDDTG]_{section1})$

$\mathbf{\Delta POS\_LONG} = POS\_LONG\_new(LastOf[LAST\_UDDTG]_{section1}) - POS\_LONG(LastOf[LAST\_UDDTG]_{section1})$

New position of all the points of the previous section:

$\mathbf{POS\_LAT\_cor} = POS\_LAT(allOf[LAST\_UDDTG]_{section1}) + \Delta POS\_LAT$

$\mathbf{POS\_LONG\_cor} = POS\_LONG(allOf[LAST\_UDDTG]_{section1}) + \Delta POS\_LONG$

G. Change the position source of the new calculated positions to **ADR_cor**, resp. **DRP_cor**, that changing can be found again later.

7.2: FDR / RDR

The position source usually changes from "Fixed Route Dead Reckoning" to Radar crossing the boundary southbound between the two VTS zones Comox and Victoria. The transfer to Radar, resp. FDR happens not exactly between two recordings, but the sources alternate during a certain time period. This factor leads often to a zigzag course around the zone boundary. To clean the trips the RDR positions outside, resp. the FDR positions inside the Victoria zone can simply be deleted. The same zigzagging appears around the border between Victoria (RDR) and Vancouver (FDR) VTS zone. The same operation as described above is applied to eliminate deviating positions. To be independent from geographical information, like the digitized zoned boundaries in a GIS, a simplification to find the points inside a Victoria zone is used: the borderlines between applying RDR and FDR are simplified to a straight line that can be expressed numerical with the latitude and the longitude.

Line1 (VIC-VAN):	0.5*[POS_LONG]-[POS_LAT]	(=12.375)
Line2 (CMX-VIC):	[POS_LAT]+0.4765*[POS_LONG]	(=108.51)

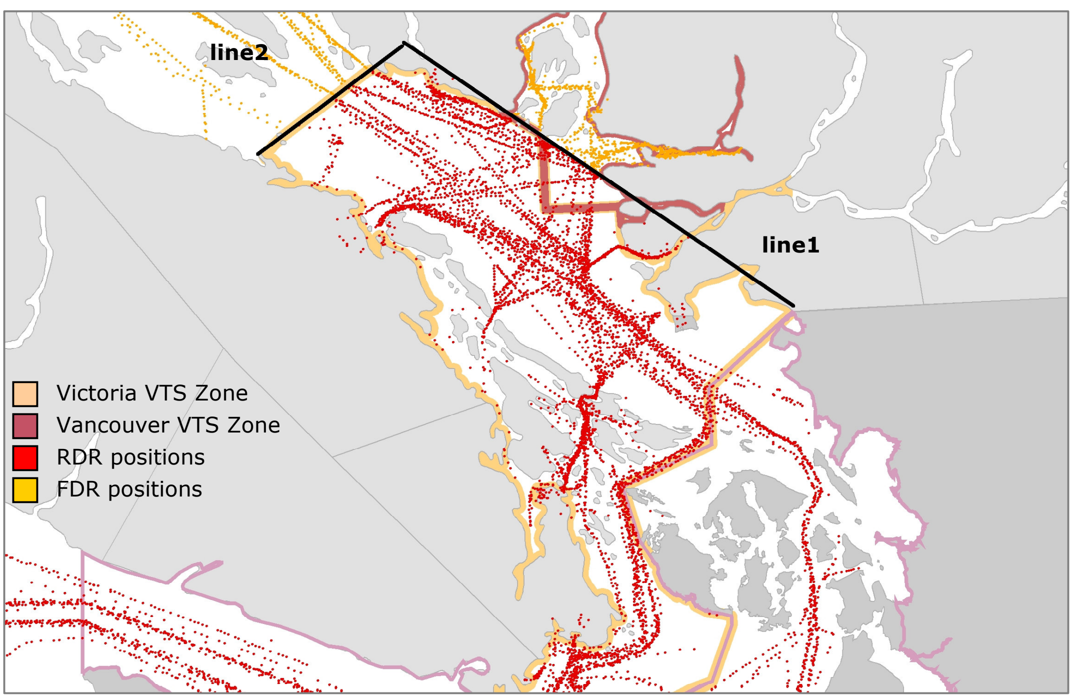


Figure 4.35: Lines for the simplified separation of different VTS zones (VIC, VAN, CMX)

Out of it the algorithm to remove deviating points looks as followed:

Algorithm1: to remove unwanted FDR positions inside Victoria zone:
line1 >= 12.375 and
line2 <= 108.51 and
[POS_SRC] = FDR ***-> delete!***

Algorithm2: to remove unwanted RDR positions outside Victoria zone:
line2 > 108.51 and
[POS_LONG] > 124.4 and
[POS_SRC] = RDR ***-> delete!***
and
line1 < 12.375 and
[POS_LONG] < 123.8
[POS_SRC] = RDR ***-> delete!***

7.3: FDR between VTS zone Comox and Prince Rupert

Vessels crossing the border between the VTS zones Prince Rupert and Comox are mostly positioned using "Fixed Route Dead Reckoning". The temporal first tracking station does not always finish the recording exactly at the boundary and the second station starts usually earlier, but they commonly use the same VSL_ID. This alternating positioning is responsible for large deviations around the changing area. To avoid zigzag courses all FDR positions recorded in Comox zone but labeled with Rupert zone in the database and vice versa are removed applying the following borderline:

Line3 (RUP-CMX): [POS_LAT]+0.2289*[POS_LONG] (=80.417)

Algorithm1: to remove "RUP-labeled" FDR positions in CMX zone
Line3 <= 80.417 and
[POS_LAT] > 50 and
[POS_SRC] = FDR and
[CVTS_ZONE] = RUP ***-> delete!***

Algorithm2: to remove "CMX-labeled" FDR positions in RUP zone
Line3 > 80.417 and
[POS_SRC] = FDR and
[CVTS_ZONE] = CMX ***-> delete!***

The application of these algorithms is not always sufficient to remove zigzagging because sequent positions can alternate between the two zones over the unequally recorded time. To smooth the route in the border crossing area, positions in a buffer around the borderline are selected; their average position is computed and used as a substitute for all the points in the perimeter.

Algorithm: select all records, where:
[POS_SRC] = FDR and
[POS_LAT]+0.2289*[POS_LONG] > 80.317 and
[POS_LAT]+0.2289*[POS_LONG] < 80.517
group by VSL_ID and recalculate:
*[M_LAST_UDDTG] = **MedianOf**[LAST_UDDTG]*
*[A_POS_LAT] = **AverageOf**[POS_LAT]*
*[A_POS_LONG] = **AverageOf**[POS_LONG]*
[POS_SRC] = FDR (remain)
[CVTS_ZONE] = "RUP-CMX"
*(for the remaining fields use **FirstOf**[])*

4.5.8 **TASK 8**: Detecting and annotating time gaps:

8.1: Inconsistent daily recording

Sometimes the tracking is not continuous during the whole day. To find large gaps in time calculate the difference in minutes between all the records sorted in time. Intervals of more than 6 minutes between two sequent entries could be evidence of a recording error.

Algorithm: *Sort the data according to the recording times [LAST_UDDTG] and compute the time difference [min] between each entry.*
*If the calculated interval is **> 6 minutes**, annotate the last record before and the first entry after the gap.*

8.1: Time gaps within unique trips

Inconsistent time recording can independently happen also within unique trips. To detect these errors the time intervals between the recordings of a single trip [VSL_ID] need to be calculated.

Algorithm: *Sort the data first according to the [VSL_ID] and second to the recording time and compute the time difference [min] between each entry.*
*If the calculated interval is **> 60 minutes**, annotate the last record before and the first entry after the gap.*

4.6 Data Cleaning Implementation

The following notes are originally written by David Cake, an M.Sc. GIS Analyst hired for the programming and the implementation of the above-defined data cleaning algorithms. The complete code can be found in appendix E.

4.6.1 Platform and structure

The data cleaning application is developed in MS Access (2000). A MCTS data file for a given day is loaded into a single, "flat" table for processing. For most tasks, it makes use of Structured Query Language (SQL) to update records according to conditions in the data, taking advantage of the query optimization in the Access database engine. For more complex processing, such as where patterns are examined in the data, record-by-record analysis is performed using Visual Basic for Applications (VBA), which forms a part of the Access development environment.

Resultant datasets are stored directly in the Access MDB file as new tables, which can be viewed graphically in ArcMap GIS software without translation. The table structure of the output data is a slightly modified version of the input table. The following additional fields were added (no changes are made to the source DBF file):

- DTG: Date datatype version of LAST_UDDTG, used extensively for internal processing
- DTG_NUM: Numeric (DOUBLE) version of LAST_UDDTG, necessary for post-processing
- CleanupNote: Annotation describing noteworthy characteristics of a data record

4.6.2 Deviations from documented algorithms

The following discussion describes deviations to the Data Cleaning Algorithms defined in chapter 4.5; the numeration refers to tasks defined in that section.

TASK 1 Acceptable records are timestamped from noon the day before the file date, to noon the day after the file date. All other records are deleted.

TASK 2 User-defined extents allow these values to be modified as necessary.

TASK 3 (Clarification) (LAST_UDDTG, VSL_ID, NAME) combinations must be unique.

TASK 4.1 Additionally, log all VSL_ID's which have POS_SRC = MAN only to a new table. This process was moved such that it occurs before task 3.

4.2 Annotates points, which are isolated locational errors. Deletes points where every second point is exactly duplicated.

TASK 5 As documented.

TASK 6 Definition of Spatial Overlap modified: if POS_SRC is the same for two temporally overlapping trips, use the documented possible distance (1.852 x minutes). If POS_SRC is different, use a static 20 km.

TASK 7.1 Only shift an ADR block if it is the first POS_SRC block in a given trip and immediately prior to a DRP block. Additionally, annotate those records with POS_SRC = ADR which are not the first POS_SRC block in a trip.

7.2 Algorithm 2 should read:

line1 < 12.375 and POS_LAT > 49.2 and POS_LONG < 123.8 or
line2 > 108.51 and POS_LONG <124.4
and POS_SRC=RDR -> delete!

7.3: As documented.

TASK 8.1 Annotate the records immediately before and after the gap with the length of the gap (in minutes).

8.2 Annotate the records immediately before and after the gap with the length of the gap (in minutes). Additionally, allow the user to exclude ferries, tugs and cruise ships from the search for gaps in logging.

4.6.3 Additional processing

Emerging questions during the implementation process and the first test runs resulted in some additional tasks to be implemented in the data cleaning; namely they are:

- Create and populate numeric and Date versions of the LAST_UDDTG field
- Where VSL_ID is null and NAME is numeric, set VSL_ID = NAME, and NAME to 'Undefined'.
- Where VSL_ID is null and NAME is not Null and not numeric, set VSL_ID = "ID_" & [NAME].
- Any remaining records with a null VSL_ID are deleted.
- Convert all POS_LONG values to negative sign.

The final application is user friendly and easy to operate (the interface is displayed in Figure 4.36), despite the fact that it has still a few bugs that cannot be fixed efficiently due to the wide variety of possible sources of error. However, in the majority of cases the program can be applied to a single day file without generating runtime errors; the sparsely exceptions can mostly be prepared manually prior to the execution to meet the programs requirements.

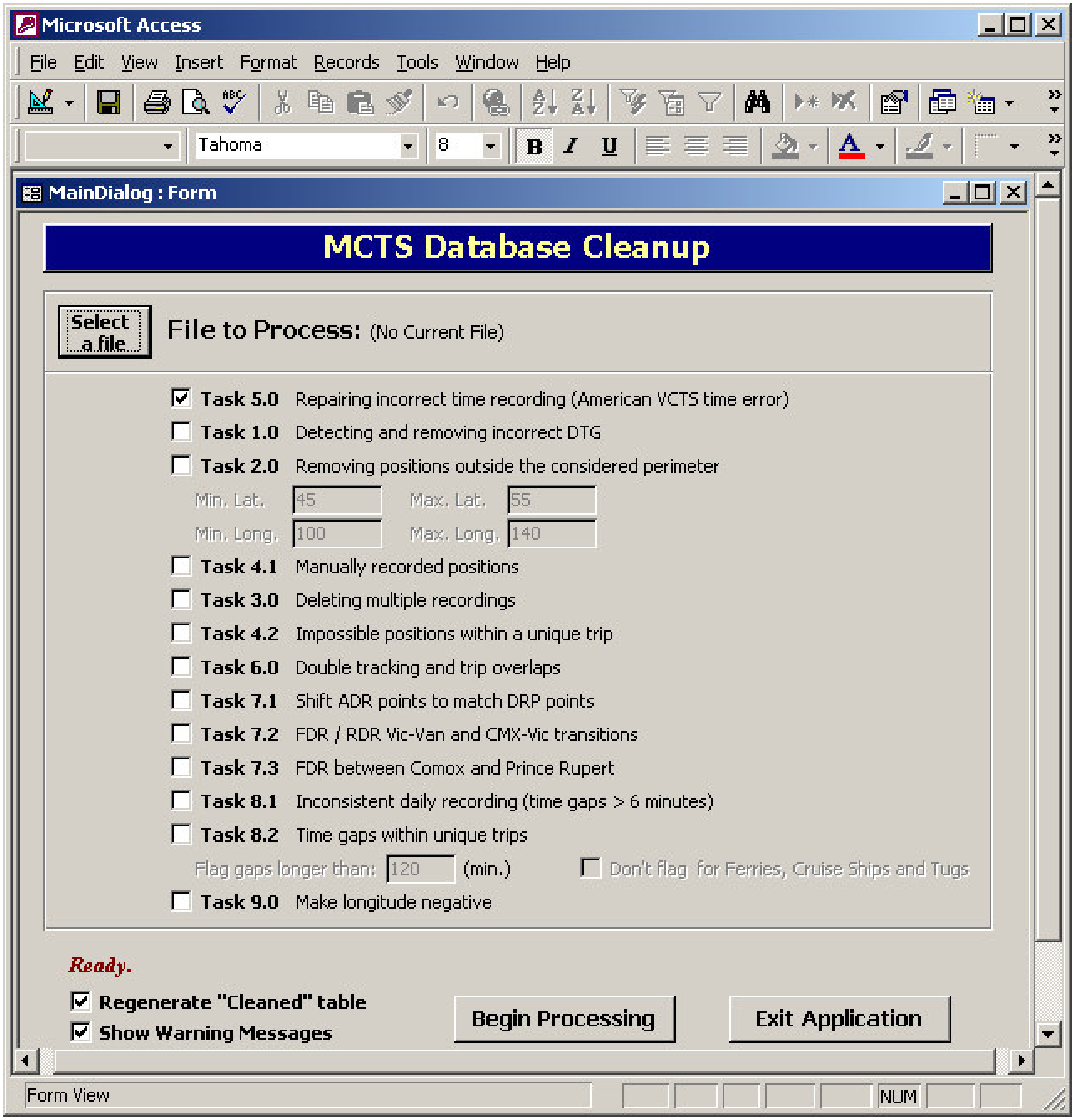


Figure 4.36: User interface of the developed data cleaning application

4.7 Data Conversion

The translation into a data format that can be opened in a GIS is not necessary anymore since the table generated in Access with the cleaned data records can be imported into ArcMap without further preparation steps (see chapter 7.2.4). From there the layer can be exported to all prevalent geographic formats, for example as a shape file that can later be used in MARIS.

VISUALIZATION OPTIONS – EXPECTATIONS AND PROSPECTS 5

5.1 General Principles of Visualization[2]

Many people believe visualization refers to the ability of computer systems to process data and display it pictorially. However, visualization does not mean the computer's ability to generate graphs and maps from data, but rather the human's capacity to "see" the meaning of the data with respects to their needs and purposes. "Visualization" therefore occurs in the user's head. What is displayed on the screen may be pictures, text or some mixture; the computer output may be auditory or tactile, supporting the human's understanding of the import of the data. The model below (known for historical reasons as "the IST-05 Reference Model") shows conceptually how the various building blocks of the visualization process relate to each other.

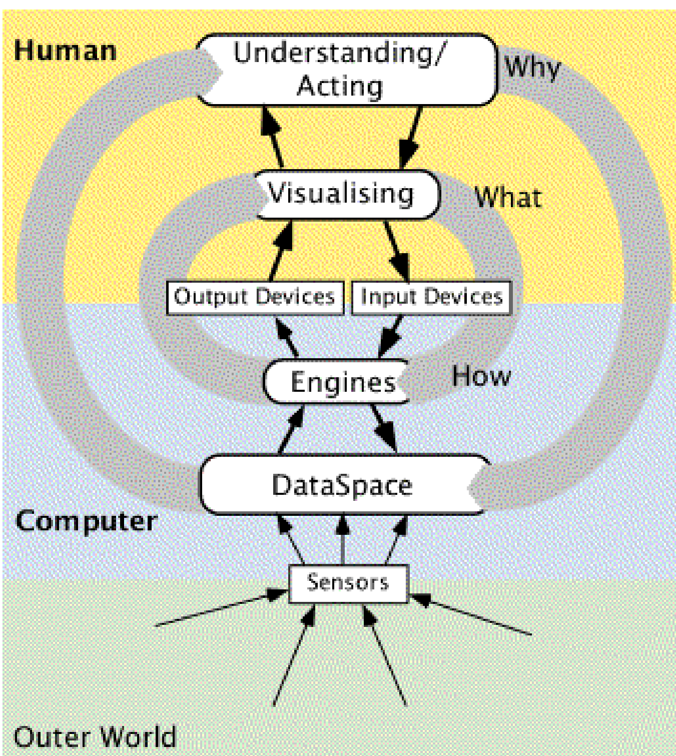


Figure 5.1: IST-05 Reference Model

It is assumed that the data in the data space are relevant to the task of the user. The data may have been entered explicitly by the user or some other person, or may have been acquired autonomously. Whatever the nature of the data, the outer loop shows the user creating an understanding and acting to change the content or possibly even the structure of the data space.

The user does not act directly on the data space, nor does he/she understand it directly. The Reference Model shows that understanding comes through visualizing. However, it is recognized that visualizing is only one means toward understanding, logical analysis being another. Logical

[2] Remarks in this chapter are based on a paper issued by the NATO Research Task Group IST-021/RTG-007 on the *"Multimedia Visualization of Massive Military Datasets"* (May 2001).

analysis and visualizing mutually support each other, the combination being more powerful than either alone. However, the Reference Model is concerned only with the visualization process. Logical analysis is a necessary but excluded part of what the user does to achieve understanding.

As an intermediary on the computer side, the Reference Model incorporates the concept of "engines". Engines interact with the data space on the one hand, and with the input-output systems on the other. The engines select data from the data space, perform algorithmic operations on the selected data, and perhaps insert data into the data space or modify data that are already there. On the other side, the engines organize the selected and manipulated data for presentation, mapping them, for example, into locations, colors, and transparencies in a 3-D space, or into textual descriptions or complex auditory signals. The user communicates with the engines to affect the data selection, the data manipulation, and the preparation of the presentation. The actual interaction between the computer and the user happens through physical devices, of which there are many. Output devices include display screens, holographic systems, immersive 3-D systems, headphones and loudspeakers, haptic devices that affect the user's tactile exploration of the data world, and so forth. Input devices include keyboards and speech recognizers, mice and wands, gloves and cameras (cameras can be used to examine the user's face for detecting eye movements or even indications of emotional responses).

5.2 Established Traffic Visualization Strategies

Innumerable graphic applications have been developed for ground transportation and the aviation sector but the maritime environment represents a relatively new field for data visualization. Needs for traffic display in the marine context arise for the same reasons as in other functional areas: traffic control, traffic safety, traffic management and traffic analysis to mention the most important. In this chapter the search for existing visualization concepts is described.

A search of the Main Library Catalogue at the University of Victoria (maps and books, keywords: marine traffic visualization/visualisation) results in just a couple of publications describing visualization approaches mainly for computer and Internet networks and world wide communication traffic. A browse through various international maps regarding transportation and traffic flows reveals no new ideas, only the commonly used line and width presentation. Search engines on the World Wide Web fed with the same keywords output just a few helpful hints to published papers and promising projects. Most links point to navigation aid products of software companies working within the marine context. However the query reveals some interesting ongoing research programs, but only a few mapping applications have been implemented that address marine traffic visualization needs. Efforts have been undertaken mainly in national government agencies and GIS developing companies (e.g. NOAA – U. S. National Oceanic and Atmospheric Administration, the National Maritime Research Institute of Japan or the ArcGIS Marine Data Model By ESRI). In contrast the navigational aspect of marine traffic is well covered with supporting graphical software called "Electronic Chart Display and Information Systems" (ECDIS), originally developed in Europe. ECDIS is an emerging technology that has the potential to support maritime piloting and increase safety. More than a graphics display, ECDIS is a real-time navigation system that combines charting, positioning, sensor information and textual data into a readily useful operational tool. An ECDIS continuously determines a vessel's position in relation to land, charted objects and unseen hazards. ECDIS has also been tested in Canada's waters in the years 1995-1996, the trial results indicate that the conceptual design of the ECDIS offers a number of useful features for navigation in ice and could substantially improve navigation performance [details can be found on the project homepage: www.tc.gc.ca/tdc/projects/marine/b/8817.htm]. Plans to use the collected data later for marine traffic visualization have apparently not been made.

Consequently, the search for suggestions, solutions and examples from current marine traffic visualization projects was unsuccessful. The reason for the lack of cartographic related documents might be the fact that cartographic publishers often miss the deadlines for the submission of papers and are therefore dropped by the citation index.

Adopting unmodified visualization approaches from established sectors would not be effective because there are major differences among the different fields of application. While ground transportation (vehicles and trains) is restricted to a road (or rail) network, marine vessels are rarely bounded to specific routes unless they are in a region of high traffic density (mainly around major ports), a sensitive environment requiring special operating procedures or an area where other restrictions apply (e.g. where all movements have to be conducted within designated shipping lanes). The primary difference between marine traffic and the aviation sector is the missing third dimension; there is no significant need to represent a third axis (altitude, height, elevation) when visualizing marine traffic on the oceans surface. However the "fourth dimension" representing time, particularly changes and movements in time, is of high interest in each application field. Despite these major differences, basic principles and concepts of common traffic visualization strategies can be applied in the marine environment.

For the above reasons, visualization approaches suitable for marine traffic have to be first defined or at least modified from well-established applications in other fields. The following section (chapter 5.3) describes an attempt to evaluate user needs in order to determine useful visualization techniques for the available database. Results should not be considered universally valid for the marine sector but rather applicable to the MCTS database examined in this thesis.

5.3 User Needs

5.3.1 Potential map users

To outline basic concepts and adapt approaches to visualizing the existing database, the needs of potential users must be known. The user requirements and their varying levels of expertise should be captured in detail and implemented as desired. The task of the potential user affects the method of visualization needed; display requirements are different for analysis based on graphical presentation than for visualizing or imparting information. Analysis, for instance, is eased by an uncluttered presentation that allows the focal objects to stand out clearly illustrating their relationship, whereas information brokering generally requires copious context.

The producer and owner of the data, the *Marine Communications and Traffic Services* (MCTS) Division of the Canadian Coast Guard, refers to the following groups as their clients: Commercial Shipping; Pilots; Fishermen; Pleasure Boaters; Ports; Agents; Customs, Immigration; Environment Canada; Foreign Affairs; Agriculture; RCMP; Transportation Safety Board; National Defence; General Public; Inland Fishing Industry and Tourism Industry (source: www.ccg-gcc.gc.ca/mcts-sctm/clients_e.htm). Obviously each of the numerous beneficiaries has specific interests, resp. tasks in making use of the MCTS services: the commercial sector and the industry are primarily interested in economic aspects; the Canadian agencies care about environmental protection and the safety, while the public is mainly involved through recreational boating (please see the table shown in figure 5.2 from the same homepage). The plethora of MCTS clients means that there is a large number of potential map users including the Canadian Coast Guard itself, industry, government, researchers, and others. It was decided to interview a CCG employee, as a representative of the most important user group to gain input about their expectations and requirements of the visualization. Interviewing other potential user groups would also be desirable but is difficult to achieve in reality due to time limitations and data confidentiality. It is practically impossible due to confidentially restraints to ask people outside the project environment about their interests with respects to visualizing the specific database. An alternative approach would be to question eligible groups about their expectations of marine traffic visualization in general without referring to the MCTS database. However this procedure is less effective because normally people are not willing to exert effort without obvious benefit. Thus, given the short time frame available, this approach was dismissed. Nevertheless it was decided to include additional people within the project's academical scope (professors and students) as potential map users to obtain more than one opinion.

Clients	Distress Safety	Screening	Regulating	Managing Information
Commercial Shipping *	x	x	x	x
Pilots	x	x	x	x
Fishermen	x		x	x
Pleasure boaters	x		x	x
Ports	x	x	x	x
Agents		x		x
Customs				x
Immigration				x
Environment Canada				x
Foreign Affairs		x		x
Agriculture		x		x
RCMP	x	x		x
TSB (Transportation Safety Board				x
DND (National Defence)	x	x	x	x
General Public **		x	x	x
Inland Fishing Industry**			x	
Tourism Industry**		x	x	

*including domestic and foreign carriers, and government vessels
**to be considered as beneficiaries

Figure 5.2: Table of MCTS' clients and their interests

5.3.2 The questionnaire

Input is sought from potential users by asking questions from a prepared questionnaire consisting of four parts. The first part is a general section containing basic questions about the desired geographical coverage, the most useful scale, classification schemes, map elements and other cartographic features. The second section refers to the base map and asks specific questions about the background displays, the coordinate system and the projection. The third part considers temporal aspects such as time frame and animation possibilities. The first three parts are composed of precise questions to gain a comparative overview of various opinions. In the last section the respondent is invited to present his or her own ideas and perceptions unconstrained by concrete questions. The complete questionnaire can be found in appendix F.

5.3.3 Questioned persons

One of the first interviews conducted was with Grant McGowan, the Information Systems Engineer responsible for the VTOSS system, during a visit to the Vancouver MCTS center. In addition to stating his own expectations he referred the researchers to the Coast Guard employees in the Victoria MCTS center who are dealing with management aspects relating to the upcoming rationalization within Marine Communication and Traffic Services. He offered to establish the first contact and to explain the purpose and potential benefits of the visualization project. However, as summertime is the busiest season for the Coast Guard and the time frame for the user needs assessment is short, it was decided to approach the Victoria Coast Guard officers directly by sending an email to John Palliser, Superintendent Search and Rescue at the Rescue Co-ordination Center in Victoria. He is the executive officer representing the Canadian Coast Guard Pacific Region within this project. He forwarded the email to a MCTS-related officer at the Institute of Ocean Sciences near Sidney, north of Victoria. A meeting to discuss visualization strategies and to answer the questionnaire was arranged for July 31 with Brian Bain, a MCTS officer under the cooperation with David Heap, superintendent of the Victoria MCTS center.

By chance it was also possible to question a vessel pilot from the Pacific Pilotage Authority at the Victoria Ogden Point Station.

In addition, three members of the research team, representing the western part of the overall project "Marine Activity Geomatics and Risk Analysis in the Coastal Zone" were questioned about their expectations. These researchers include Dr. P. Keller, Professor at the UVic Department of Geography and leading member of the GEOIDE project team; Cindy Marven, UVic M. Sc. Candidate and GEOIDE researcher and Marie-Andrée Levesque, GEOIDE internship student from Laval University Quebec and occasional auxiliary of the Canadian Coast Guard Quebec Region.

5.3.4 Interview results: Overview

It became apparent that questioned personal from outside the academical environment and management level have one common response. These respondents are accustomed to using the MCTS data in real-time during their work as traffic controllers, pilots or any other positions related to marine traffic and have not considered the possible uses of the database outside their daily work operations. However when it was mentioned that the data are available and in the preparation process to be visualized on maps their first responses were the same. While they would not envision a possible application in their own surroundings, they would imagine that their supervisors would be interested in having traffic density maps for various reasons. The pilotage dispatcher could identify the busiest times to plan resources accordingly. The manager would know the busiest MCTS center and obtain support for rationalization processes. Application options at the planning levels would be numerous and obvious in their opinions. Garnering ideas or expectations about marine traffic visualization from operational employees proved difficult and perhaps irrelevant.

The similarity of answers among the researchers is also remarkable, and can be ascribed to the similar education and work environment. Members of the project team are professionals accustomed to working with geospatial data and its digital or analog representation. They know the basic principles and cartographic requirements of visualization. However due to this connection they can lose overall perspective of the subject because they are not objective enough.

Brian Bain is employed as an officer at the Victoria MCTS center, not involved in real-time traffic control operations but on a more strategic planning level. When it was emphasized that the visualization is not meant for real-time purposes but rather for subsequent traffic analysis, there was a great interest expressed in having some graphical representations for these purposes. Apparently there are no charts displaying post-recording visualization of commercial shipping data along Canada's West Coast, at least not in the Coast Guard environment. In a nutshell (more detailed results are listed in the following subchapter) the Coast Guard is highly interested in obtaining generalized overview maps of general traffic flows as well as accurate large-scale cutouts from areas of special interest. Analyzing different overlaps between marine traffic and other marine related data is essential in order to meet their controlling and planning tasks.

Due to these different work and research environments it is thought extremely important to get answers and ideas from all the described groups to ensure a complete survey of the users needs.

5.3.5 Interview results: General aspects

This section describes the results of the first part of the questionnaire dealing with general aspects of the maps.

Researchers would like to see one integrative overview map encompassing all of Canada's West Coast. They are also interested in having multiple scale cutouts for areas of special interests such as high traffic density, sensitive environments, port gateways, etc. The detailed sub-maps can cover as little as one by one nautical miles (scale around 1:10'000). The scale should be variable throughout the area under investigation and refer to the mapped region with distinctions made between the open sea and inshore waters. Another concept mentioned is to cover areas identical to the operational regions used by the Coast Guard. These territories are mostly circular around a CCG base; the radius depends on the number of boats at the station and their size. Therefore it would be necessary to know the locations (latitude and longitude positions) and the radius to map the particular regions; the Canadian Coast Guard should be able to provide this information. Suggestions about the types of vessel shown on the map share a common theme that all available data should be presented using a reasonable classification system. Above all, the ferries should be presented apart due to their different behavior (crossing the main traffic) and the known schedules and routes. Other proposals were to separate vessels carrying dangerous cargo, recreational boats, tugs, fishing and navy vessels - in short, a classification based on the type of use is implied. Additionally all the researchers would be interested in having details about the vessel's home territory, revealing the frequency the vessels sail within Canadian waters, and the degree of familiarity with the region. In addition the age of the vessel and the number of people on board would be of interest for risk analysis purposes. Opinions about the presentation of the vessel movements diverge greatly; one of the questioned persons would prefer simply the point positions, while others like to have tracks, either lines exclusively or in combination with sporadic point locations. The reason for the dislike of route presentation is its complexity for a general overview. Small-scale maps become particularly confusing with an increasing number of lines and have no obvious advantages for modeling. The reason for mapping a combination of lines and points is to provide clues about the speed of the vessel. A regularly indicated point position (e.g. each hour) would show the unequal traveling speeds for the different vessel types. Presentation options are limited for both points and tracks; other than altering the size and form of the point symbol, respectively the width of the lines and the color, there are no other options. A more advanced approach would involve the generation of a traffic density grid, derived from the point positions and an existing grid of a certain cell size. But again, display possibilities are limited; the only option would be to alter the color range. However, it would be possible to show more data in one clearly arranged presentation by merging a longer time period into one grid. With respect to accuracy and precision there is one statement which consistently emerges: the more precise the better, recognizing that the displayed precision of course, depends on the map scale. The same is true for data generalization; completeness is fundamental but it should be consistent with the scale and the cutouts. Thinning out the data is a conceivable option in order to keep the map concise. For modeling purposes the data should be as complete and close to the original form as possible.

The Coast Guard is highly interested in both generalized overview maps of the entire coast and accurate cutouts of particular regions at a large scale. Above all they would like to see generalized traffic flows in the inside passage, meaning inside waters plus 50 nautical miles off the coast. To analyze incoming traffic from the open ocean, they prefer a geographical coverage of 200 nautical miles outside the West Coast of Vancouver. For highly accurate sector maps for bounded areas, they would like to see a representation of regions with special circumstances like "Active Pass", a busy but narrow passage between two southern Gulf Islands, or "Turn Point" where special operations procedures are in effect. Of course the CCG is interested in having information about all kinds of vessels in the maps and suggests the following classification system (more details on the classification scheme can be found in chapter 4.4.4): Tankers; Freighters; Containerships; Tugs & Barges; Ferries (Passenger and Vehicles); Rail Ferries/Ships; Fishing Vessels; Cruise Ships and Miscellaneous. In addition they would appreciate representation of pleasure craft as a separate class when the data are available in the future. Besides the type of vessels, other attributes are not required; though the home territory, resp. the flag of the fishing vessel (United States or Canada) could be interesting for their analysis. The visualization mode is not that important for them; they could make use of both point and polyline presentation, depending on what makes more sense in a cartographical context. Additionally, the visualization of particular vessel positions and tracks of great interest are established shipping routes that are not officially mandatory but are followed by most of the captains. Having the data from a long enough time period it should not be to difficult to derive the frequently used preferred vessel routes and to display them on a macro point of view. Interest in accuracy is secondary to the requested general traffic flow and shipping routes maps but naturally a basic necessity for the large-scale cutout presentations. Consequently it would be possible to use a generalized dataset for the overall display of traffic flows and routes while providing the complete detailed data for the cutout regions.

5.3.6 Interview results: Base map

The research team's expectations of the graphical appearance of the background indicate that they would prefer the maps to look similar to the well-established nautical and marine navigational charts provided by the Canadian Hydrographic Service. Thus, in addition to the common land-based map layers (coastlines and land, lakes and rivers, roads and transportation networks, place names, mountains, boundaries etc.) all existing marine related data should be included in the maps. The most important chart layers would be the depth indicated in numbers (bathymetry), hydrography, the position of navigational aids (e.g. buoys), navigational hazards, shipping lanes, VTS zones and so on. These data exist in a digital format but are quite expensive to obtain because they are distributed by a private company [Nautical Data International, NDI: www.digitalocean.ca]. Also, it would be useful to have the locations of marinas and boat launches as well as the Search and Rescue incident data. These layers are available due to work completed previously for the ongoing Marine Geomatics Project and the CCG. Despite the large volume of background information, the maps need to be clear and concise. Considerations pertaining to the selection of the appropriate coordinate system (datum) and projection lead to the same conclusions. The diversity of groups using the maps indicate that the datum and the projection should be flexible. With paper maps an appropriate system has to be chosen; the lat/long presentation and Mercator projection is favored because it is the most common projection used for nautical charts. Other possibilities might include the official BC Albers Standard Projection based on the North American Datum 1983 (NAD83) or the Gnomonic Projection.

Base map requirements are almost the same from the CCG's point of view: they would also recommend that the background of the marine traffic maps look similar to the official nautical charts. The only difference to the researchers is that the major towns, resp. cities are unnecessary because the MCTS officers can orient themselves well in the area without the support of place names. The only required symbols and names are those for the ports. Everything else not directly connected to shipping information (mountains, roads, etc.) can be eliminated for their purposes. In exchange, they would like to include all the marine-related layers described previously plus the tanker exclusion zone off Canada's West Coast (TEZ), special operation areas (SOAs), Canadian Forces Maritime Experimental and Test Ranges Exercise Area W.G. and Ocean Disposal Sites. They are interested in seeing a combined view of the marine traffic and existing datasets from the ongoing "Marine Geomatics" project, mainly the boat launches, the marinas, and the Search and Rescue (SAR) incidents. Their favored coordinate and projection system is the same as applied in the nautical charts (NAD27 or NAD83 Mercator), which is likewise used in their own operation systems that are based on the CHS maps (VTOSS and Radar).

5.3.7 Interview results: Temporal considerations

The following description refers to the time frame and temporal variance of the visualization. The researchers are naturally interested in seeing different time periods, ranging from hourly presentations up to the display of an entire year. They would also prefer a dynamic to a static visualization incorporating the ability to interactively select the time frame, or animated displays. These needs can be implemented in digital maps quite easily, but since this thesis's main interest is in paper maps, a solution for presenting changing time periods is required. The display of time series data is an adequate way for showing temporal variations on paper maps. The time frame for individual maps can be as short as an hour, or as long as a season. Temporal views also helpful for comparative studies would be to show the traffic differences between day and night or between different months. The presentation of a single month is of interest to the project researchers because most of the other marine data are analyzed on a monthly basis. An animated presentation would be necessary to display vessel traffic similar to a real-time visual marine traffic control system (like an air traffic control system) and would be used to detect dangerous adjacencies and derive so-called hot spots, meaning hazardous areas with many near-incidents. For the historical data analysis (used for medium and long-term planning) an animated system is not as useful. Interactivity is warranted in each digital visualization system.

The CCG would like almost all possible time frames from hourly to annual visualizations for their objectives. They also highlight the benefits of seeing the differences between night and day traffic during the summer peak season. Because the CCG is accomplishing its own investigations hourly, daily, monthly or annually they would be able to make the comparisons on the same temporal basis. Like the researchers, they would prefer to get mapped time series instead of a static representation that would show variations between different snapshots in time.

5.3.8 Interview results: Further ideas

The last interview question inquired about ideas for other unusual, useful presentation approaches. As mentioned earlier, it seems to be quite difficult for people connected to geospatial science to think outside known boundaries. The only approach suggested is to consider ways of predicting visualization for future traffic loads. In this respect, marine traffic is similar to other major transportation sectors like air traffic or road/rail networks. Overall, real-time map-based traffic control systems have been in use for a long time in these application fields. The work undertaken to explore visualization strategies for marine traffic data in combination with existing ECDIS (see chapter 5.2) implies the potential to build such a visual system. It should be possible to display the data of interest not only in real-time but also on a traffic map. Another suggestion is to include the third dimension into the visual display, representing the water depth or - less familiar - traffic density (more density, higher value).

The most helpful approach for the CCG is the combined display of the marine traffic with all kinds of other marine related information, above all the SAR incidents. In these overlap maps they would see the changes of occurrence levels of particular interest since the MCTS and the SAR are working together more closely. Furthermore, they are interested in having maps that portray the traffic densities around the five existing MCTS centers to gain knowledge about future activities and whether or not to incorporate particular centers.

The representation of natural resources that have an effect on the marine traffic is not an approach mentioned in the interviews but nevertheless, is interesting from the author's view and also mentioned in relevant literature [Numano, M et al. 2001]. The display of marine traffic in combination with the two major factors for vessel operations, tidal currents and wind conditions, could provide interesting information, especially for risk analysis purposes. There are various graphic possibilities to represent different environmental factors.

5.4 Traffic Visualization Approaches for Paper Maps

Based on the user needs assessment described in the previous chapter the visualization approaches for paper maps are illustrated in this chapter. Each concern described in the following subchapters is derived from the questioning or derived from the author's own considerations. It is intended as a summary and composite of the above-mentioned notions and considerations. Ideas and concepts of digital representation and real-time information systems are excluded in this listing due to the inability to produce digital maps during this thesis. They are discussed conceptually in a later chapter.
As mentioned earlier, the findings cannot be taken as universally valid for marine applications. Because the user needs evaluation is based on the MCTS database the results are mainly applicable to these specific data and region. However, the basic ideas might be relevant for other visualization efforts within the marine context.

5.4.1 Geographical coverage and scale

The desired geographical coverage consists of an overview presentation of Canada's entire West Coast and cutouts of smaller areas of interest. The favored coverage is not farther than maximal 200 nautical miles off the coast of Vancouver Island. Therefore, the scale is variable for each cutout and depends on the size of the mapped region and the specific content.

5.4.2 Base map

The interview results highlight the expectations concerning the base map that indicate a preference for a graphical presentation similar to the Canadian Hydrographic Service Nautical Charts. The content of the layers should refer to the same source and additionally, include available marine related data produced or processed for the overall project or obtained from the Canadian Coast Guards. The favored datum is a latitude and longitude coordinate system (NAD83) with a Mercator projection.

5.4.3 Time frame

A definitive statement about the desired time frame cannot be made because there are innumerable possibilities and needs. But changes over time should be represented in time series, emphasizing the traffic differences between particular points or segments of time (e.g. day/night, summer/winter). Presentations can be based on hourly, daily or monthly periods; annual analysis cannot be made because the available data time frame is to short.

5.4.4 Point locations

One strategy is to show the vessel movements using their precise recorded positions. The time frame is arbitrary; almost every period can be displayed. This approach results in map covered with point locations; the symbol of the point and its size and color can be varied to represent different types of vessel. The dataset can be complete for large-scale maps or thinned out for generalization purposes at a lower scale.

5.4.5 Track presentation

Another approach is to generate tracks from consecutive points of a unique vessel trip. An appropriate time frame has to be chosen for this type of presentation, e.g. all the routes of one day. The scale of these maps should not be too small in areas of high traffic density (e.g. around ports) to avoid confusing displays. In regions of less traffic or more consistent routes (e.g. when approaching from the open sea) the route presentation can also be useful over small scales. Again color and the width of the lines are the variables in the graphic representation of different vessel types.

5.4.6 General traffic flows

Besides generating the real tracks of the vessels it is possible to derive favored and established routes frequently used by captains. Therefore all point locations of a large time period have to be displayed in an overview map and the routes can be extracted and defined visually. This display approach is not for accurate analysis but rather for a general overview of major traffic flows.

5.4.7 Traffic densities

A traffic density grid can be calculated from all the point locations of a particular time period. Grids covering Canada's West Coast are available for this project with different cell sizes. The selected mesh depends on the expansion of the mapped region according to the scale. For presentation purposes the color range for the traffic density can be varied. Also the displayed region can be varied, ranging between one VTS zone and the entire West Coast.

5.4.8 Hot spots

Another interesting display method in order to analyze the data is the presentation of hazardous hot spots, referring to areas with frequent dangerous adjacencies. For that purpose pre-processing of the data is necessary, either with a specific developed program or through a previously mentioned animated display of the traffic. A wide variety of cartographic symbols and techniques are available to mark the hot spots and their characteristics.

5.4.9 Overlaps with other marine information

All above-mentioned approaches can finally be combined with further marine-related data. Currently available are the Search and Rescue (SAR) incidents and layers containing information on fishing procedures (ground fish, salmon, shellfish, etc.). In the future a lot more applicable data will be produced as a result of the progression of the ongoing "Marine Geomatics Project".

5.5 Traffic Visualization Prospects

For the future, real-time and animated mapping of marine traffic is desirable. This would lead to the previously mentioned real-time, map-based marine traffic information system. Similar to existing air traffic and road/rail network control systems these overall visual systems should be able to show the vessel movements in real-time, but also store the data for later graphical analysis. In addition to the marine traffic movements the system should include all kind of nautical data (depth/bathymetry, hydrographs, navigational aids and hazards, VTS zones and shipping lanes) and environmental information like wind conditions, tidal currents and so on. Comparable to the flight path representation of an airplane, the track of a vessel could be displayed in a line wiping out after a certain time. Other variables to be shown include the speed and the direction of the vessel, conceivable as an arrow of a certain length pointing in the direction the vessel is heading. The system should also be able to graphically highlight hot spots, meaning places where vessels are dangerously close to each other. These described abilities may be expected from a basic marine traffic information system. More advanced visualization approaches would include the generation of a virtual view from the captain's cockpit. Innumerable further possibilities are imaginable.

The implementation of such a system would of course raise a lot of questions, above all in the legal environment. But these questions are not part of this thesis and may be answered in another study.

CARTOGRAPHIC BASICS 6

6.1 Spatial Reference Information

6.1.1 Geographic coordinate system and projection

In 1990, Natural Resources Canada officially adopted the *North American Datum 1983 (NAD83)* as its new geodetic reference system. A datum defines how a coordinate system (geographical or rectangular) sits over an ellipsoid or spheroid. Each datum has inherent inaccuracies in it, but these are different for each datum and one or more (but not all) can be minimized or eliminated depending on the purpose of a map. The NAD83 evolved out of the former Datum NAD27 due to advances in surveying and better models of the earth's surface. Based on the Geodetic Reference System 1980 (GRS80) ellipsoid, NAD83 positions are considered to be more representative of actual locations on the earth's surface. This is because the GRS80 ellipsoid uses a geocentric (center of the earth's mass) origin. For this reasons NAD83 is also used in all the presentations of this thesis. The official projection for maps in British Columbia is the *British Columbia Albers Standard Projection (BCALB-83)*, which is based on an Albers Equal Area Conic Projection. This projection was chosen in 1994 by the Ministry of Sustainable Resource Management GIS Working Group of the Government of British Columbia to represent and store all GIS data. This projection is most appropriate because it shows the whole province on one projection plane, while maintaining sufficient accuracy for visualization needs.

However the Canadian marine society uses another coordinate system and projection for the nautical charts published by the Canadian Hydrographic Service (CHS). The older charts are mainly plotted in the former *NAD27* coordinate system; for the newer versions *NAD83* is used as well (with the note that these are equivalent at a small scale). The projection applied for all charts is *Mercator*. This projection virtually reduces the shape and direction distortions that occur during the flattening process. It's important when boating to be able to recognize features by their shape such as points of land or shapes of islands. These shapes can be compared to the charted features in an attempt to determine the vessel's position.

Because of the coexistence of two major coordinate system and projections it is not possible to assign a desired one. Depending on the purpose and the end user of the map the appropriate one has to be selected for each map individually. All the detailed datum and projection parameters can be found in appendix G.

6.1.2 Datum and projection translations

Translations between the different Coordinate Systems (especially between NAD27 and NAD83) and divers projections are accomplished using the Feature Manipulation Engine 2002 (FME) from "Safe Software" [www.safe.com]. The FME Universal Translator is a standalone spatial data converter that allows the user to move the data between divers GIS, CAD and database formats; additionally it can perform geometric and attribute operations. To execute the adjustment between NAD27 and NAD83 special parameter shift files are necessary, which are available through the Geodetic Survey of Canada. The Canadian National Transformation Grid Version 2.0 (NTv2.GSB) provides the means for transitioning from the NAD27 reference system to the NAD83 reference system, involving the use of tables containing the coordinate differences between NAD27 and NAD83. Due to the fact that FME does not provide the Mercator projection by default, the conversions to the target coordinate system used by CHS are performed in ArcToolbox Version 8.3, an application within the ESRI ArcGIS family. The required tool is called project wizard and it is capable of defining, changing or modifying the coordinate system of an existing geodataset (shape, coverage, grids and so on); the worldwide Mercator projection is supported and the appendant coordinate system can be chosen independently. The translation into the NAD83 Mercator projection is achieved by converting primarily prepared BCALB-83 shape files with the described project tool.

6.2 Base Maps

For visualization purposes various background information layers are required. The most important base map according to the user need assessment is the nautical chart. Because the layers of the official nautical charts published by the Canadian Hydrographic Service (CHS) are not available at a reasonable price, the desired information has to be assembled from other sources. First of all, it is essential to display the land, resp. the water surface by drawing the coastline. To gain a continuous presentation of the coastline both Canadian and American data is needed. The main source for spatial information for this thesis is the Internet, which offers free downloads of different kinds of geographic data. The following subchapters describe the source of each geographical layer and the applied translation, resp. shifting. All the detailed Metadata for the used layers can be found in appendix H.

6.2.1 Canadian coastlines

The shorelines of British Columbia are derived from the digital National Atlas of Canada. The files are available for download without charge on the GeoGratis homepage [http://geogratis.cgdi.gc.ca]; GeoGratis is a web and file protocol (ftp) site that distributes geospatial data of Canada. Vector mapping layers, including the metadata, are available in scales ranging from 1:50'000 to 1:30'000'000 in a variety of file formats. The site also contains a large volume of satellite imagery and online file translation services.

The National Atlas Digital Data contains amongst others 1:2'000'000 scale base map data for Canada from the years 1989-1992. The data was produced by the GeoAccess Division, formerly the National Atlas Information Service (NAIS), of Geomatics Canada. The data are in an unprojected coordinate system but in geographical coordinates (latitude, longitude). Therefore it has to be translated to the desired BCALB-83 or Mercator projection using the FME software described above.

6.2.2 United States coastlines

The adjacent shorelines to the south for the State of Washington are downloaded from the Washington State Department of Transportation [www.wsdot.wa.gov]. The major shorelines and islands for Pacific Ocean in Washington State are represented as polygons; features in this data set define the land extent of Washington State in the year of 1994. According to the provided metadata, the layer is meant for general-purpose base maps at 1:500'000 or smaller, where detailed river information is not needed. These data are only available as latitude and longitude information in NAD83. The projection translation in FME is applied to move the layer to the BCALB-83 reference system or to the Mercator projection.

The adjacent shorelines to the north in Alaska State are available through the homepage of the University of Alaska Southeast UAS [www.uas.alaska.edu]. The dataset includes the Alaska coastline in a 1:250'000 scale with some areas at 1:63'360 scale, originally available through Alaska Department of Natural Resources. The data are already in an Albers Equal Area Conic Projection but with other parameters than those used in British Columbia; and the data are stored in the former Coordinate System of NAD27. For these reasons the usage in BCALB-83 requires both a shift using the above-described National Transformation File (NTv2) and a projection translation in FME. Translations into NAD27 Mercator projection can be made in FME without applying the shift file.

6.2.3 Aggregation to one layer

As all section of the coastlines are translated to the same Coordinate System using the same projection, they can be merged together in one layer using the GeoProcessing Wizard implemented in ArcMap. During the same process the data are clipped to keep the data volume as low as possible by applying a defined frame that contains the area of interest. The merged coastlines are generalized where necessary (Alaska) with the same tool and simplified by dissolving adjacent polygons of British Columbia. This aggregated and generalized layer is then used for all following visualizations.

6.2.4 Major cities of British Columbia

Inclusion of the major cities of British Columbia provides a better orientation for the map user. A layer with the location and the names of all the cities is downloaded from the digital National Atlas of Canada on GeoGratis. The translations used in FME are the same as for the shorelines of British Columbia (chapter 4.2.1) due to their same format and source.

6.2.5 Further topographic information

The same source (digital National Atlas 1:2'000'000 on GeoGratis) and translation, as well as the identical clipping procedures are applied for other required geographical data layers, such as lakes and rivers, the one by one degree coordinate grid and the international boundary between Canada and the United States.

6.2.6 Ferry routes

Ferry routes also aid the graphical presentation. Similar to the topographic maps, there are various sources for both Canadian and American geospatial data related to transportation. The same data sources are used as often as possible to get a consistent data set for this thesis. For that reason ferry routes are downloaded from the same homepages as the topographic information (GeoGratis for Canada and Washington State Department of Transportation for the United States). Due to the same data format and spatial reference the same translations are used as are described in the relevant subchapters for the topographical data.

6.3 Marine-Related Spatial Information

Several other marine-related data layers are needed to visualize and enhance understanding of commercial shipping activity patterns in the area. These include the boundaries of the Vessel Traffic System (VTS) Zones described in the previous section of this report (chapter 3); the specific locations of communication sites within each zone to aid in understanding the tracking procedures; the positions of navigational aids and hazards; shipping lanes, separation zones, and precautionary areas; ocean depths (bathymetry); hydrography and so on. Most of these layers are shown in the official nautical charts, on which the maps should be modeled according to the user need assessment.

6.3.1 VTS zone boundaries

Initially, the intent was to obtain the digitized VTS zone boundaries from the Canadian Coast Guard. Unfortunately, the CCG does not have them in a digital format that can be used in GIS. Consequently it was decided to digitize them using existing non-geospatial information from the Internet. On the national homepage of the Marine Communications and Traffic Services (MCTS) from the Canadian Coast Guard [www.ccg-gcc.gc.ca/mcts-sctm] an online version of the "*Radio Aids to Marine Navigation (RAMN), Pacific and Western Arctic*" can be found (important pages of the document are also attached in appendix I). This document, which is available as printed manual in bookshops as well, contains in its third part the section and boundaries of the western VTS zones, expressed in latitude and longitude positions. A table of these point locations is imported into ArcGIS. The zone polygons are then constructed manually, connecting the points and using coastlines and the territorial water boundaries as well (12 nautical miles off the shore). According to the general information in the same manual, all the lat/long-positions within the document are based on the NAD27 Coordinate System unless otherwise posted. In this particular case the shift to the NAD83 system and the projection to BCALB-83 or Mercator is not performed, because the zone boundaries are just for graphical purposes and not for accurate data analysis.

6.3.2 Communication sites

A similar procedure is used for the presentation of the communication sites, apart from building the polygons. The locations of the various communication sites are available on the homepage from the MCTS Pacific Region [www.pacific.ccg-gcc.gc.ca/mcts-sctm/index_e.htm]. This latitude and longitude information is entered in the GIS, the shift and projection transformation are left out for the same reason mentioned above.

6.3.3 Nautical chart data and further datasets

As previously mentioned, it is difficult to obtain the digital nautical chart data for free through academical or government connections. The electronic charts can be purchased in either a vector or a raster format, but they are expensive and only available through a private company [NDI, www.digitalocean.ca]. For the purpose of visualization alone it is not worthwhile to buy the data layers, which are sometimes part of whole software packages for navigation support. Rather, the available data described in the previous subchapters are processed to appear similar to the official nautical charts to reach a similar map.

However, almost all marine-related information can be found on the Internet. The coordinates for the shipping lanes, resp. the new and amended official traffic separation scheme for "Strait of Juan de Fuca and its approaches", "Puget Sound and its approaches" and "Haro Strait, Boundary Pass and the Strait of Georgia" [International Maritime Organization, 2002] was obtained in a digital format from the Marine Safety Division of Transport Canada (a graphical presentation of the relevant sections can be found in appendix J). The new locations are extracted from the PDF file and converted using Excel to the proper format for ArcGIS. Positions of the shipping lanes in the Vancouver VTS Zone are read out from the official nautical chart [paper map 1:80'000 Strait of Georgia, Southern Portion CHS#3463, published 2002 and corrected with Notices to Mariners January 31, 2003] due to missing information in the amended traffic separation scheme. The point locations are then connected manually following the given order to create the GIS layers with the separation zones, traffic lanes and precautionary areas. The same procedure is applied to point data describing the extent of the Turn Point Special Operation Area (SOA) and the Tanker Exclusion Zone (TEZ); information is found in the Radio Aids to Marine Navigation (RAMN) 2003 online version on the MCTS homepage [www.ccg-gcc.gc.ca/mcts-sctm/ramn_arnm/pacific]. The boundary points of the Canadian Forces Maritime Experimental and Test Ranges Exercise Area Whiskey Golf (WG) are also taken from the MCTS homepage of the Pacific Region [www.pacific.ccg-gcc.gc.ca/mcts-sctm/ comox/wg_e.htm] and connected manually in ArcGIS. The precise locations of the active Ocean Disposal Sites are received digitally from an assistant of Environment Canada's Ocean Disposal Control Program. These data are prepared for graphical representation in ArcGIS applying an identical procedure as for the other data sources.

6.3.4 Bathymetry

International depth information is available from the General Bathymetric Chart of the Oceans (GEBCO) Digital Atlas (GDA) - GEBCO-97. GEBCO is an international project under the joint auspices of the Intergovernmental Oceanographic Commission (of UNESCO) and the International Hydrographic Organization. Its main goal is to provide continually upgrated, high quality, seamless bathymetric contour charts of the world's oceans through a digital medium. The GDA was initialized by digitizing the printed sheets of the fifth edition of GEBCO, published by the Canadian Hydrographic Service. GEBCO-97 represents the first update of the GEBCO Digital Atlas; the second release available at UVic Department of Geography consists of the GEBCO-97 CD-ROM containing the Atlas data sets and the GDA Software Interface. The specific software interface is necessary to display the data because of the unusual files formats; at the same time it provides the means to extract data from the atlas into other file formats.

Although this bathymetric dataset is not of the same accuracy as the depth information displayed in the nautical charts and the translation process into a common GIS format is complicated, it would be possible to use it for complementing the marine traffic maps.

6.3.5 Existing marine-related data from the overall project

Preliminary products of the overall "Marine Activity Geomatics and Risk Analysis in the Coastal Zone" project include several layers with information from the marine environment available in common GIS formats and familiar projections. One of these layers shows the positions of marinas and boat launches of British Columbia, important information in the context of marine traffic patterns. Another informative layer contains Search and Rescue (SAR) incident data provided and collected by CCG. Various analysis and data layers exist for different commercial fisheries. Information about recreational boating activity is currently under investigation.

A visualization of the above-mentioned data layers (with the exception of the nautical chart data, the bathymetry and the further marine-related information) would result in the following regional presentation of the area under investigation. This presentation is not designed to look similar to the nautical charts – it just illustrates the aggregated basic information.

Figure 6.1: Aggregation of all essential base maps

MAPPING – THE USE OF GIS 7

7.1 Visualization Options in MARIS

7.1.1 Software description

The Maritime Activity and Risk Investigation System (MARIS) Software is a GIS application designed for use by the CCG, primarily for maritime risk analysis and resource allocation. MARIS permits manipulation and analysis of GIS data layers to model maritime activity and show trends over time. The software is supported by various data that model maritime activity in Canadian waters. These data include search and rescue (SAR) incidents, commercial fisheries and shipping, aquaculture and non-traditional fisheries, recreational boating, ecotourism, offshore petroleum exploration and development and more. Three basics form the background of the software: A marine activity database, risk factors and equations, and human interaction achieved by controls, views and reports. The software is developed by programmers at the MARIN (Marine Activity and Risk Investigation Network) Research Lab, hosted by the Industrial Engineering Department at Dalhousie University in Halifax, NS. The first version of the GIS software using the MapBASIC programming language within MapInfo GIS was called SARMAP (Search and Rescue Marine Analysis Program). The latest version of MARIS at present is 2.1.1, developed applying the ESRI product MapObjects and visual basic. The software is under continuous enhancement and improvement by its developers.

7.1.2 Applications and features

The main applications of MARIS are: SAR resource planning, incident prevention programs, maritime safety analysis, pollution response planning and coastal security planning. In order to meet these tasks the main features of MARIS provides the display of layers of any combination of maritime activities and incidents, the calculation of incident rates and risks and the presentation of spatial and temporal distributions. Implemented functions are currently the data viewed by activity, time and location; simulation, aggregation and quantifying maritime activities; grouping in activity types; query specific data; charting and graphing; thematic mapping and risk analysis. Besides these basic GIS functionalities, MARIS offers some extended functionalities developed to satisfy the CCG's specific needs.

A special data modeling technique implemented in MARIS is the "*Track Generation*"-Function including land avoidance and diffusion algorithms. This technique is applied to waypoint based trip data with absolute temporal information. It provides more accurate spatial representation of data as trip lines and it unifies backing information to single vessel trip. The land avoidance function is the alternative to the direct waypoint connection; it uses the shortest path along a "node network" between trip waypoints. But if this algorithm is used exclusively it may create an unwanted "artificial regularity" within data. In order to avoid this phenomenon the diffusion algorithm is applied that rectifies unnatural tracks from land avoidance. It may be dynamic - based on some trip attributes. The implementation of this function is still pending at this time.

Another unique feature to MARIS is the "*Dispersion*"-Function that is applied to data with temporal accuracy, but only zonal or point-zonal spatial information. It simulates the movement of inter- and intra- zonal traffic by dispersion of points within zones. Therefore the area under investigation is split into useful zones, out of them a source port and destination zones can be chosen for the particular trips. The destination zones are divided into regular grids; the software determines the final destination cell within the raster stochastically. The track is then generated connecting each random position and the source port.

The "*Scheduled Data Generation*" is applied to data consisting of regular vessel movement information over repeating fixed schedules (e.g. ferry traffic). The tracks are generated extrapolating scheduled data over fixed time period; the result allows then a direct comparison of scheduled data with other spatially represented data.

7.1.3 User interface

The settings screen is the first screen that appears when opening MARIS. The settings screen is used to specify the base landmass used and its color. In addition the settings screen can be used to specify the default zoom. This screen has no functions that are crucial in operating MARIS. Unchecking the lower left box prevents the user from seeing this screen the next time h/she starts the software (all the settings can also be accessed though MARIS' menu bar).

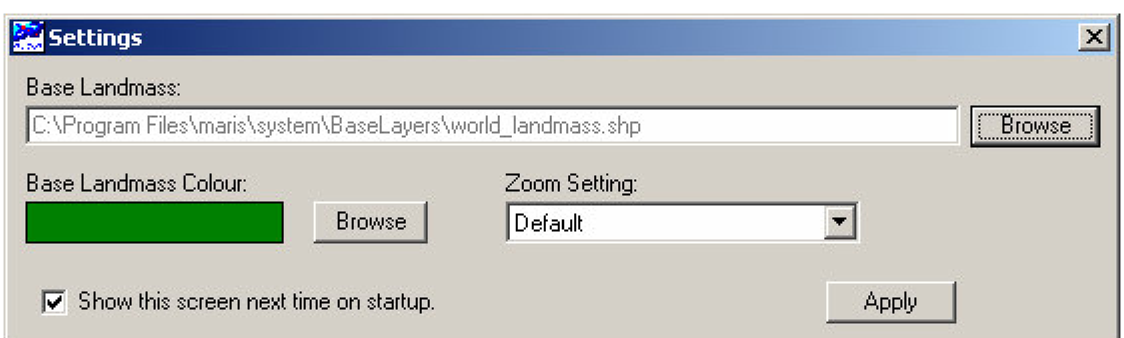


Figure 7.1: MARIS setting screen

The MARIS program screen, called GUI (graphical user interface) is the locus for the majority of MARIS' functions. The features of the program screen are the map window, the menu bar, the toolbar, the tree view/legend pane, and the message pane.

The **map window** is the primary focus of MARIS. All map layers are visualized though the map window, and several mouse functions only operate within the scope of the map window. In addition to the mouse functions provided through the toolbar, when the map window is not at its full extent, it can be panned by dragging the window's contents using the right mouse button. The scale bar in the upper left-hand corner gives the current proportions of the window, and the latitude and longitude windows at the bottom give the current cursor position.

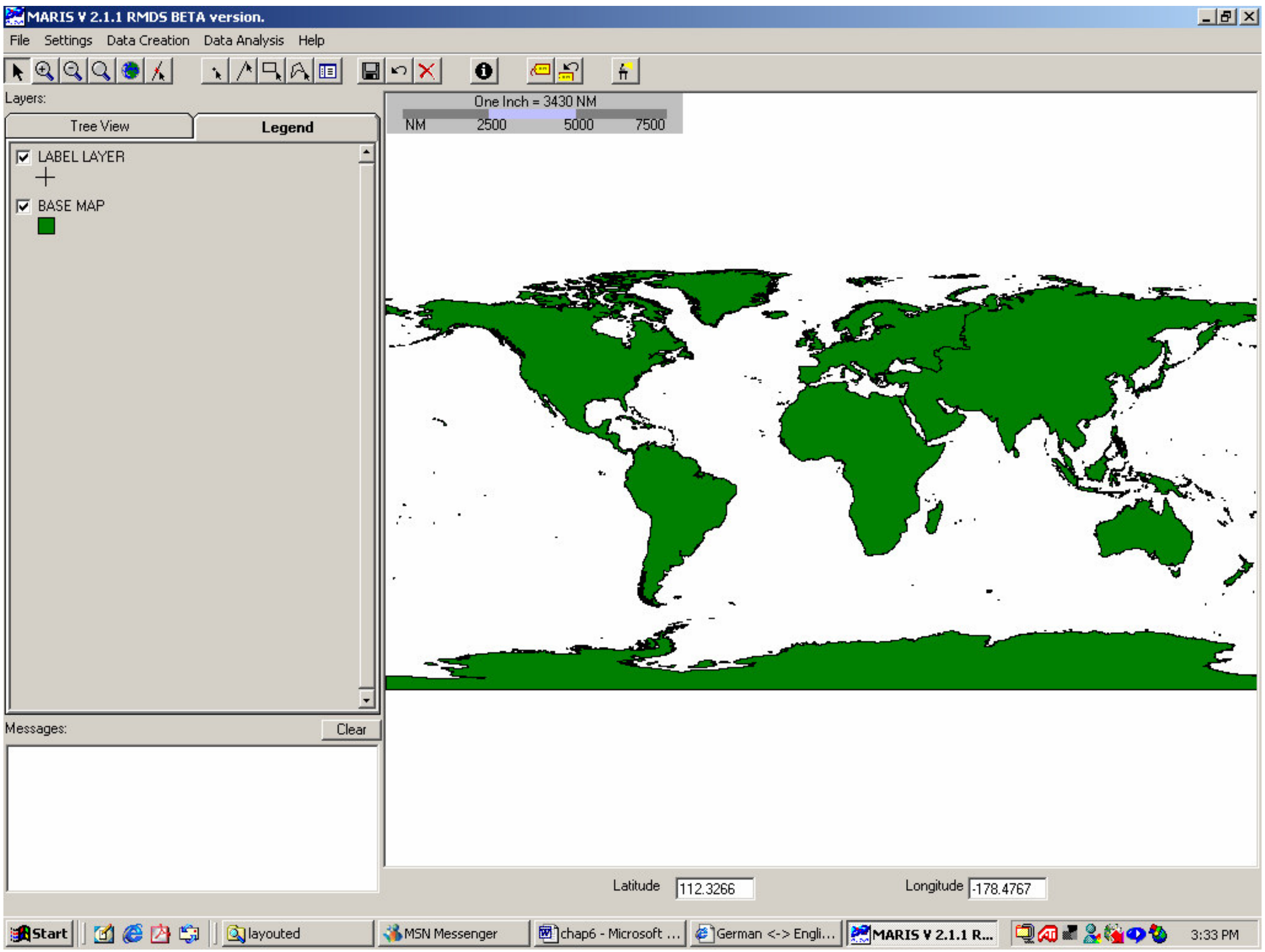


Figure 7.2: MARIS graphical user interface (GUI)

The MARIS **Menubar** covers the basic functions required to use MARIS:

Under the **File** menu, the most important menu choice is load. Shape files (single map layers) and view files (collections of layers) are loaded through the file -> load menu choice. Available with the current release of MARIS are several data sampled from the Canadian East Coast. Only one (view or shape) file may be loaded at one time, other common geographic file formats are not supported for usage in MARIS at present. New view files are created via the file -> new view file menu choice. Choosing this item prompts the user to save changes to the current view, and then unloads all loaded layers. Intermediate saving of view files is achieved using the file -> save view file menu item, while file -> unload layer can be used to remove a single layer from the current view file.

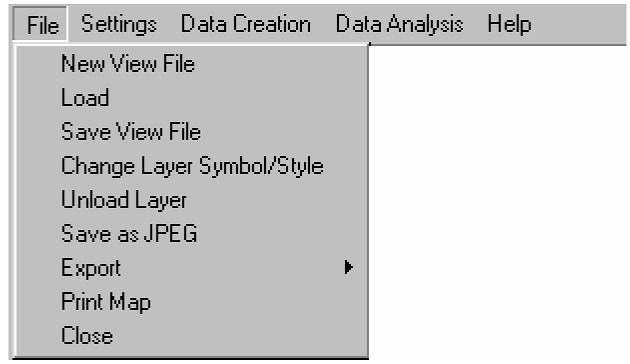


Figure 7.3: MARIS menubar

In the **Settings** menu, the primary menu function to note is the Units menu choice. This menu choice can be used to change the default MARIS units between statute miles, nautical miles and kilometers. Zoom settings can also be loaded/deleted/saved via the settings -> zoom settings menu item. Settings -> zoom settings -> zoom to scale allows the user to specify a map scale in the format (1:X) to which the map window will zoom around its center point.

The **Data Creation** menu contains the Query data function of MARIS. Currently the only useable querying function is accessed via General Query (the ECAREG and SISAR query screens are being revised). This option allows querying of loaded layers by their associated attributes. The operation is similar to SQL querying in MS Access, but query criteria are inputted field-by-field.

Under **Data Analysis**, the key menu item is the Render Layer item. This function is used to apply a "renderer" to a particular map layer that will modify the appearance of a layer to correspond to the data contained in the layer. This is for example used to allow the proper display of the "gridded" Track Counts, which otherwise appear as a transparent grid. The renderer best suited to this particular purpose is the class breaks renderer, which shades the grids differently according to the underlying data. A detailed explanation of the rendering functions is available in the help system. Other functions within the Data Analysis menu include a Grid application (generation and count) and the calculation of an incident rate.

The contents of the **Help** menu are mostly self-explanatory. "About" displays information about MARIS, "Contents" and "Index" are two methods to access the online help system.

The MARIS **Toolbar** contains a number of buttons, all of which perform functions that relate directly to the map window. In addition, the buttons are clustered by function. The mouse functions most critical for getting started with MARIS are the six leftmost buttons, primarily concerned with mouse behavior in the map window:

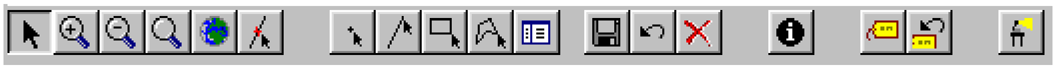


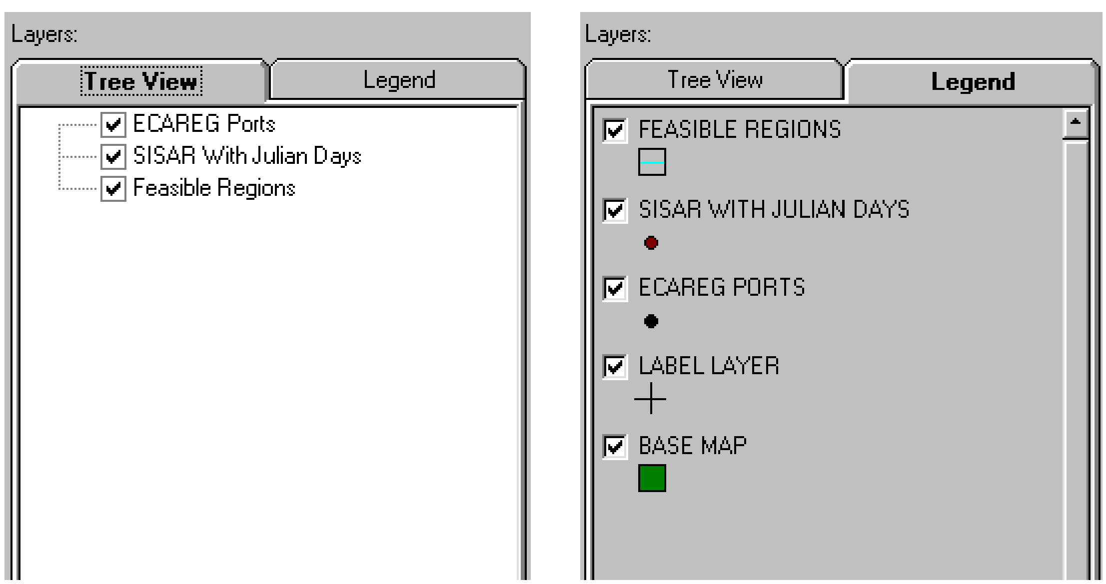
Figure 7.4: MARIS toolbar

The first **arrow mouse pointer** is the default mouse pointer, and it outputs the mouse cursor location (long/lat) to the message pane (see below) when the user clicks the left mouse button in the map window. The following four buttons refer to usual **zooming** options as zoom in, out, specific extend and full extent. The sixth button is the **time and distance** tool: it changes the mouse pointer to a distance-calculating tool. The first click of the left mouse button in the map window begins creating a line. Each successive click of the left mouse button in the map window creates another segment in the line. A double click creates the final point of the line, and ends it. Following the line creation, the user is prompted for vessel speed (which can be cancelled), and the length of the entire line and each of its segments is outputted to the message window. If a speed is specified, travel times for each segment, and the whole line are also displayed. Another important button on the toolbar is the fourth button from the right, the **information** button. When the information button is pressed, the mouse cursor changes to a crosshair over the map window, and can be used to draw a bounding box around features on the map. All underlying information about features enclosed in the bounding box is output to an information window. This is very useful in examining specific data points.

Finally, a slide consisting of the current map window and legend pane state can be output to PowerPoint by clicking the **slide show** icon on the far right of the toolbar. If PowerPoint is not open, it will be opened automatically.

The MARIS **Treeview/Legend Pane** display the names of the layers loaded into the map window. The tabs at the top of the pane allow the user to choose between legend and treeview displays.

Figure 7.5: MARIS treeview and legend pane



The **treeview** allows toggling of the display of the given layers via a checkbox, and indicates the hierarchy of layers created using successive queries where applicable. Unclicking the check box makes the corresponding layer invisible in the map window, but does not unload it. Additionally, the display characteristics of the layers can be altered double-clicking their entry.

The **legend** allows toggling the display of layers, but also allows the user to toggle the display of the base landmass and labeling layers. Finally, the order of display of the layers depends on the order in which they appear in the legend, and layers can be moved vertically with respect to each other by dragging their entries up or down.

The **message pane** is the source of all textual output from MARIS. This feature is somewhat akin to a "console window" except that it does not accept user input. Message data are purged to a file periodically, and can be cleared to file using the clear button. The log file for the message data is stored in the same directory folder as the software.

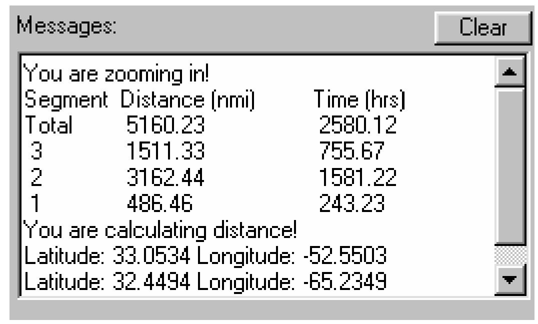


Figure 7.6: MARIS message pane

7.1.4 Strengths

The advantages of MARIS can be found in the applications it was originally designed for. The "Track Generation" function allows the user to create reasonable vessel trips out of only two known positions. Even a user with no experience in spatial data analysis or GIS software can execute the operation easily, including the powerful land avoidance and diffusion algorithms. The other two unique data modeling techniques – "Dispersion" and "Scheduled Data Generation" - can be applied to geographical data without specialized knowledge as well. Further analysis tools like the grid generation and count or the incident rate calculation are also useful features in the intended area of application. According to the MARIS Quickstart Guide all the main features of MARIS are in a continuous process of improvement based on user feedback. This steady review of the software is another strength to be mentioned: further enhancements of MARIS will be implemented adapted from specific user experiences and needs. In summary, the latest release of MARIS (V2.1.1 RMDS BETA Version) is a helpful tool for well-defined users to analyze and display very specific data.

7.1.5 Weaknesses

As mentioned above MARIS is a strong software package for the analysis and visualization of very specific data. Processing other data formats and structures is more difficult as the applications are specifically aimed at the data available for the area-of-interest on Canada's East Coast. This fact is proven by all the errors appearing while trying to execute the functions on a dataset of the Pacific Region. The "Track Generation" algorithm for example is not working without a proper Network Layer, even though the dense data from the West Coast would not need special handling other than connecting the points.

Another remarkable disadvantage – particularly for used GIS operators – is the lack of user-friendliness and the weak graphical possibilities. Functions are sometimes provided by buttons and actions the user is not expecting or reworked ordinary commands are difficult to find. The right click on the mouse for example is not working in the entire program screen, except for panning the map cutout around (which is usually provided by a button with a little hand on it). The confirmation of the entries in a dialogue box requires a mouse click while it mostly can be done in other programs by pressing the enter button on the keyboard.

From a cartographic point of view MARIS is missing most of the minimal mapping requirements. There are only four different styles for a point symbol and their size cannot be adjusted at all. Line styles are similar limited and not to be varied in width. Only the color can be chosen from a complete palette as known from other graphical software applications. In addition the software is not capable of handling data formats other than latitude and longitude positions. Loading a correct projected file (BC Albers Projection) into MARIS results in a large displacement against the lat/long files that should be in the same region.

7.1.6 Conclusion

Summarizing the weaknesses of MARIS the question arises as to why the developers did not adapt an established Geographic Information System for their needs. All the powerful functionalities of MARIS could be straightforwardly included in several commonly used GIS packages using basic programming languages. In addition to the functionality extensions, the software would also have all the necessary potential and functions of a regular GIS which MARIS is currently missing. It is assumed that the developers did not follow this approach because they wanted to keep the software thin and easy to handle. However, given the adjustments and extensions they have made based on user feedback since the first version, this goal cannot be maintained.

In conclusion, the functionalities provided by MARIS are not sufficient to meet the mapping and visualization needs of this thesis. The graphical and technical applications within MARIS are not developed sufficiently to meet the specific visualization demands. It is doubtful at this stage in its development that MARIS would be able to effectively process datasets different form those it was developed with.

7.2 Mapping in ArcGIS

7.2.1 Software description

ArcGIS is a scalable new software family released in 2001 by the Environmental Systems Research Institute (ESRI). As a combination of previous commonly used GIS programs, it joins the user-friendly interface of ArcView and the geospatial analysis power of ArcInfo. It can be run in three modes: as ArcInfo, ArcEditor or ArcView. Since the Department of Geography at University of Victoria has neither an ArcEditor nor ArcView lincense, the software is used in "ArcInfo mode" that provides the full functionality of the former ArcInfo software. ArcGIS can be applied through three different interfaces: ArcMap, ArcToolbox and ArcCatalog. ArcMap is used for all mapping and editing tasks, as well as map-based analysis; ArcCatalog is the application for managing spatial data holdings and database designs, additionally for recording and viewing metadata; ArcToolbox simplifies many common GIS data conversion and geoprocessing tasks. All three components are used during this thesis and it emerges that the ArcGIS software package (used version is 8.3) is capable of processing the required actions for the preliminary analysis and the visualization of the MCTS database.

7.2.2 Extensions used

Particular operations necessitate the installation of special extensions that can be obtained at no charge from the Internet. A free version for unregistered users of the ET GeoWizards 8.6 is downloaded from Ianko's GIS page [www.ian-ko.com] and added to ArcMap to enable certain data processing functions currently available only in ArcEditor. This tool is mainly used for the conversion of points into polylines but also for creating new shape files and other spatial tasks. Another useful extension is the established XTools (Version 3.0) that contains useful vector spatial analysis, shape conversion and table management tools. This extension is available on the American USDA Service Center Agencies GIS homepage [www.gis.sc.egov.usda.gov] for free download. The 'Spatial Analyst' and 'ArcPress' are further extensions that are applied during this thesis to accomplish certain operations; the both come originally with the software package and simply have to be activated.

7.2.3 Data preparation and import

The MCTS database has to be prepared prior to the import into ArcMap and the graphical presentation. All major preparation steps are accomplished while applying the data cleaning algorithm in MS Access (defined and described in chapter 4.5 and 4.6). The only outstanding task of defining the spatial reference parameters can be fulfilled during the import procedure with the 'Add XY data'-tool provided by the software. ArcMap automatically demands the proper coordinate system when importing a table; the wizard either provides a large variety of predefined reference systems to choose from or gives the possibility to create a new one. Due to missing information about the datum used for the positioning procedure in VTOSS, NAD83 is adapted because it is known that this datum is used for recording radar data. This choice can be justified with the lower accuracy of the VTOSS data collection procedure in any case than the positions derived from the radar system. ArcMap imports all records of the selected table in the cleaned Access database to a separate layer keeping all the original attribute fields; however it in not a geographic layer unless exported to a spatial file format, for instance ESRI coverage or shape. Non-converted point locations layer can be used for current spatial analysis tasks like track generation or density calculations or simply for graphical display but not for editing purposes.

Geographic background data for the base map is included in ArcMap by simply applying the 'Add a layer' – operation. As many information sources as desired can be combined if they share an identical spatial reference system; when importing a data layer with another coordinate system the software shows a warning message and it is impossible to do any advanced spatial analysis and editing as long as the datum and projection is not standardized. However it is possible to simply display layer with different reference parameters.

7.2.4 Visualization procedure and results

The following sections describe how the particular maps are drawn and what information is included. The selection of the coordinate system, the geographical coverage and the time frame are mentioned in terms of the presentation tasks and the potential map user.

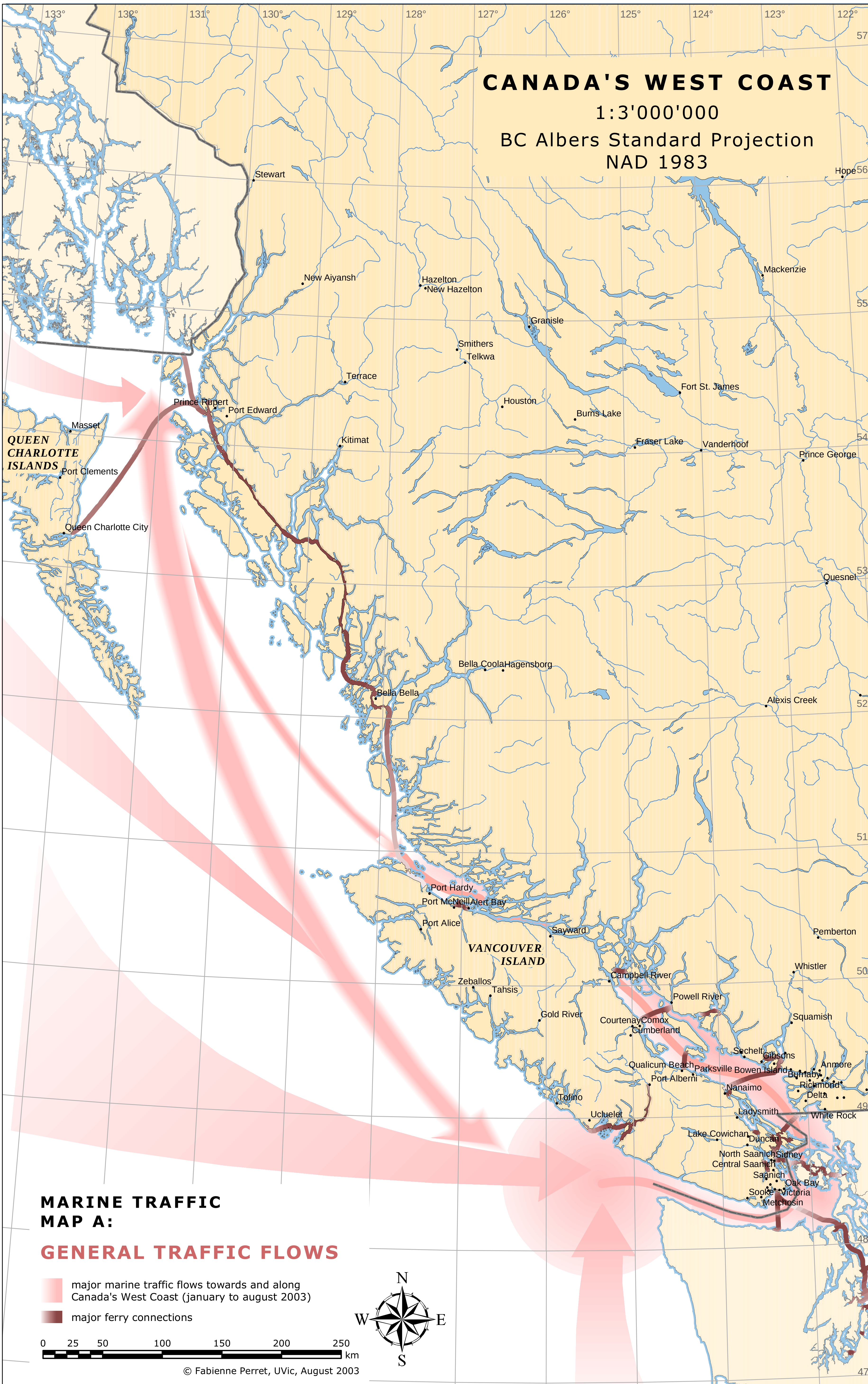
Unfortunately it was quickly realized that the processing limitations of ArcMap are almost reached when importing all cleaned point locations of a single day; common operations like changing the symbol or zooming and panning are still performed in a reasonable time period. However, if the information of one or more additional days is included, these actions get very slow. Also if the tables of different days are merged prior to use in ArcMap the software is not able to execute the required operations in a user-friendly time. It seems that the standard base map, including the landmass/coastlines, coordinate grid, cities, rivers and lakes, together with the point locations of one day (30'000 – 50'000 records) are the maximum amount of data ArcMap can process with reasonable speed and without shutting down regularly. For this reason it is impossible to create an overview map covering the entire West Coast with the information of more than one day; therefore all charts at a small scale impart only the shipping events of, at maximum, one particular day or less.

MAP A: **GENERAL TRAFFIC FLOWS**

The first map (Map A on following page) consists of arrows representing the major traffic flows towards and along Canada's West Coast. The symbols are drawn manually taking point locations from five selected days (Tuesday, June 3 to Saturday, June 7, 2003) into consideration. Their position and shapes are also influenced by the author's experience resulting from the in-depth study of the database. Therefore, arrows derived from these five days in particular are valid universally for the region due to similar traffic patterns for all days. The symbols have no specific spatial reference since they are only graphics and not geographic data layers. Colors, directions and widths are chosen arbitrarily to show major traffic flows and to impart a preliminary idea of traffic frequencies through color intensities. Information about major ferry routes provided by provincial and state-run agencies (see chapter 6.2.6) is included in the map to highlight the dissenting traffic patterns to the other traffic.

The map scale is set to 1:3 Mio to cover the relevant parts of Canada's West Coast on a tabloid format. Because this particular map is not primarily designed for the marine community but rather to give a general overview of shipping traffic for everyone, it is displayed in the common BC Albers Projection based on NAD83 (*BCALB-83*), which most people are used to from provincial maps. The landmass of the adjacent United States Alaska and Washington is presented in a "washed-out" color to concentrate the viewer's attention on Canada's West Coast. To support orientation for users who are not familiar with nautical charts, the names of important cities and water bodies (rivers and lakes) are included in the base map.

Topic:	GENERAL TRAFFIC FLOWS
Geographical coverage:	Canada's West Coast (47º - 57º North, 122º - 133º West)
Datum:	North American Datum 1983 (NAD83)
Projection:	BC Albers
Scale:	1:3'000'000
Marine information:	Arrows representing major traffic flows towards and along Canada's West Coast derived from five particular days and the author's experience.
	Major ferry connections.
Time frame:	January – July 2003 (June 3–7 in particular)
Base map:	Coordinate grid (one by one degree)
	Landmass, respectively coastlines, international boundary
	Water bodies: lakes and rivers, buffers around major coasts
	Cities labeled with names


CANADA'S WEST COAST
1:3'000'000
BC Albers Standard Projection
NAD 1983
MARINE TRAFFIC
MAP A:
GENERAL TRAFFIC FLOWS
major marine traffic flows towards and along Canada's West Coast (january to august 2003)
major ferry connections
0 25 50 100 150 200 250 km
N E S W
© Fabienne Perret, UVic, August 2003
QUEEN CHARLOTTE ISLANDS
VANCOUVER ISLAND
Stewart
New Aiyansh
Hazelton
New Hazelton
Granisle
Smithers
Telkwa
Terrace
Prince Rupert
Port Edward
Masset
Port Clements
Queen Charlotte City
Kitimat
Houston
Burns Lake
Fort St. James
Fraser Lake
Vanderhoof
Prince George
Mackenzie
Hope
Quesnel
Bella Coola
Hagensborg
Bella Bella
Alexis Creek
Port Hardy
Port McNeill
Alert Bay
Port Alice
Sayward
Pemberton
Whistler
Campbell River
Powell River
Zeballos
Tahsis
Gold River
Squamish
Courtenay
Comox
Cumberland
Sechelt
Gibsons
Qualicum Beach
Parksville
Bowen Island
Burnaby
Anmore
Richmond
Port Alberni
Nanaimo
Delta
Tofino
Ucluelet
Ladysmith
White Rock
Lake Cowichan
Duncan
North Saanich
Sidney
Central Saanich
Saanich
Oak Bay
Sooke
Victoria
Metchosin
133° 132° 131° 130° 129° 128° 127° 126° 125° 124° 123° 122°
57° 56° 55° 54° 53° 52° 51° 50° 49° 48° 47°

MAP B: **TRAFFIC DENSITIES**

The second overview map is created according to the needs of the Canadian Coast Guard. The main task of this presentation is to impart the varying traffic densities within the different VTS zones and around the MCTS centers to assist the CCG during future reorganization processes. Traffic densities are calculated using the 'Spatial Analyst' extension in ArcMap from the cleaned point locations of one random day (Monday June 2, 2003). The applied tool calculates a magnitude per unit area from the points (unit = degrees; settings: type = kernel, search radius = 0.267, output cell size = 0.01 square map units); therefore the listed values in the color legend are "magnitude per 0.01 square degrees". The kernel density calculation works the same as the simple density calculation, except the points or lines lying near the center of a raster cell's search area are weighted more heavily than those lying near the edge. The result is a smoother distribution of values. The resulting density grid is displayed as a raster with color shading according to the different density values. The classification is made automatically in ArcMap choosing the 'Quantile' method and adjusted manually to obtain classes that make sense for analysis purposes.

Covering the same region as the first map, this chart has a smaller scale (1:5 Mio) due to different reference parameters. The Mercator projection based on NAD83 is selected as coordinate system to meet the specific needs of the end users and their preferences in daily operations. It is assumed that the CCG is familiar with the area and does not require topographical assistance thus, rivers and cities are not displayed keeping the chart concise. Instead, the map shows advanced marine-related information such as the VTS zone boundaries and the communication sites of each MCTS center.

Topic:	TRAFFIC DENSITIES
Geographical coverage:	Canada's West Coast (47º - 57º North, 122º - 133º West)
Datum:	North American Datum 1983 (NAD83)
Projection:	Mercator
Scale:	1:5'000'000
Marine information:	Raster layer representing varying traffic densities along Canada's West Coast. Colors are selected to impart information about traffic frequencies. Boundaries between the different VTS zones Position and names of the communication sites
Time frame:	Monday June 2, 2003
Base map:	Coordinate grid (one by one degree); landmass, respectively coastlines and lakes

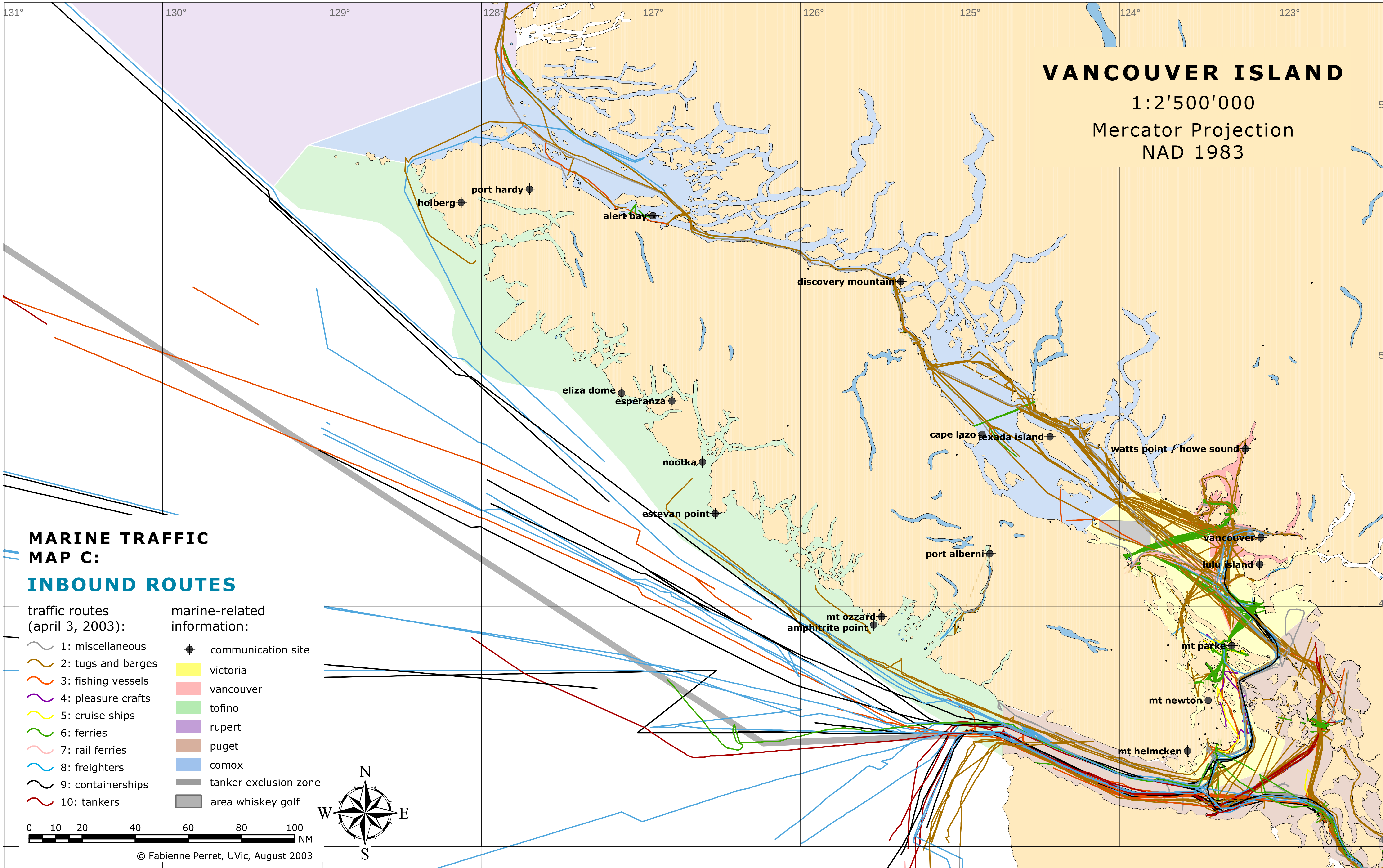

CANADA'S WEST COAST
1:5'000'000
Mercator Projection
NAD 1983
MARINE TRAFFIC
MAP B:
TRAFFIC DENSITIES
traffic densities
(june 2, 2003):
1 - 100*
101 - 200*
201 - 400*
401 - 800*
801 - 1,600*
1,601 - 6,400*
6,401 - 15,000*
15,001 - 30,000*
vts zones:
victoria
vancouver
tofino
prince rupert
puget sound
comox
communication site
* magnitude per unit area
(0.01 square degrees)
0 25 50 100 150 200
NM
© Fabienne Perret, UVic, August 2003
N
E
S
W
132°
131°
130°
129°
128°
127°
126°
125°
124°
123°
57°
56°
55°
54°
53°
52°
51°
50°
49°
47°
QUEEN CHARLOTTE ISLANDS
VANCOUVER ISLAND
mt dent
dundas island
prince rupert
mt hays
kitimat
naden harbour
mt gil
hunter point
van inlet
cumshewa
barry inlet
klemtu
rose inlet
calvert island
port hardy
holberg
alert bay
discovery mountain
eliza dome
esperanza
nootka
estevan point
cape lazo
watts point / howe sound
texada island
vancouver
lulu island
port alberni
mt ozzard
amphitrite point
mt parke
mt newton
mt helmcken

MAP C: **INBOUND ROUTES**

This map is also primarily designed to meet the analysis objectives of the CCG. It displays the inbound routes classified by vessel types from one particular day (April 3, 2003) and combines further marine related data of interest derived from the official Canadian nautical charts. This specific day is selected due to the large number of records in comparison with other days in the same time period and secondly because the vessel classification scheme is based on the April data (described in chapter 4.4.4, page 43). This reason is important because the type encoding and description is not used consistently and the classification procedure has to be done manually. However, taking data only from April means minimizing the time exposure to obtain a reasonable classification. The vessel routes are generated using the ET GeoWizard extension in ArcMap. To convert points to polylines this tool needs a cleaned point layer, an output file name (shape), at least one numeric field that identifies the points to be used for the creation of each polyline and a numeric order field. For trip identification the original vessel name from the MCTS Database is used; the order of the consecutive points is awarded through the numeric DTG field added in the data cleaning procedure (see chapter 4.6.3). The track generation can be performed in a reasonable time for one day, but it is necessary to review the results and carry out some manual corrections. This particular day resulted in more than 300 individual routes, four of them had to be split and one was removed manually. The presented dataset is still not optimized completely, but the map should also exemplify the remaining difficulties with the track generation.

The chart covers entire Vancouver Island and at least 150 NM off the coast (scale 1:2.5 Mio) to provide an overview of the incoming traffic. The Mercator projection is selected for the same reason as Map B. The background display contains the color shaded region of the six different VTS zones, the coastline/landmass and the lakes. Additional marine related information includes the tanker exclusion zone (TEZ) and the the communication sites.

Topic:	INBOUND ROUTES
Geographical coverage:	Vancouver Island (47º - 52º North, 122º - 131º West)
Datum:	North American Datum 1983 (NAD83)
Projection:	Mercator
Scale:	1:2'500'000
Marine information:	Incoming traffic tracks generated from the cleaned point locations of one specific day Communication sites; Tanker Exclusion Zone (TEZ), VTS zones
Time frame:	Thursday April 3, 2003
Base map:	Coordinate grid (one by one degree), coastlines, and lakes

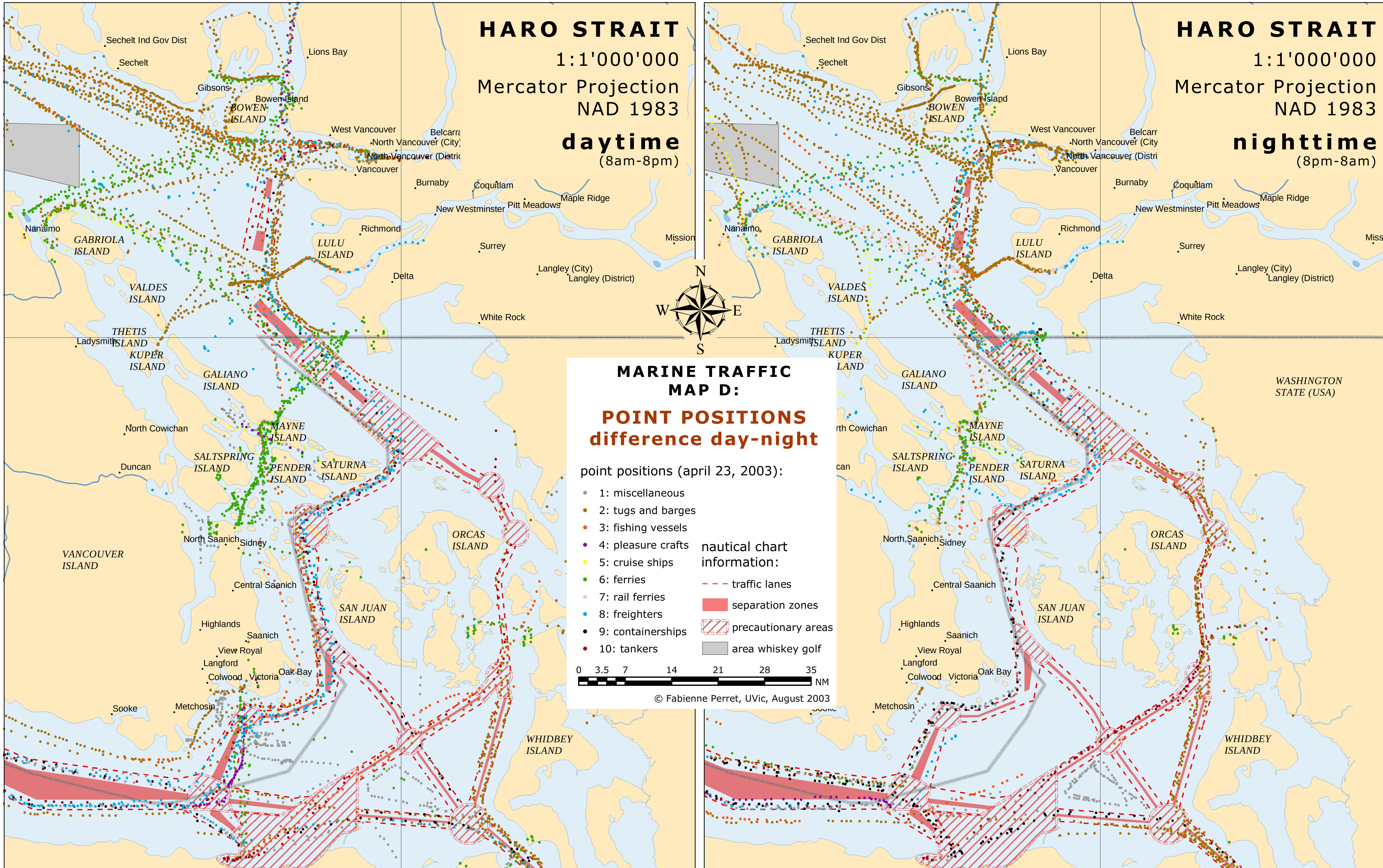

VANCOUVER ISLAND
1:2'500'000
Mercator Projection
NAD 1983
MARINE TRAFFIC
MAP C:
INBOUND ROUTES
traffic routes
(april 3, 2003):
1: miscellaneous
2: tugs and barges
3: fishing vessels
4: pleasure crafts
5: cruise ships
6: ferries
7: rail ferries
8: freighters
9: containerships
10: tankers
marine-related
information:
communication site
victoria
vancouver
tofino
rupert
puget
comox
tanker exclusion zone
area whiskey golf
0 10 20 40 60 80 100 NM
N
W
E
S
© Fabienne Perret, UVic, August 2003
131°
130°
129°
128°
127°
126°
125°
124°
123°
51°
50°
49°
port hardy
holberg
alert bay
discovery mountain
eliza dome
esperanza
nootka
estevan point
cape lazo
texada island
watts point / howe sound
vancouver
lulu island
port alberni
mt ozzard
amphitrite point
mt parke
mt newton
mt helmcken

MAP D: **POINT POSITIONS (difference day-night)**

This comparative map is designed to show the difference between daytime and nighttime traffic around the Southern Gulf Islands for all interested people, not exclusively for the CCG. Since the waters between Victoria and Vancouver, called Haro Strait, are very busy at all times of the year, understanding the difference between the traffic density during the day and at night is important for various analysis tasks. The point positions from one day in April (Wednesday April 23, 2003) are chosen for the same reason as mentioned above; classification is done manually and displayed in the same color scheme. The boundaries between day and night are drawn at 8 am and 8 pm to represent the same duration (12 hours) in each cutout. The left half of the chart shows the daytime vessel positions, classified by vessel type and the right side presents the same information for the nighttime. The side-by-side layout allows the user to interpret the differences easily.

The map shows Haro Strait, the region between Victoria and Vancouver with many islands, called the Southern Gulf Islands. The scale for each cutout is set to 1:1 Mio and displayed in the NAD83 Mercator projection like the previous maps. In addition to the water bodies (coastlines, lakes, rivers) the chart contains the international boundary with the United States and names for the cities and the most important islands to provide orientation for the "non-marine" map user. Traffic lines, separation zones, precautionary areas and the military exercise area "Whiskey Golf" from the nautical charts are included to assist marine traffic analysis.

Topic:	POINT POSITIONS; difference between day and night
Geographical coverage:	Haro Strait (48º - 49.5º North, 122º - 124º West)
Datum:	North American Datum 1983 (NAD83)
Projection:	Mercator
Scale:	1:1'000'000
Marine information:	Point positions from one day classified by vessel type, displayed separately for daytime (8am-8pm) and nighttime (8pm-8am) Separation zones, traffic lanes, precautionary areas, area WG
Time frame:	Wednesday April 23, 2003
Base map:	Coordinate grid (one by one degree) Water bodies: coastlines, lakes, and rivers Names of cities and major islands International boundary

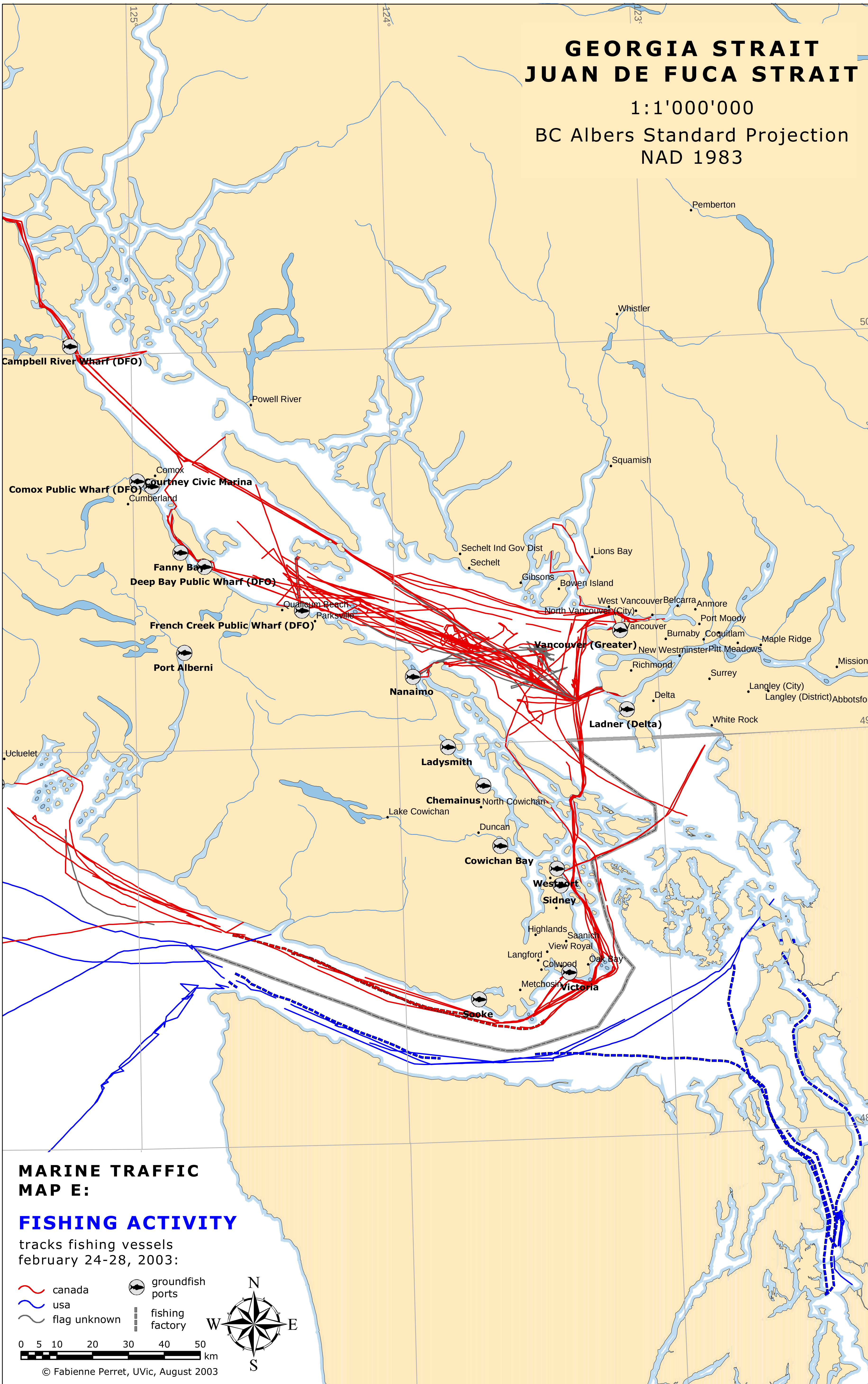

HARO STRAIT
1:1'000'000
Mercator Projection
NAD 1983
daytime
(8am-8pm)
HARO STRAIT
1:1'000'000
Mercator Projection
NAD 1983
nighttime
(8pm-8am)
MARINE TRAFFIC
MAP D:
POINT POSITIONS
difference day-night
point positions (april 23, 2003):
1: miscellaneous
2: tugs and barges
3: fishing vessels
4: pleasure crafts
5: cruise ships
6: ferries
7: rail ferries
8: freighters
9: containerships
10: tankers
nautical chart information:
traffic lanes
separation zones
precautionary areas
area whiskey golf
0 3.5 7 14 21 28 35 NM
© Fabienne Perret, UVic, August 2003
N
S
W
E
Sechelt Ind Gov Dist
Sechelt
Gibsons
Lions Bay
Bowen Island
BOWEN ISLAND
West Vancouver
North Vancouver (City)
North Vancouver (District)
Vancouver
Belcarra
Burnaby
Coquitlam
New Westminster
Pitt Meadows
Maple Ridge
Richmond
LULU ISLAND
Surrey
Mission
Delta
Langley (City)
Langley (District)
White Rock
Nanaimo
GABRIOLA ISLAND
VALDES ISLAND
THETIS ISLAND
Ladysmith
KUPER ISLAND
GALIANO ISLAND
North Cowichan
MAYNE ISLAND
SALTSPRING ISLAND
PENDER ISLAND
SATURNA ISLAND
Duncan
North Saanich
Sidney
VANCOUVER ISLAND
ORCAS ISLAND
Central Saanich
SAN JUAN ISLAND
Highlands
Saanich
View Royal
Langford
Colwood
Victoria
Oak Bay
Sooke
Metchosin
WHIDBEY ISLAND
WASHINGTON STATE (USA)

MAP E: **FISHING ACTIVITY**

Main topic of this map is fishing traffic in Haro Strait. The CCG is interested in whether there is a difference in behavior between Canadian and American fishing vessels. To meet this request information about fishing vessels from five consecutive weekdays (Monday - Friday) in February 2003 (24-28) is selected from the original database. This groups are consistent with the classification scheme described in chapter 4.4.4, 'Fish(ing) Factory FF'; 'Fishing Vessel FS/Z'; 'Crabber CZ'; 'Trawler ZT'; 'Longliner ZL'; 'Fish Packer ZP'; 'Fish Processor ZP and 'Seiner ZS'. The extraction must be carried out manually and the data-cleaning algorithm is applied only for the selected fishing-related data to ensure the processing efficiency. The cleaned point locations are imported into ArcMAP to run the 'point to polyline operation' (see detailed description of Map C). The generated tracks are merged together to one spatial layer and displayed, distinguishing between American and Canadian vessels. The information about the nationality is derived directly from the MCTS database; for a few vessels the flag is unknown, or rather simply not recorded. In addition the track presentation is different for fishing boats (FS, Z, ZL, ZS, ZC, ZD: see types above) and vessels related to the fishing factory (FF, ZF, ZP). The location and names of groundfish ports are incorporated in the presentation to provide more information about fishing activity. This point layer is the result of the fishing analysis part of the overall "Marine Geomatics" project.

The geographical coverage is chosen because this region, Georgia Strait and Juan de Fuca Strait, experienced the highest level of fishing activity recorded in the database for this particular time period. To map the relevant waters the scale is set to 1:1 Mio applying the BC Albers Standard Projection. Besides the standard coordinate grid, landmass and coastline, rivers and lakes, the base map also displays the international boundary and the locations of the major cities. If the labels conflict with the port names, they are removed to ensure the clarity of the chart.

Topic:	FISHING ACTIVITY
Geographical coverage:	Georgia and Juan de Fuca Strait (48º-51º North, 122º-125º West)
Datum:	North American Datum 1983 (NAD83)
Projection:	BC Albers Standard Projection
Scale:	1:1'000'000
Marine information:	Fishing vessel tracks for five consecutive weekdays, classified by the flag and the affiliation to the factories; Names and locations of groundfish ports
Time frame:	Monday, February 24 – Friday, February 28, 2003
Base Map:	Coordinate grid, coastlines, lakes, and rivers Names of cities, international boundary

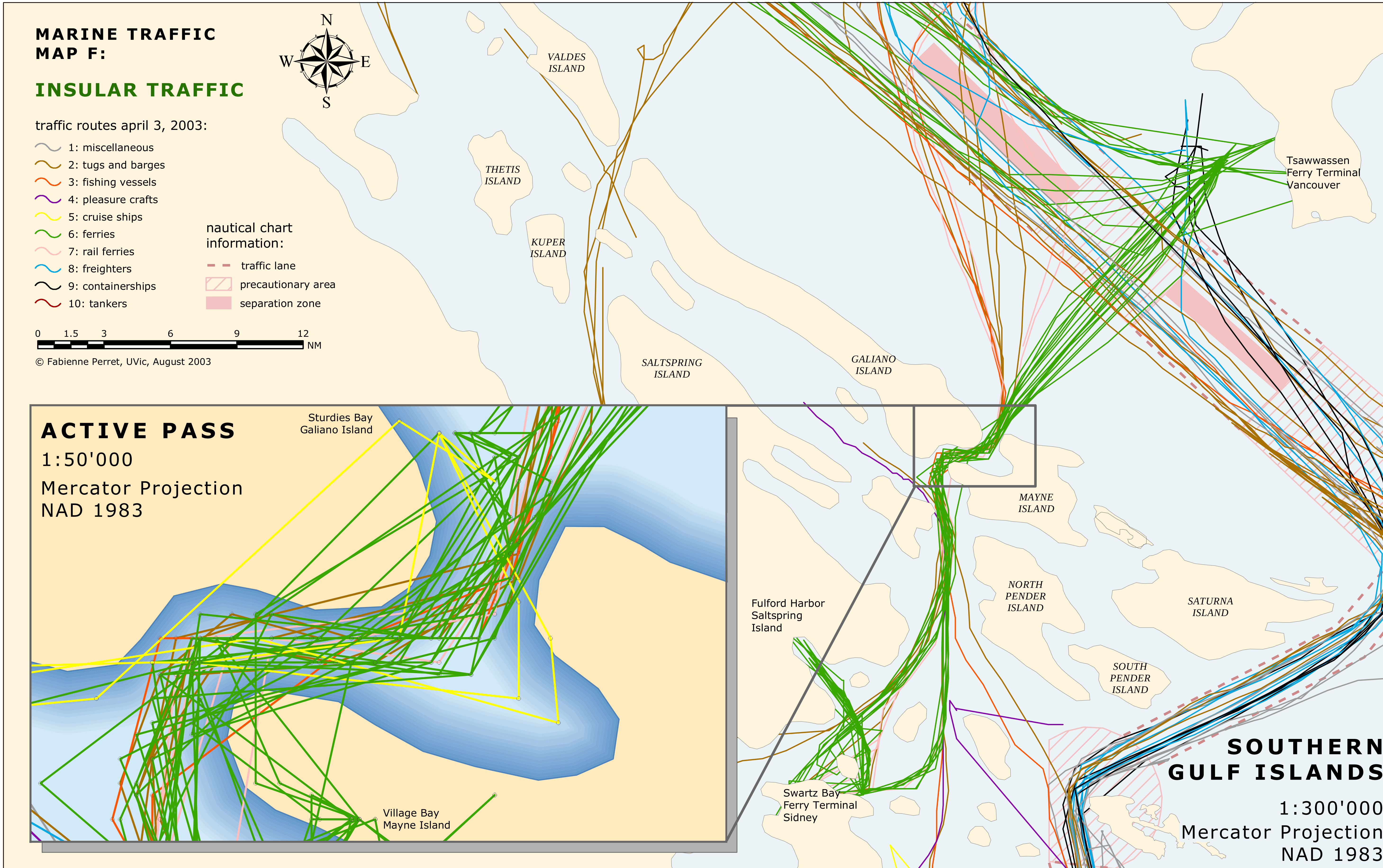

GEORGIA STRAIT
JUAN DE FUCA STRAIT
1:1'000'000
BC Albers Standard Projection
NAD 1983
MARINE TRAFFIC
MAP E:
FISHING ACTIVITY
tracks fishing vessels
february 24-28, 2003:
canada
usa
flag unknown
groundfish ports
fishing factory
0 5 10 20 30 40 50 km
N
S
W
E
© Fabienne Perret, UVic, August 2003
125°
124°
123°
50°
49°
48°
Pemberton
Whistler
Squamish
Campbell River Wharf (DFO)
Powell River
Comox
Courtney Civic Marina
Comox Public Wharf (DFO)
Cumberland
Fanny Bay
Deep Bay Public Wharf (DFO)
Qualicum Beach
Parksville
French Creek Public Wharf (DFO)
Port Alberni
Sechelt Ind Gov Dist
Sechelt
Gibsons
Lions Bay
Bowen Island
West Vancouver
Belcarra
Anmore
North Vancouver (City)
Vancouver
Port Moody
Burnaby
Coquitlam
Maple Ridge
Vancouver (Greater)
New Westminster
Pitt Meadows
Richmond
Mission
Surrey
Langley (City)
Langley (District)
Abbotsford
Nanaimo
Delta
Ladner (Delta)
White Rock
Ucluelet
Ladysmith
Chemainus
North Cowichan
Lake Cowichan
Duncan
Cowichan Bay
Westport
Sidney
Highlands
Saanich
View Royal
Langford
Colwood
Oak Bay
Metchosin
Victoria
Sooke

MAP F: **INSULAR TRAFFIC**

The sixth map is about the marine traffic happening between the mainland of British Columbia and Vancouver Island, particularly the area around the Southern Gulf Islands. Special attention is paid to the region called 'Active Pass', a narrow waterway between Galiano and Mayne Island that is used by most of the vessels traveling from Victoria to Vancouver. The tracks are generated from the same day as Map C (April 3, 2003) and the classification by vessel type is identical. The purpose of this presentation is to impart to the user an idea of daily traffic density in this region; especially in this narrow passage where almost all vessels have to navigate through and that is, at the same time, also a major crossing area for the BC Ferries. In addition, the map has a welcome side effect: it shows, due to the large scale, that the recorded positions are not always highly accurate, although this region is covered by radar. It is also proof that in certain cases the polyline building by simply connecting consecutive points is not accurate enough and it might be necessary to apply advanced track generation algorithms like the one in MARIS for instance (see chapter 7.1.2 for more details).

The covered region by the overview map lies precisely between the Swartz Bay Ferry Terminal near Sidney on Vancouver Island and the Tsawwassen Ferry Terminal on the Mainland at a scale of 1:300'000. The 1:50'000 cutout inset shows 'Active Pass' between Galiano and Mayne Islands. Both displays are in a Mercator projection based on NAD83. There is not a lot geographical information presented except for the official traffic separation scheme and the coastlines; island names and notations of ferry terminals are added orient the user. The large-scale inset shows the point positions in addition to the vessel tracks to provide an indication of the frequency with which the position is recorded. For this map the resolution of the base map containing the coastlines and cities should be more accurate (a larger scale). Originally it was intended that the bathymetry (fathoms) be included; but considering the short timeframe available for the visualization and the tremendous effort to export a common geographical file format from the GEBCO Digital Atlas (described in chapter 6.3.4) it is decided to abstain from presenting the precise water depths. Rather the gradient of the ocean bed is implied by drawing several blue shaded buffers around the two relevant islands.

Topic:	INSULAR TRAFFIC
Geographical coverage:	Haro Strait (48.5º-49.5º North, 123º-124º West), Active Pass
Datum:	North American Datum 1983 (NAD83)
Projection:	Mercator
Scale:	1:300'000 / 1:50'000
Marine information:	Vessel tracks, classified by the vessel type, traffic separation
Time frame:	Thursday, April 3, 2003
Base Map:	Coastlines; names of islands and major ferry terminals

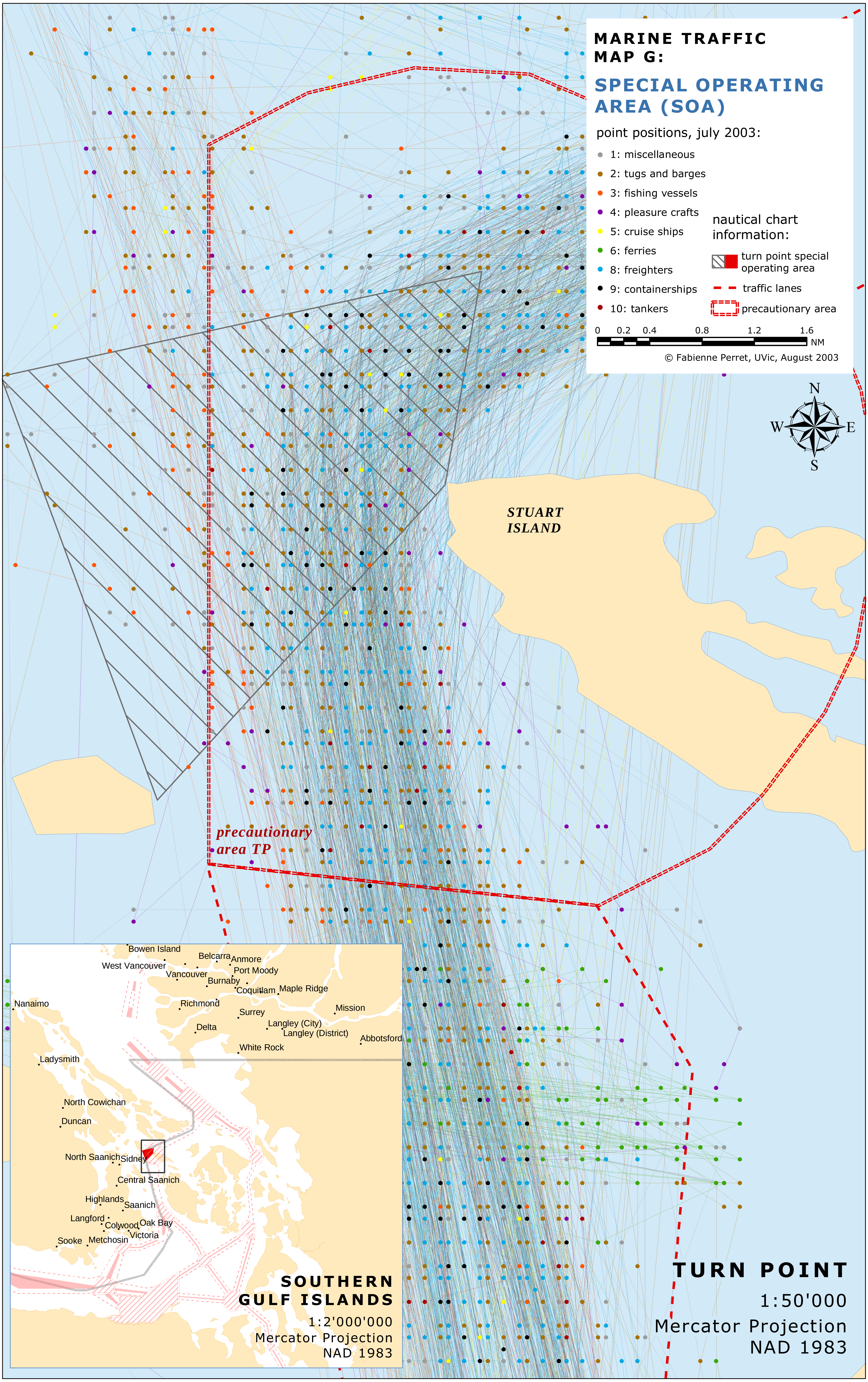

MARINE TRAFFIC
MAP F:
INSULAR TRAFFIC
N
W
E
S
traffic routes april 3, 2003:
1: miscellaneous
2: tugs and barges
3: fishing vessels
4: pleasure crafts
5: cruise ships
6: ferries
7: rail ferries
8: freighters
9: containerships
10: tankers
nautical chart information:
traffic lane
precautionary area
separation zone
0 1.5 3 6 9 12 NM
© Fabienne Perret, UVic, August 2003
VALDES ISLAND
THETIS ISLAND
KUPER ISLAND
SALTSPRING ISLAND
GALIANO ISLAND
Tsawwassen
Ferry Terminal
Vancouver
MAYNE ISLAND
NORTH PENDER ISLAND
SATURNA ISLAND
SOUTH PENDER ISLAND
Fulford Harbor
Saltspring
Island
Swartz Bay
Ferry Terminal
Sidney
ACTIVE PASS
1:50'000
Mercator Projection
NAD 1983
Sturdies Bay
Galiano Island
Village Bay
Mayne Island
SOUTHERN
GULF ISLANDS
1:300'000
Mercator Projection
NAD 1983

MAP G: **TURN POINT SPECIAL OPERATING AREA**

As the title implies this map's main topic is the "Turn Point Special Operating Area (SOA)", lying in both Canadian and American waters off Stuart Island. Because this is only a small region it is possible to show vessel information for more than just one day. All day tables are clipped during the data cleaning procedure by the limiting coordinates 48.6º and 48.8º North, respectively 123.2º and 123.3º West to reduce data volume prior to further cleaning. The cleaned tables are joined together using Access before importing to ArcMap to minimize the processing time. Information is loaded in ArcMap in one single layer, containing all point locations and attributes for the entire month of July 2003 for the area of interest. Vessel locations are classified by previously described vessel types and displayed as points; additionally the tracks are shown in a "washed-out" layer in the background to impart an idea of the traffic routes. The trips are produced in ArcMap applying the already mentioned GeoWizard operation to this point layer. The track generation is not errorless because the layer contains information of more than one day; consequently VSL_IDs are not unique and may occur for more than one date. Nevertheless, the procedure is connecting all points in the correct time order but without interrupting when the day changes. For that reason, the tracks can be wrong and are not be used for analysis purposes but only as helpful background information.

The entire "Turn Point SOA" area around Stuart Island, including the precautionary area "TP" and the adjacent shipping lane to the south are covered by this map at a scale of 1:50'000. In addition the map layout contains a smaller overview box, showing the position of the "Turn Point SOA" and the complete traffic separation system within Haro Strait on a 1:2 Mio map. No further background information is displayed in the large-scale map besides the coastline; in the location map the names of cities are added for to facilitate orientation.

Topic:	TURN POINT SPECIAL OPERATING AREA
Geographical coverage:	Turn Point (48.6º-48.8º North, 123.2º-123.34º West), Haro Strait
Datum:	North American Datum 1983 (NAD83)
Projection:	Mercator
Scale:	1:50'000 (1:2'000'000)
Marine information:	Vessel positions classified by vessel type
	Vessel tracks classified by vessel type
	Traffic Separation Scheme, Turn Point SOA, precautionary area TP
Time frame:	July 2003
Base Map:	Coastlines; (names of cities)

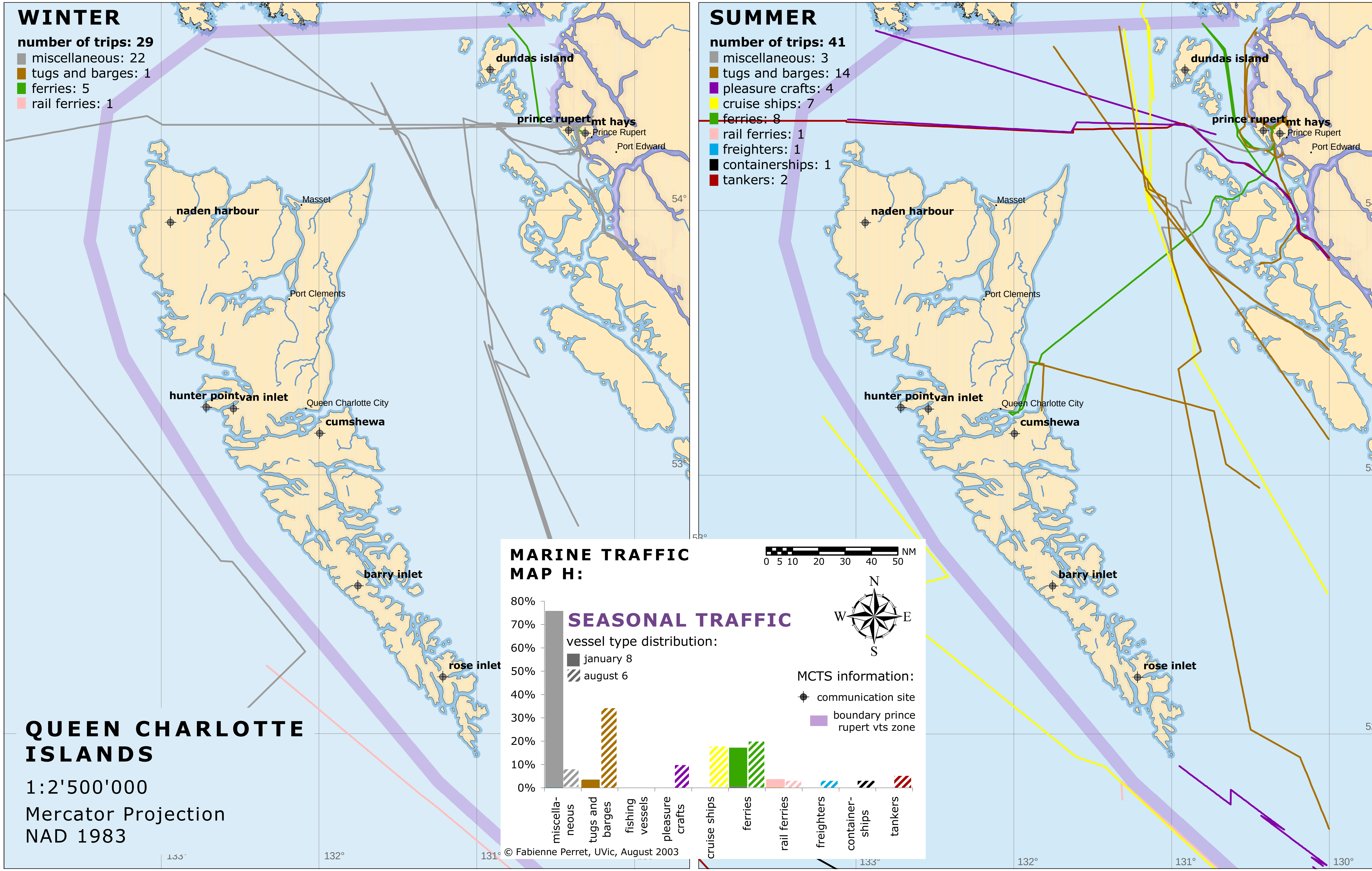

MARINE TRAFFIC
MAP G:
SPECIAL OPERATING
AREA (SOA)
point positions, july 2003:
1: miscellaneous
2: tugs and barges
3: fishing vessels
4: pleasure crafts
5: cruise ships
6: ferries
8: freighters
9: containerships
10: tankers
nautical chart
information:
turn point special
operating area
traffic lanes
precautionary area
0 0.2 0.4 0.8 1.2 1.6
NM
© Fabienne Perret, UVic, August 2003
N
W
E
S
STUART
ISLAND
precautionary
area TP
Bowen Island
West Vancouver
Belcarra
Anmore
Port Moody
Vancouver
Burnaby
Coquitlam
Maple Ridge
Nanaimo
Richmond
Mission
Surrey
Langley (City)
Langley (District)
Delta
Abbotsford
White Rock
Ladysmith
North Cowichan
Duncan
North Saanich
Sidney
Central Saanich
Highlands
Saanich
Langford
Colwood
Oak Bay
Victoria
Sooke
Metchosin
SOUTHERN
GULF ISLANDS
1:2'000'000
Mercator Projection
NAD 1983
TURN POINT
1:50'000
Mercator Projection
NAD 1983

MAP H: **SEASONAL TRAFFIC**

This map is designed to highlight the seasonal variances in marine traffic flows. Traffic in the waters around Queen Charlotte Island is considered representative and suitable for this purpose. Information from two days from each of the peak seasons, winter and summer is contrasted (Wednesday, January 8 and Wednesday, August 6, 2003). The selected dataset at first consisting only of cruise ship data could be extended due to little traffic density. All vessel trips of the two selected days, classified by vessel types, are displayed in two independent dataframes; the left map presents the traffic situation in wintertime, while the right chart contains the same information for the specified summer day. Numbers of total vessel trips and their allocation to classes are added to help the user understand the traffic variations between these two seasons. In addition to the list of absolute numbers, the percentage shares of each vessel type are displayed in a histogram created in MS Excel.

The two maps encompass an identical region around the Queen Charlotte Islands, which are located about 100 nautical miles West of Canada's northern mainland at the latitude of Prince Rupert. The Mercator projection and a scale of 1:2.5 Mio is chosen for each map to display an area large enough to portray the surrounding waters. The base map contains the coordinate grid and the coastlines as usual; plus city names, rivers and lakes, as well as a blue buffer around the main island to give the impression of the nautical chart. The presentation also includes MCTS-related information such as the boundary of the Prince Rupert VTS zone and the positions and names of the corresponding communication sites.

Topic:	SEASONAL TRAFFIC
Geographical coverage:	Queen Charlotte Island (51º-56º North, 130º-134º West)
Datum:	North American Datum 1983 (NAD83)
Projection:	Mercator
Scale:	1:2'500'000
Marine information:	Vessel tracks (classified by vessel type) of two different days from summer and winter season
	Absolute and relative indication of trip numbers
	Prince Rupert VTS zone boundary, communication sites
Time frame:	January 8 and August 6, 2003
Base Map:	Coordinate grid, coastlines, cities
	Water bodies: rivers, lakes, buffer around Queen Charlotte Island


WINTER
number of trips: 29
miscellaneous: 22
tugs and barges: 1
ferries: 5
rail ferries: 1
dundas island
prince rupert
mt hays
Prince Rupert
Port Edward
naden harbour
Masset
Port Clements
hunter point
van inlet
Queen Charlotte City
cumshewa
barry inlet
rose inlet
54°
53°
52°
133°
132°
131°
SUMMER
number of trips: 41
miscellaneous: 3
tugs and barges: 14
pleasure crafts: 4
cruise ships: 7
ferries: 8
rail ferries: 1
freighters: 1
containerships: 1
tankers: 2
130°
MARINE TRAFFIC MAP H:
SEASONAL TRAFFIC
vessel type distribution:
january 8
august 6
80%
70%
60%
50%
40%
30%
20%
10%
0%
miscella-neous
tugs and barges
fishing vessels
pleasure crafts
cruise ships
ferries
rail ferries
freighters
container-ships
tankers
0 5 10 20 30 40 50 NM
N
S
E
W
MCTS information:
communication site
boundary prince rupert vts zone
QUEEN CHARLOTTE ISLANDS
1:2'500'000
Mercator Projection
NAD 1983
© Fabienne Perret, UVic, August 2003

7.2.5 Map layout and printing

The 'Layout View' in ArcMap shows the virtual page upon which geographic data and map elements can be placed for printing. The software offers a wide range of supportive tools and functions for designing the map layout as well as for printing, or exporting the created map. Assistance includes a great choice of cartographic features and display options for the symbolization of the geographical data as well as predefined templates for a large variety of map styles. However, two templates (one for the tabloid format landscape and one for the same format but portrait) are designed to meet the specific needs of this thesis. These two templates are later used as basis for all maps and adjusted to the specific topic and task of the particular chart.

Different approaches can be followed for printing the final map. The most obvious possibility is to print directly to a connected printer using the proper printer driver provided by ArcPress; this procedure was chosen originally because it contains the fewest intermediate steps and is most efficient for printing. The printer used is an inkjet EPSON Stylus Color 3000 that is capable of printing tabloid-sized pages in high quality resolution and colors. Unfortunately, the colors of this straight print output diverge greatly from the colors presented at the computer screen. This process is dismissed for this reason and because it is unreasonable to need to print many test maps to reach the desired colors. Instead the approach suggested by cartographic experts at the UVic Geography Department is to print the map to a postscript file (.ps, the proper driver is provided in ArcMap) and use the Photoshop Software from Adobe to rasterize and print the map. This procedure results in authentic colors, but the rasterizing process required to reach a sufficient resolution (at least 150 dpi) takes an unreasonable amount of time and can therefore not be executed for each map. Ultimately, it is decided to use the ArcMap 'Export Map' function to create a Portable Document Format (PDF) file that is supported by numerous software packages and is independent from a specific printer. High quality resolution with color fastness can be obtained with this approach. Also, the maps are then prepared for the digital PDF version of this report. Another advantage of this procedure is the smaller size of the final file; one PFD map is a little more than 1 MB while the same postscript file and the rasterized image file is almost ten times bigger. In the export options the resolution is set to 360 dpi, the same resolution as is warranted for printing on special inkjet paper with the above-mentioned printer.

7.2.6 Conclusions on using ArcGIS for mapping

ArcMap is primarily a Geographical Information System, not cartographical software. Regardless, the capabilities of this software program are satisfactory for most of the mapping tasks accomplished during this thesis. Graphical improvements are obvious especially in the comparison to its "older brother" ArcView, a former GIS release from ESRI previously used extensively by the author. ArcMap offers may more cartographical properties, including a large choice of predefined symbols, templates and styles. At the same time, the user has always the potential to customize desired graphical elements. Another advantage is the potential coexistence of more than one dataframe in the same layout; features and elements in each one can be adjusted independently. However, there is a disadvantage in that the layout display cannot be detached from the activities in the data view window (e.g. panning and zooming). The inability to create more than one layout pertaining to the same project is questionable too. These two handicaps are even more significant since they are implemented in the less powerful ArcView. Another issue arising during this work is that the ArcMap layout view display is "WYSIWYG" (what you see is what you get) because of the earlier described color problems when printing directly. However, because ArcMap has a large variety of other print and export options, this disadvantage is less of a problem. Also, this issue could be partially attributed to the printer.

Aside from the pros and contras of using GIS for mapping purposes, for this particular thesis, ArcMap meets the visualization requirements. The program's usability and clear design allowed the author to take advantage of the graphical functionalities without spending too much time reading the extensive user manual or searching the desktop help.

7.3 Variations from specified Visualization Approaches

This chapter is concerned with the achievement of the objectives outlined in the user needs assessment and the derived visualization strategies in chapters 5.3 and 5.4. The evaluation follows the same order as the listed strategies to provide a good overview on the deviations.

The need for a flexible geographical coverage and adjustable scale is met with the created maps ranging from displaying the entire West Coast (MAP A, 1:3 Mio and MAP B, 1: 5 Mio) to the presentation of two small areas of special interest (MAP F: Active Pass at 1:50'000 and MAP G: Turn Point at 1:50'000).

In the author's opinion the requirements of the base map are also fulfilled with the maps looking similar to the official nautical charts provided by the CHS. Exceptions to this are the lack of terrestrial topography (including mountains, altitude, and names); place names for different water bodies such as sounds and bays; and water shallows displayed in blue color shading. Also, as mentioned in the descriptions of the relevant maps, the coastlines used are not detailed enough for large-scale maps.

The least achieved task is probably the temporal mapping requested by the potential users. This failure has to be ascribed to the software that is unable to efficiently process large amounts of data. At very least, attempts were made to present a comprehensive overview of the available data. As the geographical coverage getting smaller (Turn Point SOA in MAP G) or as the selected vessels are fewer in number (only fishing vessels in MAP E) it is possible to display data from a longer time period. However, the procedure needed to clean and aggregate the individual day files takes an unreasonable amount of time, even though excess information is clipped from outside the area of interest.

The strategy of mapping point locations was accomplished in two maps (MAP D and G) without significant difficulties, apart from the manual effort required for the vessel type classification. Track generation is somewhat more complex due to the necessity of visually checking the cleaned data for remaining errors and ambiguities. It would be necessary to apply a land avoidance algorithm for the large-scale maps to prevent vessel routes from crossing the landmass.

The deduction of general traffic flows could be performed taking into consideration just a couple of days. The displayed arrows are effective, since they are drawn by the author who has in-depth knowledge of the database, enough.

Calculation of traffic density presented in MAP B, symbolize the traffic frequencies along Canada's West Coast for only one day, due to the same data processing restrictions previously mentioned. In this case, the inclusion of further days would not make a big difference in the display because the daily traffic patterns are similar: only the density values and the classification in the legend would change noticeably.

Mapping "hot spots" is set aside because this visualization method would require extensive data analysis and programming efforts that cannot be done in the scope of this thesis. However, displaying traffic densities and routes imparts a first impression of potential hazardous regions within the area of interest.

The approach of combining traffic information with other marine related data (called overlap approach in chapter 5.4.9) is fulfilled in part. Several layers containing project-generated marine information such as the groundfish ports or the ferry routes are included in the designed maps. Outstanding tasks include the incorporation of the Search and Rescue Incident data and the fishing activity layers. It is found that the latter is problematic to include because of permission restraints. Information that was not displayed consists of the ocean disposal sites (which are not of specific interest in the shown topic) and as previously mentioned the bathymetry due to translation difficulties.

CONCLUSIONS 8

8.1 Achieving the defined Tasks and Time Allocation

All three main tasks defined in chapter 2, namely the data cleaning and preparation; the marine traffic visualization and the data conversion for usage in MARIS, are achieved at the end of the thesis. However, time distribution between the three issues was not equal, the longest period in the beginning (around ten weeks) was spent on understanding, analyzing and scanning the MCTS database for errors. Another significant length of time (about two weeks) was used to actually define the data cleaning algorithms because it involved the tedious manual application of the exemplary procedures. The implementation of the defined algorithms by a project-outside computer expert took even longer. Therefore not more than one fourth of the available time frame remained for the accomplishment of the second and third task. The last duty of converting the day files into a MARIS-compatible format could be set aside because it was found that the software can import common shape files, which can be generated in ArcGIS. On the other hand the application possibilities in MARIS are found to be limited anyway, for that it was not worthwhile to spend too much time on this task. The second fundamental objective of defined visualization strategies for marine traffic and produce maps to that effect was performed in the last four weeks of this thesis. The efforts of mapping the contents of the MCTS database could be continued open-ended because of the large data volume and the various visualization approaches. However, the author believes that a complete overview on visualization possibilities is provided with the presented eight charts.
The available time period had to be allocated unequally between the different issues due to the reason that it does not make sense to visualize the information as long as it contains unfixed errors. Background information and base map layers were prepared in advanced to ensure an efficient visualization process, as soon the data were cleaned and ready for presentation.
Additionally it was tried to keep this report up to date during the entire period to back up important information and avoiding long periods of writing towards the end. The first few work steps, including the MCTS database description and the preliminary analyzing results are also documented in the progress report from the end of May 2003.

8.2 Database

The intense study on the MCTS database uncovered several facts about the data that were not known before this thesis. Above all it brought out that the recorded vessel and trip information is not collected in terms of a post-processing analysis but only for real-time traffic control purposes. For that reason the data cleaning is an extensive and time-consuming procedure prior to the use for analysis and visualization objectives. The double tracking of single vessels is mentioned here as an example of making the post-processing much more complex; however, it is not of a problem for the MCTS officers executing their daily operations. As long as the operators at one particular VTS center get the information they need for their traffic controlling tasks, it is non-relevant to them if another station is working the same vessel. But at the later aggregation of the different databases, the information will be stored double, complicating analysis.

Some suggestions for the future are made here in order to reduce data cleaning expenses and visualization difficulties. It would make sense to add an attribute field on the general type of the vessel (similar to the adopted classification scheme for this thesis, chapter 4.4.4) because the currently used types are too numerous for visualization purposes. An alternative approach to that problem is the implementation of an automated reclassification in the data cleaning algorithms. The CCG should create a fixed procedure to "deliver" a vessel from one VTS station to another; this recommendation is not only useful in terms of post-processing but also helps reducing work efforts for the MCTS officers themselves. Instead of duplicating the work when double tracking a vessel during a certain time period, there would be a fixed point in time and space where the vessels is assigned to the following zone and the proper MCTS center. Further efforts should be undertaken towards the standardization of the vessel information between the different MCTS stations. A unique vessel owning the same identification number in the entire Pacific Region would support their own objectives, as well as simplify analysis and visualization tasks. However, it is questionable with regards to the coming "Universal Automatic Identification System" (AIS) if these improvements are profitable at the present time. The implementation of the AIS would produce many advantages as described in chapter 3.6; above all the unique identification code (MMSI) and the higher accuracy of the locations due to the use of GPS would be a great simplification for the described visualization approaches.

8.3 Cooperation with the Canadian Coast Guard

This thesis required a certain degree of communication between the author and the CCG employees; experiences made in the cooperation are varying from very good to unsatisfactory. Communication was conducted mainly via e-mail and with a few phone calls. In addition the MCTS centers in Vancouver and Victoria were visited to get a better understanding on the ongoing data recording processes and to discuss the visualization needs.

Contact to the Vancouver MCTS officials existed already prior to this thesis in the scope of the overall "Marine Geomatics" project; thus Mr. Grant McGowan was instructed to load all the day files on the mentioned ftp-site to secure the access to the data. He was also responsible for providing information about the database itself, the tracking procedure and the recording system; he did so in a detailed explanation during the visit at this particular station. Unfortunately, information requested by e-mail was not answered in a helpful time.

The first time contacted MCTS officers from the Victoria MCTS center were very helping and showed a big interest in this work; Mr. Brian Bain assisted in a great manner during the visit and also in the preparative and concluding phase of the cooperation.

Other inquiries to CCG divisions without referring to specific persons, such as requesting digital information about VTS zone boundaries from the CCG GIS Services Group, were unfortunately not answered at all. Several attempts to obtain digital spatial information from the CCG earlier in this "Marine Geomatics" project failed similar or due to non-availability of the requested data. It is surprising how little geographic data they seem to own in a digital format or rather, they might not be willing to distribute it for free. However, in the author's understanding it should be possible to obtain spatial information for academical and educational purposes at a reasonable price.

Other institutions asked for assistance such as the Marine Safety Division of Transport Canada or Environment Canada's Ocean Disposal Program were quite fast with providing the requested digital information.

Altogether, the experienced cooperation with the Canadian Federal employees was satisfactory and an essential part in the success of this thesis.

8.4 Outlook

This chapter is intended to conclude the thesis with a look into the future. The logical next step would include delivering the created maps to the CCG and other involved groups to obtain their opinion on the results. The charts should also necessarily be presented and explained to the overall "Marine Geomatics" project researchers on Canada's East Coast. This information transfer is important in terms of a possible improvement of the existing MARIS software through the implementation of the developed marine visualization strategies. The maps could then be improved based on the user feedback, realizing the requested modifications.

In case of a continuation of the mapping, several other work steps are to be undertaken; first of all the further development of the MS Access data cleaning application. The remaining bugs have to be "caught" and removed in order to simplify the data preparation prior to visualization. Advanced approaches would also include additional algorithms to automate the import of single day files and to facilitate the aggregation of different cleaned tables. But in the author's opinion it is unlikely that the manual and visual checking through a person could ever be replaced, not even with the best possible algorithms. The potential to advance the data preparation and consequently the visualization procedure can rather be found in the improvements of the existing data recording system as suggested in the previous chapter 8.2 or even more in the future adoption of the described AIS (Automatic Identification System).

The author hopes to have assisted the "Marine Activity Geomatics and Risk Analysis in the Coastal Zone" project and the Canadian Coast Guard with her research on marine traffic visualization strategies and the created maps. The results of this thesis are available for further investigations on the specific topic.

It was a scientific honor for the author to account her work to such an interesting project that is of great importance for Canada's future environmental development, not only in the marine context but hopefully as an example for other fields of activity.

BIBLIOGRAPHY 9

9.1 Papers and Articles

ENV#60 - Marine Activity Geomatics and Risk Analysis in the Coastal Zone. GEOIDE Progress Report Form November 2000.

IMO (2002). New and Amended Traffic Separation Schemes. International Maritime Organization, London.

Jackson, E., Rifkin, D. and Tsui, Oliver (2002). Creating a GIS for a Marine Emission Inventory: Data Input, Analysis and Display. BCIT Geographic Information Systems.

MARIS v2.0.0 Quickstart Guide Draft (2002). Maritime Activity and Risk Investigation Network (MARIN). Department of Industrial Engineering, Dalhousie University Halifax.

NATO RTO Technical Report 30 (2001). Visualization of Massive Military Datasets: Human Factors, Applications and Technologies. NATO Research and Technology Organization, Neuilly-sur-Seine Cedex, France.

Numano, M., Itoh, H. and Niwa, Y. (2001). Sea Traffic Simulation and its Visualization in Multi-PC System. In Proc. of International Congress on Modelling and Simulation (MODSIM) 2001, pp. 2093-2098, Canberra, Australia, December 2001.

Pelot, R., Shields R. and Sandblom, C.L. (1997). The Development of a Model of the Demand for Search and Rescue Services Provided by the Canadian Coast Guards: Phase I. Atlantic Industrial Research Institute, Halifax.

Pelot, R., Deveaux, J.P., McWhirter, P. and Hawes S. (1998). The Development of a Model of the Demand for Search and Rescue Services Provided by the Canadian Coast Guards: Phase II. Atlantic Industrial Research Institute, Halifax.

Traffic Separation Schemes in the Strait of Juan de Fuca and its Approaches, in Puget Sound and its Approaches, in Haro Strait, Boundary Pass, and in the Strait of Georgia. Note by the Governments of the United States and Canada (2001).

Times Colonist Newspaper. May 25, 2003. The shipping news: Big ships, big worries.

VTS Puget Sound User Manual, Section 5 (2003). U.S. Coast Guard, VTS Directory Puget Sound, Seattle.

9.2 Publications by the Canadian Coast Guards, Fisheries and Oceans Canada

Brochure on Marine Communications and Traffic Services (MCTS). June 2001.

Radio Aids to Marine Navigation (Pacific and Western Arctic) Annual Edition 2003.

McGowan, G. and Athwal, R. (2003). VTOSS (Vessel Traffic Operations Support System) Technical Introduction Documentation.

McGowan, G. and Athwal, R. (2003). AIS Data Integration into VTOSS.

9.3 Internet Sources

AXYS Environmental Consulting Ltd.:
www.axys.net (August 5, 2003)

Alaska Ferry Adventures, Schedules:
www.akmhs.com/schedules/ (June 25, 2003)

BC Ferries:
www.bcferries.bc.ca (April-August 2003)

British Columbia Albers Standard Projection:
srmwww.gov.bc.ca/gis/bceprojection.html (May 12, 2003)

Canadian Coast Guard – Pacific Region
www.pacific.ccg-gcc.gc.ca/index_e.htm (April-August 2003)

Canada / U.S. Cooperative Vessel Traffic Service (CVTS) for the Strait of Juan de Fuca
www.piersystem.com/external/index.cfm?CID=398 (April-August 2003)

Coho Ferries:
www.cohoferry.com (April – August 2003)

Digital Ocean Distribution of nautical charts:
www.digitalocean.ca (July 30, 2003)

ESRI – GIS and Mapping software:
www.esri.com (July 30, 2003)

GeoGratis, free download of the National Atlas of Canada:
www.geogratis.com (July 21, 2003)

GEOIDE project descriptions:
https://geoide.goldsystem.ca/internet/u_703_00.asp (April 14, 2003)

Guide to Coastal Information in Atlantic Canada
www.dal.ca/aczisc/ (July 14, 2003)

Ianko's GIS page, ET GeoWizard 8.6 download:

www.ian-ko.com (April 29, 2003)

Latitude and Longitude Format Conversion

www.geology.enr.state.nc.us/gis/latlon.html (April-August 2003)

Lloyds Register Fariplay:

www.fairplay.co.uk (April 17, 2003)

Maritime Activity and Risk Investigation Network MARIN:

www.dal.ca/~marin/ (July 23, 2003)

Marine and Coastal Geographical Information Systems:

http://dusk.geo.orst.edu/book/index.html (July 25, 2003)

Marine Communication and Traffic Services MCTS:

www.ccg-gcc.gc.ca/mcts-sctm/ (April-August 2003)

Marine Communication and Traffic Services MCTS, Pacific Region:

www.pacific.ccg-gcc.gc.ca/mcts/ (April-August 2003)

NATO Research and Technology Organization Research Task Group IST-021/RTG-007:

www.vistg.net (July 14, 2003)

Nautical Data International, distribution of nautical charts

www.digitalocean.ca (July 28, 2003)

Ocean Disposal Sites in the Pacific and Yukon Region:

www.pyr.ec.gc.ca/EN/ocean-disposal/english/sitemap_e.htm (August 6,2003)

Official Marine Navigation Charts and Nautical Publications (Canadian Hydrographic Service):

www.charts.gc.ca (July 28, 2003)

Online ArcGIS Tutorial University of Victoria:

http://godzilla.geog.uvic.ca/manual, password protected (April 16, 2003)

Pacific Pilotage Authority Canada:

www.ppa.gc.ca (July 26, 2003)

Project Homepage University of Victoria

http://godzilla.geog.uvic.ca/marinerisk/homepage, password protected (April 16, 2003)

Puget Sound Vessel Traffic Services:

www.uscg.mil/d13/units/vts/psvts.html (April-August 2003)

Safe Software – FME Universal Translator:

www.safe.com (April 16, 2003)

Traffic Management System for the World, Denbridge Digital:

www.denbrigdedigital.com (July 14, 2003)

Transport Canada, Marine Projects:

www.tc.gc.ca/tdc/projects/marine/menu.htm (July 25, 2003)

University of Alaska Southeast, geospatial data download:

www.uas.alaska.edu (July 21, 2003)

USDA Service Center Agencies GIS homepage:

www.gis.sc.egov.usda.gov (July 30, 2003)

Victoria Clipper:

www.victoriaclipper.com (April-August 2003)

Washington State Department of Transportation, geospatial data download:

www.wsdot.wa.gov (July 21, 2003)

Washington State Ferries:

www.wsdot.wa.gov/ferries/ (April-August 2003)

APPENDIX 10

APPENDIX A

(source: McGowan, G. and Athwal, R. 2003)

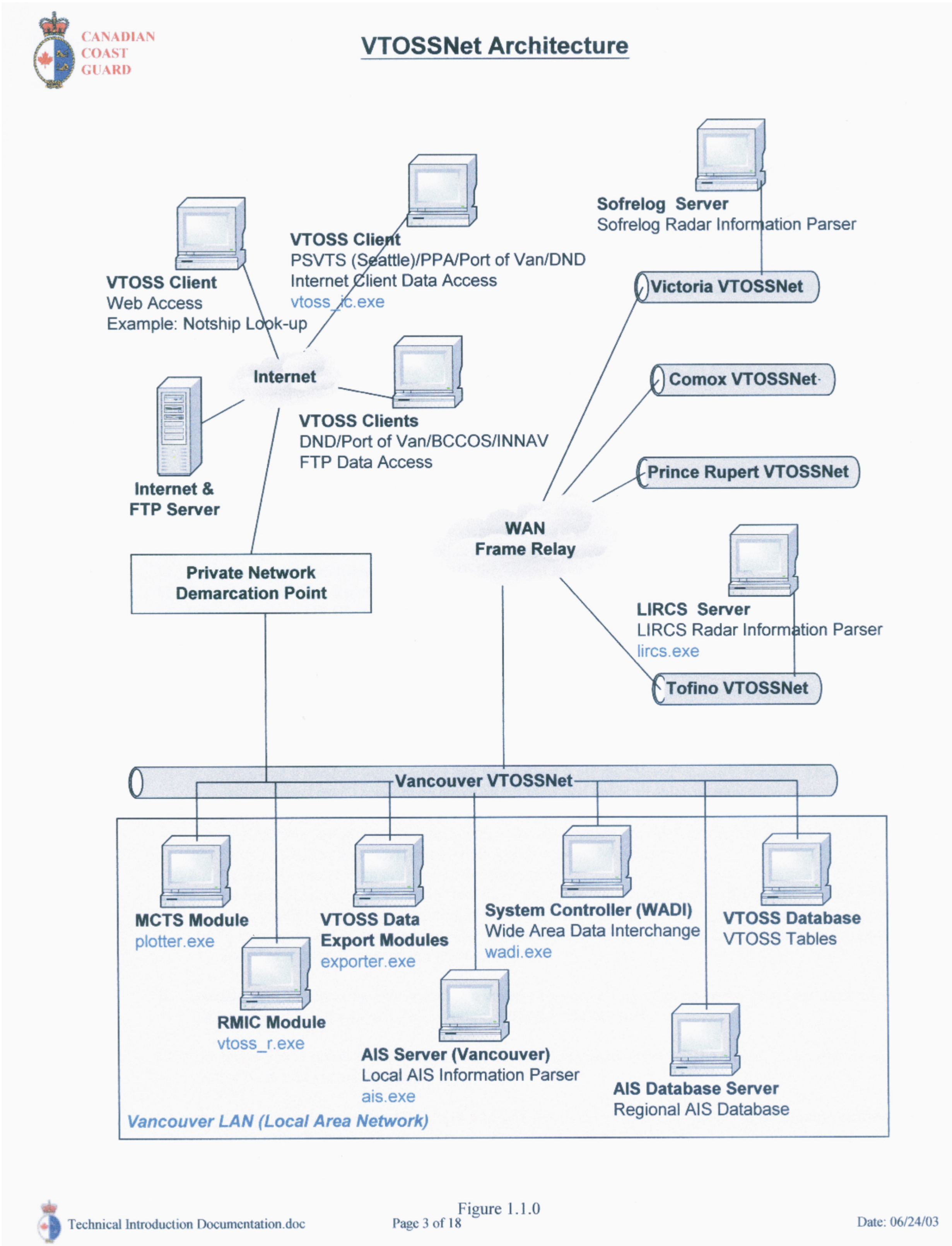
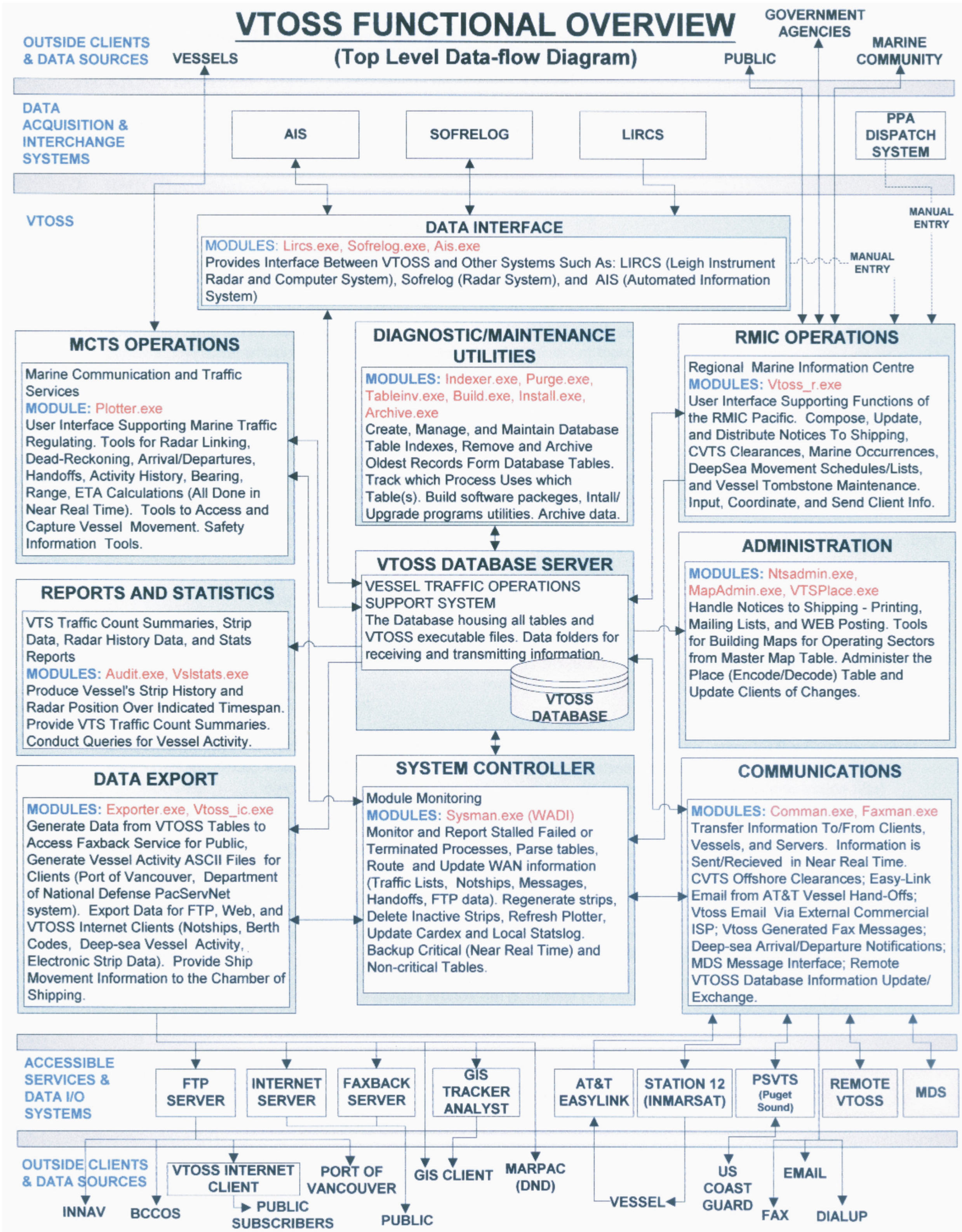


Figure 1.1.0

APPENDIX B

(source: McGowan, G. and Athwal, R. 2003)



(source: McGowan, G. and Athwal, R. 2003)

The VTOSS Functionality Groups and their Modules

The VTOSS "functionality groups" as indicated in the Figure 1.1.5 are:

1. **MCTS Operations** – The GUI (Graphical User Interface) regulating marine traffic.
   Module: mcts_module (multiple sessions running at all sites with site-specific data tables)

2. **RMIC Operations** – The user interface(s) regulating RMIC information.
   Module: rmic_module (multiple sessions running at Vancouver – the only RMIC site)

3. **VTOSS Database Server** – The database of all files, tables, and executable program modules. Two dedicated VTOSS Database Servers (Primary and Backup) are running at each site.
   Module: None

4. **Administration** – The interface that manages administrative duties such as budgets, shift schedules, and employee benefits. The administration of VTOSS data is conducted via some of these modules.
   Modules: mapadmin_module (session opened as required by Administrators/ Supervisors to manage sector maps)
   notship_module (opened as required by Administrators to manage Notship data)
   place_module (session opened as required to administer the Place table)

5. **Data Interface** – Modules that interface with other information platforms to receive/transmit data.
   Modules: sofrelog_module (single session opened in Victoria – the site-specific modules for Sofrelog Radar data input/output)
   lircs_module (single session opened in Tofino – the site-specific modules for LIRCS Radar data input/output)
   ais_module (single session opened in Comox/Vancouver – the site-specific AIS test modules for AIS transponder data input/output)

6. **Data Export** – Modules that export data to various clients outside of VTOSS
   Modules: export_module (single session running at Vancouver – Primary Data Export Site by designation)
   vtoss_internet_client_modules (multiple sessions for selected clients with access to VTOSS data via the Internet.

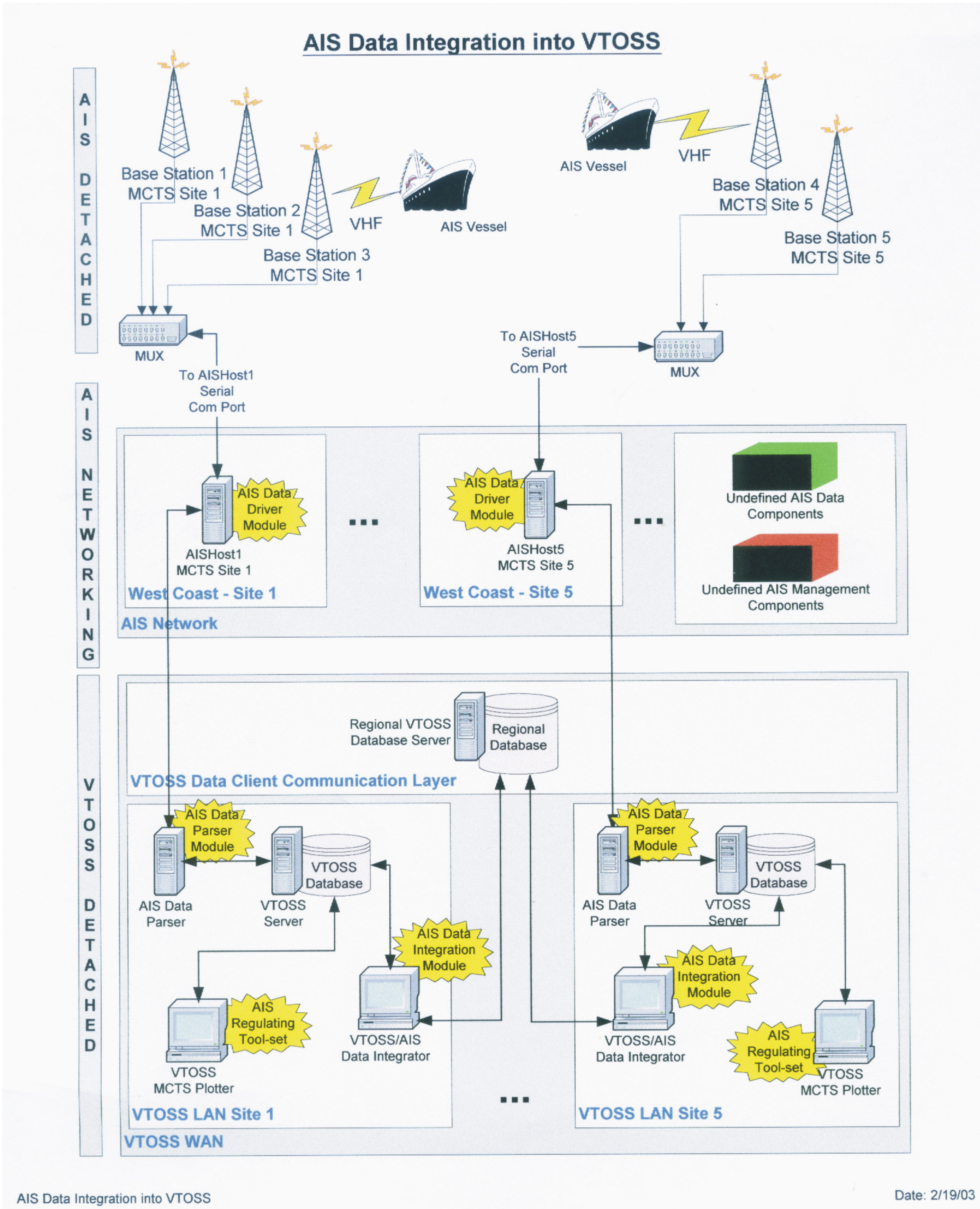
7. **Communications/Networking** – Modules that communicate data amongst the LANs, other VTS authorities such as PSVST (Puget Sound Vessel Traffic System), MDS (Message Distribution System) servers, and vessels.
   Modules: com_module (single session at Vancouver – designated as Primary Communication Site)
   fax_module (single session at Vancouver – part of RMIC backup operations to electronic fax)

8. **System Controller** – Modules that monitor, control and manage data flow, and back up data
   Module: system_modules (WADI) (single session in WAN mode at Vancouver – designated as primary site) (single sessions in LAN mode at all other sites – designated as secondary sites)

9. **Utilities** – Modules that create, manage, and maintain the VTOSS database.
   Modules: maintenance_module (single session run as needed at any site for maintenance of VTOSS tables and their indices – index, purge, and manage table inventory)
   install_module (single session run as needed at a site to install/update VTOSS applications)
   archive_module (single session run as needed at a site to archive VTOSS data onto an external medium)

APPENDIX C

(source: McGowan, G. and Athwal, R. 2003)



APPENDIX D

Required Format for Advanced Reports

IMO standard ship reporting system [Resolution A.648(16), MSC/WP6]:

ALPHA	Vessel name, call-sign, flag and IMO International Number (Lloyd's Register No.); if vessel does not have an assigned IMO international number, the official number of the vessel.
BRAVO	Current date and time. (UTC - Coordinated Universal Time)
CHARLIE	Current position.
ECHO	True course.
FOXTROT	Speed in knots.
GOLF	Name of port or place of departure.
HOTEL	ETA (UTC) to Buoy "J" at the entrance to Juan de Fuca Strait (if applicable).
INDIA	Destination and ETA (UTC) to port or place of destination;
MIKE	ISM, if applicable, and if any issued to the vessel: 1 What is the Name of the Issuing Authority? 2. ISM Safety Management Certificate: a. What is the date of issue?; and b. What is the date of expiration? 3. ISM Document of Compliance: a. What is the date of issue?; and b. What is the date of expiration?;
NOVEMBER	Vessel MMSI Number;
OSCAR	Maximum present static draught;
PAPA	1. If bound for a Canadian port, dangerous or POLLUTANT cargo by name, **UN#,** or IMDG Code # if applicable; 2. If bound for a U.S. port, name and UN# or IMDG Code # of certain dangerous cargoes as defined in 33 CFR 160.203 (The vessel must also report the items required in 33 CFR 160.211 (a)(1) through (a) (16) and (b) when applicable);
QUEBEC	Any defects or deficiencies in hull, steering gear, propulsion machinery, navigation equipment, anchors or cables; required radio communications equipment; incomplete complement of officers and crew as required by flag state; or any other hazardous conditions;

NOTE:
By regulation, vessels 1600 GRT and more, bound for a U.S. or Canadian port are required to inspect and fully test their steering gear and main propulsion machinery, both ahead and astern, within 12 hours prior to entering the Strait of Juan de Fuca.

When transiting on a West Coast approach to the entrance of the Strait of Juan de Fuca, vessels are strongly encouraged to conduct their pre-arrival tests in accordance with 33CFR164.25 before crossing longitude 125 25W.
Vessels on a coastwise voyage not exceeding 25 miles from the entrance of the Strait of Juan de Fuca are encouraged to conduct their pre-arrival tests as far as practicable from shore and maintain radio contact with Tofino Traffic when changing direction of propulsion.

If testing at sea must be delayed for safety reasons, then report this to CVTS and request permission to conduct the test in the open but more protected waters of the Strait of Juan de Fuca before arriving at the pilot station.

Do not test propulsion in the Traffic Separation Scheme (TSS) or within 12 miles of the coastline unless you have permission from CVTS. Test farther from the coastline if onshore wind and sea conditions are severe, and there is no immediately available tug; coordinate with CVTS.

SIERRA On scene weather, if severe;

TANGO Agent name; owner name; and name of operator or person in charge of vessel;

UNIFORM Vessel gross tonnage;

WHISKEY Ballast Water - If **in-ballast,** has your vessel:

1. Conducted open ocean ballast water exchange in accordance with the destination Port requirements since your last port of call? **YES** or **NO;**
2. A **Ballast Water Management Plan** [Section 7.1 of IMO Resolution A.868(20)]**?** **YES** or **NO**; and
3. Made the required notification and reports to Canada/United States authorities as applicable? **YES** or **NO**

XRAY

1. **If bound for a Canadian port**, expiration date of:
   a. International Oil Pollution Prevention Certificate or Certificate of Compliance;
   b. International Noxious Liquid Substance Certificate, or Certificate of Compliance
   c. Certificate of Fitness (Chemical tankers)
   d. International Convention on Civil Liability for Oil Pollution Damage Certificate of Insurance
   e. Indicate if a shipboard oil pollution emergency plan is on board and
   f. Indicate if oil spill response arrangements are in effect with a designated spill response organization for your port of destination

2. **If bound for a U.S. port**
   a. Indicate intention to transfer fuel and/or lube oil. If yes, specify type/amount
   b. Indicate name of Washington State spill contingency plan
   c. Classification society of the vessel; and
   d. Name and phone # of a 24 hour point of contact for vessel related concerns.

APPENDIX E

Data Cleaning Implementation: Complete Code

```
 ------------------------------------------------------------------------------------------------------------------
'
'   Name:           MCTS Data Cleaning Application
'   Date:           August 2003
'   Author:         DC
'   Description:    Performs a variety of cleanup tasks on a DBF file containing position/time observations
'                   of vessels reporting into Vessel Traffic Services.  All processing is as per accompanying
'                   documentation "Data Cleaning Algorithms" (F. Perret).  Task numbers here correspond
'                   to those identified in the document.
'
'   Assumptions: - DBF files must be named in the form XXYYMMDD.DBF, e.g., TK030601.DBF (June 1, 2003)
'
'   Revision History:
'
' ------------------------------------------------------------------------------------------------------------------

Option Compare Database

' Global Declarations
Dim CurrentTable As String



Private Sub AddFields(Tablename As String, Ctl As Control)
    Dim dbs As Database, tdf As TableDef
    Dim fld As Variant

    ' Return reference to current database.
    Set dbs = CurrentDb
    ' Return reference to table
    Set tdf = dbs.TableDefs(Tablename)

    ' Enumerate all fields in Fields collection of TableDef object.
    For Each fld In tdf.Fields
        If Ctl.ListCount > 0 Then
            Ctl.RowSource = Ctl.RowSource & ";" & fld.Name
        Else
            Ctl.RowSource = fld.Name
        End If
    Next fld
    Set dbs = Nothing
End Sub



Private Sub bt_Add_Click()
    Dim PathStr As String
    Dim Tablename As String

    ' get the DBF file
    ' use the MS CommonDialog control to get the file
    CommonDialog1.Filter = "Dbase Files|*.DBF"
    CommonDialog1.ShowOpen

    ' make sure something is selected
    If Len(CommonDialog1.FileTitle) = 0 Then
        Exit Sub
    End If
```

```
    ' Sort out file location, table name, etc.
    PathStr = Left(CommonDialog1.FileName, InStr(1, CommonDialog1.FileName, CommonDialog1.FileTitle) - 1)
    Tablename = Left(CommonDialog1.FileTitle, Len(CommonDialog1.FileTitle) - 4)

    ' check if this table already exists in this Access MDB.
    If CheckTableExistence(Tablename) Then
        If MsgBox("Table of this name exists already." & vbNewLine & "Use existing table?", vbYesNo, "File Exists") =
vbYes Then
            CurrentTable = Tablename
            lblCurrentFile.Caption = CurrentTable
        Else
            MsgBox "Exiting.  To import a table of the same name delete or rename the file or existing table(s)."
            Exit Sub
        End If

    Else
         ' try to add this as a table
        On Error GoTo Importerror
        DoCmd.TransferDatabase acImport, "dBase IV", PathStr, acTable, CommonDialog1.FileTitle, Tablename, False,
False
        CurrentTable = Tablename
        On Error GoTo 0

        ' add it to the listbox
        lblCurrentFile.Caption = CommonDialog1.FileName
    End If

    Exit Sub

Importerror:
    MsgBox "File Open Error: " & Err.Description
    Exit Sub
End Sub

Private Sub bt_Quit_Click()
    DoCmd.Quit
End Sub

Private Sub bt_Start_Click()

    Dim SQL As String

    If cb_Warnings = 1 Then
        DoCmd.SetWarnings True
    Else
        DoCmd.SetWarnings False
    End If

   ' make sure there is a table selected
    If IsNull(CurrentTable) Or CurrentTable = "" Then
        MsgBox "No data table selected."
        Exit Sub
    End If

    ' validate the time gap
    If cb_Task_8_2 = -1 Then
        If Not IsNumeric(txt_TimeGap) Then
            MsgBox "Invalid Time Gap."
            Me.txt_TimeGap.SetFocus
            Exit Sub
        End If
    End If


    ' Copy this table to a working table
    SQL = "SELECT * into " & CurrentTable & "_Cleaned from " & CurrentTable
    'MsgBox SQL
    If cb_Regen = 1 Then
```

```
        ShowMessage ("Copying table contents...")
        DoCmd.RunSQL SQL

    End If
    CurrentTable = CurrentTable & "_Cleaned"

    ' do all the processing tasks
    If cb_Task_5 = 1 Then
        ShowMessage ("Task 5...")
        Call Task_5_Processing(CurrentTable)
    End If

    ' see if we need to regenerate the _Cleaned table and fix up the VSL_ID's
    If cb_Regen = 1 Then
        ShowMessage ("Reformatting LAST_UDDTG and cleaning up VSL_ID's...")
        Call AddDateField(CurrentTable)
        Call AddNoteField(CurrentTable)
        Call AddNumericTime(CurrentTable)
        Call Clean_VSL_IDs(CurrentTable)
    End If

    If cb_Task_1 = -1 Then
        ShowMessage ("Task 1...")
        Call Task_1_Processing(CurrentTable)
    End If

    If cb_Task_2 = -1 Then
        ShowMessage ("Task 2...")
        Call Task_2_Processing(CurrentTable)
    End If

    If cb_Task_4_1 = -1 Then
        ShowMessage ("Task 4.1...")
        Call Task_4_1_Processing(CurrentTable)
    End If

    If cb_Task_3 = -1 Then
        ShowMessage ("Task 3...")
        Call Task_3_Processing(CurrentTable)
    End If


    If cb_Task_4_2 = -1 Then
        ShowMessage ("Task 4.2...")
        Call Task_4_2_Processing(CurrentTable)
    End If

    If cb_Task_6 = -1 Then
        ShowMessage ("Task 6.0...")
        Call Task_6_Processing(CurrentTable)
    End If

    If cb_Task_7_1 = -1 Then
        ShowMessage ("Task 7.1...")
        Call Task_7_1_Processing(CurrentTable)
    End If

    If cb_Task_7_2 = -1 Then
        ShowMessage ("Task 7.2...")
        Call Task_7_2_Processing(CurrentTable)
    End If

    If cb_Task_7_3 = -1 Then
        ShowMessage ("Task 7.3...")
        Call Task_7_3_Processing(CurrentTable)
    End If

    If cb_Task_8_1 = -1 Then
```

```
        ShowMessage ("Task 8.1...")
        Call Task_8_1_Processing(CurrentTable)
    End If

    If cb_Task_8_2 = -1 Then
        ShowMessage ("Task 8.2...")
        Call Task_8_2_Processing(CurrentTable, Val(txt_TimeGap))
    End If

    If cb_Task_9 = -1 Then
        ShowMessage ("Task 9...")
        Call Task_9_Processing(CurrentTable)
    End If

    ShowMessage ("Done processing " & CurrentTable & " at " & Now())
    CurrentTable = ""
    lblCurrentFile.Caption = "(No Current File)"

    DoCmd.SetWarnings True
End Sub

Private Sub cb_Task_2_AfterUpdate()
    If cb_Task_2 = -1 Then
        Me.MinLat.Enabled = True
        Me.MinLong.Enabled = True
        Me.MaxLat.Enabled = True
        Me.MaxLong.Enabled = True
    Else
        Me.MinLat.Enabled = False
        Me.MinLong.Enabled = False
        Me.MaxLat.Enabled = False
        Me.MaxLong.Enabled = False
    End If
End Sub

Private Sub cb_Task_8_2_AfterUpdate()
    If cb_Task_8_2 = -1 Then
        Me.cb_FerriesTugs.Enabled = True
        Me.txt_TimeGap.Enabled = True
    Else
        Me.cb_FerriesTugs.Enabled = False
        Me.txt_TimeGap.Enabled = False
    End If
End Sub

Private Sub Form_Activate()
    DoCmd.SetWarnings True
End Sub
```

APPENDIX F

"Visualization User Needs Assessment": Questionnaire

1. General:

1. What **geographical coverage** (e.g. open sea, coastal regions, gulf islands, ports etc.) is interesting, resp. helpful for you to look at on a map?

   …….

   …….

   …….

2. What **scale** would be useful for your purpose?

   …….

   …….

   …….

3. Would you like to have **different (smaller) cutouts** side by side or the whole area as **one (larger) integrative map**?

   …….

   …….

   …….

4. What **types of vessel** (e.g. tanker, ferries, tugs etc.) should be represented on the map? What would be a **practical classification** for your intention?

   …….

   …….

   …….

5. What **attributes** (e.g. length, tonnage, flag etc.) are necessary for your interests?

   …….

   …….

   …….

6. Would you prefer **point locations** or **polylines** for the vessel routes?

   …….
   …….
   …….

7. How **accurate** need the positions, resp. lines to be?

   …….
   …….
   …….

8. Do you prefer the **complete original data** (about one point each 5-6 minutes) or would a **generalized dataset** be enough for your intents?

   …….
   …….
   …….

2. Base Map:

9. What **background displays** (e.g. coastlines, cities, forest etc.) would you desire?

   …….
   …….
   …….

10. What **Coordinate System**, resp. **Projection** would you prefer for your analysis?

    …….
    …….
    …….

11. Would one (or more) layer with existing "official" **marine-related data** (e.g. shipping lanes, tanker exclusion zone etc.) be helpful for your purpose?

    …….
    …….
    …….

3. Temporal considerations:

12. What **time frame** (e.g. one hour, one day or a whole season) is appropriate for your object?

    …….
    …….
    …….

13. Would you prefer **static** or **dynamic** visualization? If the presentation is dynamic, should it be **animated** or showed in **time series**?

    …….
    …….
    …….

14. Would you like to be able to **change the time frame interactive**?

    …….
    …….
    …….

4. Further visualization conceptions:

15. Can you think of other **useful presentation approaches** of the commercial shipping data detached from commonly used strategies?

    …….
    …….
    …….
    …….
    …….
    …….
    …….
    …….
    …….
    …….

APPENDIX G

Detailed Projection and Datum Parameter

1. BC ALBERS STANDARD PROJECTION:

Coordinate System Parameters
============================

CS_NAME:	BCALB-83	*British Columbia Albers Standard Projection*
DT_NAME:	NAD83	*North American Datum 1983*
MAP_SCL:	1.0	*Map Scale*
ORG_LAT:	45.0	*Latitude of projection origin*
ORG_LNG:	-126.0	*Central meridian*
PARM1:	50.0	*First standard parallel*
PARM2:	58.5	*Second standard parallel*
PROJ:	AE	*Albers Equal Area Conic*
UNIT:	METER	*Map Units*
X_OFF:	1000000.0	*False easting*
Y_OFF:	0.0	*False northing*

Datum Parameters
================

DESC_NM:	North American Datum of 1983
ELLIPSOID:	GRS1980 (Geodetic Reference System of 1980)
SOURCE:	US Defense Mapping Agency, TR-8350.2-B, December 1987
USE:	NAD83

Ellipsoid Parameters
====================

DESC_NM:	Geodetic Reference System of 1980
E_RAD:	6378137m (equatorial radius)
P_RAD:	6356752.31414035m (polar radius)
SOURCE:	Stem, L.E., Jan 1989, State Plane Coordinate System of 1983

Accuracy
====================

Albers distortions within all of BC:

Maximum north/south linear distortion:	0.36 %
Maximum east/west linear distortion:	0.36 %
Maximum area distortion:	0.00 %
Mean north/south linear distortion:	0.069 %
Mean east/west linear distortion:	0.069 %
Mean area distortion:	0.00 %

2. MERCATOR PROJECTION:

Coordinate System Parameters
==============================

CS_NAME: 3TM120-27
DT_NAME: NAD27
GROUP: CANADA
MAP_SCL: 1
MAX_LAT: 84
MAX_LNG: -118
MIN_LAT: 48
MIN_LNG: -122
PARM1: -120
PROJ: TM
QUAD: 1
SCL_RED: 0.9999
SOURCE: Mentor Software Client
UNIT: METER
ZERO_X: 0.001
ZERO_Y: 0.001

Datum Parameters
=================

DELTA_X: -8
DELTA_Y: 160
DELTA_Z: 176
DESC_NM: North American Datum of 1927 (US48, AK, HI, and Canada)
ELLIPSOID: CLRK66 (Clark 1866)
SOURCE: US Defense Mapping Agency, TR-8350.2-B, December 1987
USE: NAD27

Ellipsoid Parameters
=====================

DESC_NM: Clarke - 1866
E_RAD: 6378206.4
P_RAD: 6356583.8
SOURCE: US Defense Mapping Agency, TR-8350.2-B, December 1987

APPENDIX H

Detailed Metadata for the used Base Maps

1. TOPOGRAPHIC DATA OF BRITISH COLUMBIA

```
GeoAccess Division

Geomatics Canada
Department of Natural Resources Canada

   * * * * *

NATIONAL ATLAS DIGITAL DATA:

This directory contains 1:2 million scale National Atlas
digital base map data for Canada. The data was produced by the
GeoAccess Division, formerly the National Atlas Information
Service (NAIS), of Geomatics Canada.


        GENERAL INFORMATION
        Scale:                  1:2 000 000
        Data Format:            uncompressed ARC/INFO .e00 (.e00)
        Data Type:              2D layered vector data
        Geographic Extent:      British Columbia
        Transfer Method:        ISO 9660 CD-ROM
                                3.5" diskette (DOS)
                                8 mm cassette (UNIX)

        Date:                   Information current as of 1989-1992.

                                Population categories determined from
                                Statistics Canada 1986 Census data.

        LIABILITY
        The Government of Canada and the Department of Natural
        Resources Canada assumes NO liability for any errors or
        ommisions in the digital data it provides to users.

        SOURCE
        Derived from National Topographic Series maps at a scale of
        1:250 000 and International Map of the World Series maps at a
        scale of 1:1 000 000. Other data such as transport and urban
        were usually taken from maps and statistical documents
        produced by Canadian governmental agencies.

        ACCURACY/PRECISION
        Co-ordinate Precision: +/- 100 metres
        Co-ordinate Accuracy:  +/- 2 kilometres

        PROJECTION INFORMATION
        Projection:             unprojected - Geographical coordinates
                               (Latitude/Longitude)
```

```
THEMATIC COVERAGES

Note: Disregard any layers not listed below.

      Occasionally small errors may be encountered but should
      not effect the quality of the data set.

      If you discover any discrepancies we would appreciate it
      if you would notify us so that we can amend our master
      files. Thank you.



*prefix "bc"=British Columbia(province)
 suffix "g"=geographic coordinates only (no projection)

File Name       Layer   Type/Description
---------       -----   ----------------
                *this is a complete list of layers - note that
                 not all layers will appear in every file.


bclandg.e00             LINE

                35      International boundaries
                36      Provincial & Territorial boundaries

                        POLY

                11      Provincial fill


bcboundg.e00            LINE

                35      International boundaries
                36      Provincial & Territorial boundaries
                37      District boundaries
                38      Undemarcated boundaries
                39      Canada-Greenland(Kalaallit Nunaat)
                51      Land District boundaries
                52      County boundaries
                53      Principal Meridian
                54      Other meridians
                55      Baselines
                56      Township boundaries
                57      Range lines
                58      MRC (Municipal Regional Counties)
                        (QUEBEC ONLY)
                61      Municipality limits


bcdraing.e00            LINE

                10      Connector lines
                15      Coastline
                16      Lake shorelines
                17      Rivers
                19      Falls
```

```
                        20      Rapids
                        21      River shorelines
                        35      International boundaries
                        36      Provincial & Territorial boundaries

                                POLY

                        0       Polygon feature created by
                                administrative boundaries enclosing
                                water boundaries
                        16      Lake water fill
                        21      River water fill


        bcroadg.e00             LINE

                        65      Dual/Divided highways
                        66      Main roads
                        67      Secondary roads
                        68      Other roads
                        74      Ferries
                        75      Seasonal ferries
```

If you have any questions or comments regarding the content or quality of this data set or the availablity of other Digital Geographic products, please contact:

GeoAccess Division
Geomatics Canada
Rm 650-615 Booth Street
Ottawa, Ontario
Canada K1A 0E9

Internet email: - info@geogratis.gc.ca

NOTICE: The Data provided is protected under the Copyright Act of Canada.

It is NOT for redistribution or resale.

Other restrictions may apply. In order to ensure that your intended usage conforms with the Copyright Act of Canada and/or any other rules, regulations, etc. that may be applicable, please contact us at the above address.

Thank you for using our Products.

2. SHORELINES OF WASHINGTON STATE (USA):

Identification Information

Citation:
Citation Information:
Originator: GIS Implementation Team, Washington State Department of Transportation
Publication Date: 19950101
Title: Major Shorelines of Washington State
Geospatial Data Presentation Form: map
Publication Information:
Publication Place: Olympia, Washington
Publisher: Washington State Department of Transportation
Description:
Abstract: Major hydrography for Washington State represented as polygons. Features in this data set define the land extent of Washington state.
Purpose: This data set is for general-purpose base maps at 1:500,000 or smaller, where detailed river information is not needed.
Time Period of Content:
Time Period Information:
Single Date/Time:
Calendar Date: 7/1/1994
Currentness Reference: ground condition
Status:
Progress: Complete
Maintenance and Update Frequency: inactive
Spatial Domain:
Bounding Coordinates:
West Bounding Coordinate: -125
East Bounding Coordinate: -116.875
North Bounding Coordinate: 49.05
South Bounding Coordinate: 45.5
Access Constraints: none
Use Constraints: none
Point of Contact:
Contact Information:
Contact Person Primary:
Contact Person: Ron Cihon
Contact Organization: Geographic Services, Washington State Department of Transportation
Contact Position: GIS/Cartography Supervisor
Contact Address:
Address Type: physical address
Address: 1655 S. 2nd Avenue
City: Tumwater
State or Province: WA
Postal Code: 98512
Country: USA
Contact Address:
Address Type: mailing address
Address:
Mail Stop: 7384
PO Box 47384

City: Olympia
State or Province: WA
Postal Code: 98504-7384
Country: USA
Contact Voice Telephone: 360-709-5510
Contact Facsimile Telephone: 360-709-5599
Contact Electronic Mail Address: cihonr@wsdot.wa.gov

Native Data Set Environment: Arc/Info coverage, version 7.1.2 for NT 4.0, and ESRI shape file

---

Data Quality Information

Attribute Accuracy:
Attribute Accuracy Report: none
Logical Consistency Report: Polygon topology was verified by the Arc/Info "BUILD" command.
Completeness Report: The data depicts: Washington State coastlines of the Pacific Ocean; the San Juan Islands; Puget Sound and its major islands; and the Columbia, Snake and Pend O'reille Rivers.
Positional Accuracy:
Horizontal Positional Accuracy:
Horizontal Positional Accuracy Report: Positional accuracy has not been determined.
Lineage:
Source Information:
Source Citation:
Citation Information:
Originator: Cartography Section, Washington State Department of Transportation
Publication Date: Unpublished Material
Title: state.dgn, 1994
Geospatial Data Presentation Form: map
Source Scale Denominator: 500000
Type of Source Media: online
Source Time Period of Content:
Time Period Information:
Single Date/Time:
Calendar Date: 7/1/1994
Source Currentness Reference: ground condition
Source Citation Abbreviation: state.dgn, 1994
Source Contribution: The graphics depicting Washington state's major hydrography.
Process Step:
Process Description:
Selected streams were digitized using Intergraph's IGDS software. The resulting design file was intermittently revised to reflect newly compiled data from 1:100,000 USGS sources. Major water features were extracted from the file to portray the state's coastlines and biggest rivers. The DGN file was converted to an Arc/Info coverage using Arc command "IGDSARC," and then transformed to geographic coordinates with Arc commands "PROJECTDEFINE" and "PROJECT."

Source Used Citation Abbreviation: state.dgn, 1994
Process Date: 19941130
Process Contact:
Contact Information:
Contact Person Primary:
Contact Person: Gordon Kennedy
Contact Organization: Washington State Department of Transportation
Contact Position: Coordinator, Information Resources Management
Contact Address:
Address Type: mailing address
Address: PO Box 47430
City: Olympia
State or Province: WA
Postal Code: 98504-7430
Country: USA
Contact Address:
Address Type: physical address
Address: 809 Legion Way SE
City: Olympia
State or Province: WA
Postal Code: 98501
Country: USA
Contact Voice Telephone: 360-705-7641
Contact Facsimile Telephone: 360-705-6817
Contact Electronic Mail Address: gkennedy@wsdot.wa.gov
Hours of Service: 0700 to 1530, Pacific Time, M-F

Spatial Reference Information

Horizontal Coordinate System Definition:
Geographic:
Geographic Coordinate Units: Decimal degrees
Geodetic Model:
Horizontal Datum Name: North American Datum of 1983
Ellipsoid Name: Geodetic Reference System 80
Semi-major Axis: 6378137
Denominator of Flattening Ratio: 298.257222101

Distribution Information

Distributor:
Contact Information:
Contact Person Primary:
Contact Person: Michelle Blake
Contact Organization: Washington State Department of Transportation
Contact Position: GIS Data Administrator
Contact Address:
Address Type: mailing address
Address: PO Box 47430
City: Olympia
State or Province: WA
Postal Code: 98504-7430
Country: USA

Contact Address:
Address Type: physical address
Address: 809 Legion Way SE
City: Olympia
State or Province: WA
Postal Code: 98501
Country: USA
Contact Voice Telephone: 360-705-7797
Contact Facsimile Telephone: 360-705-6817
Contact Electronic Mail Address: blakem@wsdot.wa.gov
Contact Instructions: Call, email or write with requests for geo-spatial data sets.
Resource Description: \gisosc\geodata\maps\500k\dot_cartog\coast\coast
Distribution Liability:

The Washington State Department of Transportation shall not be liable for any activity involving these data with regard to lost profits or savings or any other consequential damages; or the fitness for use of the data for a particular purpose; or the installation of the data, its use, or the results obtained.

C. SHORELINES OF ALASKA STATE (USA):

Identification_Information:
Citation:
Citation_Information:
Originator: AK Department of Natural Resources, Land Records Information Section
Publication_Date: 19980211
Title:
coast63
Edition: 1.0
Geospatial_Data_Presentation_Form: vector digital data
Series_Information:
Series_Name: PHYSICAL
Issue_Identification: coast63
Publication_Information:
Publication_Place: Anchorage, AK
Publisher: ADNR, LRIS
Online_Linkage: http://www.uas.alaska.edu/spatialdata/download
Description:
Abstract:
This is a first cut at a statewide 1:63,360 coastline. The entire coasline, however, is not 1:63.360; only where data was available as of January 1998. It is a mixture of sources ranging from the Department of Natural Resources, Land Records Information Section hydrography database to the Exxon Valdez Oil Spill Environmentally Sensitive Index coastline (no ESI attributes included) to the US Geologic Survey hydrography to US Forest Service (in Prince William Sound). Where the 1:63,360 data was unavailable the 1:250,000 coastline was used to fill in.

This information does not include lakes or streams. All streams are cut off at the mouth with a straight line.
Purpose:
The purpose of this information is to provide a better coastline for land data to be clipped. It's purpose is cartographic. Before this was created,land data was clipped to a 1:250,000 statewide coastline which did not include many of the islands and did not match well with the 1:63,360 hydrography. Attributes have been added to the arcs, but have not been checked carefully.

This coverage is the first of its kind at this scale; thus there are errors. Please notify DNR, LRIS so these may be corrected.

Note: The USGS is in the process of automating the hydrography statewide at 1:63,360 and should be used as a replacement when the information is ready. This hydrography was not complete and available as of January 1998, and no specific date was set.

Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 1997
Currentness_Reference:
publication date
Status:
Progress: In work

Maintenance_and_Update_Frequency: As needed
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -179.948037
East_Bounding_Coordinate: 179.997671
North_Bounding_Coordinate: 71.405316
South_Bounding_Coordinate: 49.128799

Access_Constraints: To ensure distribution of the most current public information, please refer requests for data or products to the Alaska Department of Natural Resources, Land Records Information Section.

Use_Constraints:
It is not recommended the data be used at a scale larger than 1:63,360.

Any hardcopies or published datasets utilizing these data sets shall clearly indicate their source. If the user has modified the data in any way they are obligated to describe the types of modifications they have performed. User specifically agrees not to misrepresent these data sets, nor to imply that changes they made were approved by the Alaska Department of Natural Resources.

Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: GIS Public Access Coordinator
Contact_Organization: AK Department of Natural Resources - Land Records Information Section
Contact_Position: GIS Public Access Coordinator
Contact_Address:
Address_Type: mailing and physical address
Address:
550 W. 7th Suite 706
City: Anchorage
State_or_Province: AK
Postal_Code: 99501
Country: USA
Contact_Voice_Telephone: 907/269-8833
Contact_Facsimile_Telephone: 907/269-8920
Contact_Electronic_Mail_Address: GIS_Public_Access@dnr.state.ak.us
Hours_of_Service: 800-1600 AST
Contact Instructions:
See Distribution_Information
Data_Set_Credit:
Alaska Department of Natural Resource, Land Records Information Section
US Geologic Survey
US Forest Service, Chugach
US Forest Service, Tongass
EVOS Trustee Council
Native_Data_Set_Environment:
Microsoft Windows 2000 Version 5.1 (Build 2600) ; ESRI ArcCatalog 8.2.0.700

Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:

null (used to close mouth of rivers), and the Canadian border. Since a mix of sources were used, this was not always calculated. No QC was done to check accuracy. Will be corrected as problems arrise or more time is allowed.
Logical_Consistency_Report:
Polygon and chain-node topology present.
Completeness_Report:
DNR, LRIS - reselected the hydrography features coded WATER_TYPE = 'S' or 'N'
Did some clean up.
EVOS - selected and added as need to fill in.
USGS - downloaded ITM quads, where needed to fill in. Selected coastline arcs and closing arcs.
USFS, Chugach - selected Prince William Sound coastline and filled in.
USFS, Tongass - was included into DNR, LRIS hydrography database.

There are attribute errors. Polygons all closed.
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
Information was cleanup on the screen. Polygons were closed, dangles deleted, and information edgematched.
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator: Alaska Department of Natural Resources, Land Records Information Section
Publication_Date: 1990
Title:
ITM hydrography
Series_Information:
Series_Name: ITM hydrography data
Issue_Identification: hydro
Publication_Information:
Publication_Place: Anchorage, AK
Publisher: ADNR, LRIS
Source_Scale_Denominator: 63360
Type_of_Source_Media: online
Source_Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 1950
Ending_Date: 1997
Source_Currentness_Reference:
ground condition
Source_Citation_Abbreviation:
none
Source_Contribution:
Source used USGS 1:63,360 topographic maps ranging in date from 1950's to 1990's. These were photo revised by BLM. Only hydrography meeting the needs of the State Status Plats were automated. Arc features were coded with source and water type. US Forest Service,Tongass hydrography data was integrated into datbase to fit DNR's model.
Source_Information:
Source_Citation:
Citation_Information:

Originator: USGS
Publication_Date: 1950-1990
Title:
ITM hydrography
Series_Information:
Series_Name: DLG
Issue_Identification: hydrography
Publication_Information:
Publication_Place: Reston, Virginia
Publisher: USGS
Source_Scale_Denominator: 63360
Type_of_Source_Media: web
Source_Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 1950
Ending_Date: 1997
Source_Currentness_Reference:
ground condition
Source_Citation_Abbreviation:
none
Source_Contribution:
Selected coastline information where needed
and where available.

Source_Information:
Source_Citation:
Citation_Information:
Originator: USFS, Chugach
Publication_Date: 1996
Title:
Chugach National Forest coastline
Publication_Information:
Publication_Place: Anchorage, AK
Publisher: USFS
Source_Scale_Denominator: 63360
Type_of_Source_Media: magnetic tape
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 1950
Source_Currentness_Reference:
ground condition
Source_Citation_Abbreviation:
none
Source_Contribution:
Chugach National Forest has had significant
changes in their shoreline, particularly near Columbia Glacier and Copper
River Delta. They have generated a new coastline to reflect these
changes. This information was selected and added as the best source for
Prince William Sound.
Source_Information:
Source_Citation:
Citation_Information:
Originator: EVOS Habitat/Restoration and ADNR
Publication_Date: 1996
Title:
EVOS Research and Restoration CD-ROM

Series_Information:
Series_Name: State Coastline
Issue_Identification: coastst
Publication_Information:
Publication_Place: Anchorage, AK
Publisher: ADNR
Source_Scale_Denominator: 63360
Type_of_Source_Media: CD-ROM
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 1989
Source_Currentness_Reference:
ground condition
Source_Citation_Abbreviation:
none
Source_Contribution:
Was used to fill in missing areas of data.
Process_Step:
Process_Description:
From the DNR, LRIS hydrogrpahy, the arcs were selected where water-type = 'S' for shoreline or 'N' for null (closing mouth of streams). This information was used first as it had the most logical coding for arc attributes. The USGS information was downloaded from the web where holes existed. EVOS was used to fill in also. USFS, Chugach was used to completely replace the Prince William Sound area. The statewide 1:250000 alaska coastline was used to fill in where no other data was available. Attributes are structured the same as the ADNR, LRIS hydrography and were added. The attributes were not qc'ed and has errors.
Process_Date: 19980101
Process_Step:
Process_Description:
Metadata imported.
Source_Used_Citation_Abbreviation:
C:\c_byers\update_cs\coast63.xml

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Map_Projection:
Map_Projection_Name: Albers Conical Equal Area
Albers_Conical_Equal_Area:
Standard_Parallel: 55.000000
Standard_Parallel: 65.000000
Longitude_of_Central_Meridian: -154.000000
Latitude_of_Projection_Origin: 50.000000
False_Easting: 0.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.026635
Ordinate_Resolution: 0.026635
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1927

Ellipsoid_Name: Clarke 1866
Semi-major_Axis: 6378206.400000
Denominator_of_Flattening_Ratio: 294.978698

Distribution_Information:
Distributor:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: AK Department of Natural Resources - Land Records Information Section
Contact_Position: GIS Public Access Coordinator
Contact_Address:
Address_Type: mailing and physical address
Address:
550 W. 7th Suite 706
City: Anchorage
State_or_Province: AK
Postal_Code: 99501
Country: USA
Contact_Voice_Telephone: 907/269-8833
Contact_Facsimile_Telephone: 907/269-8920
Contact_Electronic_Mail_Address: GIS_Public_Access@dnr.state.ak.us
Hours_of_Service: 800-1600 AST
Contact Instructions:
Fax completed "Request for DNR GIS Data" form.
Form can be found at
<URL:http://www.asgdc.state.ak.us/homehtml/orderform.html>
Resource_Description: Downloadable Data
Distribution_Liability:
The State of Alaska makes no express or implied warranties (including warranties of merchantability and fitness) with respect to the character, function, or capabilities of the electronic services or products or their appropriateness for any users purposes. In no event will the State of Alaska be liable for any incidental, indirect, special, consequential or other damages suffered by the user or any other person or entity whether from the use of the electronic services or products, any failure thereof or otherwise, and in no event will the State of Alaska s liability to the requestor or anyone else exceed the fee paid for the electronic service or product.

APPENDIX I

Cut-out of the RADIO AIDS TO MARINE NAVIGATION, Pacific and Western Arctic

VESSEL TRAFFIC SERVICES ZONE SCHEDULES

PRINCE RUPERT VTS ZONE

SECTORS AND BOUNDARIES

Sector	Boundaries
1	All Canadian waters north of Vancouver Island between a line joining Triangle Island 50°52'00"N, 129°05'00"W; with Cape Caution light 51°09'50"N, 127°47'06"W; and the Alaska/British Columbia border, but not including those waters described in Sector 2.
2	All Canadian waters bounded by a line running from Bareside Point 53°54'12"N, 130°16'31"W; to Swede Point 53°53'16"N, 130°15'35"W. Then following the northern shoreline of Pitt Island to a position of 53°48'03"N, 129°58'31"W; thence to a position of 53°48'41".4N, 129°57'07".9W; thence northward following the mainland shore to a position of 54°09'38"N, 129°57'37"W; thence to a position of 54°11'53"N, 129°58'51"W; thence northward following the mainland shore to 54°37'57" N, 130°26'31"W; thence to a position of 54°38'02"N, 130°26'31"W; thence northward along the west shore of Maskelyne Island to Maskelyne Point 54°38'55"N, 130°26'42"W; thence to Wales Point 54°42'17"N, 130°28'33"W; thence westward along the shore of Wales Island to 54°42'06"N, 130°31'47"W; thence to a position of 54°42'27"N, 130°36'50"W; thence westward along the International Boundary to Cape Muzon light 54°39'48"N, 132°41'30"W; thence westward along the shore of Dall Island to Point Cornwallis light 54°42'12"N, 132°52'17"W; thence southward to Langara Point 54°15'23"N, 133°03'30"W; thence southward along the west coast of Langara Island to Lacy Island 54°13'18"N, 133°05'24"W; thence southward to Cape Knox on Graham Island 54°11'00"N, 133°05'00"W; thence eastward along Graham Island shoreline to Rose Spit 54°11'12".5N, 131°38'43"W; thence south-eastward to Seal Rocks 54°00'00"N, 130°47'26"W; thence to Oval Point on Porcher Island 53°56'24"N, 130°43'15"W thence eastward following Porcher Island shoreline to Bareside Point.

IDENTIFICATION AND FREQUENCIES

Sector	Identifier	Channel	Frequency (MHz)
1	*"Prince Rupert Traffic"*	11	156.55
2	*"Prince Rupert Traffic"*	71	156.575

TOFINO VTS ZONE

SECTOR AND BOUNDARIES

Sector	Boundaries
1	Excluding those United States waters within that portion of the Canada/US CVTS administered by the Tofino MCTS Centre, all Canadian waters contained within the area bounded by a line drawn from: 48°28'36"N 124°40'00"W to 48°34'58"N 124°40'00"W thence following the shoreline to 48°40'00"N 124°51'00 "W to 48°40'11".5N 124°51'29"W thence following the shoreline to 48°43'18"N 125°05'54"W to 48°47'16"N 125°12'59".5W thence following the shoreline to 48°53'03"N 125°04'24"W to 48°56'00"N 125°01'50".5W thence following the shoreline to 48°56'51"N 125°00'02".5W to 48°57'28"N 124°59'15"W thence following the shoreline to 49°14'27"N 124°48'46"W to 49°14'27"N 124°50'13".5W thence following the shoreline to 49°04'13".5N 124°51'16"W to 49°03'20".5N 124°51'44"W thence following the shoreline to 48°59'03"N 124°57'54"W to 48°58'41"N 124°59'34"W thence following the shoreline to 48°57'19"N 125°01'50"W to 48°57'57"N 125°04'50".5W to 48°59'06"N 125°09'39".5W to 48°58'48"N 125°10'57"W thence following the shoreline to 49°00'59".5N 125°18'39"W to 49°01'54"N 125°19'26".5W thence following the shoreline to 48°55'18"N 125°30'29"W to 48°55'18"N 125°32'06".5W thence following the shoreline to 49°05'41"N 125°53'18"W to 49°17'03"N 126°13'44"W to 49°23'00"N 126°32'34"W to 49°44'57"N 126°58'54"W to 49°51'35"N 127°08'56"W to 49°59'49"N 127°27'06".5W to 50°04'48"N 127°48'47" thence following the shoreline to 50°13'14"N 127°47'54"W to 50°19'28"N 127°58'26"W thence following the shoreline to 50°21'09"N 127°59'27".5W to 50°26'38"N 128°02'43".5W to 50°28'11"N 128°06'05"W thence following the shoreline to 50°38'23".5N 128°19'35"W to 50°40'15"N 128°21'40"W thence following the shoreline to 50°46'57"N 128°25'32"W to 50°52'00"N 129°05'00"W thence following a line 220° (True) to the limit of the Territorial Sea 50°42'11"N 129°18'00"W thence following the Territorial Sea boundary south-eastward to intersect the International Boundary at 48°28'36"N 124°40'00"W thence a line northward to the Canadian shoreline at 48°34'58"N 124°40'00"W

IDENTIFICATION AND FREQUENCIES

Sector	Identifier	Channel	Frequency (MHz)
1	*"Tofino Traffic"*	74	156.725

VANCOUVER VTS ZONE

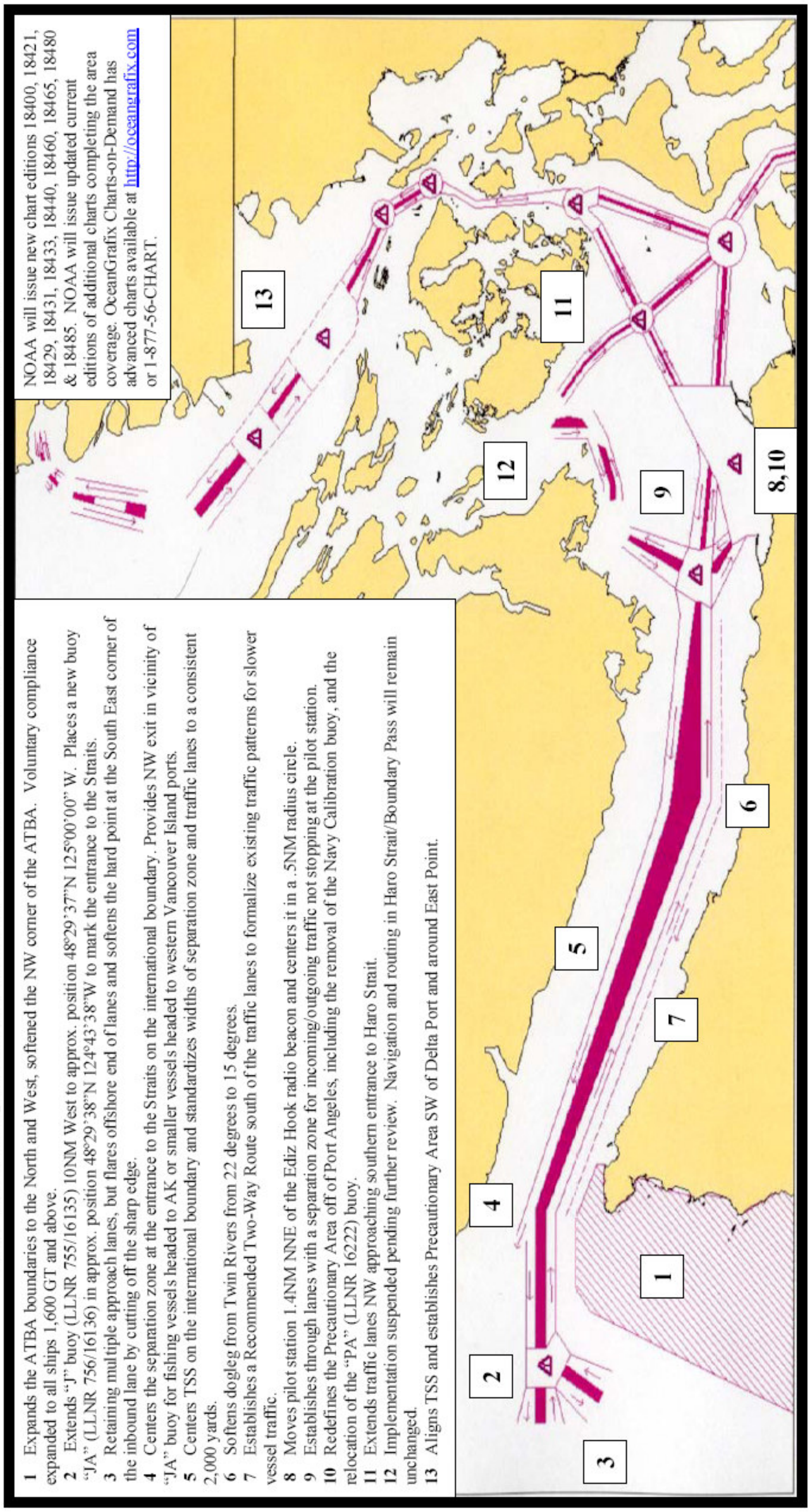
SECTORS AND BOUNDARIES

Sector	Boundaries
1	All Canadian waters north of and included within a line from the shoreline of Vancouver Island at 48°34'58"N, 124°40'00"W; southward along the meridian of longitude 124°40'00"W, to a point which intersects the International Boundary; thence following the International Boundary eastward and northward through the waters known as the Strait of Juan de Fuca, Haro Strait, Boundary Passage, and the Strait of Georgia to a point which intersects the Canadian shoreline at 49°00'00"N, 123°05'20"W; thence to Roberts Bank light 49°05'16"N, 123°18'31".5W; thence to Sandheads light 49°06'23"N, 123°18'04"W; thence to the Iona breakwater light 49°12'18"N,123°15'50"W; thence 270° (True) 6.6 nautical miles to 49°12'18"N, 123°25'53"W; thence 000° (True) 8.15 nautical miles to Cape Roger Curtis light 49°20'24"N, 123°25'53"W; thence 303° (True) 4.8 nautical miles to Gower Point 49°23'01"N, 123°32'06"W; thence following the shoreline to a line joining Reception Point light 49°28'15".9N, 123°53'12"W; to Merry Island light 49°28'03".5N, 123°54'40"W; to Ballenas Island light 49°21'02"N, 124°09'32"W; to Cottam Point 49°18'57"N, 124°12'45"W.
2	All Canadian waters of the south or main arm of the Fraser River east of the Sandheads light 49°06'23"N, 123°18'04"W; to a line running 090° (True) from Shoal Point 49°11'45"N, 122°54'51"W., to the opposite south shore.
3	All Canadian waters contained north and east of a line from the Iona breakwater light, 49°12'18"N, 123°15'50"W; thence 270° (True) 6.6 nautical miles to 49°12'18"N, 123°25'53"W; thence 000° (True) 8.15 nautical miles to Cape Roger Curtis light 49°20'24"N, 123°25'53"W; thence 303° (True) 4.8 nautical miles to Gower Point 49°23'01"N, 123°32'06"W; including all the waters of Howe Sound and Burrard Inlet.
4	All Canadian waters bounded on the south by a line from Reception Point light, 49°28'15".9N,123°53'12"W; to Merry Island light 49°28'03".5N,123°54'40"W; to Ballenas Island light 49°21'02"N,124°09'32"W; to Cottam Point 49°18'57"N,124°12'45"W; and bounded on the north by a line from Cape Scott light 50°46'57"N, 128°25'32"W; to 50°52'00"N, 129°05'00"W; to Cape Caution light 51°09'50"N, 127°47'06"W.

IDENTIFICATION AND FREQUENCIES

Sector	Identifier	Channel	Frequency (MHz)
1	*"Seattle Traffic"* *(CIP 1 and 3 only)*	05A	156.25
1	*"Victoria Traffic"*	11	156.55
2	*"Victoria Traffic"*	74	156.725
3	*"Vancouver Traffic"*	12	156.6
4	*"Comox Traffic"*	71	156.575

APPENDIX J



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