A SYSTEMS ENGINEERING APPROACH TO DESIGNING AN OCEAN AND COASTAL INFORMATION MANAGEMENT STRATEGY

KATALIN KOMJATHY

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Katalin Komjathy

Department of Geodesy and Geomatics Engineering
University of New Brunswick
P.O. Box 4400
Fredericton, N.B.
Canada
E3B 5A3

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PREFACE

This technical report is a reproduction of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Engineering in the Department of Geodesy and Geomatics Engineering, September 2007. The research was supervised by Dr. Sue Nichols, and support was provided by the Natural Sciences and Engineering Research Council of Canada.

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ABSTRACT

With the enactment of the *Oceans Act* [1996], Canada made a commitment towards the sustainable development of its ocean and coastal resources. This new approach is based on the principles of collaborative and integrated management. The implementation of modern ocean management objectives must take place in an environment surrounded by a complex legal and institutional framework, changing economic priorities, escalating resource use conflicts, and increasing pressure to address problems at the ecosystem level.

An examination of major legislative and policy directions, technological and conceptual background, and information management initiatives contributed to the formulation of a set of information requirements. A review of the existing information services in support of the ocean and coastal stakeholder community revealed a sporadic, disconnected collection of regional and sectoral initiatives without capacity for interaction while often duplicating efforts and expenses. These results are in conflict with an all-inclusive, systematically organized information framework that would better position the stakeholder community to address present and future challenges.

Based on the principles of systems engineering, this research provides a conceptual design for an ocean and coastal information management strategy. The proposed design is iterative, and is built on a high level assessment of information requirements.

ACKNOWLEDGEMENTS

The essence of education is the ability to recognize what you do not know, but need to know. [Churchman, 1973]

The following words of gratitude are not adequate to express my deepest appreciation for all the support I have received during my studies. This thesis is a partial documentation of the knowledge I have obtained during my research. I have also learned that without the generosity of others, I would have not been able to accomplish the goal I have set many years ago. I am especially indebted to the following organization and individuals:

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LIST OF ABBREVIATIONS

ACAP	Atlantic Coastal Action Plan
ACIP	Atlantic Coastal Information Portal
CCAR	Colorado Center for Astrodynamics Research
CCCM	Canadian Centre for Marine Communications
CHS	Canadian Hydrographic Service
CLCS	United Nations Commission on the Limits of the Continental Shelf
COINAtlantic	Coastal and Ocean Information Network for the Atlantic
COINPacific	Cooperative Information Network for the Pacific
COS	Canada's Oceans Strategy
DFO	Department of Fisheries and Oceans/Fisheries and Oceans Canada
ENC	Electronic Navigational Charts
ECDIS	Electronic Chart Display and Information System
ESSIM	Eastern Scotian Shelf Integrated Management
EEZ	Exclusive Economic Zone
GIS	Geographic Information System
GOSLIM	Gulf of St. Lawrence Integrated Management
ICM	Integrated Coastal Management
ICOIN	Inland Waters, Coastal and Ocean Information Network
ICT	Information and Communication Technologies
ICZM	Integrated Coastal Zone Management
INCOSE	International Counsil on Systems Engineering
MMS	Minerals Management Service
OAP	Oceans Action Plan
OSTP	Ocean Science and Technology Partnership
PNCIMA	Pacific North Coast Integrated Management Area
SOA	Service-Oriented Architecture
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea

CHAPTER 1

INTRODUCTION

We don't need new technologies to solve our problems, we 'just' need the political will to apply solutions already available. [Diamond, 2005]

1.1 Overview

The surrounding oceans – the Atlantic, the Arctic, and the Pacific – as well as the Great Lakes and inland waterways play a substantial role in the life of all Canadians. Historically, ocean resources and activities were viewed as uninterrupted basis for prosperity. Until a decade ago, little appreciation was given to the threat posed by exclusively focusing on resource exploitation, while failing to balance ocean-related economic, environmental, and cultural objectives. In the mid 1990s, domestic and international fishing and pollution problems generated sufficient public and political interest to develop the legislative base for a modern ocean governance framework, in the form of the *Oceans Act of 1996* [Mageau et al., 2005, VanderZwaag, 2007].

Subsequent strategic and policy-formulating documents include Canada's Ocean Strategy and Integrated Management Framework [DFO, 2002], and Canada's Ocean Action Plan [DFO, 2005b]. These documents discuss in detail the nation's commitment to the sustainable development of its ocean resources, the need for science and technology to achieve this goal, and remark on the opportunities and challenges of complying with international regulations. Furthermore, this new direction in oceans policy highlighted the importance of *"expanding working partnerships among oceans* *stakeholders"* and *"replacing the current, fragmented approach to oceans management with a collaborative, integrated approach"* [DFO, 2002].

The relevance of this research is supported by the inconsistencies between the present ocean management objectives and the associated information management arrangement. An effective information management strategy in support of addressing the objectives, however, is required regardless of the direction of the regulatory framework.

1.2 The Research Problem

The above mentioned concept of a collaborative, integrated approach to oceans governance based on stakeholder participation is waiting to be implemented. Implementation must be done in an environment that is surrounded by a complex legal and institutional framework, changing economic and political priorities, escalating resource-use conflicts, and increasing pressure to address problems at the ecosystem level.

Initiatives aimed at addressing various ocean and coastal problems at all levels and scope are numerous (e.g., ESSIM, PNCIMA, GOSLIM). Data and information collection and processing are aided by rapid developments in science and technology. Yet, a review of the existing information services available for the ocean and coastal stakeholder community revealed a sporadic, disconnected collection of regional (COINPacific, COINAtlantic) and sectoral (SmartBay) initiatives, without a capacity for interaction, while often duplicating efforts and expenses (see e.g., Canessa et al., 2007). In many cases little or no attention is given to the existing legal and institutional framework. Information and its management are often regarded with limited concern or their focus is restricted to data management technology.

The value of terrestrial spatial information management has been long acknowledged, while technology developments facilitated its recent widespread application. Comparable progress in the management of ocean and coastal spatial information, however, has yet to take place. The spatial attributes of ocean and coastal information have the capability to offer a context to the systematic collection, processing, visualization, and storage of this information. In turn, this facilitates an integrated approach to not only information management, but also to projects and initiatives that are regionally separated but share common objectives or sectorally separated with shared geographic extent.

1.3 Research Objectives

The first objective of this research was to investigate how science, technology, institutional and policy arrangements work together to manage and improve access to ocean and coastal information resources. To accomplish this:

a) information management issues relevant to high level ocean and coastal management were reviewed;

b) contributions and requirements of science and technology to ocean and coastal information management were analyzed; and

c) existing and proposed initiatives focusing on ocean and coastal information management were evaluated.

It was found that an all-inclusive, systematically organized information management framework would better position the ocean and stakeholder community to address present and future challenges. This determined the scope of the next objective.

The second objective was to design a strategy that enables decision and policy makers and practitioners at various levels of government, as well as in the non-government sectors, to develop information management frameworks responsive to the requirements of an ocean and coastal management project or initiative. To accomplish this:

a) relevant engineering design principles were reviewed;
b) the most suitable approach was identified;
c) applicability of the design was demonstrated by discussing implementation; and
d) the presented design was evaluated.

1.4 Research Methodology

To address the objectives outlined above, this research was carried out relying on various methodologies:

- an extensive review of literature on ocean and coastal management, information management, and systems engineering principles;
- active participation in conferences and workshops to gain a better understanding of stakeholder interests and concerns and to fill in gaps in personal experience;
- evaluation of a sample of past and present ocean and coastal information management initiatives in terms of inputs, outputs, and outcomes;

- in response to an initial high level assessment of requirements, a step-by-step process, based on systems engineering principles was outlined to address the information management requirements of the ocean and coastal stakeholder community.

1.5 Definitions

The focus of this research is the management of ocean and coastal spatial information. The *Oceans Act* [1996] defines **oceans** as the Arctic, the Pacific, and the Atlantic, and gives legal definitions to the extent of the boundaries. This definition was found sufficient for this research. Defining the extent of a **coast**, however, is somewhat more ambiguous, and is a discipline in itself. For the purposes of this research **coastal** resources and activities are referred to as those that take place, are associated with, have impact on, or of affected by the *"interface between [the] marine environment and the terrestrial one"* [Goodchild, 1999].

The definition of **information management** is adopted from Nichols [1992] as the *"effective use of available* [information] *resources to achieve certain ends."* Geospatial information refers to *"information that identifies the geographic location and characteristics of natural or constructed features and boundaries on the earth"* [Clinton, 1994]. In this thesis the terms spatial or geographic information are seldom used. Kralidis [2005] notes that the principal technologies of spatial information management (e.g., Geographic Information Systems) are capable of storing information and performing queries, both spatially and aspatially. Therefore, for the purposes of this research there has been no distinction given between spatial and aspatial ocean and coastal information.

Rather, it is assumed that the majority of ocean and coastal information have geospatial attributes or the available geospatial information is capable of interacting with aspatial information [Kralidis, 2005].

The **stakeholders** in ocean and coastal information management are individuals, groups or institutions with interests or concerns in related projects [Hutchison, 2006]. It is acknowledged that members in the stakeholder community and the degree of their involvement are subject to change. The *Oceans Act* [1996], however, declares that the three oceans *"are the common heritage of all Canadians."*

The information management strategy presented in this research is based on the principles of **systems engineering**. It is defined by the International Council on Systems Engineering [INCOSE, 2004] as an *"interdisciplinary approach and means to enable the realization of successful systems."* Further definitions and discussion will be given in Chapter 6.

1.6 Organization of the Thesis

Chapter 1 introduces the research problem and the objectives in the context of ocean and coastal management. The research methodology is discussed and key definitions are given.

Chapter 2 examines the role of information in ocean and coastal management. National level priorities are outlined with a focus on the Oceans Strategy [DFO, 2002], Oceans Action Plan [DFO, 2005b], and touches upon the significance of information management regarding the ratification of the UNCLOS. It was found that information management is given an inadequate and restricted role; therefore modifications to the existing oceans management strategy are proposed.

Chapter 3 follows some of the conceptual and technological developments supporting ocean and coastal information management. Masser [1998] points out that the *"adoption of a new technology and its effective utilization were two very different things."* This common link was also identified among the innovations discussed. A more comprehensive way to employ them is illustrated through a recent oil spill accident.

Ocean and coastal spatial data infrastructures have been developed in the past with limited success. Evaluating the key initiatives in Chapter 4 captures the third element in the review of the existing information management setting.

Summarizing the contributions of the previous three chapters, Chapter 5 underlines the relevance of a systematic approach to assessing information requirements. As a contrast, the implications of the present ad hoc information management are discussed.

Chapter 6 presents the new strategy that was designed in response to the high level requirements identified in Chapter 5. A brief overview of systems engineering and its relevance to the research problems introduces the chapter. The main body of the chapter follows the design of an information management strategy, then issues regarding implementation and limitations of the design complete the chapter. Chapter 7 concludes the thesis by summarizing the major contributions.

1.7 Research Contributions

The contributions of this research originate from the distinctive approach employed to address the problem of harmonizing disconnected information management practices in Canada in the context of integrated ocean management objectives. Unlike previous efforts, which have focused on short term sectoral and regional objectives, the proposed design strategy relies on the systematic examination of critical factors in ocean and coastal management, and emphasizes the roles of requirements analysis and integration in information management. The specific contributions of this research include the repositioning of information management as an interconnection among ocean management clusters and the development of a conceptual design of an ocean and coastal information management strategy based on systems engineering principles.

CHAPTER 2

CANADA'S OCEANS AND COASTS: A HIGH LEVEL ASSESSMENT OF KEY INFORMATION MANAGEMENT ISSUES

… rulemaking and implementation phases are complex - and fraught with political and economic pitfalls. [Wood, 2007]

2. 1 Introduction

Oceans and coasts are an integral part of Canada's economy, security, culture, and identity. The three oceans bordering Canada's coasts, as well as the Great Lakes, offer immense resources for economic development (Figure 2.1). Revenues from transportation and renewable, as well as non-renewable resource exploitation are estimated to contribute over $20 billion annually to the economy [DFO, 2002].

Figure 2.1: Three oceans and the Great Lakes border Canada's coastlines and shorelines [CIA, 2006]

The social impacts of oceans and coasts on coastal communities are increasingly being recognized. It is better understood today that environmental processes, such as rising sea level, not only affect coastal communities but also influence society as a whole [ArcticNet, 2006].

The issues of sovereignty and security are strongly connected to protecting human and natural resources. Canada's international borders on the east, west, and north are also located at sea. Some of these ocean boundaries are still unresolved [Mageau et al., 2005, Cockburn, 2005]. At present Canada has a right to enforce its laws regarding exploitation of resources and preservation of coastal and ocean environment within the 200 nautical miles Exclusive Economic Zone (EEZ) under the UNCLOS. Successfully exercising this power implies that the nation's interests in resource management and environmental matters are adequately met.

To govern these activities and responsibilities, the Government of Canada introduced key legislation in 1996 in the form of the *Oceans Act* [1996]. Policy documents such as Canada's Ocean Strategy (COS) [DFO, 2002] and Oceans Action Plan (OAP) [DFO, 2005b], supporting the legislation, were unveiled in 2002 and 2005, respectively. The maritime boundaries within which these activities take place are also of great importance. By ratifying the *United Nations Conventions on Law of the Sea* (UNCLOS) [UN, 1983] Canada has also become eligible to submit a claim to the outer edge of its continental shelf [Canada, 2003] (Figure 2.2). In 2006 the Government of Canada contracted the private sector to *"conduct marine data acquisition"* [Fugro, 2006] off the coasts of Newfoundland and Labrador to establish the limits of its continental shelf in the Northern Atlantic. Similar works are being planned for the Arctic region as well [DFO, 2006a; Fugro, 2006].

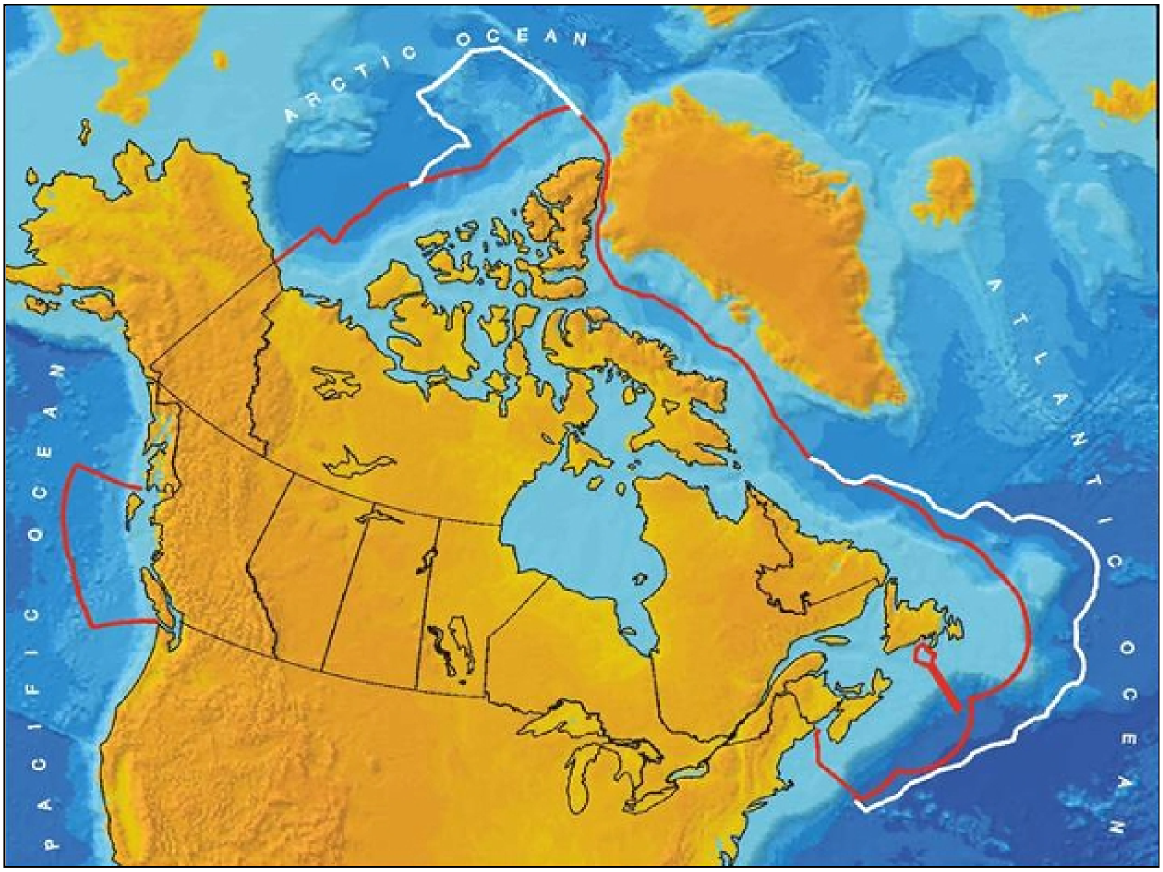


Figure 2.2: Canada's current and prospective offshore jurisdiction
(Red line: the EEZ, white lines: areas outside of EEZ.) [MacDougall et al., 2006]

In light of these developments, an effective strategy for the management of information on ocean and coastal spaces and activities is required to facilitate meeting the responsibilities and objectives outlined in the above documents. A Committee on the US Coastal Zone highlighted the role of information resources in the management of the coastal zone [Committee, 2004]. These observations can also be extended toward ocean spaces:

> *In order to understand and address the effects of complex natural and anthropogenic forces in the coastal zone* (and oceans), *a holistic multidisciplinary framework must be developed to adequately describe the interconnectivity of processes in the system. At the base of this framework will be accurate information about the locations of important features and processes, both onshore and offshore. [Committee, 2004]*

2.2 The Role of Information in the Management of Ocean and Coastal Environment

There have been extensive efforts put forth to study the vast oceans. Advances in science and technology have improved our understanding about its constantly changing conditions and how it carries its influences to areas far from the coasts (see e.g., NASA, 2005; JPL, n.d.). Two-thirds of the total surface of the Earth is covered by the oceans' salt water. By taking into account the immense depths below the surface, research studies have suggested that oceans and coasts also *"represent over 99% of the living space on Earth"* [NASA, 2005[1]]. Indeed, discovery of new ocean species are frequently reported (see e.g., Canadian Press, 2006).

Nevertheless, information on this vast area is scarce. The mapping of the seafloor is an example, as it is estimated that less than 10 percent of the seafloor has been directly measured [Monahan, 2007]. In consequence, Monahan [2007] suggests that "*because deepwater data is so scant, all the data has to be used"* and "*most data has no redundancy"* and co-operation needs to extend beyond national borders.

Figure 2.3 displays two maps of the Northern Atlantic region [NASA/GES DISC, 2006]. These maps depict the change in sea surface temperatures between the two

[1] *"… life in the oceans can be found from the surface all the way down to the very bottom of the deepest submarine trench, … the oceans represent over 99% of the living space on Earth*." http://science.hq.nasa.gov/oceans/

selected dates, showing spatial as well as temporal variations. Sea surface temperature is but one geospatially referenced parameter that is being observed in order to predict weather patterns [JPL, n.d].

The production and distribution of these maps are an example of a complex information management process pertaining to the ocean environment, reaching over sectoral and regional institutions. Data gathering is assisted by two internationally funded ocean remote sensing satellites (TOPEX/Poseidon and Jason1). A number of government agencies and academic research institutions (e.g., NASA, NOAA, University of Colorado/CCAR) are involved in data processing and distribution while the generated information is a component in a variety of weather-related applications used by the ocean transportation, fishery, marine science communities, as well as applied for terrestrial purposes, for example hurricane predictions.

Considering the global nature of physical, chemical, and biological ocean processes, all nations rely to some degree on the ocean and coastal environment [Committee, 2004]. Coastal nations, however, are directly involved in the management of the surrounding ocean and coastal spaces.

Sea Surface Temperatures
on October 9 and December 4, 2OO6

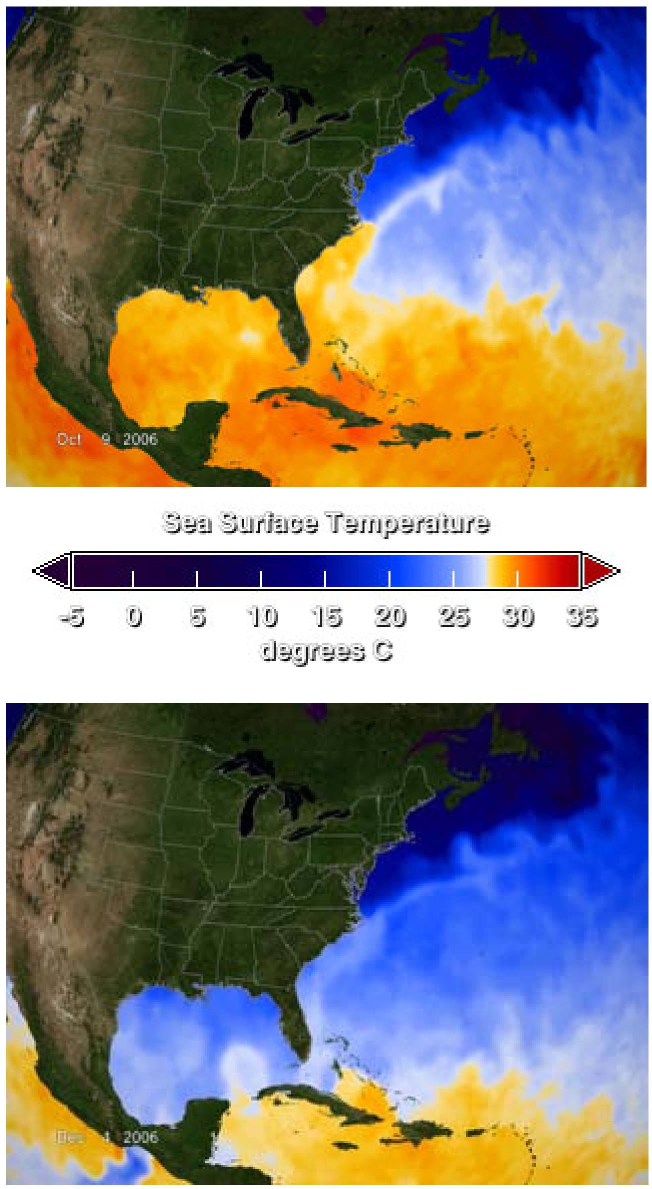


Figure 2.3: Sea Surface Temperatures over the Northern Atlantic Region
(Courtesy of NASA/GES DISC)

Oceans and coastal areas form a base for a number of economic, cultural, defense, and research activities, including:

- marine transportation;
- sovereignty and national defense;
- renewable natural resource exploitation;
- habitat management for renewable natural resources;
- non-renewable resource exploitation;
- disaster management;
- recreation;
- waste disposal;
- energy production; and
- ocean research.

These activities represent immense potential economic and social benefits for coastal nations if managed for long-term sustainability. Making decisions about the responsible use of this critical environment is a complex task that requires data and information that is [Dale and McLaughlin, 1988]:

- up to date;
- accurate;
- complete;
- comprehensive;
- understandable; and
- accessible.

There have been a number of studies directed at establishing the relationship between the quality and quantity of information available for decision makers and the quality of the resulting decisions [Edmunds and Morris, 2000; Dale and McLaughlin, 1988; Ballou and Plazer, 1985; O'Reilly, 1982; Feldman and March, 1981]. Dale and McLaughlin [1988] pointed out that good quality data and information are not guaranteed to lead to good decisions. While the quality of available information is a significant factor in decision making, there are other factors, such the "*qualities of the … user*" [Dale, McLaughlin, 1988] that will influence the quality of the decisions. On the other hand, relying on poor quality data and information will lessen the likelihood of sound decisions being made. Conducting research on the role of information in decision making, the respondents in Grieves' [1998] study reported that reliable information was useful in "*avoiding a poor decision*" in between 66.2 and 92.8 percent of the cases.

2.3 Canada's Commitment to its Oceans and Coasts

2.3.1 Canada as a Maritime Nation

The importance of oceans and coasts to a nation, and in particular to coastal communities, is well documented in Canada and world wide (see for example: *Oceans Act*, 1996; UN, 1998; DFO, 2002; FAO, 2004; The US Commission on Ocean Policy, 2004). Several economic evaluations took place to estimate sectoral and regional dependency on ocean and coastal activities (e.g., Newfoundland and Labrador, 2001; Australia, 1998, UN and ISA, 2004).

The management of ocean and coastal resources and spaces is not a novel concept. Some of the traditional management objectives are, however, in the process of transformation due to outcomes that harmed the ocean and coastal environment and in turn, society. A case in point is the collapse of the Atlantic Cod fishery in 1992 that is yet to show signs of recovery after a fishing ban of nearly 15 years [DFO, 1995, 2003, 2005b; Gough, 2001].

The introduction of the *Oceans Act* in 1996 was regarded as a step toward a new direction in the management of Canada's oceans and coastal waters [Mageau et al., 2005]. The implementation of its objectives, however, greatly depends on the political priorities, including those shaping environmental and oceans policies.

2.3.2 The Legacy of the Conventional Legislative and Institutional Framework

Sutherland [2005] and Mageau et al. [2005] capture the complex legislative and institutional framework surrounding coastal and ocean spaces and activities in Canada. Their findings identify (as of 2005):

- ten federal government agencies with major roles in ocean management;
- thirteen federal government agencies with lesser roles in ocean management;
- fifty federal statutes with direct impact on ocean activities;
- over eighty provincial laws with ocean and coastal planning mandate.

In addition to federal and provincial jurisdictions, territorial and local governments, and aboriginal authorities are also active participants in ocean management issues. This multifaceted arrangement falls into an ocean management environment that is traditionally focused on a single species, single activity, and mostly regional agendas

(Figure 2.4). The Oceans Strategy [DFO, 2002] and the Oceans Action Plan [DFO, 2005b] acknowledge that these arrangements are not sufficient to confront current and future challenges in managing ocean and coastal resources and spaces. Among the current challenges are:

- the fishery crisis;
- conflicting use of ocean and coastal resources and spaces, and
- lost revenues in ocean-related industries[2].

These problems may have resulted from the established managerial framework that can be characterized by:

- fragmented, disconnected approach;
- lack of transparency;
- failure to anticipate impending problems; and
- exclusion of coastal communities and traditional ecological knowledge from decision making.

The need for a new and comprehensive approach to ocean management was first proposed in 1987 [Mageau et al., 2005; Coffen-Smout, 1996]. A decade later the *Oceans Act* [1996] came into force outlining a new ocean management model that is based on the sustainable development of Canada's oceans and its resources.

[2] E.g., Revenues lost in the salmon aquaculture industry since 1996 due to the spread of infectious salmon anemia in the Bay of Fundy [Chang et al., 2006]. The findings of Chang et al. [2006] suggest that hydrographic considerations were not given appropriate weight during the selection of aquaculture sites.

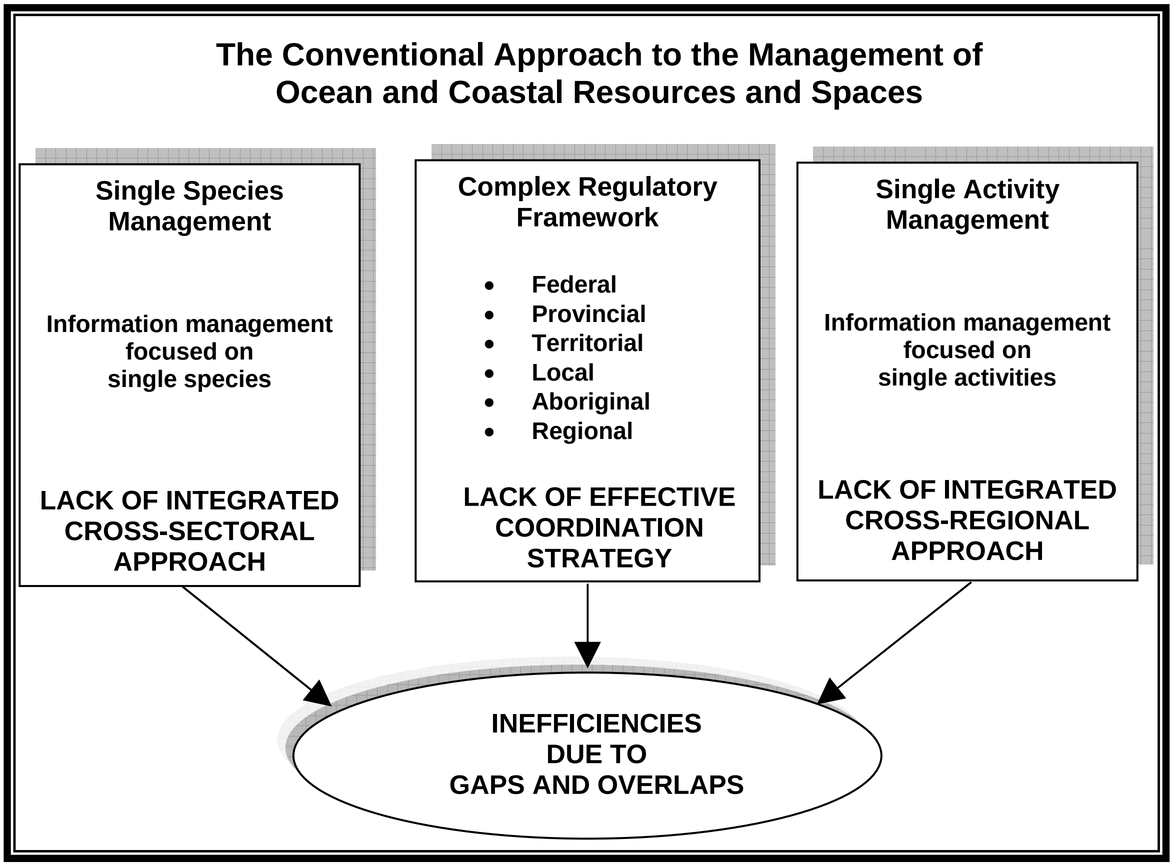


Figure 2.4: The conventional approach to the management of ocean and coastal resources and activities

2.3.3 Overview of the Defining Policy Directions

One of the subjects of this research is to design a spatial information management framework that corresponds to the present and future needs of ocean and coastal management, the existing policies and strategies for ocean and coastal management must be taken into account. The two major policy directions that will be given considerable attention throughout this research are:

1. the introduction of the *Oceans Act* [1996] and the resulting policy documents – the Oceans Strategy [DFO, 2002] and the Oceans Action Plan [DFO, 2005b], and
2. the ratification of the UNCLOS and claiming an extended oceans territory for Canada.

With over 23 federal government agencies involved in ocean and coastal management there is no shortage of agendas and commitments to ocean and coastal spaces and activities. Adding the provinces, territories, local and aboriginal authorities, industries and other stakeholders to the mosaic of interests and good intentions means there is little surprise that some of these commitments are conflicting and have been unsustainable or even harmful.

To rectify this situation, the *Oceans Act* [1996] calls for a single coordinating body that oversees the implementation of the integrated management concept. Part Three of the *Oceans Act* [1996] identifies *"the Minister of Fisheries and Oceans as the lead federal authority responsible for oceans management within Canada"* while Part Two of the same Act gives the task of developing and implementing Canada's integrated ocean management approach to the Minister of Fisheries and Oceans as well. It can be argued that these two functions are not clearly specified in the *Oceans Act* [1996] and a probable cause for conflicting mandates within DFO. Part Three of the *Oceans Act* [1996], however, reduces the power of the Minister of Fisheries and Oceans to matters *"not assigned by law to any other department, board or agency of the Government of Canada."* This reflects a presumption that ocean and coastal related mandates and activities are well understood and separated among the federal government agencies.

Supporting framework to the *Oceans Act* [1996] include the Oceans Strategy [DFO, 2002] and the Oceans Action Plan [DFO, 2005b]. These documents propose a number of principles for the management of ocean and coastal resources and activities but fall short on producing measurable objectives, as illustrated by Figure 2.5.

2.3.4 The Missing Element: Information Management

The Oceans Action Plan [DFO, 2005b] attempts to address the individual requirements of four critical ocean management areas. While addressing the needs of these four areas, as shown by Figure 2.6, is undoubtedly crucial, it is equally as important to establish the connection among the proposed pillars. Without these connections, the Oceans Action Plan model is inconsistent with the principles articulated in the *Oceans Act* [1996] and in the Oceans Strategy [DFO, 2002]. Although introducing modern management schemes, (i.e., integrated management, and modern ocean governance) this policy framework appears to carry the conventional model of sector and region specific approach. Ng'ang'a [2006] also points out the lack of any reference to "*integrated inventories of information to mitigate growing oceans user conflicts as well as administrative, jurisdictional and regulatory complexities.*"

Discussing the formulation of integrated coastal zone management in Chapter 3, this research will argue that the concept of integrated management has strong ties to information management. Sorensen [1993] asserts that in the early 1970s it was difficult to evaluate coastal zone initiatives due to the lack of comparable information. Hence there was a need "*to develop a framework for information exchange, particularly for new* *entrants in the field in benefit from the experience of their predecessors"* [Sorensen, 1993].

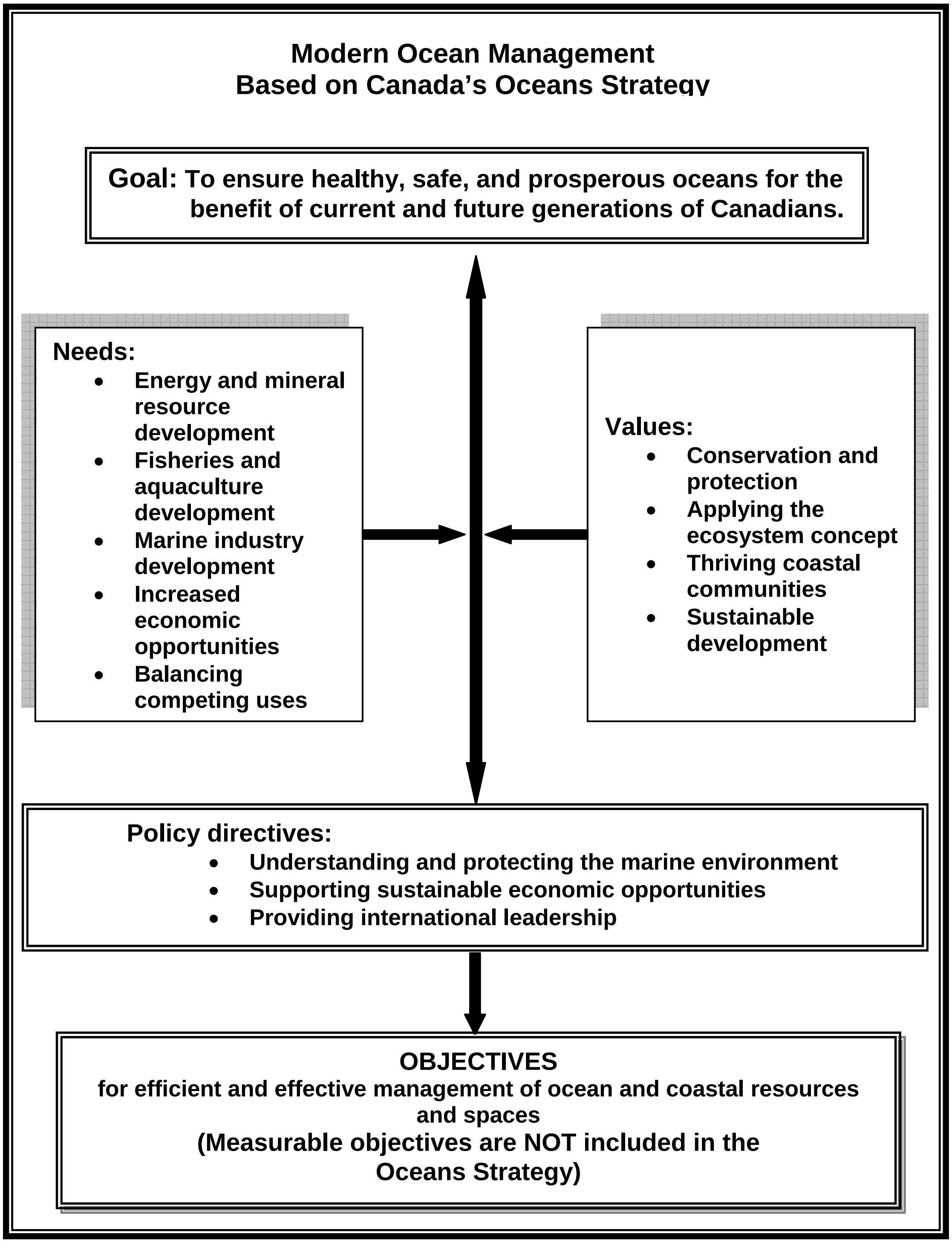


Figure 2.5: Modern ocean management priorities based on Canada's Oceans Strategy

Arguing that information management is an integral part of the integrated ocean management policy proposed by the Oceans Strategy [DFO, 2002], this research recommends extending the Oceans Action Plan [DFO, 2005b] with information management as a connection among the four interconnected pillars, illustrated in Figure 2.7.

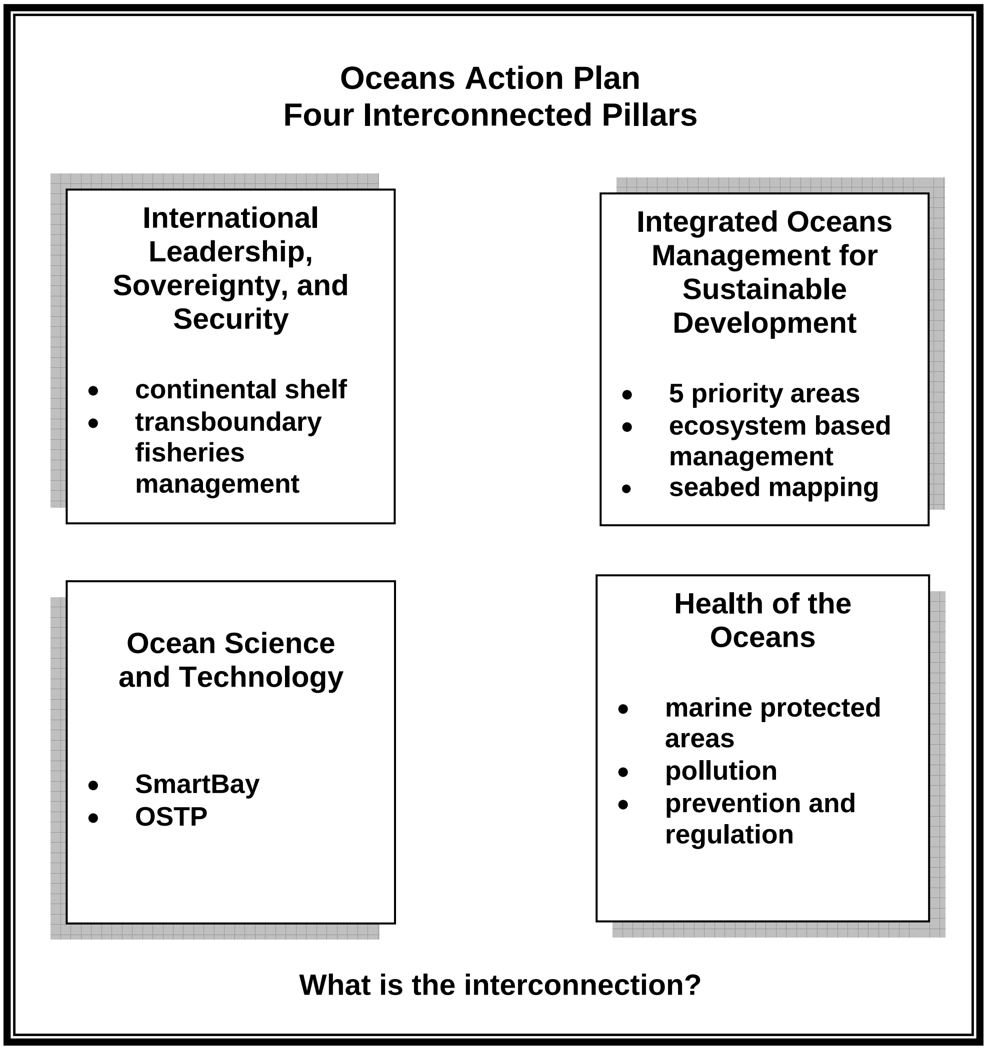


Figure 2.6: Canada's Oceans Action Plan [DFO, 2005b]

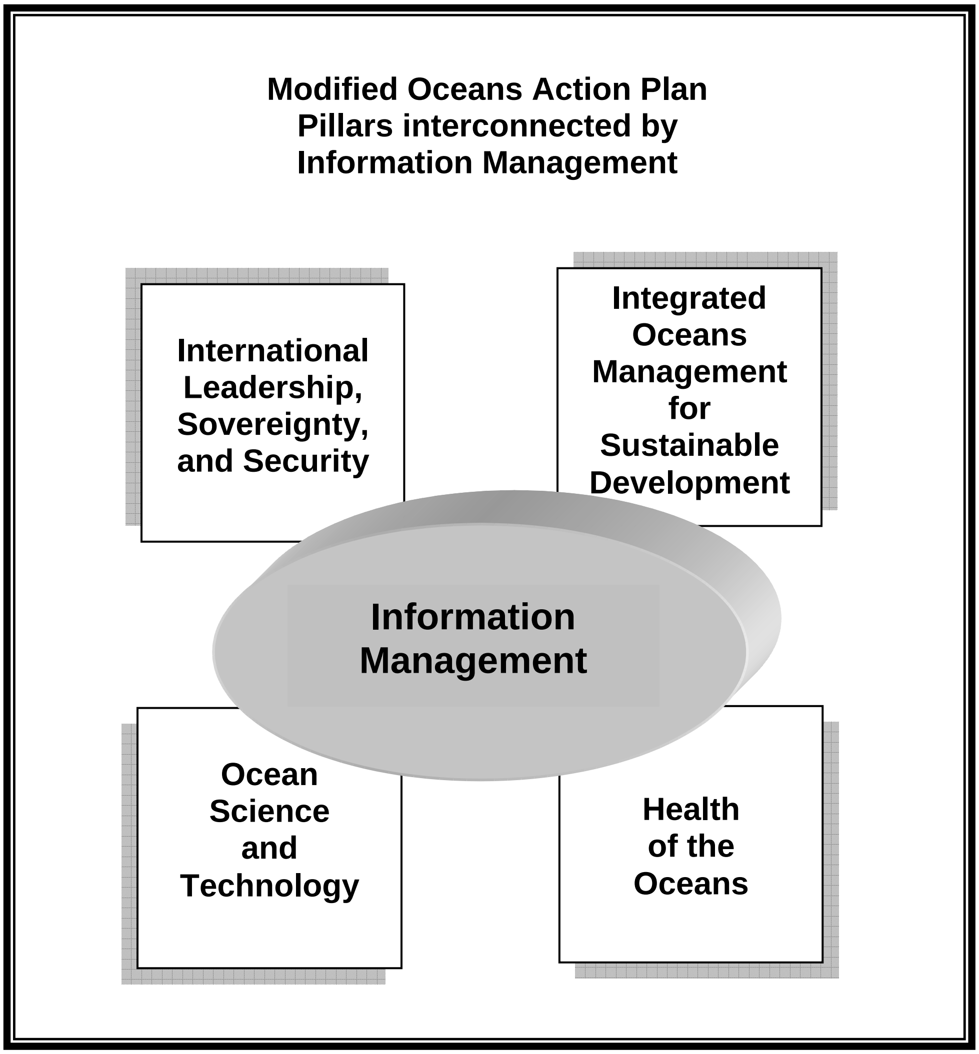


Figure 2.7: The modified oceans action plan

2.4 International Issues: Ratifying the UNCLOS

Under Article 76 of the *United Nations Convention on the Law of the Sea* a coastal nation is granted jurisdiction over the EEZ that extends 200 nautical miles seaward from the coast [Monahan, 2002; Cockburn, 2005; Calderbank et al., 2005]. A coastal nation may also extend its national jurisdiction beyond this limit provided the nation submits a claim to the United Nations Commission on the Limits of the Continental Shelf (CLCS), proving that the alleged seabed meets certain conditions [Monahan, 2002; Cockburn, 2005]. Canada ratified the UNCLOS in 2003 and has made commitments to marine data collection in preparation of submitting a claim to extend its jurisdiction to the outer limits of the extended continental shelf. Coastal nations are allowed 10 years from the ratification of UNCLOS to determine the outer edge of the continental shelf. A finalized continental shelf limit is politically significant for it is *“final and binding”* under international law [Cockburn, 2005].

The Russian Federation submitted the information on the proposed outer limits of its continental shelf beyond the 200 nautical miles in December, 2001 [CLCS, 1999]. This development is significant to Canada as it has been suggested that this claim may infringe upon Canada’s claim to its extended continental shelf in the Arctic Ocean [Calderbank et al., 2005; UN, 2001]. The Government of Canada took the position of *“inability to comment”* on the Russian Federation’s claim *“without the provision of further supporting data to analyze”* [UN, 2002].

In 2006, the actual surveying and mapping work on the Arctic and Atlantic regions of Canada have been contracted out. The Minister of Foreign Affairs [DFO, 2006a] summarized the importance of these proceedings by saying that:

> *Establishing the limits of the extended continental shelf will allow Canada to delineate precisely the full extent of the area over which it exercises sovereign rights for the purpose of exploring and exploiting its natural resources. [Honourable Peter MacKay as quoted in DFO, 2006a]*

2.4.1 UNCLOS and Marine Boundary Delimitation

Cockburn [2005] argues that changes in marine boundary laws (that ratifying UNCLOS will result in) have an effect on:

- the method of how property rights, restrictions and responsibilities are managed;
- the application of established and emerging technologies;
- spatial information management.

Cockburn [2005] summarized the above observation in a framework model (Figure 2.8) highlighting the influences between the components. (The dashed lines imply that there might be occasions when a connection is not present.)

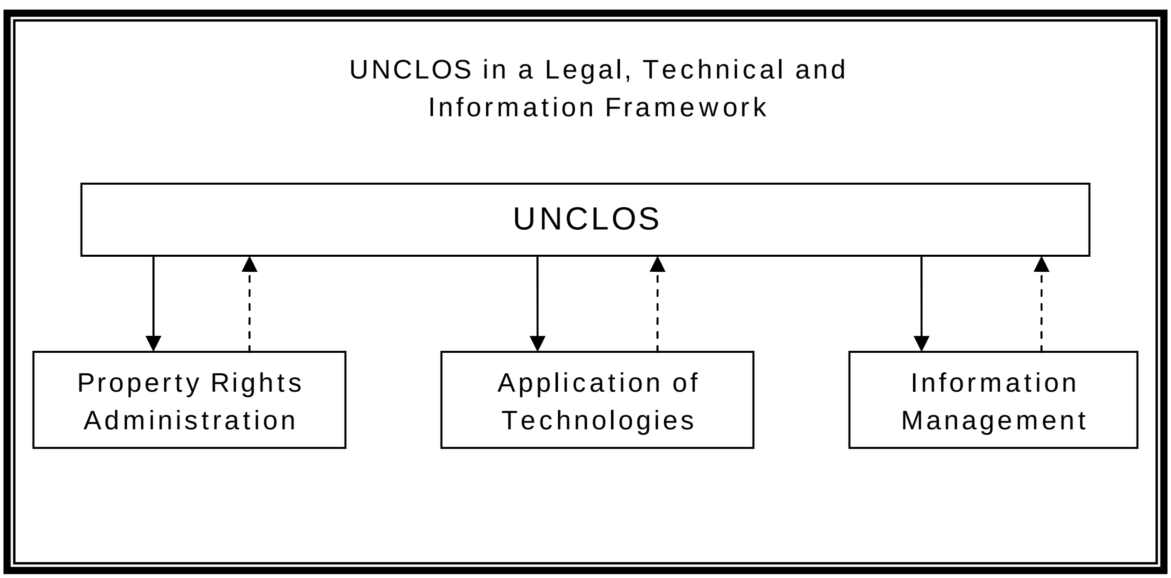


Figure 2.8: UNCLOS in a legal, technical, and information framework (from Cockburn, 2005)

2.4.2 Information Management Requirements for Submitting a Claim to the CLCS

Two relevant aspects of information management concerning the delimitation of the outer edge of the extended continental shelf are:

- collecting data for the preparation of the claim and
- submitting the information to the CLCS in support of the claim.

Mapping the area claimed under Article 76 of the UNCLOS is a joint federal government project. It is led by the Department of Foreign Affairs and International Trade, Natural Resources Canada and Fisheries and Oceans Canada [DFO, 2006a]. Within this arrangement there is further diversification of tasks with international and private sector involvements (e.g., joint Canada-Denmark seismic project for mapping the Arctic Ocean or Fugro Jacques GeoSurveys Inc. collecting multi-beam survey data [DFO, 2006a; Fugro, 2006]). With an increasing number of participants, it is essential to have an information management framework in place to make sure the data collection methods are harmonized and compatible and conform to the requirements of the CLCS. Monahan [2002] extensively discusses the information requirements for submitting the claim and delimiting the boundaries.

The significance of data collection and information management is illustrated by Cockburn [2005] noting that "*the data collected to formulate an outer continental shelf claim will eventually dictate the amount of territory a coastal nation can administer*." Furthermore, the prioritization and presentation of the data to the CLCS will probably shape the decision of the CLCS which in turn will influence the international recognition of the boundaries. The CLCS has published *Scientific and Technical Guidelines [1999]* that coastal nations are expected to adhere to if their submission is to be considered. Furthermore, Part Six, Article 76 of the UNCLOS requires that

> *[t]he coastal State shall deposit with the Secretary-General of the United Nations charts and relevant information, including geodetic data, permanently describing the outer limits of its continental shelf. [UN, 1983]*

2.5 Summary and Conclusions

The purpose of this chapter was to introduce the key domestic and international legislative and policy directions aimed at managing Canada's ocean and coastal resources and activities. An important new element in the outlined direction is the intent to move away from the fragmented, disconnected approach toward an integrated, collaborative, and sustainable development. This new ocean management approach has a compelling connection to information management.

The existing structure for the management of ocean and coastal information resources matches the outdated ocean management framework based on single species and single activity management. In order to meet the requirements of modern ocean management, the stakeholder community needs to adapt an information management strategy corresponding to the overall objectives.

The following conclusions and recommendations are drawn from the analysis of the present state of ocean management:

- using the terminology "integrated" with regards to ocean and coastal management does not mean that integrated management is actually practiced. Integrated management needs to be defined, the scope and nature of integration highlighted. Then the identified principles need to be carried out in practice to justify a management approach as integrated;

- referring to interconnected pillars in the Oceans Action Plan [DFO, 2005b] without giving details on the interconnection gives way to different interpretations as to the connection;
- systematically managing ocean and coastal information resources is an interconnection among the different pillars of the OAP;
- overlooking, instead of understanding, the complex legal, institutional, political, and jurisdictional framework surrounding ocean and coastal management is not likely to benefit any initiative in the long term. A marine cadastre (as discussed in Chapter 3) is an instrument capable of helping to clarify these issues;
- establishing an information management framework prior to developing information resources and technologies in connection to the delimitation of Canada's outer continental shelf would facilitate their use in other ocean management fields.

CHAPTER 3
EVOLUTION OF GEOSPATIAL INFORMATION MANAGEMENT IN THE COASTAL AND OCEAN ENVIRONMENT: EXAMPLES OF THE CHALLENGES

3.1 Introduction

> *Well-designed … initiatives create a common good and … are not subject to "zero-sum game" limitations (i.e., there are no losers). This feature makes it possible and necessary to significantly broaden the number of policy and project stakeholders and build productive partnerships among them. [Sankovski, 2000]*

Chapter 2 concluded that the present information management structure is not sufficient to enable the realization of ecosystem-based integrated ocean management. The objective of this chapter is to evaluate the potential contribution of the geomatics community to a new direction in ocean and coastal information management. The questions being asked here are:

- Did recent evolutions in geomatics technologies and concepts enable the geomatics profession to contribute to the new information management requirements of modern ocean management?
- In what way do these technologies and concepts influence the formulation of an information management strategy?

The origin of this review lies with the examination of major developments in the collection, processing, and management of ocean and coastal information during the last

30 years[3]. The geomatics applications discussed in this chapter share one or more of the following characteristics:

- they were developed for a specific purpose, mirroring the fragmented ocean management approach (e.g., offshore cadastre for revenue collection, nautical charts for navigation, etc). An exception would be ICZM: however, it can be argued that, in most cases, this process was applied with a specific purpose and without real integration (Section 3.6);
- technological advances greatly enhanced the capabilities of these technologies and concepts for information sharing and integration. Even though some of these technologies are discussed in the OAP [DFO, 2005b] (e.g., ocean mapping), there is no reference to these technologies as potential tools for information management;
- barriers to information sharing and management are increasingly not technological in nature;
- improved management of information resources would facilitate the continued development of these technologies and concepts.

This chapter will follow the thread of developments in information sharing and management in the ocean and coastal environment as it moved from many separate interests towards common objectives in managing and governing ocean spaces [Sutherland, 2005]. Even though the emphasis of this research is on coastal and ocean information management, this chapter will begin with a brief review of the major

[3] This arbitrary timeframe refers to the formulation of the Victoria Principles in 1978 that publicized the need for an integrated coastal management in Canada [Ricketts et al., 2004].

advancements in land information management for the lessons learned in this field are relevant to the present discussion.

The second part of Chapter 3 is dedicated to following the developments of spatial information management initiatives that focused on managing offshore resources and activities that were launched between the mid 1950s and 1980s. In the mid 1950s, the Public Land Survey System (PLSS) in the United States was extended to federal offshore waters in states where mineral leasing programs were already underway [Thormahlen et al., 2003].

Increasing the safety and efficiency of navigation were the driving forces behind the design of digital charts or Electronic Navigational Charts (ENC) and the information system that manages and displays the ENC, the Electronic Chart Display and Information System (ECDIS). As a decision making tool, the ECDIS utilizes improvements in digital data base management technologies and communication technologies while heavily relying on the legal framework set for the operation of vessels in the maritime environment.

Although the ECDIS might be viewed as a *"real-time GIS optimized for maritime navigation,"* a point of view espoused by Alexander [2004], this chapter will summarize the beginnings of marine GIS separately from the ENC and ECDIS. The challenge of organizing and thus expanding the applications of digital ocean and coastal information that contain geospatial attributes was first addressed in the late 1970s[4]. A decade later it was followed by the emergence of additional marine and coastal applications of GIS and innovations in ocean mapping.

[4] Patent in the U.S. for the "Electronic Chart System" was filed in 1981 [USPTO, 1984].

The remainder of Chapter 3 will consider an institutional response to coastal problems and challenges. While several environmental management and planning efforts are underway to address various issues in the coastal zone (e.g., estuarine management, coastal defense, pollution management), only programs that are built on a multisectoral approach and include a systems perspective are recognized as Integrated Coastal Zone Management (ICZM) programs [Sorensen, 1993].

The initiatives discussed in this chapter cover several decades of information management developments in the ocean and coastal environment. This chapter will investigate how these programs and tools meet the needs of the stakeholders, what overlaps, if any, can be identified among them, and how the evolution of these concepts and practices contribute to the concept of marine geospatial information infrastructure (Chapter 4).

3.2 Modernization of Land Information Management

McLaughlin and Nichols [1989] outlined the rapid developments in the principle of land information management that began in the 1960s with integrated mapping. The management of data was further advanced when the multiple cadastre concept [McLaughlin, 1975] was introduced. A decade later the field of Information Resources Management (IRM) gained acceptance and its influence on the management of spatial information proved critical [Bergeron, 1996]. In the 1980s Geographic Information Systems (GIS)[5] were able to organize information by linking it to geographical locations. In the 1990s emphasis on human resources, policies, technologies, and standards were

[5] *"A GIS facilitates the integrated analysis of geospatial information, by storing information spatially (e.g., Earth location, elevation), temporally (e.g., imagery acquisition date/time) and aspatially (e.g., information related to an object which is not necessarily geospatial in nature)." [Kralidis, 2005]*

drawn together for effective sharing of spatial data across government, the private sector, and the research communities. By the turn of the century several national or regional Spatial Data Infrastructures came into existence with Australia and New Zealand (ANZLIC), Canada (CGDI), the European Community (EUROGI), and the United States (NSDI) leading the way. Efforts have also begun to address the development of a Global Geospatial Data Infrastructure [Coleman and McLaughlin, 1998; Groot and McLaughlin, 2000]. These developments are summarized in Table 3.1.

Table 3.1: Developments in Spatial Data Management and Sharing
(after McLaughlin and Nichols, 1989)

Time frame	Development	Tools	Application
1960s	integrated mapping	registration, overlay, and analysis of layers	land use planning; resource inventory
1970s	multipurpose cadastre	topographic and cadastral base mapping	reducing duplications; thematic layers
1980s	distributed land information networks GIS	information resource management; integrated analysis of spatial information	linking land management organizations together; resource management; navigational information management
1990s	Spatial Data Infrastructure	information infrastructure	linking spatial data and information vertically and horizontally

These initiatives primarily focused on (dry) land. Environmental, economical, and political pressures, however, required new information management approaches in the ocean and coastal areas as well. The following section presents an overview of the developments in the management of geospatial data in coastal and ocean environment.

3.3 Revenues and Neighbours: The Case for an Offshore Cadastre

Although fishing is the oldest industry concerning natural resources in the coastal and ocean environment, it was not among the first areas that were associated with the need for improved information management. As recently as the 1970s the fish stock was viewed as an undiminishing natural resource being part of the "commons," accessible to all. The need to actively manage this resource was only recognized in the 1970s, after signs of overfishing appeared [DFO, 1995, 2005a].

Prior to acknowledging the need for the management of aquatic living resources, there were efforts underway for the management of non-renewable and perhaps more lucrative natural resources, such as oil, gas, sulphur, and salt. When the first offshore oil rig began to operate on November 14, 1947, 45 miles south of Morgan City, Louisiana [Hill, 2006], a new approach for the management of information on the affected offshore areas was introduced. The Louisiana, Texas, and California offshore cadastres in the United States, administered by the Bureau of Land Management (as being part of the Department of Interior) managed the leasing activities of offshore mineral exploration and exploration purposes.

3.3.1 The extension of the cadastre concept to the marine environment

The concept of a cadastre was initially applied to land. McLaughlin and Nichols [1989] define it as *"a primary tool for recording interests in land encompassing both the nature and extent of these interests."*

In Canada, GeoConnections [n.d.] narrowly defines a cadastre as a *"public record, survey, or map of the value, extent, and ownership of land as a basis of taxation."*

In the United States, the Federal Geographic Data Committee [2005] adds a temporal aspect to the definition, including the *"geographic extent of past, current, and future rights and interests in property."*

Grant [1999] defines a marine cadastre as a *"system to enable the boundaries of marine rights and interest to be recorded, spatially managed and physically defined in relationship to the boundaries of other neighbouring or underlying rights and interests"* Extending this definition, Ng'ang'a and Nichols [2002] suggest an information system view of marine cadastre that *"facilitates the visualisation of the effect of a jurisdiction's private and public laws on the marine environment."*

The complex nature of a marine cadastre, boundary delimitation and assigning property rights in ocean and coastal areas have been underscored by recent works of Ng'ang'a [2006], Cockburn [2005], Treml et al. [2002], Widodo et al. [2002], and Sutherland [2005].

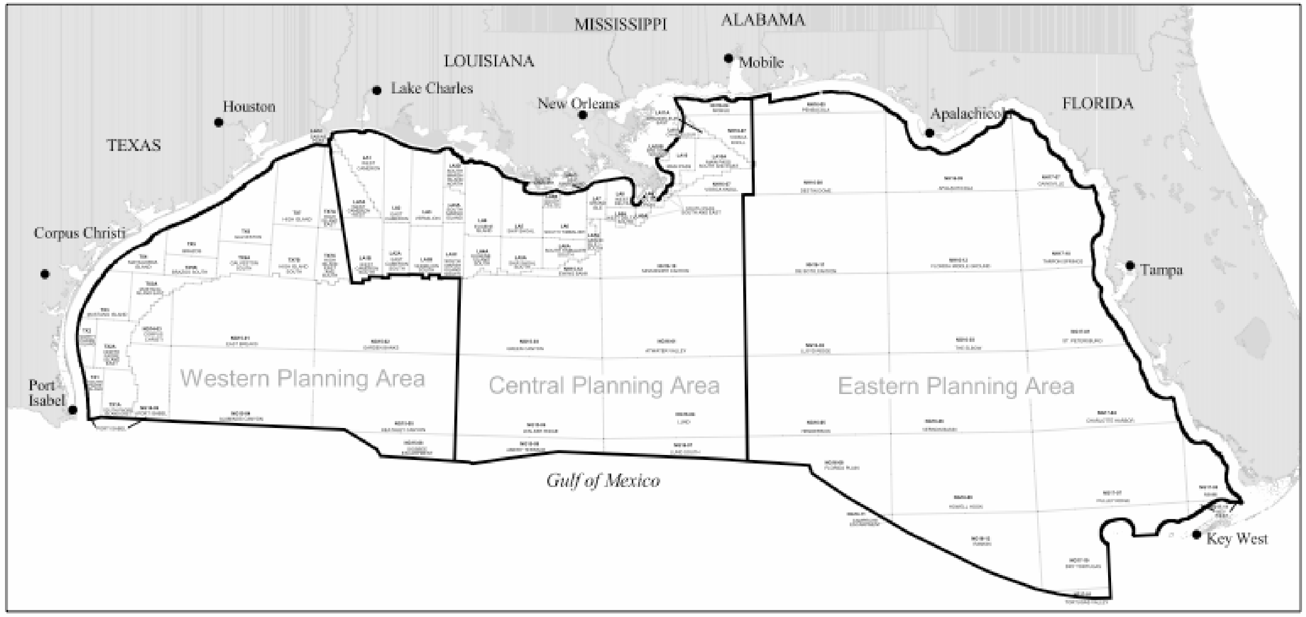
3.3.2 An early offshore cadastre: The North American approach

In 1945, in advance of international treaties addressing the jurisdictional issues of offshore areas, the United States Federal Government claimed ownership of offshore natural resources (Truman Proclamation on the Continental Shelf, 1945[6]) [Eckert, 1979]. By passing the *Outer Continental Shelf Lands Act* of 1953 [AGI, 2003], the U.S. Federal Government opened the door for leases in offshore areas for mineral resource exploration. The first federal offshore leasing map was issued in 1954 in the state of Louisiana, in the Central Gulf of Mexico region [Thormahlen, 1999; Rogers, 1993],

[6]http://www.oceanlaw.net/texts/truman1.htm

followed by leases in the Western Gulf of Mexico in Texas, then the Pacific Outer Continental Shelf Region's Channel Island area off the state of California. Figure 3.1 is an example of current leasing activities in the Gulf of Mexico region. Marine parcels are distinguished by an alphanumeric identifier and a geographic name. Parcels are further subdivided into numbered blocks. Marine boundaries shown in the leasing map are the U.S. - Mexico Continental Shelf Boundary Article IV "Area" Limit and the federal and state boundaries (Texas: 9 nautical miles from MHHW; Louisiana: 3 nautical miles from Highest Winter Tide; Alabama: 3 nautical miles from MHW; Florida Gulf Coast: 9 nautical miles from MHW).

These cadastres were not free of technical difficulties due, for example, to the lack of seamless data on the shore and the different coordinate systems being used onshore and offshore [Rogers, 1993]. However, their benefits included aiding in revenue collection, reducing confusion when leases were transferred, and assisting in the resolution of boundary-related litigation. They also established a foundation for addressing future priorities, such as environmental protection and supporting science and technology research [MMS, 2005]. The topics of expanding offshore leased areas for mineral exploitation or introducing marine protected areas and the distribution of revenues derived from the leases continue to be the part of the political, economical, and environmental debates. Information in the cadastre plays an important role in aiding decision making with regard to disputes.



Gulf of Mexico Region Planning Areas
December 6, 2006

	Total Blocks	Total Acres	Blocks Leased	Acres Leased
Westen Planning Area	6,517	35,930,495.793	2,770	15,658,351.74
Central Planning Area	9,113	47,798,125.396	4,811	24,873,868.52
Eastern Planning Area	13,457	75,585,243.528	242	1,393,920.00
Totals	29,087	159,313,864.717	7,823	41,926,140.26

MG06009 12/08/2006

Figure 3.1: Leasing Activity in the Gulf of Mexico Region [MMS, 2006]

n Canada, property rights regimes in the offshore were also instigated by oil and gas exploration. In 1959 the first exploration permit was issued by the federal Department of Indian Affairs and Northern Development to cover the Sable Island area off the coast of Nova Scotia [DFO, 2006e]. This mandate was taken over by the federal Department of Energy, Mines and Resources in 1966. The complex jurisdictional matters between federal and provincial authorities as it applies to offshore mineral resources are discussed in detail by Ng'ang'a [2006].

Figure 3.2 illustrates federal petroleum exploration permits for Nova Scotia in 1969 [DFO, 2006e]. DFO notes, that this map *"should not be considered a complete record of all activity that … occurred … in the offshore."* Proprietary industry data and *"changes in the regulatory structure for the offshore … have resulted in discontinuity in data records"* [DFO, 2006e].

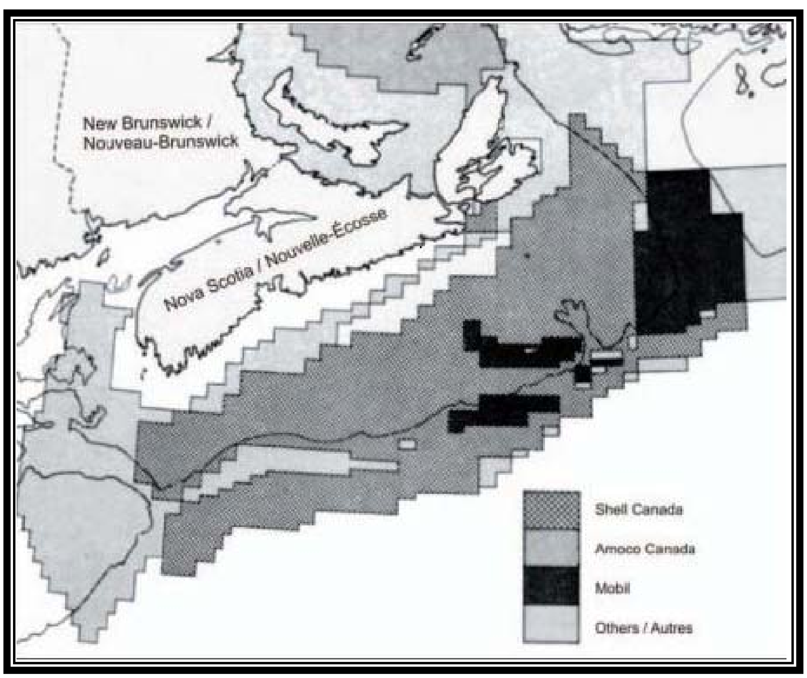


Figure 3.2: Federal petroleum exploration permits in 1969 [DFO, 2006e]

3.3.3 The North Sea cadastre in the Netherlands

For centuries the North Sea has been a scene of numerous disputes among the neighbouring countries over fishing rights and busy shipping routes [Barry et al., 2003]. The list of conflicting issues increased with the discovery of non-renewable natural resources, primarily natural gas, and the question of environmental protection.

With the intention of coordinating policies, directives, and legislation formulated by various government agencies, the Netherlands established the Interdepartmental Coordinating Committee for North Sea Affairs in 1977 [Barry et al., 2003]. To what degree this Committee relied upon the North Sea Cadastre defined as a "*formal arrangement of rights of occupation, usage and access to the Netherlands North Sea that supports tenure security and fiscal and environmental management*" is undocumented [Barry et al., 2003]. However, on the divided territorial sea, the North Sea Cadastre registered the rights to sea parcels, noting the utilization of the parcel, e.g., whether it was leased for aquaculture or for mineral exploitation (Figure 3.3).

3.3.4 Contribution of offshore cadastres to the management of ocean and coastal spatial information

The early offshore cadastres in the U.S. outer continental shelf, in Canada, and in the Netherlands North Sea are significant in many respects. These examples show recognition that it is:

- critical to manage resources, and information on those resources in the ocean and coastal environment;

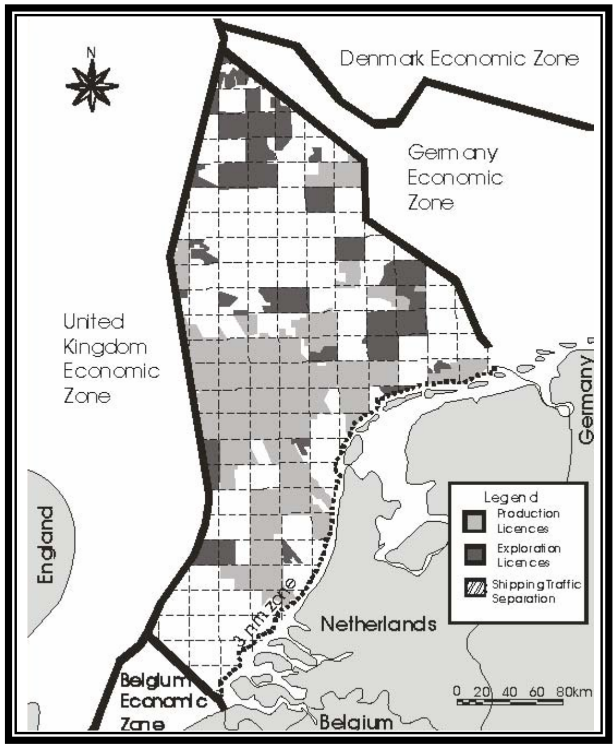


Figure 3.3: Netherlands North Sea oil and gas permit areas
[from Barry et al., 2003]

- a governmental responsibility to establish institutions that oversee competing activities in ocean and coastal areas and thus manage the information about ocean rights and activities;
- beneficial to maintain a cadastre for it is an effective instrument in managing revenue collection from offshore leases;
- necessary to collect and maintain information regarding the spatial extent of rights and responsibilities of interests in ocean and coastal areas employing a methodology that is comparable to the practices on dry land;
- valuable to inventory resources and monitor spatial and temporal changes;

- useful to establish an information management system in a way that it may provide information to multiple stakeholders.

Although these early offshore cadastres would not have the capability to meet the demands of the present day, they were significant in introducing a shift towards managing ocean and coastal resources and activities by employing spatial information. Table 3.1 summarizes current challenges that are not met in Canada due to limited support to the establishment of a comprehensive marine cadastre [Ng'ang'a, 2006; Nichols and Monahan, 1999].

Table 3.2: Information Management Challenges in the Development of a Marine Cadastre

Challenges	Information Requirements	Technological Requirements	Institutional Arrangements	Legal Arrangements	International Cooperation
lack of seamless data coverage of offshore areas	X	X	X	X	
delimitation of marine boundaries	X	X	X	X	X
jurisdictional uncertainty	X		X	X	X
proprietary data not shared	X		X	X	
discontinuity of data production/sharing	X		X	X	X
fragmented tenure information	X		X	X	
outstanding First Nations interests	X		X	X	

3.4 Innovations in Nautical Data Management and Presentation

Along with fishing, transportation was among the earliest activities taking place in ocean and coastal areas. Navigating rivers and the vast waters of the seas requires aids to determine direction, location, and situation (location relative to an object). Nautical charts have been of use since ancient times. The Marshall Islanders of the Pacific Rim, for example, used stick charts (Figure 3.4) to plan sea voyages between the islands [Rogoff, 1990; Bryan, 1938]. (Shells represent islands and curved sticks represent ocean swells and currents.)

Some nautical charts prepared in the Middle Ages are still recognizable. Figure 3.5 depicts a chart created by Amsterdam chartmaker Johannes van Keulen in 1650, a century prior to solving the longitude problem. Rogoff [1990] suggests that computation of longitudes in the mid 18th century has been the last major innovation regarding the nautical chart before the emergence of the digital chart in the early 1980s.

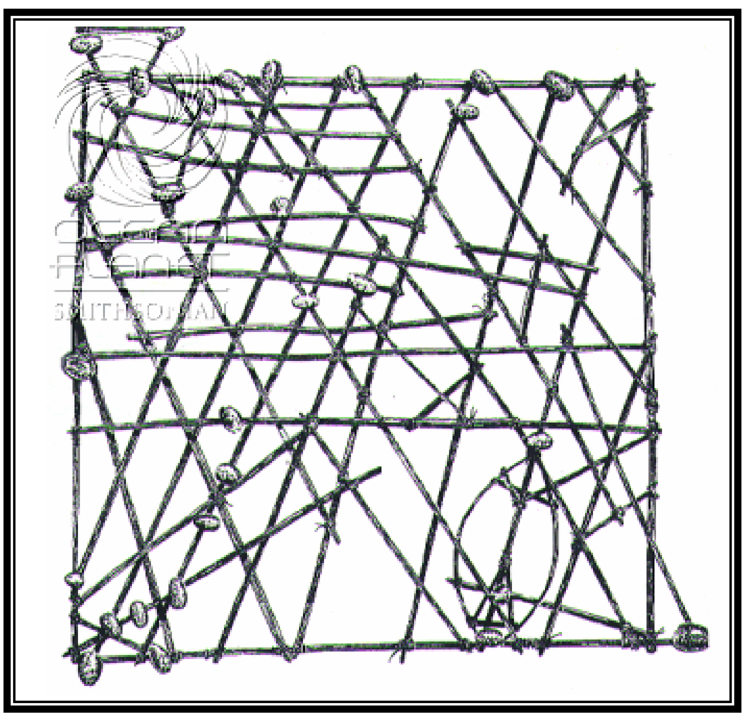


Figure 3.4: Diagram of Marshall Island Stick Chart[7]

[7]From http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/IMAGES/O-78.gif

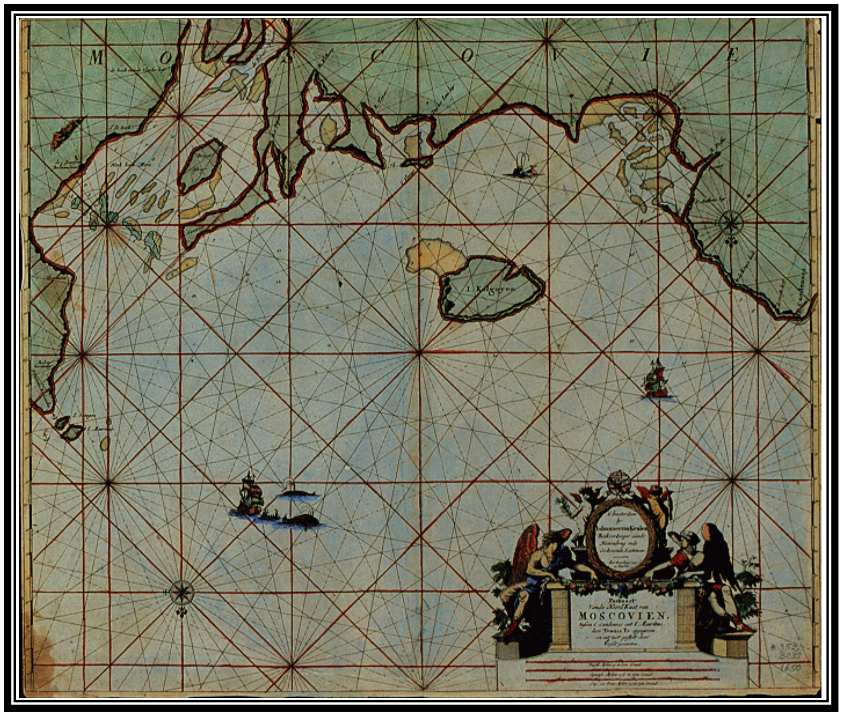


Figure 3.5: Navigational Chart from 1650[8]

While the paper navigational chart has been an essential and also a legally recognized requirement for navigation, Ward et al. [1999] remarks that it is also a *"passive representation of known navigational hazards and the aids which are installed to avoid them."* Consequently, static paper charts have a number of disadvantages over electronic systems which have the capability, for example, to continuously update the position of the vessel in relation to charted features, while the positions of charted features are also being regularly updated, thus lessening the likelihood of navigational errors. Ward et al. [1999] estimates that these errors are cause for 95 per cent of ship groundings, which are responsible for 33 per cent of pollution incidents on the open oceans and near shore. These errors may include [after Ward et al., 1999]:

[8]Paskaart vande Noordkust van Moscovien, Amsterdam, by Johannes van Keulen http://www.library.yale.edu/MapColl/mosc1650.gif

- inaccurate plotting of vessel's position;
- inaccurate setting of courses;
- failure to adjust the course when necessary;
- failure to comprehend hazards.

The Electronic Chart Display and Information System is designed to advise mariners of their present location and tracks a course for safely navigable routes. While paper charts are effective tools for planning, the ECDIS is a real-time navigational tool providing tactical and situational awareness [Alexander, 2004; Alexander and Goodyear, 2001; Perugini, 2007].

In some ways the emergence of the electronic chart is also connected to offshore hydrocarbon exploration. Grant and Goodyear [2004] and MacPhee [2005] put the beginning of the electronic chart to the late 1970s, when hydrographic surveying companies working for the offshore petroleum industry on Canada's eastern seaboard, developed navigational systems that *"utilized rudimentary graphics and integrated navigation systems"* aiding accurate navigation in *"confined waterways"* [Grant and Goodyear, 2004]. Thus the development of digital hydrographic charts can be traced back to 1979 as the CARIS corporation launched the first commercial hydrographic data processing and mapping software, a product of research supported by the Canadian Hydrographic Service (CHS) [Alexander and Goodyear, 2001].

3.4.1 Information management requirements for safe navigation

3.4.1.1. Information requirements

To be able to safely navigate, mariners require positioning information that includes [Edmonds, 1998; Rogoff, 1990]:

- information on the horizontal and vertical position of the mariner's own ship;
- information on the position of external features;
- a technique that integrates these information sets.

3.4.1.2 Institutional requirements

Navigational information comes from many different sources in many different formats. Manually updating traditional paper nautical charts by mariners holding copies of them, for example, can be made by relying on radio signal transmissions or by reading the various publications on marine safety published either periodically (e.g., Notices to Mariners) or on an as-needed basis (e.g., Warnings for Mariners). Eaton [n.d.] points out the importance of this information being continuous, precise, sensitive, and ready for decision making without delay. For centuries the paper nautical chart was responsible to comply with these functions.

The nautical chart's standing as a legal document required government authorities – mostly government authorized hydrographic or navy agencies – to collect, manage and disseminate the required information and to produce paper nautical charts. Supplying the updates to these charts and providing additional safety information, however, fall into the mandates of myriad other agencies. In Canada, for example, the following government agencies take part in ensuring the safety of navigation [CCG, 2004]:

- Department of Fisheries and Oceans publishes the Notices to Mariners and is the host for the Canadian Hydrographic Service, the national agency entrusted with the production of hydrographic charts, including Electronic Nautical Charts (ENCs);
- Transport Canada provides a host of publications on Marine Safety and Ship Safety;
- Environment Canada is responsible for notices on weather conditions and for the production of daily charts on ice conditions (the Canadian Ice Service (CIS) Branch) [Dias, 2006];
- Canadian Coast Guard (periodically being reassigned between government departments; currently part of DFO) is responsible for protection and rescue missions and maintains and provides information on navigational aids.

3.4.1.3 Technological requirements

There were a number of communications and technological innovations in the early 1980s that directly affected the information component of the nautical chart:

- positioning technologies, (e.g., GPS) provide accurate, near real-time locational information;
- computing technologies, specifically developments in GIS and database management capabilities facilitate the rapid assimilation and display of information from different sources; and

- communication technologies related to data transmission (e.g., the INMARSAT network of geostationary satellites) enabling the faster download of updates.

3.4.1.4 International coordination and legal arrangements

Apart from the innovations in the fields of science, technology, and communications, the functionality of ENCs and the Electronic Chart Display Information System (ECDIS) is strongly influenced by institutional, international, and legal arrangements. It started out with *"uncertainty and confusion"* [Norris, 1998] and brought a host of problems that needed to be addressed before the ECDIS achieved the same legal status as the paper nautical chart. However, the potential benefits associated with its ability to manage, combine and display navigational information in real time generated notable collaborations.

Examples of collaborations include committees launched under the International Hydrographic Organization (IHO), e.g., the World-Wide Electronic Navigational Chart Database (WEND), and the Committee on Hydrographic Requirements for Information Systems (CHRIS). The IHO also established international standards in regards to Electronic Navigational Charts, including:

- S-52: Specifications for Chart Content and Display Aspects of ECDIS;
- S-57: IHO Transfer Standard for Digital Hydrographic Data;
- S-58: Recommended ENC Validation Checks;
- S-61: Product Specifications for Raster Navigational Chart;
- S-63: IHO Data Protection Scheme s (RNC);

- S-65: ENC Production Guidance.

The Canadian *Charts and Nautical Publications Regulations* [1995] authorized the use of navigational charts in electronic format if the ENC, ECDIS, and back-up arrangements met certain standards, such as [Dias, 2005]:

- the International Maritime Organization (IMO) requirements for International Convention for Safety at Sea (SOLAS) class vessels;
- the International Hydrographic Organization (IHO) standards S-52 and S-57;
- the Radio Technical Commission For Maritime Services recommended standards; and
- the Canadian Coast Guard's *Standard for ECDIS and DGPS.*

3.4.2 Problems or opportunities?

In 2005, Williams and Klepsvik estimated that the number of Electronic Chart Systems (ECS) on the market had reached the 4500 mark. They also note that:

> *… it is one thing to have such a document available, it is quite another to ensure that those who will benefit from it are aware of its existence and can easily access it. [Williams and Klepsvik, 2005]*

While the availability of ECSs is on the rise, there is still confusion about which of these charts and display information systems can be considered as a legal replacement of paper nautical charts. Official ENCs are supplied by national hydrographic offices and are compliant with the international standards of IMO and IHO and national regulations as discussed in Section 3.4.1.4.

It is estimated that a high percentage of ECSs in use do not meet those standards [see e.g., Pereira, 2002; Ward, 2003; Alexander, 2004; Williams and Klepsvik, 2005; Hecht, 2004], thus do not legally qualify as navigational aids. Yet, in many instances electronic (raster or vector) charts meeting official standards are available for the desired coverage area. According to Alexander [2004], problems associated with the incorrect use of ENCs and ECDIS fall into the following categories and in most cases are listed under the national governments' responsibilities:

- hydrographic surveys: e.g., due to the increased expectations associated with digital charting, some areas that were previously considered charted may need to be resurveyed;
- database management;
- production of data; and
- distribution services.

Table 3.3 applies an information management approach to categorize the problems identified by the following authors: Pereira [2002], Ward [2003], Alexander, [2004], Williams and Klepsvik [2005], and Hecht [2004].

Table 3.3: Information Management Challenges of ENCs and ECDIS

Problems	Information Requirements	Technological Requirements	Institutional Arrangements	Legal Arrangements	International Cooperation
lack of official ENC production by HOs	X	X	X		
mariners using unofficial ECS	X		X	X	
lack of worldwide coverage for official ENCs	X	X	X		X
reluctance to invest in dual system charts covering previously uncharted areas	X		X		
lack of understanding of regulations relevant to ECDIS and ENCs			X	X	
questioning the commitments of national HOs, the IHO and IMO			X		X
lack of suitable ECDIS training			X		
meeting customer requirements is a low priority for HOs, the IMO and IHO			X		X
possible multi-use of the data is not addressed	X		X		X
disregarding the already existing ECSs	X		X		
potential users are unaware of existing ENCs			X		
no “one-stop-shop” for integrated services			X		
wider availability of supplementary data for unofficial ECDIS	X	X	X	X	
charts are produced without attention to seamless and uniform display		X	X		

3.5 Linking Ocean and Coastal Sciences and Management with Geomatics

The Canadian Geographic Information System (CGIS), operational in 1964, introduced a new approach to cartography. Computer-based Geographic Information Systems (GIS), available commercially and operating on widely-used platforms, emerged in the mid 1980s. GIS is able to capture, store, edit, maintain, disseminate, display, and provide access to georeferenced information [Kralidis, 2005]. GIS reached beyond the fields of software and hardware engineering by bringing together participants from governmental and non-governmental sectors to agree upon a set of standards, and evolved as an integrating element among disciplines formerly functioning with little or no cooperation. Applications for GIS are diverse and traditionally terrestrial, as geography is frequently associated with land.

3.5.1 Decision supporting tools in the three- and four-dimensional environment

Lucas [1999] points out that *"no single data source provides a complete view of the nature of ocean phenomena."* Early applications of GIS in the coastal environment involved studying coastal environmental problems (such as erosion, pollution, degradation) by combining multidisciplinary (hydrographic and satellite) datasets and environmental models [Bartlett, 1999; Hock, 1986]. The growing number of georeferenced ocean and coastal datasets was a compelling force for inviting the GIS community to develop tools that are designed specifically to accommodate the unique characteristics of ocean and coastal data [Andrews, 2006].

Land-based GIS is capable of supporting decision-making in the relatively static, two-dimensional environment. In contrast, ocean and coastal features have the following distinctive characteristics:

- oceans and coasts are a dynamic, three-dimensional environment (vessels, fish, currents, pollution, tides move, salinity and temperature changes with ocean depth) where time series data are also of great importance;
- the sample distribution of attributes is often "abnormal" because data is not evenly distributed among the three-dimensions [Gold et al., 2004].

Extending GIS technologies toward the three- or four dimensional, fluid ocean environment with fuzzy boundaries faced a host of obstacles. As Gold et al. [2004] points out, "*an attempt to simulate the sea requires a major overhaul of the appropriate algorithms and data structures*" [Gold et al., 2004; Wright, 1999; Nichols and Monahan, 1999]. Examples of datasets used by marine GIS include but are not limited to ocean terrain, contour and slope variation, wind speed, ice conditions, ocean currents, offshore boundaries, fisheries distributions. Hatcher and Maher [1999] refer to GIS as a highly valued technology to oceanographers:

> *Although the GIS display is an abstraction of reality it can provide much more information to the oceanographer about their surroundings than a look out of a ship's porthole across the featureless sea. [Hatcher and Maher, 1999]*

Challenges of data and information management in the ocean and coastal environment are confronted by abundance, i.e.:

- the abundance of ocean science disciplines (including but not exclusive to marine geology, geophysics, chemistry, fluid mechanics, biology);
- the abundance of observational data and results. Data output for oceanographic projects are often measured by gigabytes or even in terabytes.

GIS responds to these challenges with its capabilities to [Bartett, 1999; Shyka et al., 2006]:

- efficiently store, manipulate and provide access to geospatially referenced data and information;
- use spatial variables to relate information from different disciplines and different sources;
- handle large databases and synthesize data from a wide range of criteria. Therefore it is able to collect, analyze, and display data and information for coastlines, regardless of the length of the area;
- promote agreements on standards and definitions, which in turn endorse compatible methods for data processing and uniformity over time;
- work with shared databases across horizontal and vertical aspects of decision making.

An example of marine GIS is illustrated in Figure 3.6. This map features the water temperatures along the U.S. Atlantic coast and is also available with time laps animation. Along with water temperature information, there are ten additional parameters (including air temperature, wind speed, wind direction, etc.) is being supplied by NOAA data buoys and freely available to users. The maps are updated hourly and are intended for use by the public to identify conditions along the coasts.

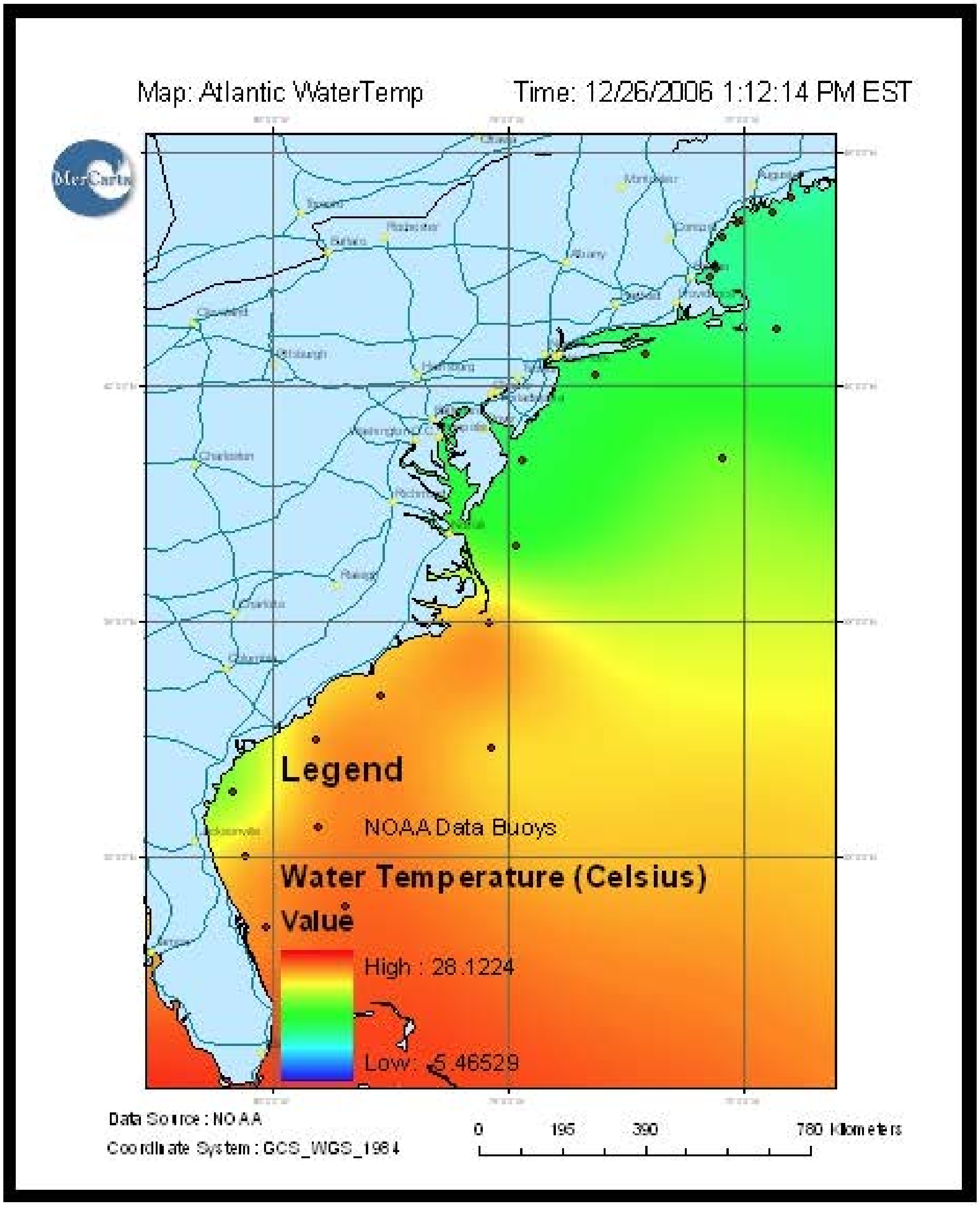


Figure 3.6: Water Temperature Map of the Eastern Seaboard of the US
(from http://www.mercarta.com/index.php)

3.5.2 Collection and management of data in the ocean and coastal area

Accurate seafloor maps are valuable resources for fish habitat protection, delineation of marine reserves and monitoring changes in the ocean and coastal environment [Barnhardt et al., 2006]. Ocean mapping technologies are being utilized to collect process and visualize information of the characteristics of seafloor as well as the water column [Ocean Mapping Group (OMG), 1999, Monahan, 2004]. Initially, driven by the requirements of safe navigation, the focus of ocean mapping was on seafloor bathymetry [OMG, 1999, Monahan, 2007]. However, incorporating developments in positioning, remote sensing, database management, and other evolving technologies (e.g., ship-based multibeam bathymetry, sidescan sonar, photographic and video imagery, multichannel seismics [Wright et al., 2003]), the objective of ocean mapping became to realize *"ocean transparency"* [OMG, 1999]. Ocean mapping is also considered to have a potential to serve as a spatial information management tool that considers all marine features, processes and properties in four dimensions and to function as an infrastructure for ocean data and activities [OMG, 1999].

The areas of application for ocean mapping products and services are growing [NOAA, 2006; OMG, 1999]:

- surveying and mapping living marine resources, fish habitats, coral communities, hydrothermal vents, gas seeps, and underwater archaeology sites;
- marine transportation;
- coastal zone management;
- sovereignty and security; and

- offshore mineral exploration and exploitation.

Conducting these surveys and processing the collected datasets, however, require considerable investments in human and technological resources. Consequently, the value of yielded information is high not only in terms of potential environmental benefits but also in economical terms. As suggested by the OMG [1999] and NOAA [2006] the technology would benefit from a *"sound national ocean mapping policy direction"* [OMG, 1999] in order to maintain the long term capabilities, and increase the economic contribution of the technology. A statement from NOAA [2006] underscores the previous notion by saying that:

> *(hydrographic) surveys are often conducted as separate efforts, making it difficult to obtain, organize, and process the data collected in order to better understand how areas function as an ecosystem. Comprehensive coordinated mapping activities will better characterize the marine environments… [NOAA, 2006]*

Table 3.4 summarizes some of the obstacles for effective information management in marine GIS and ocean mapping [Gold et al., 2004; NOAA, 2006; Bartlett, 1999].

Table 3.4: Information Management Challenges of
Marine GIS and Ocean Mapping

Problems	Information Requirements	Technological Requirements	Institutional Arrangements	Legal Arrangements	International Cooperation
delimitation of marine boundaries	X		X	X	X
three- or four dimensional environment	X	X			
features represented by points and not lines and polygons	X	X			
abnormal sample distribution	X	X			
variety of disciplines in data collection	X	X	X		
large data files	X	X			
data collection is expensive	X				
expensive instrumentation	X	X			
uncoordinated data collection	X		X	X	X
fragmented, sporadic data sets	X	X	X	X	X
lack of coordinated mapping efforts	X		X	X	X

3. 6 The Coastal Zone: Diverse Resources, Interests, and Policies

… multiple use of coastal space, the implications of coastal processes on human society, and the fragility of the marine environment and its coastal fringe, all requires that rational, integrated and sustainable management strategies be developed. [Bartlett, 1999]

In the above quotation Bartlett's [1999] intention was to underscore the utilization of GIS in coastal management. His summary, however, is just as applicable for coastal management in general. The coastal environment is easily accessible and is abundant in living and non-living resources that form the base for a wide range of human activities.

These activities, along with naturally occurring processes (an example is shown in

Figure 3.7) have endangered the integrity of the coastal systems and its resources to the point when *"harvesting the coastal riches"* [Lakshminarayana, 1988] is no longer possible without compromising the sustainability of natural resources and traditional activities (e.g., settlement, agriculture, trade, fishing and defence) [Lakshminarayana, 1988; van der Weide, 1993]. Figure 3.8 illustrates the complexity of the socio-economic and ecological framework as it applies to the coastal zone.

Figure 3.7: Coastal flooding, January 2004
[Photo: A. Hanson, Environment Canada]

Figure 3.9 depicts the relationship among the socio-economic and ecological framework, natural processes, human activities and sciences in contributing towards the increasing number of challenges in the coastal area. In order to better understand and address these challenges and the interactions among the processes, the relevant information resources also need to be effectively managed.

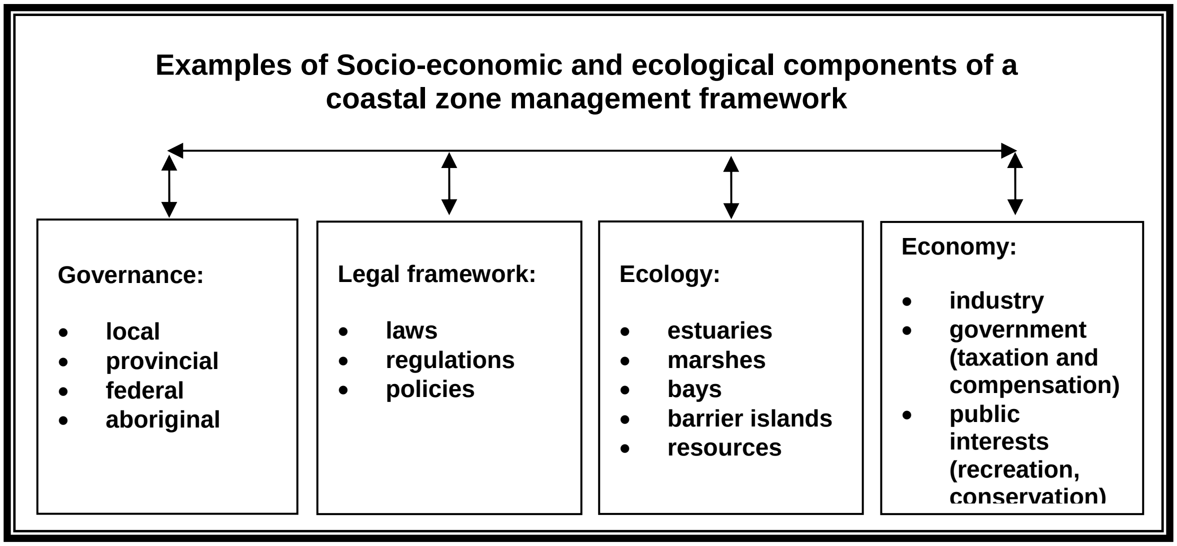


Figure 3.8: Socio-economic and ecological components of the coastal zone management framework

A detailed discussion of coastal zone management (CZM) and integrated coastal zone management (ICZM) is beyond the scope of this research. However, the main concerns related to information management and technological requirements, institutional and legal arrangements, as well as international cooperation will be reflected upon (Table 3.5).

3.6.1 Potentials of ICZM

A body of literature supports the concept that the 1992 *Rio Declaration* by the UN Conference on Environment and Development (UNCED) [1992] formed the theoretical basis of ICZM [see for example, Cicin-Sain, 1993; Vallega, 1993; Sorensen, 1993; van der Weide, 1993; El-Sabh et al., 1998]. The *Rio Declaration* [UNCED, 1992] recognized that coastal problems and programs are comprehensive and it is necessary to employ *"tools and decisions that factor in the many needs of coastal constituencies in light of the* *local environment, economy and culture”* [Hershman et al., 1999]. Cicin-Sian and Knecht [1999] define ICM as a:

> *… continuous and dynamic process by which decisions are taken for the sustainable use, development, and protection of coastal and marine areas and resources. [It is] multi-purpose oriented, promotes linkages … among sectoral coastal … activities. [Cicin-Sian and Knecht, 1999]*

Hildebrand [2002] gives a different definition and also an opinion for ICM based on experience:

> *… [ICM] is a very long and tiring swim against a continuous current of political and socio-economic interests with short-term visions strongly tending to protect the status quo. [Hildebrand, 2002]*

It is important to note, however, that the notion and the term of ICZM have been applied to coastal management prior to 1992. See, for example, the work of Lakshminarayana [1988], drawing an ICZM framework in the article published in 1988, or Hildebrand, [2002] who puts the mid 1960s as the beginning of national ICZM programs. Hildebrand also points out the example of the State of Hawaii, where, for centuries, environmental management practices were equivalent of ICZM. In 1975, the U.S. Environmental Protection Agency identified the need for an “*integrated approach*” for land use in coastal areas [Johnston and Pross, 1975]. In Canada, the participants of the Canadian Shore Management Symposium in 1978 adopted the “Victoria Principles” [Ricketts et al., 2004] calling for integrated management in the coastal areas and acknowledging the importance of:

- adopting co-operative approach to management;
- coordinating policies and programs across all government levels and departments;
- recognizing the interrelatedness of all coastal activities;

- the role of information systems to support decision-making; and
- public access to coastal areas and information on coastal resources and activities;
- public awareness of increasing coastal problems.

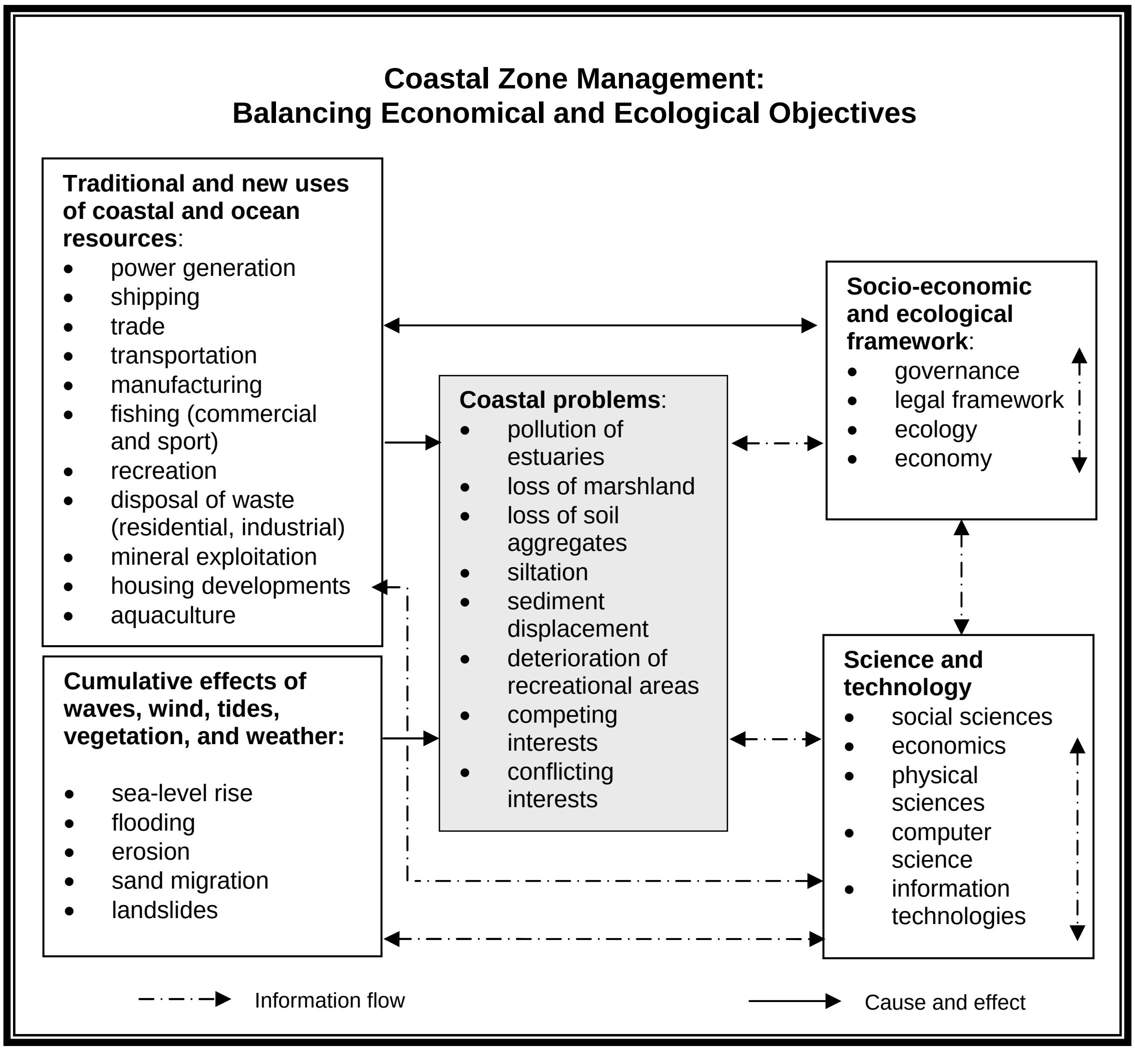


Figure 3.9: Integrated management: Balancing the economy and ecology

The implications of determining the timeframe for the establishment of ICZM concept are twofold. First, ICZM efforts undertaken after 1992, in the spirit of the *Rio Declaration* [UNCED, 1992], were likely to overlook the outcomes, and fail to build upon the lessons learned and information gathered by preceding integrated coastal management efforts. Secondly, after nearly 30 years since the articulation of the "Victoria Principles," progress reports (such as reported by Crosby et al., 2000 or Millar et al., 2004) on how to put these principles into action are still sporadic and implementation processes are not well understood and practiced. A review of integrated coastal management programs should consider the efforts undertaken prior to the *Rio Declaration* [UNCED, 1992].

3.6.2 Measuring the effectiveness of ICZM programs

The coastal zone is under provincial jurisdiction and following the legislative and policy framework set at the federal level, provinces are responsible for executing programs designed to a specific coastal area or problem. Local governments are usually the principle implementers of the programs. For the management of Marine Protected Areas federal and provincial governments are in the process of developing special administrative arrangements.

Within this three-tiered system there are a number of programs involving coastal resources and activities that exist in various stages of implementation, often relying on program-specific methods for collecting and managing information. (The actual number and nature of these projects is not known due to the diversity of overseeing institutions.

The Atlantic Coastal Action Program[9] (ACAP) alone lists 14 programs in the four Atlantic Provinces for 2006-2007.)

Without initially set standards, measurable objectives for outcomes, and an inventory of coastal programs, it is difficult to measure the success of these programs, as well as the individual and cumulative impacts these programs make on the overall regional coastal management objectives. It also makes comparisons between proposed programs and possible alternatives a challenging exercise, making it difficult to comply with Hildebrand's [2002] suggestion that *"[l]essons learned must be lessons shared."*

Hershman et al. [1999] notes that lacking formal requirements and procedures for documenting decision making and secondary outcomes allow coastal managers to forgo documentation of detailed processes. Once a decision is made, managers move to the next decision to be made with little attention to other applications for the knowledge already collected. Hershman et al. [1999] finds that this sparse documentation is often combined with a large number of agencies involved in the programs. Many of these collect information in different formats and allocate differing amounts of funds for data collection and handling, often resulting in varying degrees of accuracy. Collection of information in a systematical, standardized format about the conditions of the resources in the coastal zone would allow spatial and temporal comparisons without additional major investments in data collection.

Being able to combine information from coastal management programs would increase the understanding of the cumulative effects of climate, weather, pollution and other environmental and social stresses. As it is mentioned in Chapter 2, it is not the application of the term ICZM that makes a coastal management program integrated, but

[9] http://atlantic-web1.ns.ec.gc.ca/community/acap/default.asp?lang=en&n=A2828E7D

rather the coordination of its elements, including but not limited to the objectives, information management requirements, institutional arrangements, the underlying legal framework, and international agreements.

Table 3.5: Information Management Challenges of ICZM

Problems	Information Requirements	Technological Requirements	Institutional Arrangements	Legal Arrangements	International Cooperation
inconsistency of ICM efforts	X		X	X	X
lack of cooperation on the regional, national, intl. level	X		X	X	X
no measurement framework for outcomes	X	X	X		
putting socio-economic values on ecology			X		
lack of adequate models to analyze alternatives	X	X	X		X
lack of sufficient information to analyze alternatives	X	X	X		
lack of independent analysis	X	X	X		X
lack of shared objectives	X		X	X	X
short term costs are high for a few - benefits takes long for many	X	X	X	X	
lack of decentralization to resource users	X		X	X	
division (interests, economy, etc) of coastal population			X	X	X
determining the boundaries of the coastal program	X		X	X	
lack of sharing of lessons & information	X	X		X	
high percentage of unsuccessful or uncompleted programs			X		
slow or no incorporation of information from other programs	X	X	X	X	X
no easily searchable information base	X	X			X
integration of TEK with conventional science	X	X	X		
science and technology in support of CZM	X	X			

3.7 Summary and Conclusions

To summarize the contribution of this chapter toward the design of an ocean and coastal information management strategy, a potentially hazardous event that recently (December 24, 2006) took place in the U.S. Gulf of Mexico will be introduced. As shown in Figure 3.1, 7823 blocks are leased out of the 29 087 total blocks (26%) in the region by the MMS for hydrocarbon exploration and exploitation [MMS, 2006].

On December 24, 2006, *"a portion of the High Island Pipeline System ruptured"* when allegedly, *"a ship trying to moor in the area, where the water is about 90 feet deep, might have dropped its anchor on the pipeline"* reports Porretto [2006]. The following will briefly discuss how the information management technologies and concepts presented in this chapter could have approached the situation to prevent or respond to such an accident.

Marine Cadastre:

Cadastral maps depict the geographic and legal extent of some of the activities occurring in this region. It is not known however, if the location of the pipeline in question was included in the area leasing map. Ng'ang'a [2006] advocates the inclusion of cable and pipeline locational and attribute information in a marine cadastre.

ECDIS:

A data layer in the electronic chart database is intended to display legal maritime boundaries. The presence of hydrocarbon activity often signals the presence of pipelines.

Spatial information in 3-D regarding the location and property interests in hydrocarbon pipelines is invaluable not only for the pipeline owners, the commercial shipping industry but also for federal authorities, such as the Coast Guard. An ECDIS is able to facilitate the timely and accurate visualization of navigational hazards, such as oil rigs and pipelines, in relation to the vessel's position.

Ocean Mapping and Marine GIS:

Ocean mapping and marine GIS technologies enable property interests (as they relate to hydrocarbon leases and pipelines in this problem), to be visualized, and incorporated into a data layer in ECDIS. Combining real-time positioning and spatial information management technologies allow mariners' to know their position in relation to the surrounding man-made and natural hazards in real-time [Barron, 2006].

ICZM:

This incident took place 17 nautical miles into federally administered ocean space. Ocean currents moved the 44,500 gallons leaked oil away from land. Various oceanographic and marine GIS tools were used to assist federal, state, and local agencies monitoring the situation and prepare for contingencies.

Standing alone, none of the above technologies or concepts would have been able to prevent or effectively respond to the oil leak cited. These and other technologies and concepts, together with a strategy to manage the information resources, are needed to effectively address complex ocean and coastal problems.

These technologies and concepts have demonstrated capabilities for information sharing. However, without an information management strategy, this information sharing capacity is largely underutilized. The following chapter will investigate a cluster of initiatives that are aimed at communicating and integrating the data and information produced by, including but not limited to, marine cadastre, digital navigational systems, ocean mapping, marine GIS and ICZM.

CHAPTER 4
EMERGING OCEAN AND COASTAL SPATIAL DATA INFRASTRUCTURE INITIATIVES

> *The challenge is to look for additional ways we can cooperate and innovate in order to enhance our capabilities to address ocean and coastal issues that are critical to sustainable development. [West, 2001]*

4.1 Introduction

Chapter 2 discussed some of the recent policy developments at the national and international levels (e.g., Canada's Oceans Strategy, UNCLOS). These developments highlighted the need for

> *balance amongst goals such as economic competitiveness, environmental protection and coastal community sustainability, as well as all the elements of good governance that allow these to happen. [OSTP, 2006]*

Undoubtedly, setting priorities and managing ocean and coastal resources and activities are primary examples of shared responsibilities between the various levels of governments, the private sector and other non-governmental entities [Dawes et al., 1999; Anderson, 1989]. Chapter 3 argued that geomatics technologies and concepts are not only capable of supporting ocean and coastal activities with data and information collection, but are also tools for the management of these information resources.

In order to utilize this management capability, a number of regional and sectoral geospatial information management initiatives have been established. This research has found that a national level information management strategy would greatly benefit from accessing the knowledge base and social capital developed by these initiatives (further discussed in Chapter 6).

The objective of this chapter is to introduce some of the key initiatives and gain an understanding on how the outcomes of these initiatives would be able to further the formulation of an overall information management strategy for the ocean and coastal stakeholder community. Figure 4.1 presents the framework that supports the analysis of the initiatives reviewed in Chapter 4.

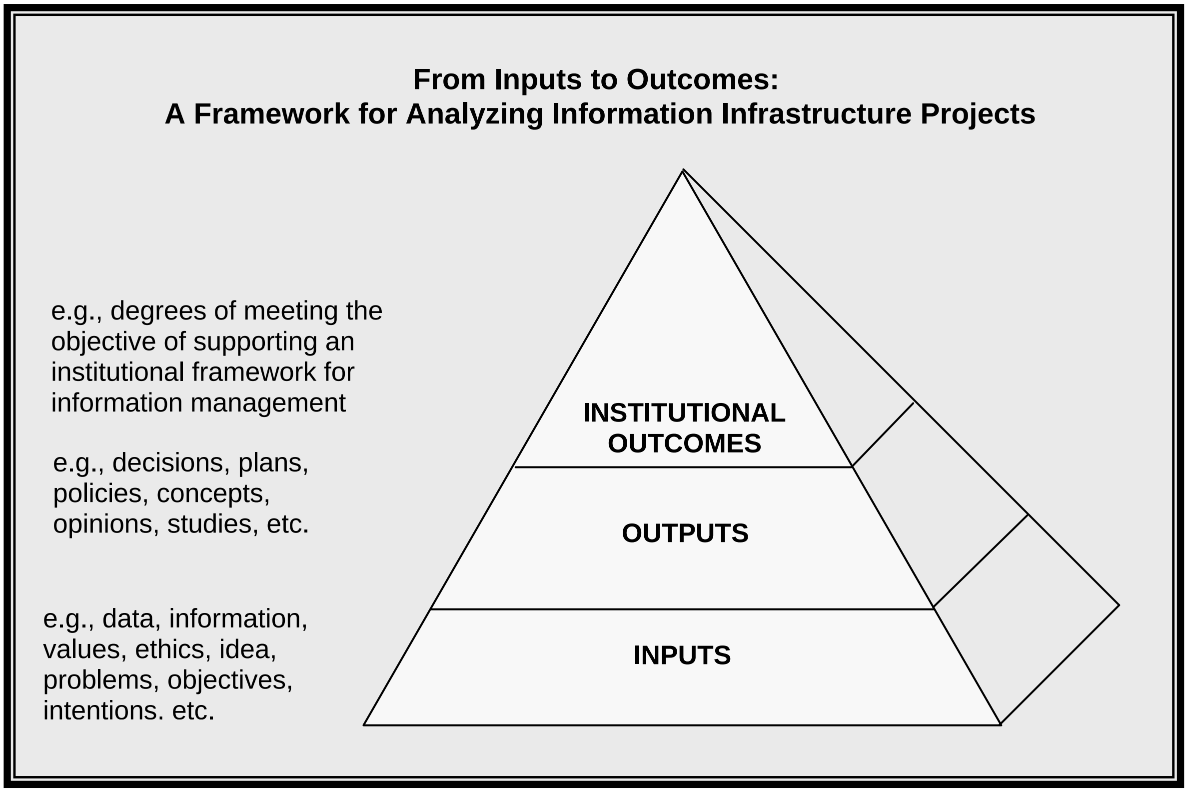


Figure 4.1: From inputs to outcomes: A framework for project analysis
[after Patterson, 1996]

4.2 A Network for Coastal and Ocean Information Management

Anderson [1989] identified a number of challenges facing the horizontal and vertical integration of ocean and coastal information. Table 4.1 is built on those observations and it also gives consideration to the character of the issues listed.

Addressing the problems featured in Table 4.1, Anderson [1989] proposed an information infrastructure referred to as the Inland Waters, Coastal and Ocean Information Network (ICOIN). Anderson [1989] argued that establishing ICOIN would benefit decision-making by ensuring the availability of required information *"in the right format, in the right place at the right time"* [Anderson, 1989].

4.2.1 The ICOIN Concept

Aided by GIS, ocean mapping and digital charting technologies, there was a notable shift regarding the collection and analysis of offshore data in the late 1980s. Realizing that offshore datasets managed by the Canadian Hydrographic Service for the purpose of producing nautical charts are potentially valuable resources for other applications, Anderson [1989] outlined a framework that facilitated sharing of spatial ocean and coastal information between different levels of government, the private sector and academia (Figure 4.2). The ICOIN directory, positioned at the centre of the linkages, would facilitate integration and access to the spatially referenced information system. Maintaining, updating and controlling these data bases would be the responsibility of the institutions owning the data bases. The following quote highlights the basic premise of Anderson's [1989] argument for improved and more efficient information management:

> *Data is seldom collected, processed or managed with a view to use by other programs, departments, or by non-governmental users and is often unable to meet the demands of new priorities or issues. [Anderson, 1989]*

Although the infrastructure functions of ICOIN are not fully elaborated, Anderson [1989] captures the preliminary relations between ICOIN and the products and activities it is intended to support as shown in Figure 4.2.

Table 4.1: Information Management Issues for ICOIN [after Anderson, 1989]

Issues/Responses	Information Requirements	Technological Requirements	Institutional Arrangements	Legal Arrangements	International Cooperation
integration of disparate databases based on the common framework of location	X		X	X	
conflicting economic activities	X		X	X	
governance: federal/provincial/local	X		X	X	
international agreements	X			X	X
dispersed databases (institutionally, regionally, sectorally)	X	X	X		
discipline specific databases	X		X		
databases not conforming to standards	X	X			
incomplete databases	X	X	X	X	
databases of uncertain quality	X	X	X	X	
databases unavailable and/or unusable by non-proprietary agencies	X		X	X	
survey and mapping departments are mandated to collect data in support of their specific disciplines or programs only	X		X	X	
available data is often inadequate for environmentally and economically sound decision-making	X	X	X		X
increasing importance of multidisciplinary environmental projects	X		X		X
need to integrate environmental, resource and economic information			X	X	X

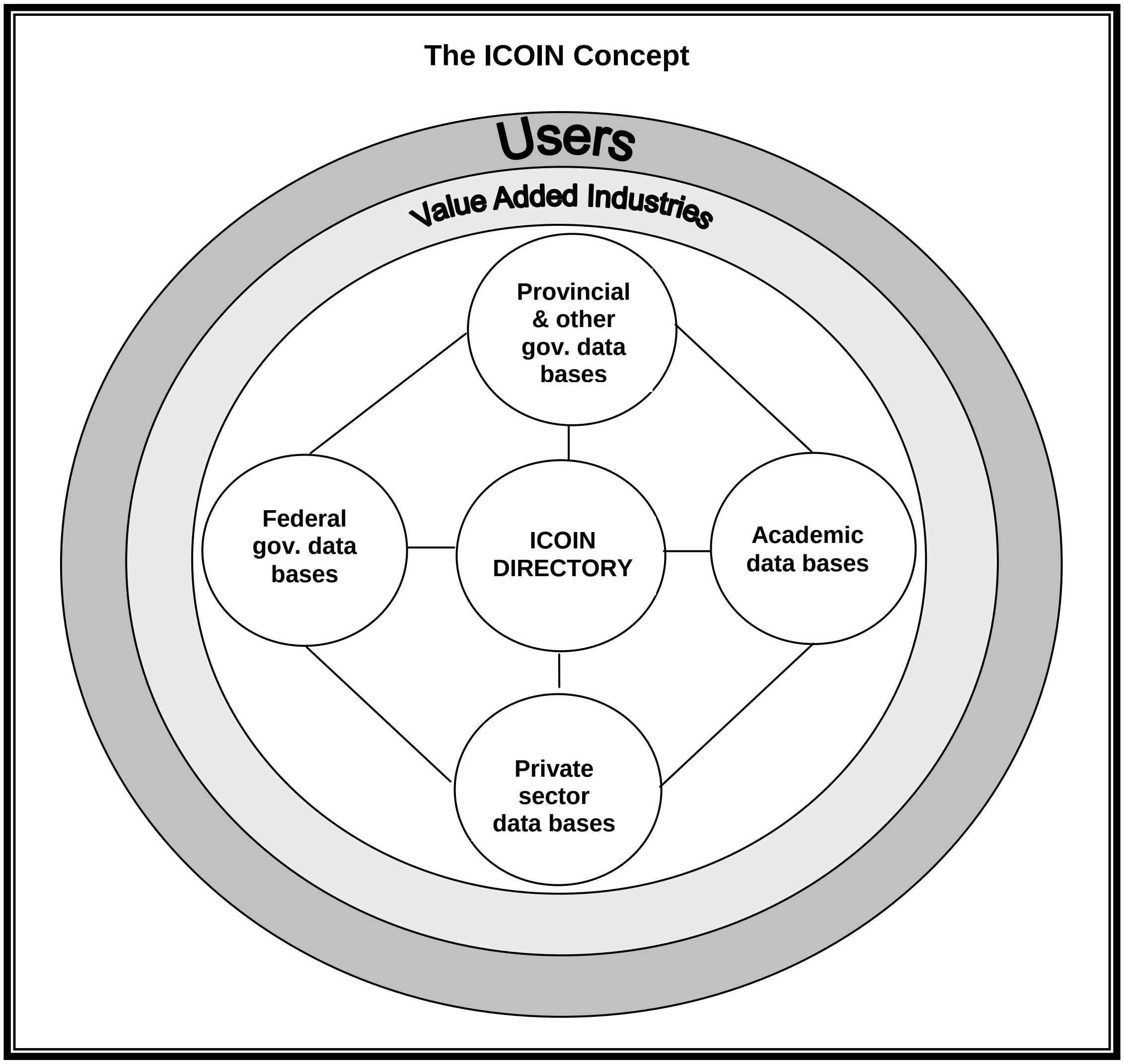


Figure 4.2: The ICOIN Concept [from Anderson, 1989]

Figure 4.3 is built upon Anderson's [1989] illustration of geomatics and ICOIN. The focus of Figure 4.3 is on ICOIN's capability to provide an organizational framework for spatially referenced but disparately located data bases while supporting a host of activities relying on access to these data bases. The arrows added to the figure represent the communication and information flows characteristic to information networks.

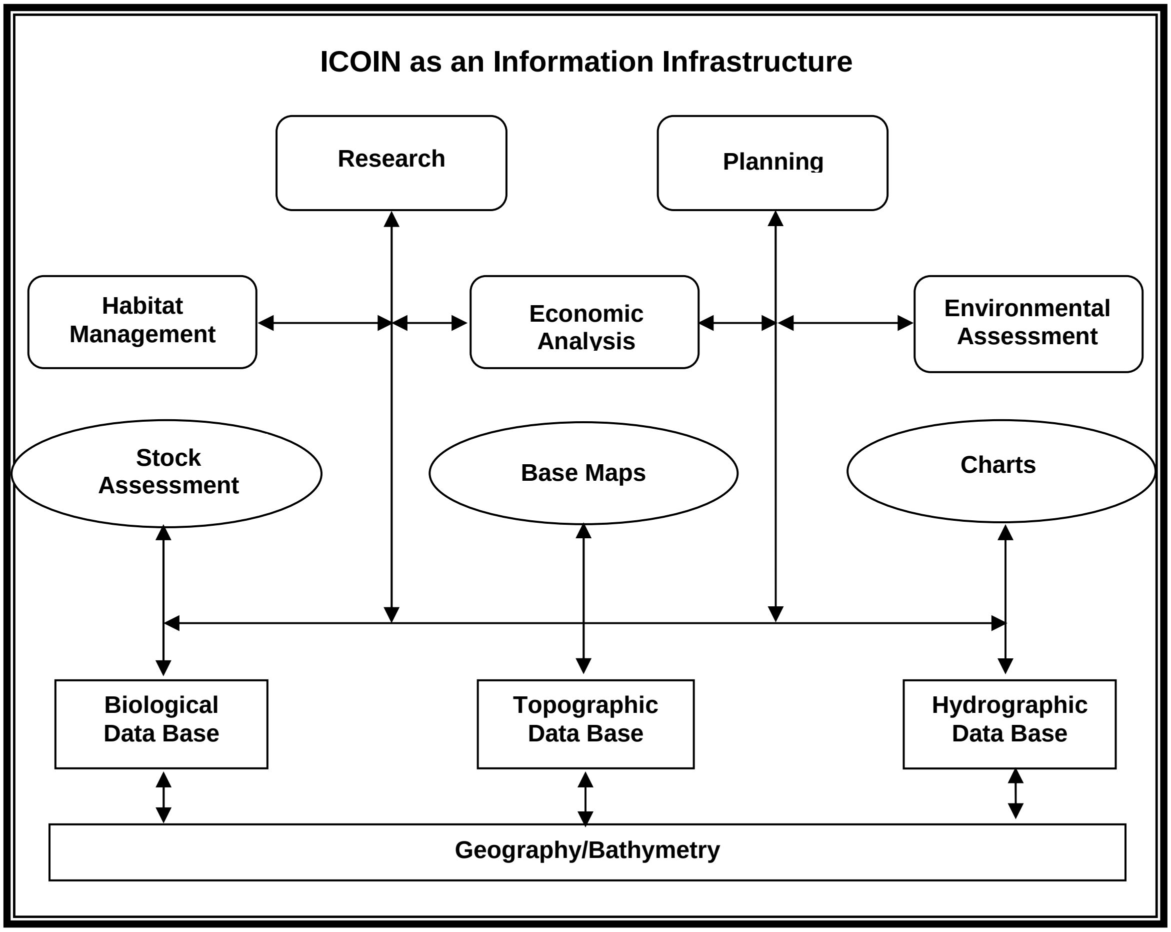


Figure 4.3: ICOIN as an information network [after Anderson, 1989]

4.2.2 Conclusions of the ICOIN concept

The barriers to the successful implementation of ICOIN were frequently acknowledged during the design stage. In addition to the technical challenges of establishing an information network, ICOIN's advancement also depended upon the *"collective understanding and will of the principal players to find ways to cooperate within the available programs"* [Anderson, 1989]. Canessa et al. [2007] note that the lack of progress regarding ICOIN was *"owing to management and personnel challenges rather than technical problems."* As a result, the effort put into the design of ICOIN was not followed by implementing its principles, and the ICOIN Program Office at DFO was closed in 1995 [Canessa et al., 2007]. The concept of ICOIN, however, regained legitimacy a decade later as part of a national effort to build the Canadian Geospatial Data Infrastructure. The results of the project analysis as proposed in Figure 4.1 are illustrated in Table 4.2.

Table 4.2: From Inputs to Outcomes: Analysis of the ICOIN Concept

Inputs	Ocean and coastal information management issues: Table 4.1 CHS data and information holdings
Outputs	Concept of ICOIN as an information infrastructure: Figure 4.3 Identifying barriers: institutional and not technical Establishment of the ICOIN directory: Figure 4.2
Institutional Outcomes	A national level information infrastructure was not established The ICOIN concept serves as a foundation for future information management efforts

4.2.3 The Marine Information Management System

The concept of ICOIN was further studied by Ford [1990]. Ford [1990] highlights the overlaps of information requirements between the various ocean stakeholders. By addressing technological, organizational, and operational requirements for improved management of information resources, Ford [1990] proposes the establishment of a marine information infrastructure. Figure 4.4 illustrates the technology and process components as identified by Ford [1990].

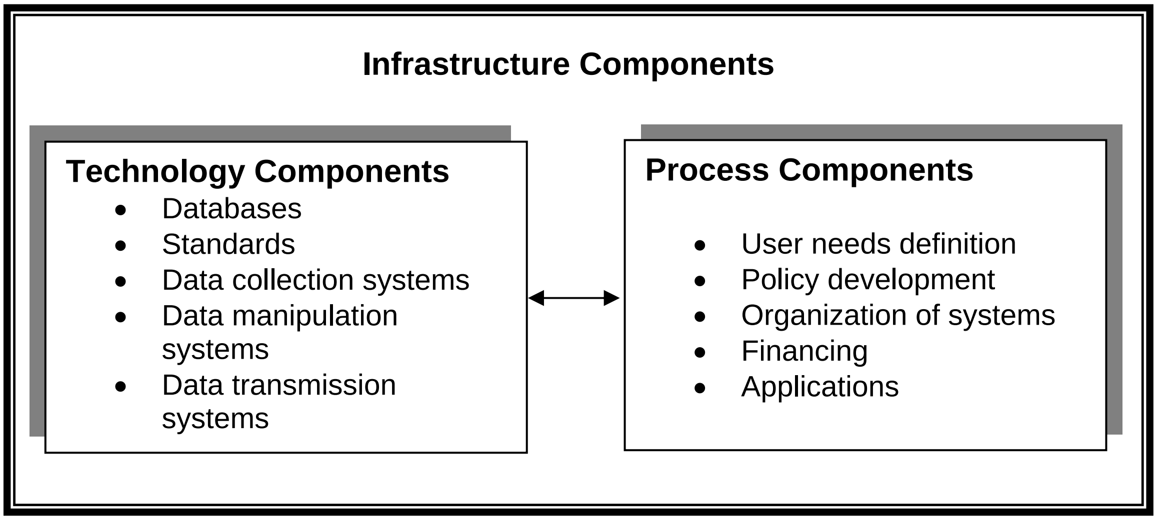


Figure 4.4: Infrastructure components [after Ford, 1990]

4.3 The Marine Node of CGDI

4.3.1 The Canadian Geospatial Data Infrastructure

The GeoConnections secretariat was established under the leadership of Natural Resources Canada (NRCan), and was charged with a mandate to coordinate the efforts of building a national spatial data infrastructure. The resulting Canadian Geospatial Data Infrastructure (CGDI) received federal financial support in 1999, permitting the implementation of its first 5 year program. The vision of CGDI is analogous to the vision articulated by ICOIN (stated in Section 4.2.1). The CGDI's objective is to *"enable access to the authoritative and comprehensive sources of Canadian geospatial information to support decision-making"* [GeoConnections, 2005].

Among the top priorities of the CGDI are:

- facilitating decision-making and policy development;

- promoting partnership and information sharing across all levels of federal and provincial governments and the non-government sector;
- advance the development of geospatial standards and specifications;
- ensuring continuous and sustainable operation of the infrastructure.

To guide the development of the CGDI, twelve advisory committees were established. These advisory committees, also called nodes, were "*formed at the appropriate stages in the development of the CGDI and their level of activity fluctuates as required*" [GeoConnections, 2001]. The Marine Node of CGDI, under the co-leadership of DFO and the Canadian Centre for Marine Communications (CCMC), began its work in 1999, with a program designed to *"ensure that the full functionality of the …CGDI being implemented under GeoConnections extends to, and serves the interests of, all marine stakeholders"* [GeoConnections, 2001].

4.3.2 The MGDI concept

It has been long recognised that marine information should be accessible in an organized manner to stakeholders within governments and among governmental and non-governmental organizations (see Section 4.2) [Gregory, n.d.; Gillespi et al., 2000]. These efforts are not unique to Canada, as for example there are efforts underway in Australia, in the U.S. and in the United Kingdom to assess feasibility and benefits of an information infrastructure supporting ocean and coastal environment, resources and activities [UKHO, 2003; Bartlett et al., 2004]. In the United Kingdom, for example, Pepper [2003] noted that disparate, incomplete, inconsistent marine data accompanied by uncoordinated, ad hoc data collection, processing and dissemination failed to meet the expectations of governmental and industry users.

In Canada, along with the efforts of building the CGDI, representatives of the marine stakeholder community proposed a distinct, yet connected infrastructure within the CGDI for serving the needs of the ocean and coastal stakeholders. Longhorn [2006] highlights the uniqueness of coastal and marine SDI, suggesting that:

- the political, ecological and economical environment of ocean and coastal activities are multi-disciplinary, multi-jurisdictional, multi-dimensional;
- the early geospatial data standards were too topographic, thus were not easily adaptable for the ocean and coastal environment;
- the ocean and coastal environment is not just four dimensional but these dimensions are also dynamic;
- the interconnectedness of land, air and sea environments represents problems unique to the ocean and coastal areas;
- the coast should be considered as a “complex information territory” as opposed to merely a place.

In response, as the ICOIN concept was updated and positioned within the CGDI framework, the Marine Node specified the objectives of the Marine Geospatial Data Infrastructure (MGDI) as [CCMC, 1999]:

- the establishment of a common marine information infrastructure, primarily for use by the offshore oil and gas community on Grand Banks;
- the promotion of Canadian ocean technology and expertise;

- the global delivery of Canadian integrated geospatial applications and services.

These MGDI objectives primarily focus on the Atlantic coast. They also endorse the advancement of the ocean technology sector in general, as opposed to building a marine geospatial data infrastructure. In fact, these objectives mirror the objectives of the CCMC [CCMC, n.d.; Poulin and Gillespie, 2002].

The infrastructure proposed in 2000 lifted its focus from the offshore oil and gas industry and the ocean technology sector to include a wider selection of stakeholders, including [Anderson, 2000]:

- marine transportation;
- habitat management;
- integrated coast and oceans management;
- renewable resources and biodiversity;
- non-renewable resources;
- emergency response;
- defense and sovereignty;
- climate change and ocean monitoring;
- recreation and tourism;
- engineering works and services.

Anderson [2000] also identified the following elements as part of the proposed infrastructure:

- user needs;

- framework data and information;
- data collection technologies;
- data management technologies;
- decision support;
- information access technologies;
- policy;
- standards;
- capacity building;
- information utility.

4.3.3 Progress of the MGDI

At the time of conducting this research, the GeoConnections website indicated that the last meeting of this Node was held in October, 2002 [GeoConnections, 2002]. Longhorn [2006] also remarks that MGDI is not referenced in the Technical Developers' Guide published by the GeoConnections Secretariat in 2004 [GeoConnections, 2004]. The same document, however, lists nautical charts and marine inventories under geospatial databases being part of the CGDI [GeoConnections, 2004]. Following the recent reorganization of GeoConnections, ocean and coastal issues are theoretically considered under the Environment and Sustainable Development User Community heading [GeoConnections, 2007]. This User Community, however, did not embrace the concept of the MGDI. To date only the Public Safety and Security User Community made a reference to matters concerning ocean spatial information (e.g., an ice jam off the coast of Newfoundland). Table 4.3 reports the findings of the project analysis.

Table 4.3: From Inputs to Outcomes: Analysis of the MGDI Concept

Inputs	Problem: CGDI is limited in serving the needs of ocean and coastal stakeholders Ocean Technology Sector involvement
Outputs	Marine Node of CGDI Concepts for an MGDI (1999 and 2000) Study: Marine User Requirements for Geospatial Data [DFO, 2001] Identifying the elements of the MGDI infrastructure Identifying barriers: institutional and not technical Funding for regional and sectoral initiatives
Institutional Outcomes	A national level information infrastructure was not established

Although the activity level of the Marine Node significantly decreased after 2002, the organizations co-leading this advisory committee (DFO and CCMC) have been actively pursuing other spatial information management coordination initiatives, including, but not limited to the Oceans Management Internet Mapping Application (OMIMA), a pilot project within DFO's Ottawa Headquarters [Wojnarowska and Ady, 2002] or the Information Seaway™ program lead by the CCMC in Newfoundland [CCMC, 2006].

While the lack of publicized progress is notable in regards to the Marine Node's operation, the number of sectoral and regional initiatives aimed at improving the management of ocean and coastal spatial information has greatly increased in recent years. As a representation of the efforts underway, the following sections will provide a brief summary of four regional/sectoral initiatives.

4.4 Organization of Collaboration: Sectoral and Regional Initiatives

Ricketts and Harrison [2007], ACZISC [2004, 2005, 2007] and Canessa et al. [2007] provide detailed accounts of the increasing number of sectoral and regional initiatives accommodating industrial, local, and international interests. Canessa et al. [2007] assembled a list of key marine information infrastructure initiatives supporting Integrated Coastal and Ocean Management. The authors identified 32 initiatives taking place between 1975 and 2006, ranging from coastal resource atlases (e.g., Great Lakes Basin Coastal Zone Atlases, Coastal Resources Inventory Mapping Program) through information hubs (e.g., ACZISC) to geospatial data infrastructures (e.g., ICOIN, MGDI) [Canessa et al., 2007]. The number of applications in support of ocean and coastal activities that rely on multi-agency data collection, processing and distribution are actually much higher (e.g., ice observation and mapping systems by Environment Canada providing information to ENCs, the various systems maintained by the Coast Guard, etc.).

The objectives, methodologies used, and expected outcomes of these projects are diverse and in most cases are not comparable. Most of these projects, however, stalled at the design phase or halted shortly after implementation (e.g., ICOIN, MGDI). Most of the new additions to the list of collaborative approaches to the management of ocean and coastal data concentrate on the technical aspects of data collection for ocean observation (e.g., SmartBay). Therefore, having legitimate and credible information sharing arrangements linking ocean observation information to the stakeholder community is even more critical than ever.

The interest in a reliable, collaboration-based ocean and coastal geospatial information system or infrastructure has been present for nearly three decades with at least two major (ICOIN and MGDI) attempts to create an information infrastructure with a national scope [Nanton, 1993; Ford, 1990; Graves et al., 2005]. Ricketts and Harrison [2007], however, conclude that

> *the lack of coordinated national comprehensive planning process made it very difficult for integrated, multisectoral strategies to succeed and be sustained over time. [Ricketts and Harrison, 2007]*

The next section gives an overview of some of the emerging sectoral and regional initiatives. Referring to the similar situation in Australia, Strain [2006] observes that

> *A common theme from many of the initiatives … is the desire for access to appropriate and reliable spatial information to support these initiatives. [Strain, 2006]*

Although the scope of the following projects is termed as either regional or sectoral, it is difficult to make assumptions for the actual extent of their influence. The financial and technical resources and expertise employed in the various stages of these projects go beyond the respective regions and sectors. For example, in all cases, federal financial contributions were essential, just as the expertise developed and shared by GeoConnections, which is a primarily federal initiative. However, the principal objectives of these initiatives were region and sector specific.

4.4.1 COINPacific

The establishment of the Cooperative Information Network for the Pacific (COINPacific) was first proposed in 2002 and it was incorporated in 2006 as the

COINPacific Ocean Technology Inc. Figure 4.5 provides a summary of the partnership arrangements, objectives and product supplied by the COINPacific [COINPacific, 2005].

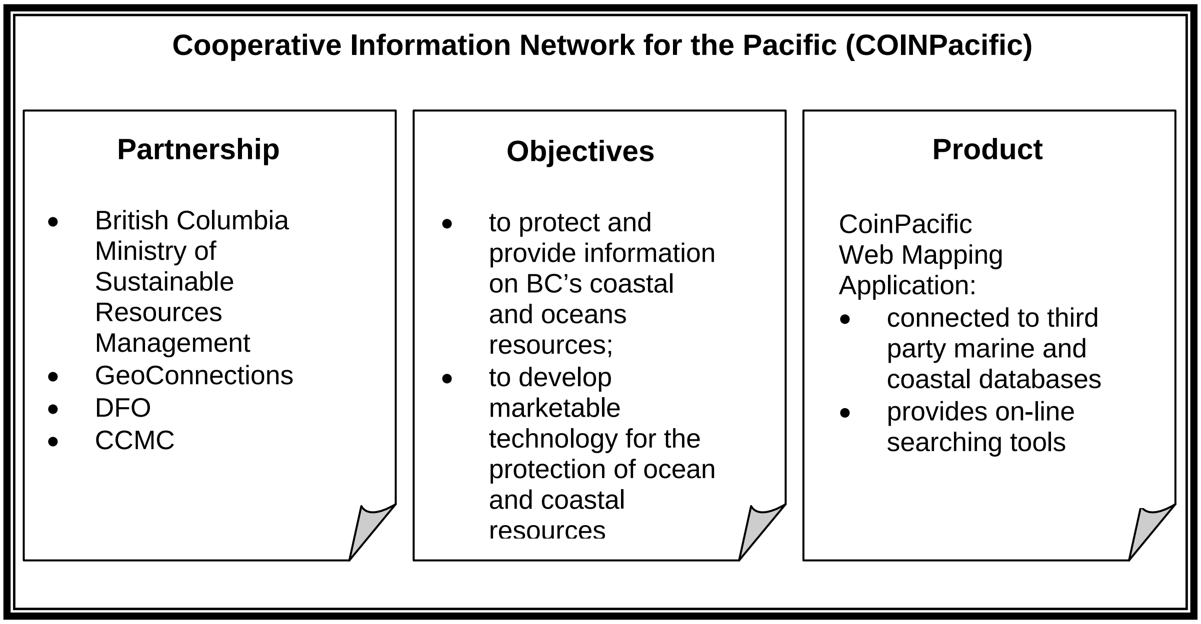


Figure 4.5: COINPacific: Partnership arrangements, objectives, and product

There are a number of initiatives in progress on the west coast that consider spatial information management an integral part of the project development. Among the responsible parties for these initiatives are:

- federal governmental departments (e.g., DFO – Pacific North Coast Integrated Management Area (PNCIMA), NRCan - Geoscan);
- provincial governmental departments (e.g., BC Ministry of Environment – Coastal Resource Information Management System (CRIMS), BC Marine Oil Spill Response Information System (OSRIS);

- academic groups (e.g., University of Victoria – Maritime Port Security Project for the Coast Guard, BC Centre for Applied Remote Sensing, Modelling and Simulations (BC CARMS);
- non-governmental, not for profit organizations (e.g., Ocean Gliders, Pacific Marine Analysis and Research Association (PacMARA);
- public-private-academic collaborative arrangements (e.g., Victoria Experimental Network Under the Sea (VENUS), North-East Pacific Time-Series Undersea Networked Experiments (NEPTUNE).

The role of COINPacific in harmonizing these and other ocean and coastal programs, for example, by identifying overlapping activities and gaps in data production and information management, is not yet apparent. However, as Kenk [2004] pointed out, COINPacific can already claim two important accomplishments in terms of (1) providing an information-sharing web application on the provincial government's Land Information BC web site[10] and (2) bringing *"virtually all of the people involved in preserving and developing the ocean environment into one place"* [Kenk, 2004]. It should be noted that First Nations were not parties in the development of COINPacific, while they take an important part of the management of ocean and coastal resources in British Columbia. Although COINPacific is among the few initiatives that did materialize after a lengthy process its sustainability depends on the long term political, institutional, and financial commitment of the collaborating organizations. Table 4.4 summarizes the results from the project analysis.

[10] http://aardvark.gov.bc.ca/apps/coin/

Table 4.4: From Inputs to Outcomes: Analysis of the COINPacific Initiative

Inputs	Recognising and articulating the need for improved information management with regards to BC's ocean and coastal resources Provincial and federal governmental data and information holdings Financial and technology support from GeoConnections Recognising and articulating the need for a marketable technology
Outputs	Partnership arrangements: Figure 4.5 CoinPacific Web Mapping Application Industry studies on ocean observation
Institutional Outcomes	The objective of developing a marketable technology has been met Operation too short to determine sustainability of partnership arrangements

4.4.2 SmartBay

In OAP Phase One, SmartBay was one of the two funded initiatives under the Science and Technology pillar. (The other initiative, OSTP, will be briefly introduced in the next section.) The Placentia Bay (area of 3600 sq km), jointly with the Grand Banks (500 000 sq km) is also listed as one of the five priority areas for integrated management planning under the OAP. Placentia Bay is a major marine transportation route supporting industrial activities (e.g., smelter, oil refinery) on the south shores of Newfoundland. The Grand Banks, once one of the richest fishing grounds, encompasses Canada's eastern continental shelf, where the data collection for submission to CLSC in support of Canada's boundary claim has already been contracted out [Fugro, 2006].

Prior to the publication of OAP, SmartBay, *"a local implementation of the MGDI concept"* [Gillespie, 2005] was already in progress in the Placentia Bay area. (SmartBay is also referred to as the Placentia Bay Marine Electronic Highway (MEH), the Information Seaway™ pilot project, the Placentia Bay Demonstration Project – Technology Solutions for Integrated Management, and the Ocean Observing System for Placentia Bay [CCMC, 2004].) The vision of SmartBay is to provide:

> *Simple access by all stakeholders to data and information in support of effective management and sustainable development of coastal ocean areas and safety and security of life at sea. [CCMC, 2005]*

This pilot project was built around the concepts of [CCMC, 2004]:

- ocean mapping;
- integrated ocean management; and
- spatial data infrastructure.

The intertwined roles of SmartBay under the two OAP pillars are somewhat open to different interpretations [Hogan, 2006]. As part of the integrated management pillar objectives of the OAP [DFO, 2005b], DFO established a new local planning committee and launching a technology advisory council was also proposed. SmartBay is considered as a complimentary project to this DFO initiative [CCMC, 2006]. It is, however, primarily viewed as a technology demonstration platform. While these two roles are not mutually exclusive, there has been little documentation on how SmartBay will undertake the expanded objectives while only receiving funding to build a technology demonstration platform.

Figure 4.6 captures a map of Placentia Bay and information supplied by Buoy 1, located at the mouth of the Bay. The other buoys on the map are not yet operational at the time of this research (Buoy 2 and 3) or have already been decommissioned (IOT#1). The real time meteorological and oceanographic data is available for the public free of charge from the SmartBay website and is also utilized to support weather and sea-state forecast development for the Placentia Bay area[11]. The Coast Guard and local fishermen have reported that using this improved forecast data had a positive impact on their operations [White, 2007]. Conclusions of the SmartBay project evaluation are presented in Table 4.4.

Table 4.5: From Inputs to Outcomes: Analysis of the SmartBay Initiative

Inputs	OAP [DFO, 2005b] Science and Technology Pillar Need: increasing safety and security offshore Objective is to build a technology demonstration platform OAP [DFO, 2005b] Integrated Management Pillar also covers this geographic location Oceans technology expertise
Outputs	Improved weather and sea-state forecast (for a short period of time) Meteorological buoys deployed Partnership arrangements
Institutional Outcomes	Intended as a technology demonstration platform: technology demonstration successful Operation too short to determine sustainability of partnership arrangements

[11]It should also be noted that at the time of the publication of this research, none of the buoys were operational. Buoy #1 was however operational for a short period of time when this research was conducted. www.SmartBay.ca

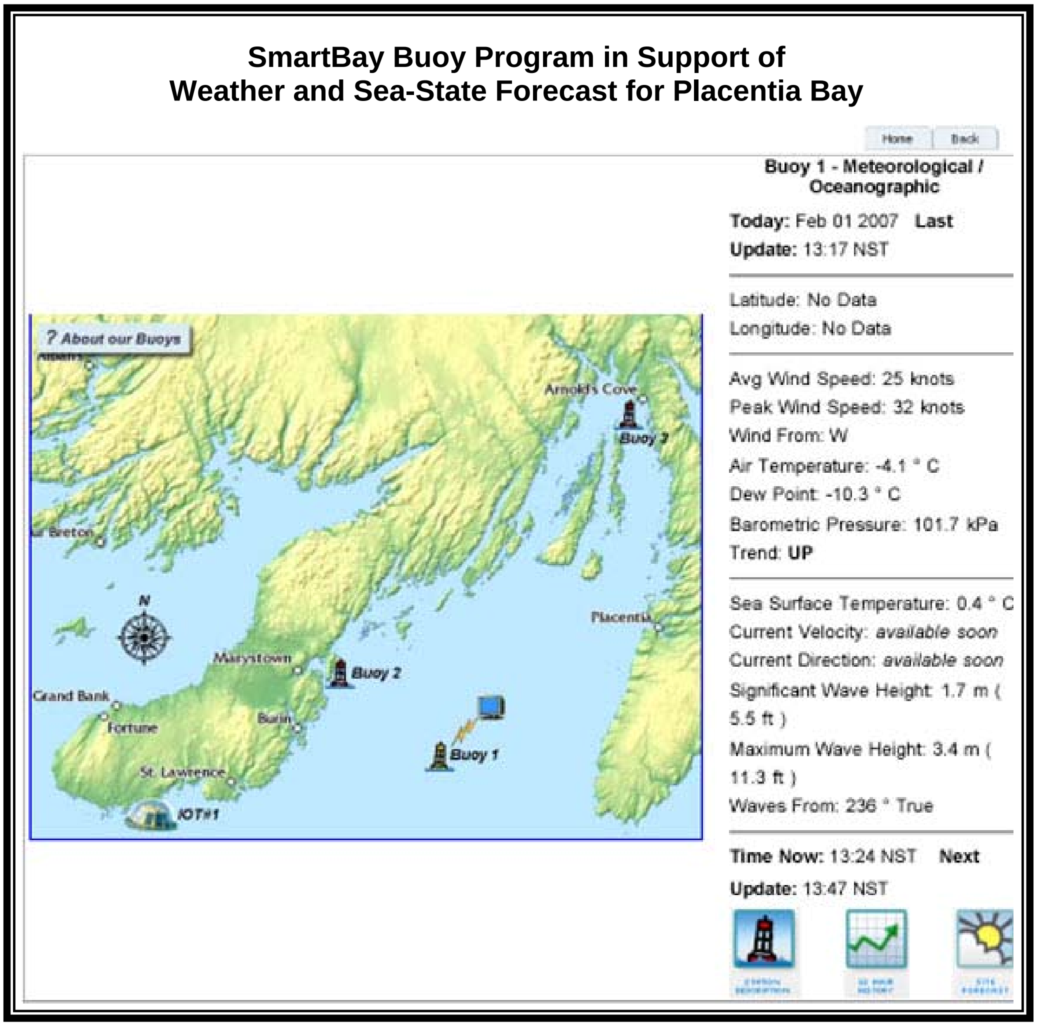


Figure 4.6: SmartBay Buoy Program
[http://www.smartbay.ca/buoy-data.php#]

4.4.3 COINAtlantic

The scope of institutions involved in ocean and coastal management initiatives on Canada’s Pacific coast spans from federal government departments to First Nations authorities. However, on the provincial governmental level the only stakeholder is the

Government of British Columbia. Canada's Atlantic coast is adjacent to five provinces and the already complex interactions among the various marine stakeholders (as seen in Figure 4.7) are further complicated with the additional levels of the five provincial governments, four First Nations as well as the necessity of international cooperation (Gulf of Maine).

The SmartBay project (Section 4.4.2) is but one initiative among the increasing number of ocean and coastal management collaborative efforts focusing on Canada's Atlantic waters. The Atlantic Coastal Database Directory for example was created in 1992 and was hosted by the Atlantic Coastal Zone Information Steering Committee (ACZISC). In 2005, extending the collaboration with the GeoConnections Discovery Portal, it became the Atlantic Coastal Information Portal (ACIP)[12], an online directory for data, organizations and services pertinent to ocean and coastal management in the Atlantic.

Other initiatives in various stages of development include but are not exclusive to the Eastern Scotian Shelf Integrated Management (ESSIM)[13], SeaMap[14], and the Gulf of Maine Mapping Portal (GoMMap)[15] as an international collaboration. These examples capture only some of the information management initiatives that form the complex information management backdrop to the proposed establishment of the Coastal and Ocean Information Network for the Atlantic (COINAtlantic).

COINAtlantic follows the concept of ICOIN (Section 4.2) and is proposed to *"provide open access to regional data and information within the CGDI, focusing on the*

[12] http://aczisc.dal.ca/acip/
[13] http://www.mar.dfo-mpo.gc.ca/oceans/e/essim/essim-intro-e.html
[14] http://www.bio.gc.ca/ED_RESOURCES/seamap-e.html
[15] http://www.gommap.org/gommap/index.html

needs of the Integrated Coastal and Oceans Management Community of Practice" [DFO, 2006c]. Its development is in the early phases at the writing of this thesis, and the operational details are yet to be announced. At this time it is being proposed as [ACZISC, 2007, McIlhagga, 2006, Sherin, 2006]:

- a coordinating body facilitating ocean and coastal information and data transactions in Atlantic Canada;
- an Internet application based on Australian and COINPacific examples.

Similar to COINPacific, COINAtlantic intends to rely on agreements and Memoranda of Understanding between cooperating partners for data and information sharing [Canessa et. al., 2007; ACZISC, 2007]. Prospective partners in COINAtlantic, such as the ACZISC and CCMC have been cooperating in other ocean and coastal management projects and would be able to bring substantial expertise to this new initiative. Although this initiative has not reached operational level, the inputs and outputs are summarized in Table 4.6.

Table 4.6: From Inputs to Outcomes: Analysis of the COINAtlantic Initiative

Inputs	ACZISC social capital ICOIN Need: access to coordinated regional ocean and coastal data and information
Outputs	Proposal to GeoConnections (User requirements-based on the MGDI user requirements and the Web Mapping Application is that of COINPacific and an Australian example) [ACZISC, 2007]
Institutional Outcomes	Not yet operational

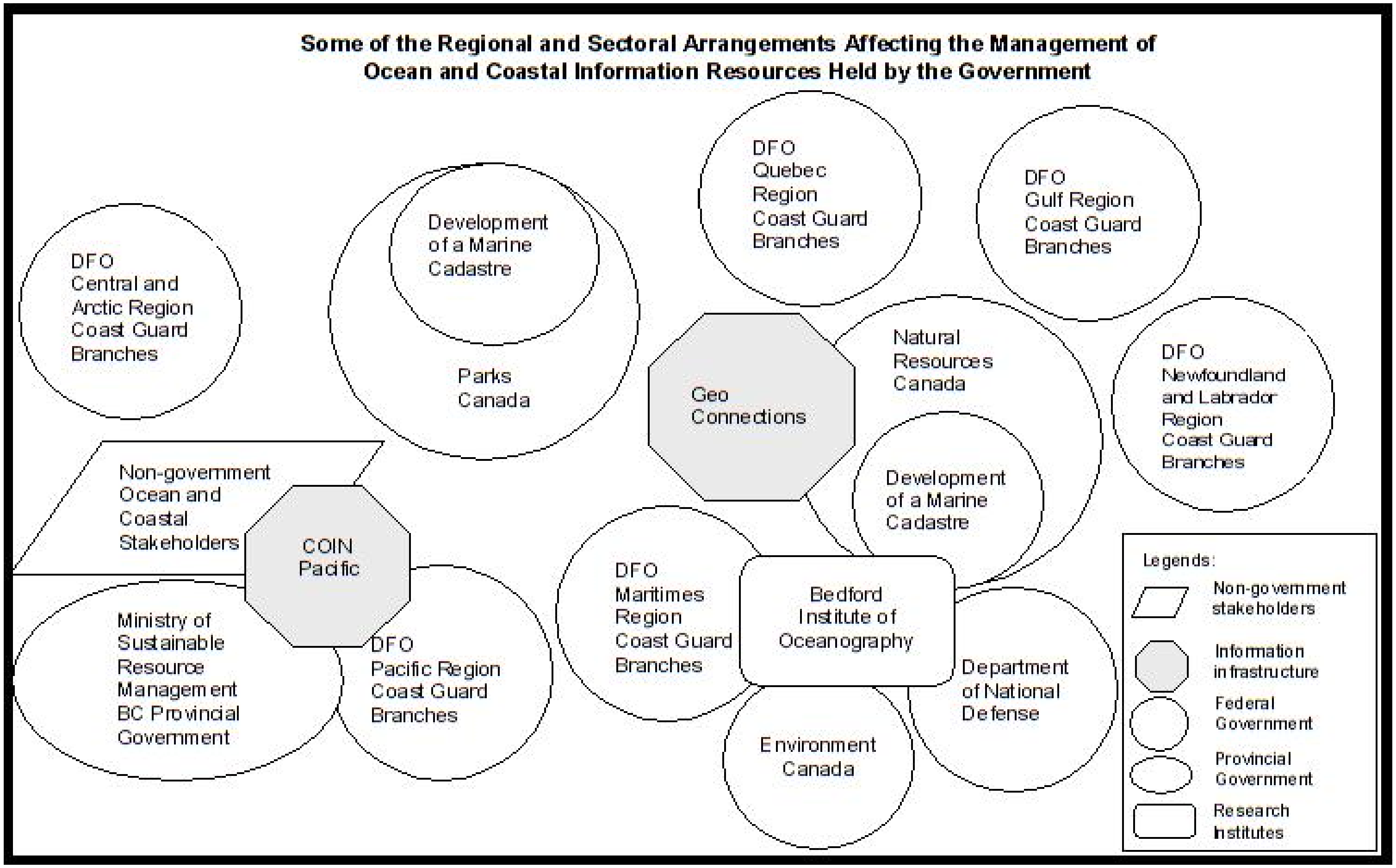


Figure 4.7: Governmental Holdings of Ocean and Coastal Information Resources

4.5 The Ocean Science and Technology Partnership

One of the four pillars of the OAP [DFO, 2005b] (Figure 2.6) is dedicated to address ocean science and technology issues. Section 4.4.2 introduced SmartBay, a regional technology demonstration platform. On the national level, the Ocean Science and Technology Partnership (OSTP) was initiated to *"capture the links between ocean science researchers and technology innovators"* [DFO, 2005b]. Although the focal point of this initiative is not the management of ocean and coastal spatial information, it is the only initiative under the OAP [DFO, 2005b] that has a mandate associated with information management and knowledge sharing, and therefore it is considered relevant to this research.

As a result of several workshops conducted across the nation, the OSTP found that isolating the Ocean Science and Technology Pillar from the other three pillars restricts its capability to effectively address the objectives identified in the Oceans Strategy [DFO, 2002]. Therefore the repositioning of this pillar was recommended to emphasize the role of science and technology as an integrating foundation for the remaining pillars [OSTP, 2006]. Figure 4.8 illustrates this new approach, also including sustainable communities and economies, as a new pillar.

While an extensive discussion on the contributions of the OSTP is beyond the scope of this research, it should be mentioned that this initiative provided specific recommendations for ocean management to meet the objectives of the Oceans Strategy [DFO, 2002]. One such recommendation advocates the development of a strategy for a systems approach to oceans observation. It recognizes that information needs to be collected on the various environmental, technological, and social aspects of Canada's oceans and this information need to be efficiently managed in order to meet *"both specific operational and broad strategic applications"* [OSTP, 2006].

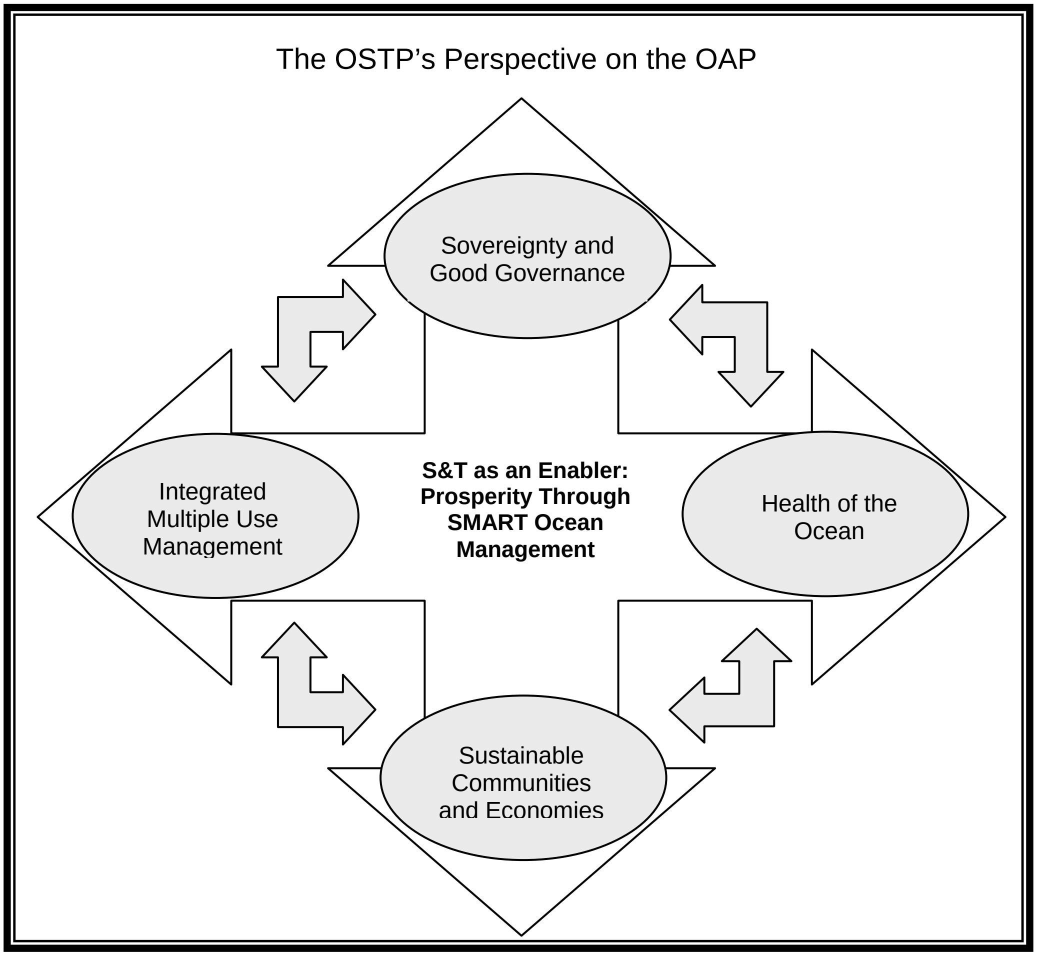


Figure 4.8: The OSTP's perspective on the OAP (from OSTP, 2006)

Table 4.7: From Inputs to Outcomes: Analysis of OSTP

Inputs	OAP [DFO, 2005b] Science and Technology Pillar Wide stakeholder expertise Need: link between science and technology
Outputs	Nationwide workshops and consultation Identifying user requirements at a high level Report and Recommendations: Prosperity through SMART Ocean Management Redesigned objectives for ocean strategy
Institutional Outcomes	Recommendations were proposed for OAP II. OAP II no longer exists. There was insufficient government support to continue with the implementation of the recommendations

4.6 Summary and Conclusions

The landscape of information management efforts aimed at Canada's ocean and coastal resources is diverse and sporadic. The three coastal regions all share objectives of national relevance, as well as objectives that are unique to a specific region. Common themes include those that are listed in the *Oceans Act* [1996], such as:

- sustainable development;
- integrated management of activities;
- precautionary approach.

Along with the above legislated and shared objectives, priorities of the four distinct coastal regions often differ in terms of geographical scope, resource issues, stakeholders, timeframes, and expertise available. For example, current issues on the Pacific coast include matters relevant to the opening up of offshore areas for oil and gas exploration (areas that have been under moratorium for decades), as well as First Nations' claims to offshore marine territories. On the Atlantic coast, work is in progress to survey the outer continental shelf as part of Canada's submission to claim the extended continental shelf under UNCLOS. Ensuring Canada's sovereignty, submitting a claim to the Continental Shelf under UNCLOS, climate change, and native self government are among the key issues relevant to the Arctic region. The Great Lakes is a major seaway for transporting goods, and balancing safety and environmental protection with efficiency and economic considerations requires collaboration among the stakeholders.

To what extent have the chosen geospatial information management initiatives addressed some of these regional and sector specific objectives, or the objectives that were set constituted as the foundation of these initiatives? Tables 4.2 – 4.7 suggest that a systematic collection and analysis of user requirements were not an integral part of the input phase of any of these initiatives. Although the MGDI initiative produced a user requirement study as an outcome, an infrastructure, based on those requirements has not been developed. Instead, five years later, another initiative is proposed founded on those requirements.

In conclusion, determining the degree of the impact these initiatives left on the ocean and coastal management and information management scene is problematic. The following chapter will discuss the role of requirements analysis in designing an information management strategy for the ocean and coastal community.

CHAPTER 5

CRITICAL EXAMINATION OF REQUIREMENTS FOR OCEAN AND COASTAL INFORMATION MANAGEMENT

> *Management of Information is an element of every job function in the GoC* [Government of Canada] *that has to do with treating the information used or produced in the course of performing the job duties as a strategic business resource and in line with legal and policy requirements. [Treasury Board of Canada Secretariat, 2004]*

5.1 Introduction

The focus of this thesis is to develop a spatial information management strategy supporting national-level ocean and coastal policy and decision making. Throughout the previous chapters critical factors in ocean and coastal management and the associated information management were identified (Figure 5.1). This chapter will direct attention to some of the inadequacies of the existing practices and present the rationale for an alternative approach.

According to the above quotation, government information is viewed as a strategic business resource and its management is expected to be given appropriate weight. In the above context information management, however, is left with ambiguity, for the legal framework surrounding not only ocean and coastal information and information management, but government information in general is often considered ambiguous and even archaic. Policies, such as access and cost recovery, direct information management towards further fragmentation [Alasdair, 1999; Bronskill, 1999; Hubbertz, 1999; Nilsen, 1999]. Nevertheless, as the previous chapters argued and is summarized in Section 5.2, there is an increased need for an operational and sustainable information management model for the ocean and coastal communities. Identifying this need is not original (see Chapter 4), but the motivation to proceed this time might be more compelling, due to the awareness of problems and opportunities regarding ocean and coastal resources. Apart from political and financial support, building an ocean and coastal information management system also relies on a framework design.

In developing marine information management systems, the importance of harmonizing strategic objectives and user requirements with information system development is often overlooked (see Chapter 4). It also needs to be pointed out that the role of information and the management of information are considerably marginalized in ocean management policies (Chapter 2). Meanwhile, as presented in Chapter 3, geomatics technologies and concepts offer opportunities for supporting a wide array of information management needs.

Chapter 5 follows the outline presented in Figure 5.1, summarizing the contributions of national level objectives, technologies, and initiatives in terms of requirements, constraints, and opportunities enabling the design of an information management strategy.

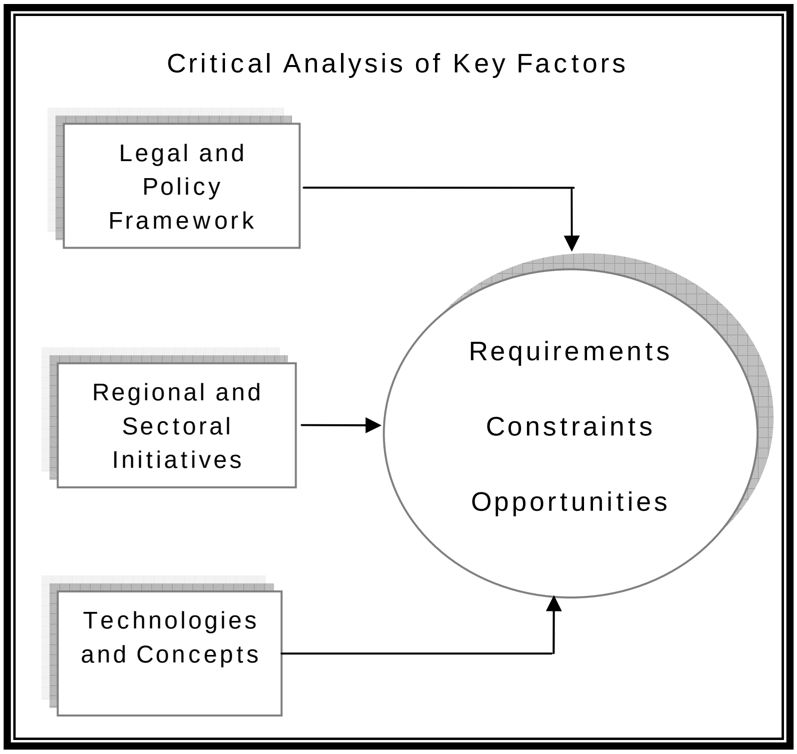


Figure 5.1: Critical assessment of key factors

5.2 Some Implications of Ad Hoc Ocean and Coastal Information Management

Fisheries and Oceans Canada, working closely with the Treasury Board Secretariat, will co-ordinate the development of the Expanded Oceans Information Framework by spring 2006. The framework will measure and report on the progress and results of the 18 initiatives. The framework will contribute to the scoping and planning of Phase II of the OAP by fall 2006. [Office of the Auditor General of Canada, 2005]

The above quotation highlights several problems associated with an ad hoc approach to ocean and coastal information management:

- There is no documentation on the establishment of the above mentioned Expanded Oceans Information Framework as of spring 2007.
- Although the objectives of the above quoted framework are well stated, the required progress reports on the initiatives are yet to be made public.
- Furthermore, the *"scoping and planning of Phase II of OAP"* have not been completed by the timeframe indicated.

The mandate of developing and implementing ocean management programs and policies on behalf of the Government of Canada is vested in DFO (Treasury Board, 2006). The COS [DFO, 2002] and the OAP [DFO, 2005b] give a brief summary of ocean management areas where past and present practices failed to protect the nation's ecological (e.g., degradation of ocean environment,), social (e.g., sustainability of coastal communities), and economic (e.g., collapse of north Atlantic cod fishery) interests. (Chapter 2 offers a more detailed overview of the current challenges.)

Although the importance of information sharing is mentioned on several occasions in the above policy documents, there have been no indications on how this information sharing needs to be managed. In fact, a DFO Workshop Report [2006b] found that

> *[o]ver the past years, several DFO data access initiatives have been undertaken but the lack of common strategy has resulted in DFO having invested into the development of many data and information systems that are not necessarily able to access one another. [DFO, 2006b]*

Chapter 3 introduced technologies and concepts used by the ocean and coastal management communities to collect, process, and manage large amounts of data and information. Prior et al. [1997] points out that demand for geoscience data to support ICZM efforts in Canada is expected to grow. It is also well documented that other ocean management areas, especially if the principles of ecosystem-based management are followed, are heavily dependent upon information products. These *"information products are derived from the synthesis of a wide variety of data being collected and managed by others"* [DFO, 2006c]. Nichols [1992] has previously observed that

> *[w]hereas the need for managing other resources is generally recognized with the decreasing availability of the resource, information requires more explicit management practices as the volume, demand, cost of accessing and value of the information increases. [Nichols, 1992]*

The majority of information management initiatives to date have evolved in a fragmented, sporadic manner addressing the short term objectives of a specific stakeholder community (examples are presented in Chapter 4). In a number of cases the projects were terminated in the design phase (or as in the case of the above mentioned Extended Oceans Information Framework, there is a lack of information on the status of the project). This leads to outcomes that adversely affect the ocean and coastal stakeholder communities, including but not exclusive to:

- falling short of supporting ocean and coastal management programs and policies;
- making the evaluation of programs and policies difficult;
- failing to recover the substantial human, technical, and financial resources spent (e.g., ICOIN, MGDI);
- fostering the development of other ad hoc initiatives to replace the failed ones without giving considerations to the factors leading to failure;

- investing in the latest technological trends without coordinating with the requirements (e.g., DFO Science Branch Service-Oriented Architecture (SOA) and Interoperability Plan) therefore running the risk of becoming indebted to sunken costs;
- access to known-quality information is limited, compromising informed decision making.

In addition to the above listed implications that have been derived from the author's research, an audit of DFO's activities by the Office of the Auditor General [Rafuse et al., 2005] also underlined a number of deficiencies in regards to ocean management while it also highlighted issues on information management, including:

- DFO's poor reporting of performance information to Parliament and to the public on accounting for its *Oceans Act* [1996] responsibilities;
- DFO not meeting its periodical reporting commitments on the state of the oceans;
- individual agencies and departments failing to create consolidated reports on the COS initiatives, therefore it is difficult to evaluate the overall standing of the initiatives;
- COS not providing sufficient details on collaborative arrangements or assigning leadership roles, although collaborative decision making across the federal government was emphasized in the policy;
- differing approaches to management within DFO's mandate. The *Oceans Act* [1996] calls for integrative and collaborative approach, while the

Fisheries Act [1985] requires active and direct approach. What are the consequences of these two differing approaches to information management?

- using different information collection and management procedures by departments and agencies which hinders the measurement and evaluation of program and policy outcomes.

The above listed challenges highlight the potentially damaging effects of the present information management arrangements. Supporting this recognition, at least on the theoretical realm, a growing number of recently proposed and ongoing projects (e.g., DFO Science SOA and Interoperability [DFO, 2006b]) are focusing on various aspects of integration and interoperability of information assets. It confirms that despite prior unsuccessful efforts, coordination of information systems is still a main concern. However, this research found that the present institutional framework-based on the ad hoc approach, permits the following problems to persist:

- information management objectives are not adequately addressed when ocean management objectives are planned;
- projects are launched without taking user requirements into account, or plan to look at user requirements after decisions and investments on other issues (e.g., technology, sectoral and regional coverage) are made;
- no projects have been designed to reconcile national level objectives with user requirements.

The next section outlines a design for an ocean and coastal information management strategy that is requirements driven and supported by technology. Its aim is to support ocean management objectives across horizontal and vertical levels of government.

5.3 Requirements Assessment

The importance of discovering user requirements during information systems development is well documented [see e.g., Nichols, 1981; Nichols 1992; Palmer and McLaughlin, 1984; Rubin, 1986; Markus, 1983; Clarke, 2001]. Citing literature reviews, Clarke [2001] concludes that this commitment to user participation remains "*ideological rather than actual*." Relying on actual user input during the design of an information system is still not without difficulties. The literature on failed decision support and management information systems that points to users' faulty identification of requirements is quite extensive (e.g., Davis, 1982; Rubin, 1986; Wetherbe, 1991; Bahill and Henderson, 2004).

The complexities of collecting and analyzing requirements for various information management projects have been expressed by a number of authors [e.g., Davis, 1982; Jacobsson et al., 2002; Goguen, 1994]. Given the high failure rate of large, highly technical projects, as large scale information management projects can be characterized, Goguen [1994] suggests that:

> *… the requirements phase of a large system development project is the most error-prone, and these errors are the most expensive to correct. … Consequently, this phase has the greatest economic leverage. [Goguen, 1994]*

Figure 5.2 indicates that information requirements encompass more than data requirements. It is also strongly influenced by other processes, such as technology, the institutional framework, and the system environment.

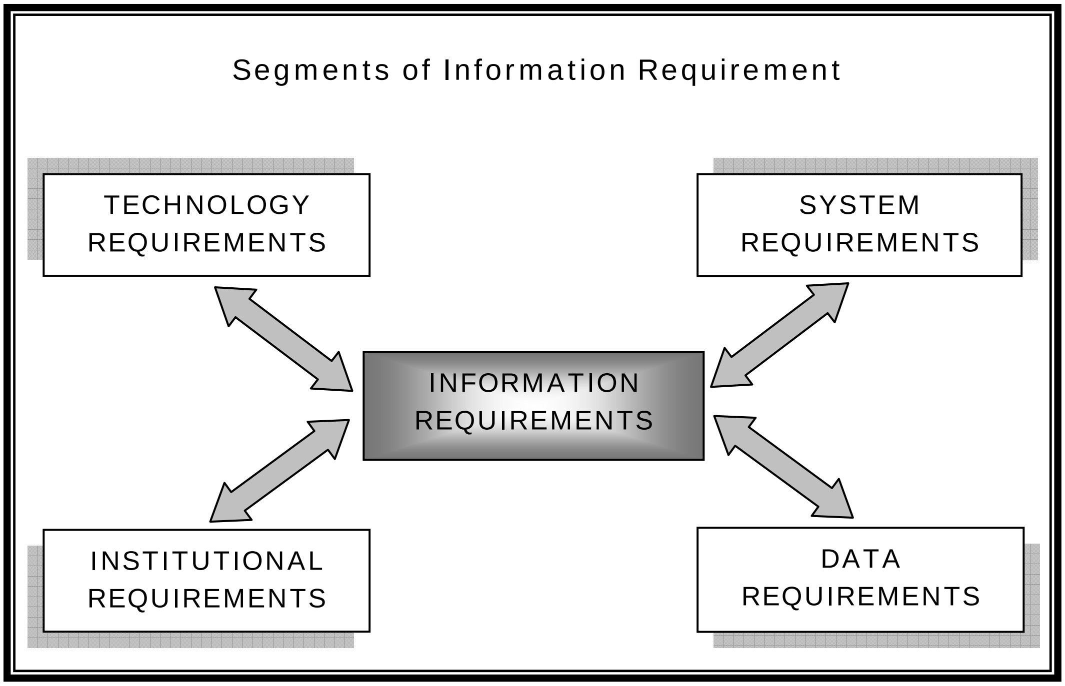


Figure 5.2: Segments of information requirements

Geomatics professionals are able to contribute to the processes of requirements compilation and analysis by, for example [Palmer and McLaughlin, 1984]:

- deciding what information is to be collected;
- identifying the amount and level of detail to be obtained to comply with metadata and task requirements;
- identifying common data sets, potential conflicts, degree of commonality, patterns of information flow, formalized information exchange, established procedures;
- determining who should collect the data;

- coordinating the flow of information with analytic requirements of decision making process;
- determining who should have access to the information under what conditions;
- facilitating technological and institutional processes by collaborating with professionals from other fields;
- bridging the divide between decision makers and technology experts: users of spatially referenced data and information may not have sufficient understanding of the complexities of computing and other technologies involved while the same time computer experts may do not fully appreciate the decision making process as it relates to ocean and coastal management;
- coaching decision makers on identifying requirements: *"it takes time before non-specialists are able to clearly state their requirements."*

Based on this methodology, the information management design introduced in this research differs from previous approaches by:

- staging user requirements at the core of the design concept;
- proposing a systems engineering approach for developing an information management strategy;
- aiming at harmonizing national level priorities with the delivery of local programs and policies;
- bringing attention to the cross-functional nature of ocean and coastal information management projects;
- synchronizing project requirements with information management.

There have been no formal user requirement surveys done during the course of this research. The following methods supplied an initial list of requirements that were grouped into four categories following system architecture principles proposed by Sage [1999]:

- a desk study of current priorities in ocean and coastal management;
- a review of case studies, meeting minutes, critical analysis of literature, government documents, and consultation with experts.

The compilation of the preceding chapters resulted in two key outcomes led to providing (1) an overview of the legal and policy framework, the technologies and concepts of ocean and coastal management, and some of the regional and sectoral information management initiatives, and (2) a starting point for information requirements determination.

5.4 Information Requirements: A Discussion

Formulating an information management strategy begins with isolating the processes that require information, and examining the systems that are available to provide this information [Forgionne, 2002]. The examples given in the preceding section highlighted the inadequacies of addressing the processes needed to achieve national level objectives outlined in Chapter 2. Providing a detailed analysis of the numerous processes involved in ocean management is beyond the scope of this research. This limitation, however, is taken into account during the construction of an information management strategy.

Figure 5.3 gives a detailed outline of some of the critical information requirement elements. The following subsection further explores the components of these elements. Some components are listed under more than one category, and in most cases will be discussed under one of the categories only.

5.4.1 Institutional Requirements

This research has found that the present institutional arrangements for information arrangements are not capable of efficiently supporting national level ocean and coastal management priorities (e.g., uncertainty about the outcomes of OAP I). Information management research studies involving the private sector often recommend adjusting a business' organizational design to solve information management challenges (e.g., Feldman and March, 1981). With respect to ocean and coastal management, carrying out a major organizational redesign is not likely, and may not be even desirable in Canada. Therefore, an information management strategy that is capable of accommodating the distinctive needs of this sector needs to be formulated. Table 5.1 elaborates on key requirements in this regard.

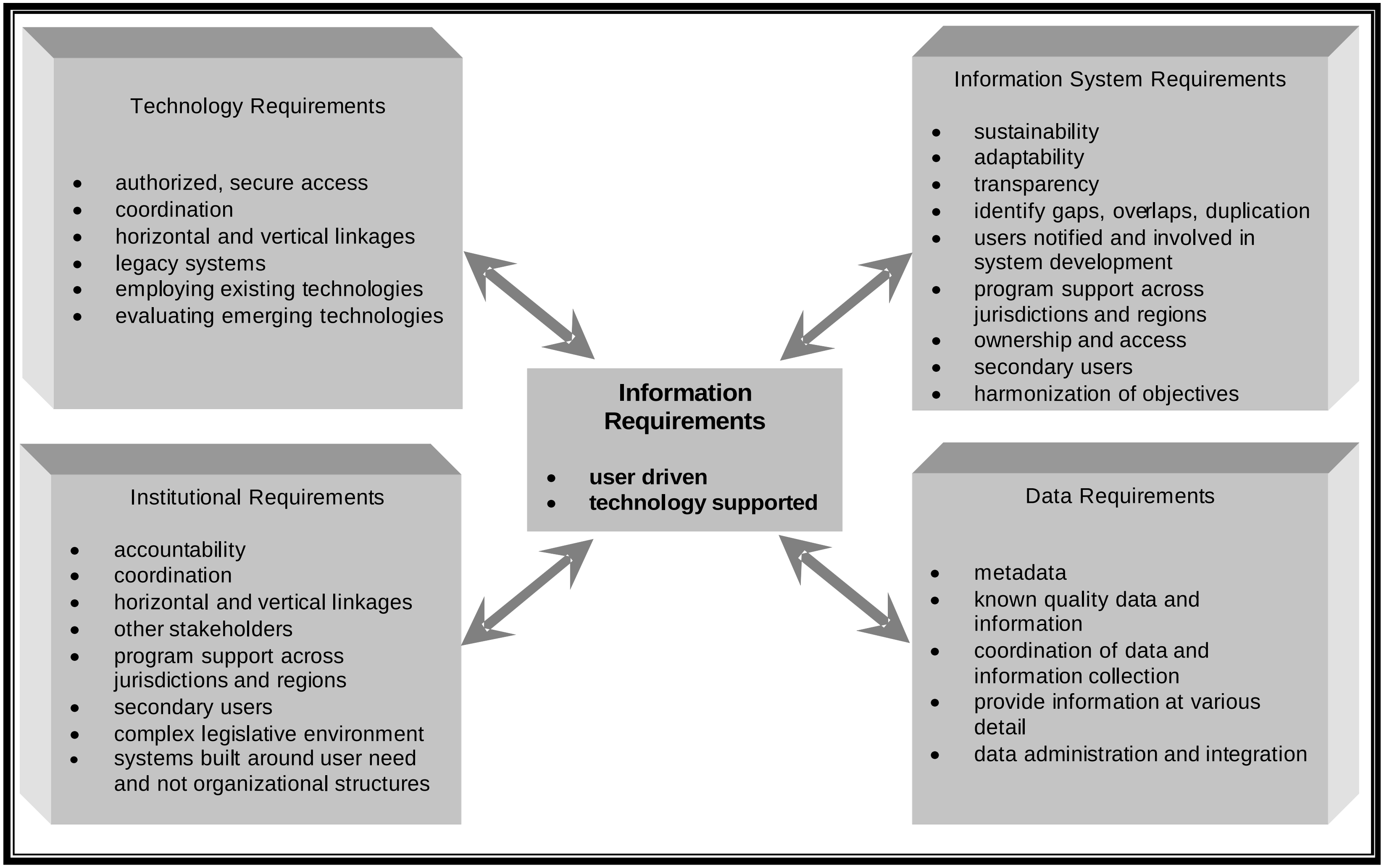


Figure 5.3: Information Requirements for Ocean and Coastal Information Management

Table 5.1: Institutional Requirements

accountability	Funds are appropriated accordingly to perceived priorities. Data and information flow needs to reflect the progress of programs and policies.
coordination	Given the high number of stakeholders with ocean management mandates and the complexities of programs being carried out, coordinating data and information management activities not only makes economic sense, but also ensures that results from programs are accessible to other participants and stakeholders.
horizontal and vertical linkages	Large scale information management projects need to support information flow in all directions.
other stakeholders	One of the major premises of constructing an information management strategy is to recognize various stakeholders and take advantage of their capabilities in program and policy delivery.
program support across jurisdictions and regions	A crucial feature of ocean and coastal programs is the importance of following these programs from national level decision making to local level implementation. Funding is often allocated according to the priorities of the upper level decision makers. It is, however, the local authority that directly needs to deal with the consequences of carrying out objectives or not being able to address local priorities due to, for example, lack of funding.
secondary users	It is often acknowledged in the marine management community that data and information are often collected and managed for a single and immediate purpose. It is also agreed that the collection and management of these data and information is very costly in terms of the required human and technological resources. Keeping other uses in mind would increase the economy of scale.
complex legislative environment	To accommodate this requirement, information management arrangements need to account for the present legal framework. An effective information management strategy might provide recommendations on how possible regulatory changes might affect the sector or what changes are required.
systems built around user needs and not organizational structures	Previous efforts has showed that for ocean management to function according to stated objectives, an information management strategy that serves a single agency will not be able to support programs and policies involving stakeholders across jurisdictions, regions, and sectors.

5.4.2 Technology Requirements

Computer technologies that support tailoring the technical phase of an information system according to user requirements are already widely available with demonstrated capabilities [Clarke, 2001; Mora et al., 2002]. Features that are fundamental for ocean and coastal information management in particular are discussed in Table 5.2.

Table 5.2: Technology Requirements

authorized, secure access	The protection of valuable data and information resources are critical to the realization of a new information management strategy. Data and information that are compromised lose their value and hinder future utilization.
coordination	It makes economic sense to coordinate the acquisition of technical resources. It may lessen the likelihood of building overlapping or incompatible systems.
horizontal and vertical linkages	Strongly connected to institutional requirements and coordination, the employed technologies are best able to perform if connections are provided across regions, sectors, and jurisdictions.
legacy systems	Carrying out this research underscored that it is not the lack of information management systems that impede the achievement of objectives, but rather the uncoordinated, ad hoc manner these systems are established and operated. Yet the existence of these systems, the users who are familiar with it, and the sunken costs already absorbed need to be taken into account in any new strategy.
employing existing technologies	Computer hardware and software proven to be useful should not be abandoned on the premise that a new strategy needs new applications.
evaluating emerging technologies	Following the previous trail, new technologies should not be overlooked if they offer solutions that are better from those that are already established. Considerations should also be given to upgradeable new technology.

5.4.3 Information System Requirements

The observations made in subsection 5.4.2 regarding the technical background of requirements are also valid for the technical portion of systems requirements as well. Table 5.3 puts more emphasis of the non-technical features of system development.

Table 5.3: Information Systems Requirements

sustainability	One of the major difficulties that past and present information management initiatives face is concerned with users rejecting the system. Systems that are shaped by solutions rather than problems are often not sustainable.
adaptability	Modern information management systems need to adapt to rapidly changing requirements. When the government is involved it also needs to accommodate changing political priorities without loosing its capability to address past priorities as well.
transparency	The need for increased transparency is often expressed regarding any kind of system development. Establishing processes and standards for documentation will ensure that this requirement can be adequately met.
identify gaps, overlaps and duplication	System development provides an opportunity to gain insight into the existing practices. This is an important step to improve the delivery of programs and policies while improving the economic return on taxpayers' contributions.
ownership and access	System development requires substantial investments in financial and human resources. Divisions within large organizations often consider their systems proprietary. It is not realistic to expect the acceptance of a new strategy that does not take ownership and access issues into account and provide for negotiation among system users.
harmonization of objectives	In the case of large organizations, systems often comprise of subsystems. Developing a system that concentrates on short term priorities of a small group without considering the overall objectives may appear more feasible than harmonizing the objectives with other systems. This practice, however, will jeopardize the sustainability and economic justification of any system.
users notified and involved in system development	Within the overall ocean management sector individual agencies address specific problems and have specific priorities. These problems and priorities need to be considered to gain the support of the implementers of local programs.

5.4.4 Data Requirements

The data requirements for information systems and for ocean and coastal management in particular have been reviewed by previous research (see e.g., Ford, 1990) and prior initiatives (see e.g., DFO, 2001). This, however, has not always led to practical implementation. Table 5.4 highlights some components that would merit re-examination.

Table 5.4: Data Requirements

metadata	The importance of collection and documentation of metadata is well established. Following basic data and information management requirements is fundamental to building any information system that reaches beyond the short timeframe of a single project.
known data and information quality	Accuracy is often emphasized in information systems, and it is definitely an important objective. However, documenting and understanding attributes regarding the quality of data and information is even more important.
provide information at various details	Users of a large scale information management system are positioned across the scale in terms of the amount and detail of their data requirements. Technologies permit to build a system that is capable of functioning as a decision support system at one end while serves as a data management tool at the other end of the spectrum. This is important for ocean and coastal management, for it is a sufficiently large system that requires these capacities while it is not too large to overwhelm it.
data administration, updating, and integration	In ocean and coastal management there are basic data sets (e.g., those that are produced by CHS) that have the potential to be used by variety of stakeholders. Unresolved data management issues limit the scope of collaboration.

5.5 Summary and Conclusions

Requirements development is viewed as a critical element of systems engineering projects [Bresciani et al., 2003; Davis, 1982; Goguen, 1994]. Bahill and Henderson [2005] augment requirements development with requirements and system verification and validation. It is proposed that a properly designed system is built on validated requirements that are verified at the end of the system design.

Chapter 4 introduced a number of spatial information infrastructure initiatives that have either failed or still need to provide proof of sustainability. It can be presumed that these initiatives responded to valid system requirements (e.g., COINPacific, ICOIN) but failed the system verification requirements (e.g., ICOIN). It can be argued that the ongoing operation of these initiatives will depend upon the degree the solution offered (initiatives) matches significant requirements [Bahill and Henderson, 2005].

The focus of this chapter was to build on the findings of the previous chapters and on the examples gathered in the literature in order to define the direction for the design of an ocean and coastal information management strategy. Information requirements were grouped in terms of their functions, such as institutional, system, technological, and data requirements. Based on these conclusions, the next chapter will propose an information management process that reflects the information requirements of projects and initiatives, as opposed to fitting requirements into a preconceived solution.

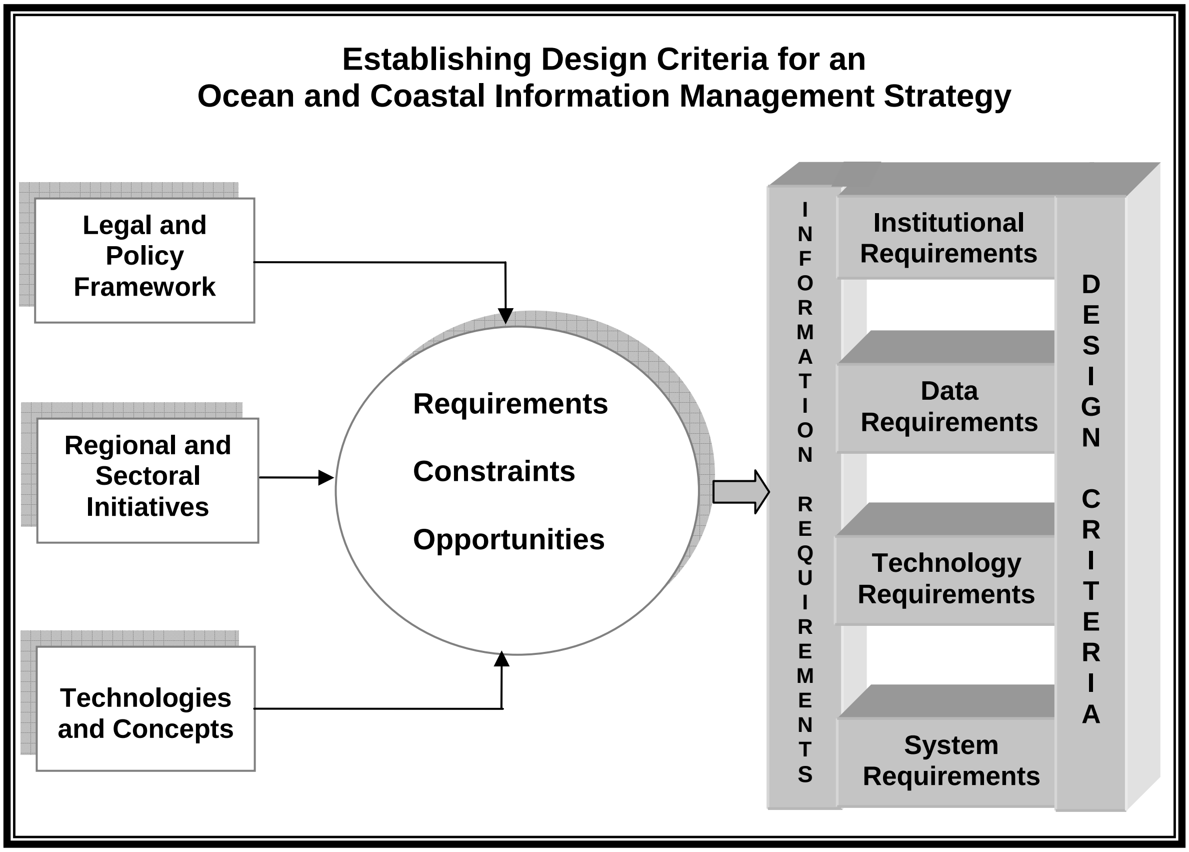


Figure 5.4: Establishing design criteria for an
ocean and coastal information management strategy

CHAPTER 6

OCEAN AND COASTAL INFORMATION MANAGEMENT STRATEGY: A SYSTEMS ENGINEERING APPROACH

We are drowning in information, while starving for wisdom. The world henceforth will be run by synthesizers, people able to put together the right information at the right time, think critically about it, and make important choices wisely. [Wilson, 1998]

6.1 Introduction

Chapter 6 builds on the findings of the preceding chapters to develop a conceptual design for an information management framework. Chapters 2, 3, and 4 presented discussions on how present and past developments drive the modernization of information management with regards to ocean and coastal spaces and activities. Four platforms were distinguished:

(1) The national level, where the role of the *Oceans Act* [1996] and subsequent policy documents such as the Oceans Strategy [DFO, 2002] and Oceans Action Plan [DFO, 2005b] were highlighted in advancing the long term political, economical, environmental, and social goals of Canadian ocean and coastal stakeholders.

(2) The international level, where the ratification of UNCLOS [Canada, 2003] calls attention to the opportunities and responsibilities accompanied by the increased ocean territory.

(3) The fields of science and technology, where innovations increasingly rely on collaborative efforts among stakeholders. At the early stage of development, these innovations were mostly driven by stakeholder specific objectives (e.g., ECDIS –

navigation, marine cadastre – oil and gas development, etc.) yet patterns of collaboration soon took over (e.g., marine GIS – computer applications supporting science, ICZM – aiming for a horizontal and vertical integration of decision making to solve coastal problems).

(4) The networks of information management, where past and present regional and sectoral initiatives reinforced the critical role of sharing ocean and coastal information, while revealing that the majority of these initiatives have been unsustainable.

The research in Chapter 6 originates from an information management planning perspective, outlined by Wexelblat and Srinivasan [1999]. The proposed conceptual design [Neff and Presley, 2000] of a framework will draw on the principles of systems engineering [Bresciani et al., 2003; Maier, 1998; Frey et al., 2004; Sage, 1999; Sage and Lynch, 1998; Miles, 1973; Nichols, 1992; McLaughlin and Nichols, 1989]. The goal is to formulate a strategy for the management of ocean and coastal spatial information with a focus on federal governmental organizations sharing responsibility for the management of ocean and coastal resources and activities.

6.2 The Relevance of the Systems Engineering Approach

The Government of Canada's monetary loss due to inadequate information management was estimated to be nearly $CDN 800 Million (2002) [Campbell et al., 2002]. Furthermore, Campbell et al. [2002] state that

> [the Government of Canada's] *ability to respond to the needs of Canadians depends on how well it can* ***create, use and preserve information*** *to make decisions and take action to achieve its operational and strategic goals. [Campbell et al., 2002]*

The four platforms outlined in Section 6.1 present the ocean and coastal community with an **opportunity** as well as a **responsibility** to call upon improved information management practices to increase the probability of achieving the operational and strategic goals. Canada's Ocean Strategy [DFO, 2002] identifies three key policy directives for modern ocean management (see Figure 2.5 in Chapter 2). Achieving these policy directives requires:

- working across vertical and horizontal levels;
- establishing long term linkages;
- coordinating initiatives that serve multiple needs;
- building initiatives upon each other;
- planning beyond electoral and yearly budget cycles.

Ramo [1973] recommends applying the systems approach when "*needs and problems originating at one level invariably have contributing factors at higher levels.*" This statement directly applies to the area of ocean and coastal management, where DFO, a decentralized federal level institution, has the leading responsibility for developing national level ocean and coastal management objectives that are being implemented across all levels of government. In order to fulfill this obligation, DFO is required to establish collaborative linkages with other federal level institutions while managing its interests in various regions in different organizational arrangements. Additional obstacles due to changing political priorities and budgetary constraints also need to be considered.

It can be concluded that ocean and coastal management, as well as the associated field of information management, is too complex to allow the introduction of any strategy that contemplates totally overhauling the existing practices. Also, a centralized approach would most likely encounter resistance at the regional and local levels, jeopardizing the success of the strategy implementation. Systems engineering, however, provides for introducing unit or objective level changes while adhering to the organization-wide strategy [Robertson, 2005].

Translated into the realm of ocean and coastal information management, a systems engineering approach facilitates the coordination of regional and sectoral initiatives with and within the overall strategy. While the creation, operation, and maintenance of initiatives would continue as prescribed in the strategy documents, the **coordination** of these initiatives would also become equally important. Furthermore, adapting the systems engineering approach would mitigate the risks associated with changes in requirements, introduction of new technologies, and political decisions.

6.2.1 A system view of ocean and coastal information management

The systematic view of ocean and coastal information management illustrated at Figure 6.1 is extended from the land information systems perspectives presented by Dale and McLaughlin [1988], Burch et al. [1989], and Nichols [1992]. This is an area where the alignment of information, social, science, and technical entities is critical to efficiently and effectively addressing and resolving ocean and coastal management challenges. Figure 6.1 brings equal attention to the aforementioned components, to the set of organizing principles that facilitate the alignment, and to the connections among them. The significance of the organizing principles and the connections will be further discussed in the following section.

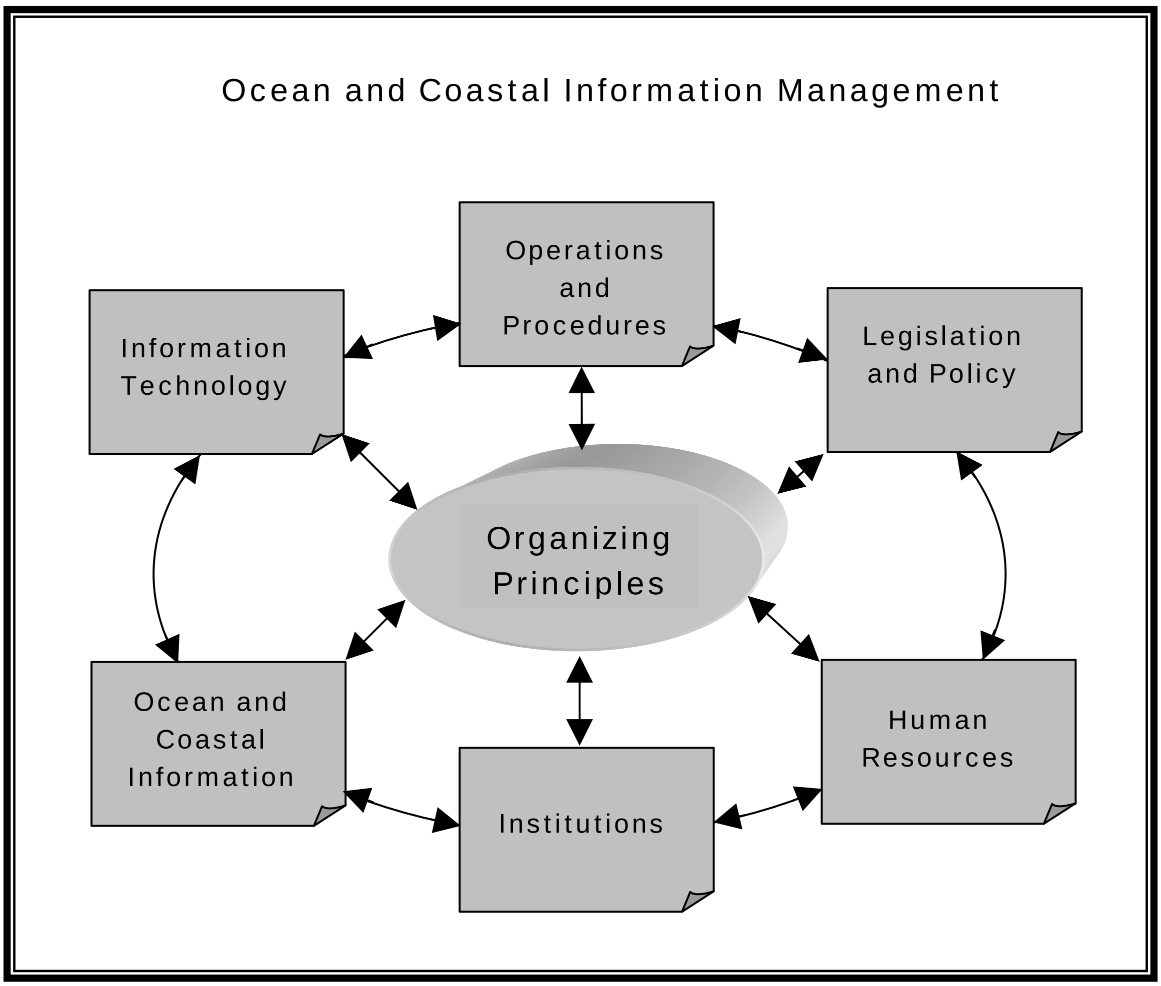


Figure 6.1: Ocean and coastal information management (after Nichols, 1992)

6.2.2 Adaptation of systems engineering approach to information management

The systems engineering approach was chosen for the conceptual design to improve information management among stakeholders responsible for the management of ocean and coastal areas. Within the systems engineering discipline there are different models describing the steps involved in the process. Sage's [2005] definition is based on a system's lifecycle, while Mar [1997] proposes a model derived from system functions, requirements, answers, and tests. Figure 6.2 illustrates the model advocated by Bahill and Dean [2006] and is also accepted by the International Council on Systems Engineering (INCOSE). This latest model includes the element of integration and is viewed as most suited to the application for the problem stated in this research.

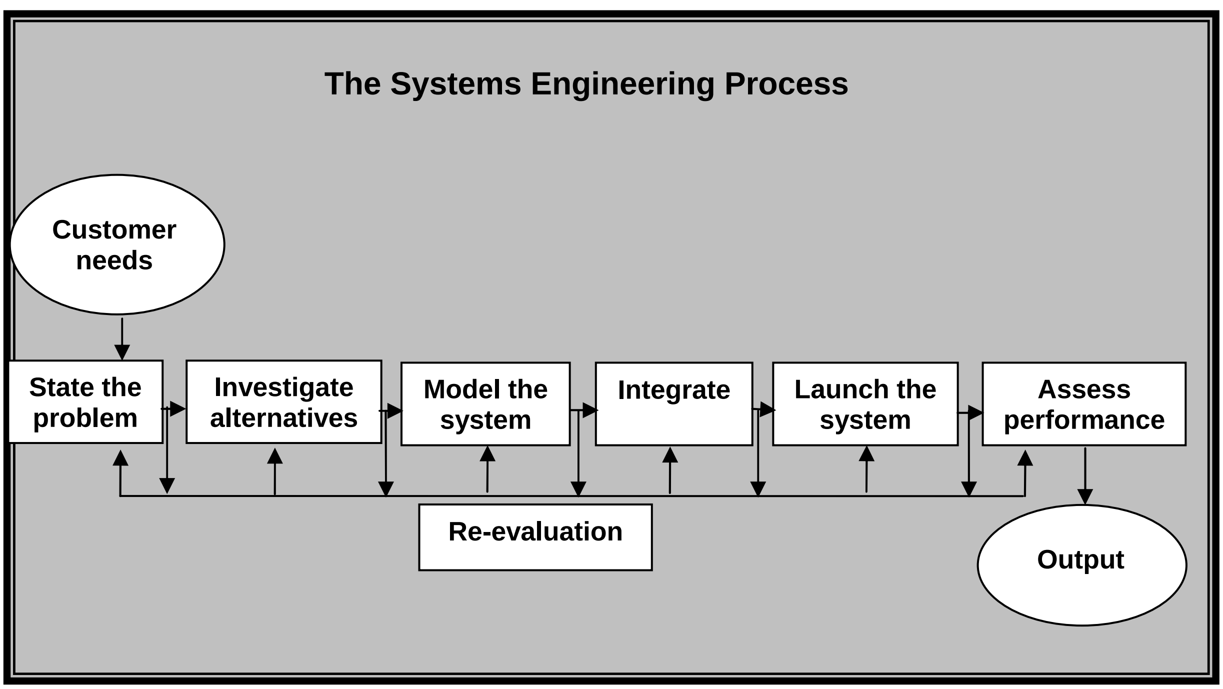


Figure 6.2: The systems engineering process [from Bahill and Dean, 2006]

Carlock and Fenton [2001] imply that systems engineering is a valid approach for information-intensive organizations when *"seeking to attain competitive advantage through leveraging of information technology resources and systems."* Clarke [2001] argues that the competitive advantage is the result of how these resources and systems are being used: therefore the importance of the human factor should not be neglected. McLaughlin and Nichols [1989] conclude that *"technical solutions should be designed to complement and support an overall management strategy."* Although a technological approach has the potential to reduce the complexities by establishing rules and procedures that provide predictable outcomes, its applicability is confined to strictly computerized environments [Clarke, 2001]. A strategy designed for the management of ocean and coastal information (Figure 6.1) needs to take into consideration the complexity of the system, where technology is but one component. Many documented system failures are caused by building a strategy around technological revolutions without paying attention to the goals and capabilities of the organization [e.g., Taylor-Cunnings, 1998; Alter, 2004; Bahill and Henderson, 2005].

Sage and Lynch [1989] highlight the integration element of the systems approach, noting that *"it is the integration of subsystems and components that give systems their superiority over a set of elements that do not work together without integration."* As discussed in the preceding chapters, the field of ocean and coastal information management is comprised of a number of scattered subsystems and components lacking interoperability or lacking the documentation of interoperability [Hankin et al., 2004]. Miles [1973] describes the systems concept as a *"viewpoint and approach involving the optimization of an overall system as distinct from the piecemeal suboptimization of its* *elements."* Translated to the practice of ocean and coastal management, it requires adopting the concept of systematic information management, based on the Ocean Information Management model presented in Figure 6.1. Extending the previous definitions, Godau [1999] observes that "*it is the relationship that bonds the parts together that gives the system meaning,"* implying that together with subsystems and components, attention needs to be given to the connections among them.

All of these approaches have elements that are directly applicable to the task of forming an information management strategy for the ocean and coastal management community. Some modifications and extensions, however, are necessary to enable the successful application of this approach to the stated problems, including:

- using information technology as a facilitator and not as a starting point or objective;
- considering all resources, including financial, human, and technological;
- building on established professional networks;
- identifying the roles of subsystems and components;
- underscoring the importance of the interfaces among the subsystems and components as they relate to system objectives;
- utilizing expertise from relevant fields (e.g., geomatics, hydrography, ocean mapping) with under the direction of experts familiar with the basic premises of ocean and coastal management as well as information management.

6.2.3 Advantages and disadvantages of applying the systems approach

The primary advantages of applying the systems approach include allowing the ocean and coastal management community to:

- identify long and short term measurable objectives;
- cross-reference long and short term goals;
- determine the time frame for achieving these objectives;
- assess the available and required resources;
- create an interface between high level objectives and local level implementation.

However, as the systems engineering method is tailored to address a problem relevant to a large and complex environment, such as the government, it may encounter the following difficulties:

- complying with all of the requirements revealed during the initial phases may not be feasible due to resource constraints, sunken costs, and vested interests;
- in a large system environment some of the requirements might be inconsistent or in conflict;
- defining and separating the clients and users in a government setting is not as unambiguous as it is in a business environment (Section 6.3.1). Therefore it is recommended to refer to these groups as stakeholders;
- evaluating alternative models is difficult: in short budgetary cycles that are typical to governments, it is often not practical to devise and test prototypes.

Therefore in some instances new evaluation criteria need to be established in place of alternatives;

- following the steps outlined in this approach requires devoting considerable resources prior to launching the system. The benefits of launching an operational system that is needed should be weighed against the short term savings of launching a system in an ad hoc manner;
- the process needs to be able to introduce new initiatives as well as to improve the operation of arrangements already in place. In the later case, the risk of severe interruptions to the existing workflow before the new system is ready to be implemented should be avoided or minimized.

6.3 Information Management Strategy Design

Figure 6.3 illustrates the steps leading toward the design of an ocean and coastal information management strategy. Phase one concluded with the outline of requirements, constraints, and opportunities resulting from the assessment of the regulatory framework, initiatives, and technologies. Phase two focused on articulating a set of requirements and organizing them into four categories. The resulting design criteria reinforced the need for a systems approach for formulating an ocean and coastal information management strategy.

Previous chapters have presented discussions on the problem statement, stakeholder needs, and examples of requirements. Building upon the version introduced by Bahill and Gissing [1998], a systems engineering process (Figure 6.2) will be followed with modifications applicable to an information management strategy in a predominantly government setting, relevant to both the introduction of new initiatives and eventually modifying the existing ones.

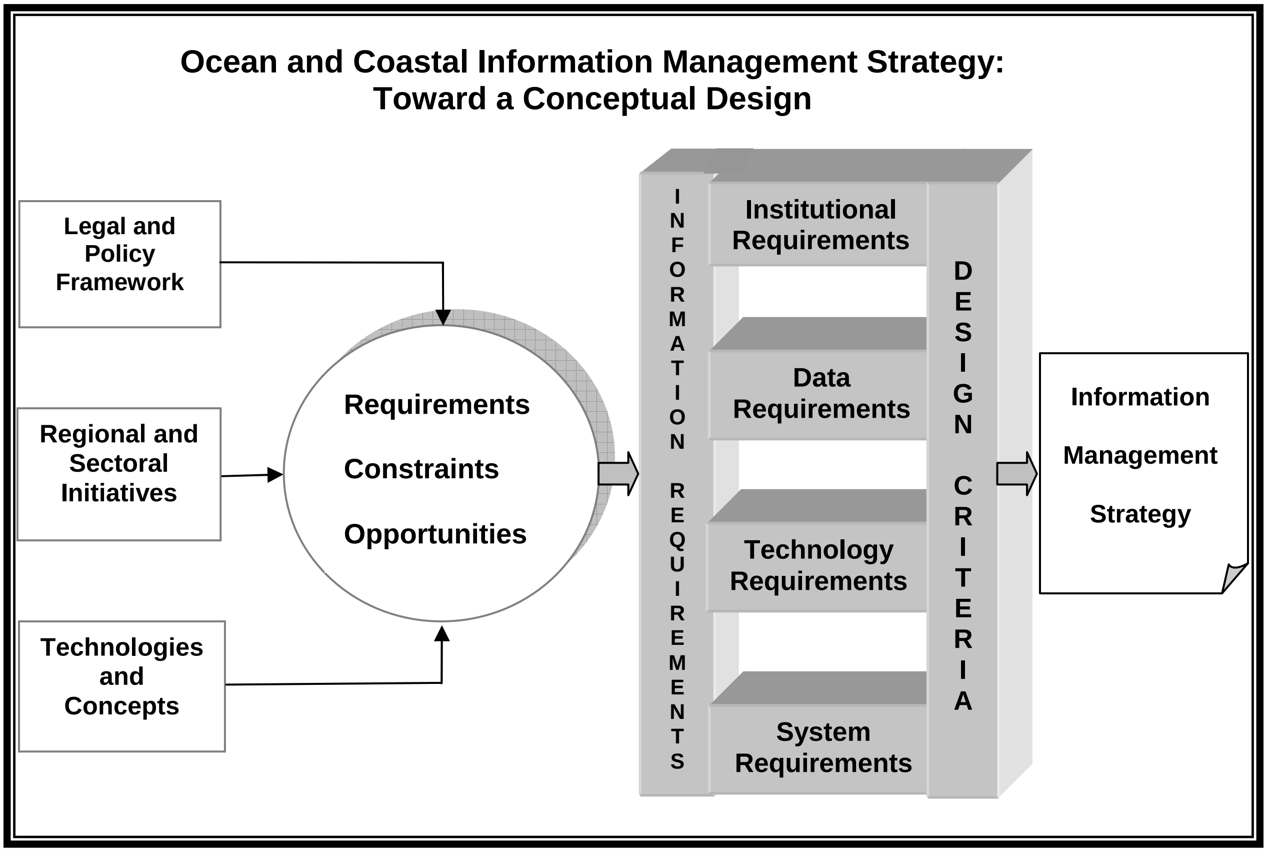


Figure 6.3: Ocean and coastal information management strategy:
Towards a conceptual design

As has been suggested, integration of information from disparate sources is a key objective in the strategy design. Therefore modelling a proposed strategy (Figure 6.2) before establishing the interfaces among subsystems and components would not be appropriate for an ocean and coastal information strategy design. The functions of modelling and integration have been combined to reflect the mission of the proposed information management strategy (Figure 6.4). The module of existing information environment is added to the modified framework, for this research has found that building on the operational ocean and coastal information management initiatives is critical for the new strategy's success. Extensive discussion on launching the system and assessing its performance is beyond the scope of this research and will be touched upon briefly.

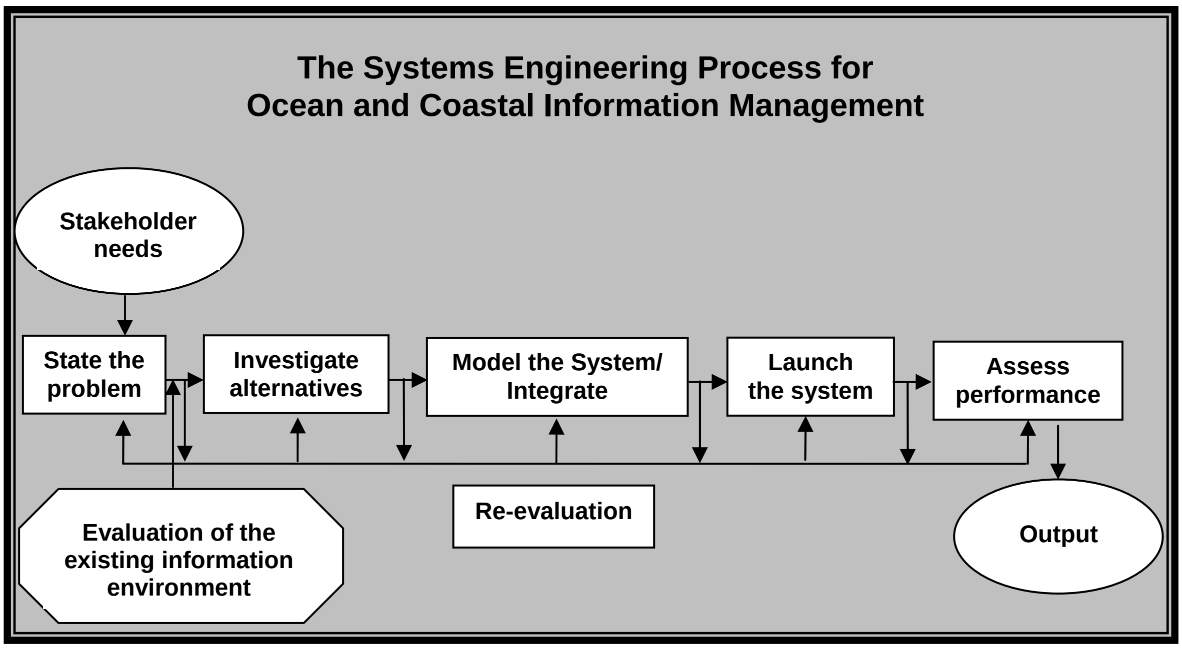


Figure 6.4: System engineering process for ocean and coastal information management [after Bahill and Dean, 2006]

6.3.1 Stakeholders needs

There are a number of stakeholders involved in ocean and coastal management. The largest stakeholder is the government itself, ranging from a number of federal departments to local level authorities. The next group involves stakeholders working closely with government agencies or receiving funding from government agencies. Stakeholders from the private sector rely on government services in a number of ways (e.g., making use of government provided navigational aids, security and rescue capabilities).

The systems engineering process calls for the identification of the users and their requirements. Churchman [1973] asserts that "*government agencies are only intermediaries that are supposed to be serving the ultimate clients.*" In this respect the users of the information system would be government agencies, and their clients would be citizens. However, many clients, informed and aided with technology, now expect increased access to government information and therefore need to be considered as part of the information management strategy. The implications are manifold, including but not limited to:

- identifying stakeholder needs and collecting reliable user requirements for the information system, while taking into consideration that priorities change;
- determining stakeholder access to data and information:
  - since users are viewed as both providers and recipients of data and information, will clients be allowed to exchange data and information as well?
  - since current information access policies often impede data and information sharing practices even among government agencies [Roberts, 1999]. Could clients, who are also users, gain access to data and information in the required format and quality?

In a government setting, a sustainable information management strategy needs to provide a clear definition of user groups and client groups (if different from the user groups) and how to address the differences in the requirements.

To illustrate the application of the systems engineering process, a scenario will be presented throughout Boxes 1 to 7. This scenario will focus on the Placentia Bay area (Figure 4.6) and contains elements from an actual project. However, the deployment of the actual project followed a different path than proposed in this research. The Placentia Bay area is targeted under two pillars (Section 4.4.2) in the OAP [DFO, 2005b]:

- Integrated Oceans Management for Sustainable Development, and
- Ocean Science and Technology.

The OAP [DFO, 2005b] suggests that "*sound science*" needs to be part of the ecosystem-based integrated oceans management along with political and administrative processes. In turn, it is also concluded that the science and technology demonstration project planned for this area *"will be able to … support the modernization of our understanding and management of marine ecosystems"* [DFO, 2005b].

Therefore it is argued that initiatives aimed at this area would benefit from the introduction of an information management strategy. Box 1 presents the first phase of the scenario aimed at illustrating the application of systems engineering principles to the development of an information management initiative at the ocean and coastal sector.

Users of the ocean and coastal areas are stakeholders who need timely access to information affecting safety conditions at sea.

The *Oceans Act* [1996] legislates the [41] *"(a) services for the safe, economical and efficient movement of ships in Canadian waters through the provision of (i) aids to navigation systems and services, (ii) marine communications and traffic management services,* …"

COS [DFO, 2002] states that "*safe and secure navigable waters are critical to the effective functioning of Canada's national economy*."

Box 1: Examples of stakeholder needs

6.3.2 Problem statement and translating the problems into measurable requirements

This stage has been explored at length in the introductory chapter and Chapters 2 and 5. (Figure 2.4: Conventional approach to the management of ocean and coastal resources and spaces gives a detailed demonstration). Clarke [2001] argues that neglecting this phase will likely result in the failure of a suitable strategy development. The following is a summary of problems identified throughout the previous chapters associated with national level ocean and coastal information management:

- The management of ocean and coastal spaces is focused on single species and single activities. The information management practices mirror this fragmentation. As the focus has shifted toward ecosystem-based integrated ocean management, a measurable objective would be to establish a system dedicated to providing access to data and information relevant to the managed area.

- The governance of ocean and coastal spaces and activities is surrounded by complex regulatory and institutional framework. Sutherland [2005] proposed a governance model based on marine boundary information. The present information management strategy is not able to meet the requirements for this improved governance model. Launching a marine cadastre could be considered as a measurable objective addressing this problem.
- National strategy objectives call for integrated management. Without effective coordination strategy, however, addressing this objective would not be possible. An example of measurable objectives is to map the extent of the existing information management arrangements for the subject area.
- A method is needed to resolve resource use conflicts with special reference to transition from traditional coastal economic activities to new economic opportunities. A measurable objective focusing on this problem would be to improve a region's economic performance.

A review of the existing information services available for the ocean and coastal stakeholder community revealed a sporadic, disconnected collection of regional and sectoral initiatives without a capacity for interaction while often duplicating efforts and expenses. These results are in conflict with the desired all-inclusive, systematically organized information framework that would better position the stakeholder community to address present and future challenges. This research proposes a strategy for including information management in future ocean and coastal management initiatives.

Boxes 2 and 3 demonstrate the application of the proposed framework in a smaller scale, based on the second step of the chosen systems engineering approach (see Figure 6.4). Box 3 lists examples of general requirements that need to be transformed into measurable requirements by the expert teams. Due to resource constraints and changing priorities in the overall ocean and coastal management objectives, requirements also need to be prioritized.

1. Placentia Bay area in Newfoundland is underserved by environmental ocean information. In addition to the existing channel marker buoys operated by CHS and Environment Canada's weather forecast, more area specific information is needed to comply with the information requirements of increasing tanker traffic, aquaculture, fishery, and ocean leisure industry.

2. Income from traditional industries is declining. To attract new industries safe navigation is essential. Year around ice free ocean surface and deep ocean channels offer great potential. Information to aid with dealing with fog, water quality issues, and stakeholder conflicts need to be accessible with known quality.

3. Limited economic resources necessitate finding a solution with multiple benefits. Ocean observing buoys have been found to provide real time environmental information as well as long term scientific information critical to assess climate change.

4. It is recognized that *"DFO [have] invested into the development of many data and information systems that are not necessarily able to access one another"* [DFO, 2006b]. In order to realize the benefits of the buoys, the information system must communicate with the information systems of the local stakeholders as well as scientists in other regions.

5. All levels of government, local stakeholders, and scientists need to participate in identifying the requirements and setting up priorities.

6. To what degree is it the federal government's responsibility to collect and manage the information identified in 2.? What are the roles of provincial and local governments and the industry? Resource allocation issues need to be addressed and resolved.

Box 2: Stating the problem: Examples of issues that require attention

1. Data requirements:
    - more accurate, easily accessible, reliable local weather information and sea conditions, e.g., wave height, fog conditions, visibility, wind speed and direction;
    - water temperature, salinity, currents for long term observation and modelling;
    - data and information processing capabilities;
    - metadata.

2. Institutional requirements:
    - coordination between data and information suppliers and users;
    - identifying horizontal and vertical information management linkages (e.g., federal, provincial, and local governmental interests;
    - research institution participation;
    - subcontractors.

3. Technology requirements:
    - providing secure access to authorized users;
    - identifying hardware and software needs.

4. System requirements:
    - sustainability;
    - reliability;
    - ownership and access issues.

Box 3: Examples of requirements assessment

6.3.3 Evaluating the existing information environment

Chapter 4 presented a summary of some of the major information management initiatives relevant to the ocean and coastal sector. The information management strategy introduced in this research intends to utilize the relevant knowledge base and liaisons already established. The past and present cases for sustainable information management initiatives are, however, not nearly reflective of the presumed need for such arrangements. A brief illustration of the complexity is given by Hutchison [2006] citing a report identifying 17 federal level departments with aquaculture related responsibilities.

In another example, Legault and Firth [2006] found that the governance of the Gulf of St. Lawrence is divided and shared by 3 DFO regions, 5 provinces, 4 levels of government, over 20 federal and provincial government departments, and hundreds of non-governmental stakeholders. The cooperation of 18 federal level departments was obtained during the first phase of the OAP [DFO, 2005b; OSTP, 2006]. The ACZISC website [2007] identifies 29 federal level departments and agencies with mandates related to oceans and coasts. In addition to the institutional information holdings, the existing information environment consists of the relevant legislative and policy framework (e.g., the *Copyright Act* [1985], *Access to Information Regulations* [1983], and *Access to Information Act* [1985] [Klinkenberg, 2003; Koontz, 2003; Lopez, 1998]), technological resources, and professional networks. To determine how the various elements of the existing information environment meet the requirements, it is recommended a gap analysis be conducted.

This research has found that the existing information management environment is able to serve some of the information management needs of ocean and coastal stakeholders; however. it is not nearly adequate to support the broader ocean and coastal management objectives (Chapter 2). Box 4 provides examples of institutions with applicable information management interests.

Federal level institutions with mandates in the areas of navigation, weather, ocean, and coastal management include:

- Transport Canada
- Fisheries and Oceans Canada
- Parks Canada
- Environment Canada
- Natural Resources Canada
- Canadian Climate Impacts and Adaptation Research Network
- Atlantic Canada Opportunities Agency
- Canadian Environmental Assessment Agency

Provincial level institutions with applicable mandates include:

- Department of Environment and Conservation
- Department of Fisheries and Aquaculture
- Department of Municipal and Provincial Affairs
- Department of Natural Resources

Information management initiatives include:

- ACZISC
- OSTP

Box 4: Examples of the existing institutional information environment for Placentia Bay

6.3.4 Investigating the alternatives

A number of information management initiatives, mostly focusing on the management of spatial information, have been developed during the last couple of decades. Some of the key initiatives are examined in Chapter 4. In light of the findings, some of the alternatives to applying the systems engineering process for ocean and coastal information management are:

6.3.4.1 Alternative 1: Existing arrangements

The ocean and coastal management community relies on an information management strategy that has shown several weaknesses and produced undesirable outcomes. For example, reliable maps and spatial information on shores and coastlines are difficult to access [Sutherland, 2007; Johnston, 2007], information related to ice conditions is not provided by using the latest available and affordable technologies [Dias, 2005]. There is no mechanism exists to resolve access to data that was collected and processed by one government agency incurring high expenses. Access to the resulting images depends on personal connections and good will (e.g., 3D images of Placentia Bay seafloor and water column).

This alternative would fail to ensure meeting stakeholder needs and requirement. Furthermore, it would enhance the problems stated as oppose to solve them.

6.3.4.2 Alternative 2: Strict top – down planning

The lead agency to administer ocean and coastal spaces and activities is DFO. Appendix 1 contains DFO’s 2006-2007 Program Activity Architecture [DFO, 2006d]. The linkages among the activities are weakly established, and most of them are missing. Hutchison [2006] points out the problems associated with DFO’s conflicting mandates, for example its role as promoting aquaculture while protecting wild fishery.

In a top-down planning approach it would be required that top level decision makers are capable of equally representing the interests of these and other groups. However, the majority of these decisions are carried out at the local level and it can be argued that local level decision makers are better equipped to deal with the problems and do most of the planning. These findings are consistent with the suggestion of Wexelblat and Srinivasan [1999], *"… in an organization with a strong central management but where sub-divisions have considerable autonomy, strict top-down planning is neither feasible nor desirable."*

Another key point is that 18 federal departments and agencies took part in formulating the Oceans Strategy. Although the *Oceans Act* [1996] gives DFO a leading authority, it is imperative that the other 17 departments and agencies contribute to ocean and coastal management. For example, Natural Resources Canada has the capability of mapping the ocean floor, while Environment Canada provides information critical to safe navigation. Emphasis should be on managing cooperation and not on establishing hierarchy.

6.3.4.3 Alternative 3: Strict bottom-up planning

Examining DFO's Program Activity Architecture (Appendix 1) again, it can be concluded that relying on the bottom-up planning would result in the following problems:

- local agencies do not have the resources to locate all the required information;
- there is the possibility of even more overlapping projects, duplication of efforts;
- without aligning to national policies, there would be areas and activities that are underserved or neglected;
- adhering to the integrated management objective cannot be realized.

6.3.4.4 Alternative 4: “Umbrella framework”

In this alternative, the systems engineering approach is followed (Figure 6.2). It is not uncommon to employ systems engineering principles within a systems engineering design, for every system is part of a larger system [Bahill and Dean, 2006]. The process of identifying connections between systems and subsystems can follow the process of identifying connections among the components of subsystems. In this way new projects and initiatives can be designed parallel with other projects and initiatives, for the process of problem solving is the same for every project. Changes are introduced gradually, and as modification to existing arrangements are needed, these can be transformed using the SIMILAR process (Figure 6.2).

Following this approach requires considering each new initiative in detail, comparing it to other alternatives, and aligning it to the stated problems. The identified alternatives should be recorded as it may provide input during the re-evaluation loop. Box 5 applies this phase to the Placentia Bay scenario discussed in the preceding boxes.

1. Foregoing new data collection methods altogether: traditional industries have managed without it. This however runs the risk of new industries, and new sources of income moving away or there will be an increased risk of loss of life and property due to accidents at sea. – **Unacceptable.**

2. Other methods of information collection and management, e.g., remote sensing, ship logs, historical data, and anecdotes: Do not address some of the issues that were initially identified, e.g., water quality issues key to the aquaculture industry. Limited contribution to climate change research. – **Not recommended.**

3. A strictly local planning is not feasible due to regulatory (navigation) and monetary constraints. – **Not feasible.**

4. Establishing an ocean observation system according to national level objectives **and** in response to local needs. For a sustainable system, both of these conditions must be met (although meeting these conditions alone does not guarantee a sustainable system). – **Recommended**.

Box 5: Examples of alternatives

6.3.5 Modelling the system and integration

The purpose of running a model of the chosen alternative [Bahill and Dean, 2006], or if resources permit some or all of the alternatives, is to increase the probability of meeting customer needs as well as reducing cost by:

- refining the requirements;
- exposing bottlenecks;
- uncovering duplication of efforts and fragmented activities.

This research has found that an ocean and coastal information management strategy is best suited to meet the needs of the ocean management and user stakeholder community if it is considered as part of the overall ocean management strategy. To demonstrate the parallel strategy development, a perspective was adopted from the literature on information technology planning sequence and cycle proposed by Wexelblat and Srnivisan [1999], and then applied to information management planning for the ocean and coastal community (Figure 6.5).

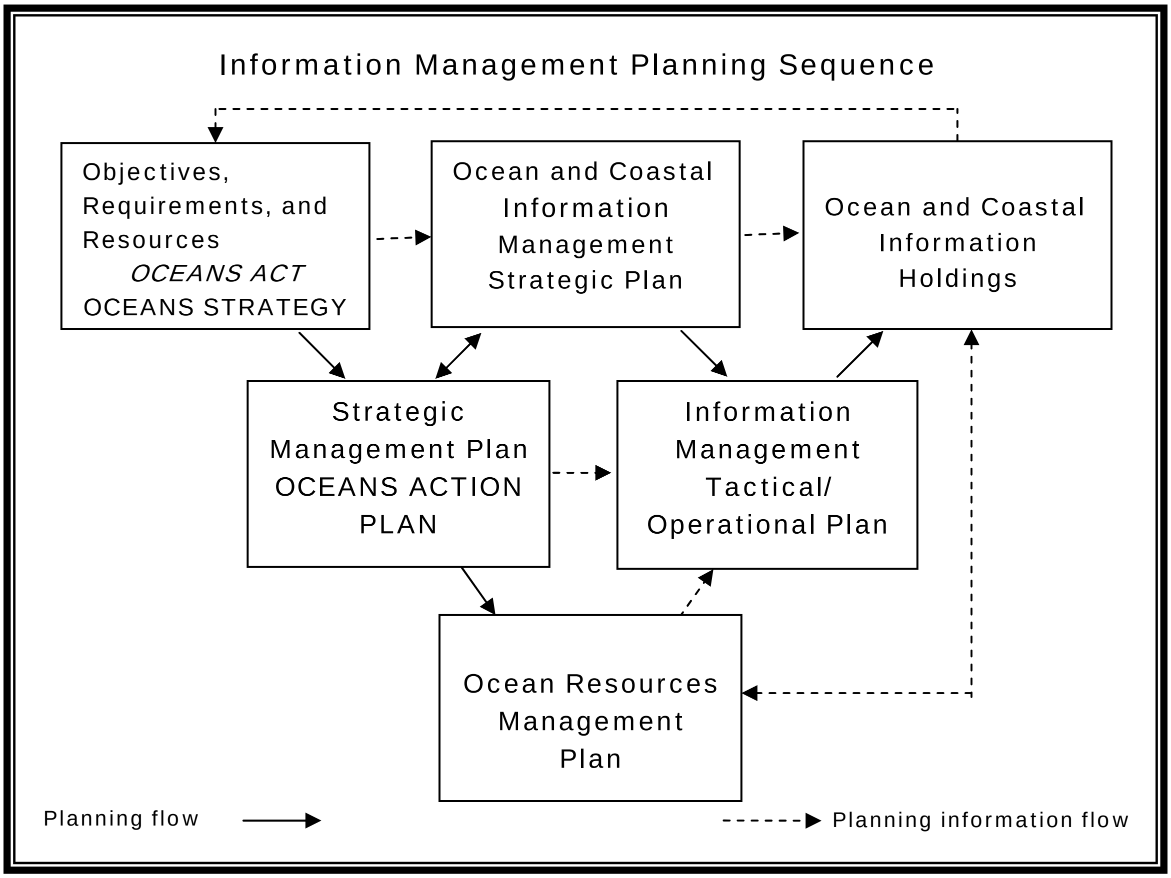


Figure 6.5: Information management planning sequence
(after Wexelblat and Srinivasan, 1999)

Figure 6.5 positions the development of an ocean and coastal information management strategic plan following the development of the overall strategy such at the *Oceans Act*, [1996] and Oceans Strategy [DFO, 2002]. Formulating the information management strategic plan at this point ensures that its elements are incorporated into the development of strategic oceans management plan. Dawes et al. [1999] suggest that in order to increase the value of both of these plans, policies should specifically indicate how information management will contribute to attaining the objectives of the strategic management plan.

It has been recognised that the Oceans Action Plan [DFO, 2005b] did not follow this planning sequence (Section 2.2.7). The sequence model (Figure 6.5), however, is applicable to initiatives of lesser scope as well. Additional support to the planning of regional or sectoral information management strategies is provided in Figure 6.6 focusing on the iterative nature of the design and the linkages between subcomponents.

The tactical plans represent the functional decomposition of information management. At the national and regional levels the primary purpose of information management is to assist policy and decision making. At the departmental level – and it is important to emphasize that DFO is not the only department that needs to be considered here (strategic and tactical plans are used in plural form) – the attention is on the integration and alignment functions of information management.

For example, in the preparation of the OAP, 18 departments at the federal level cooperated [OSTP, 2006]. This is an opportunity where addressing and evaluating the benefits and costs of inter-governmental and inter-regional cooperation and integration need as well as setting priorities to take place. Tables 6.1 and 6.2 summarize some of the anticipated benefits and barriers of integration in a government setting [Landsbergen and Wolken, 2001]. The previously discussed scenario of Placentia Bay efforts to improve weather related ocean information provision stakeholders is continued in Box 6 with the integration process.

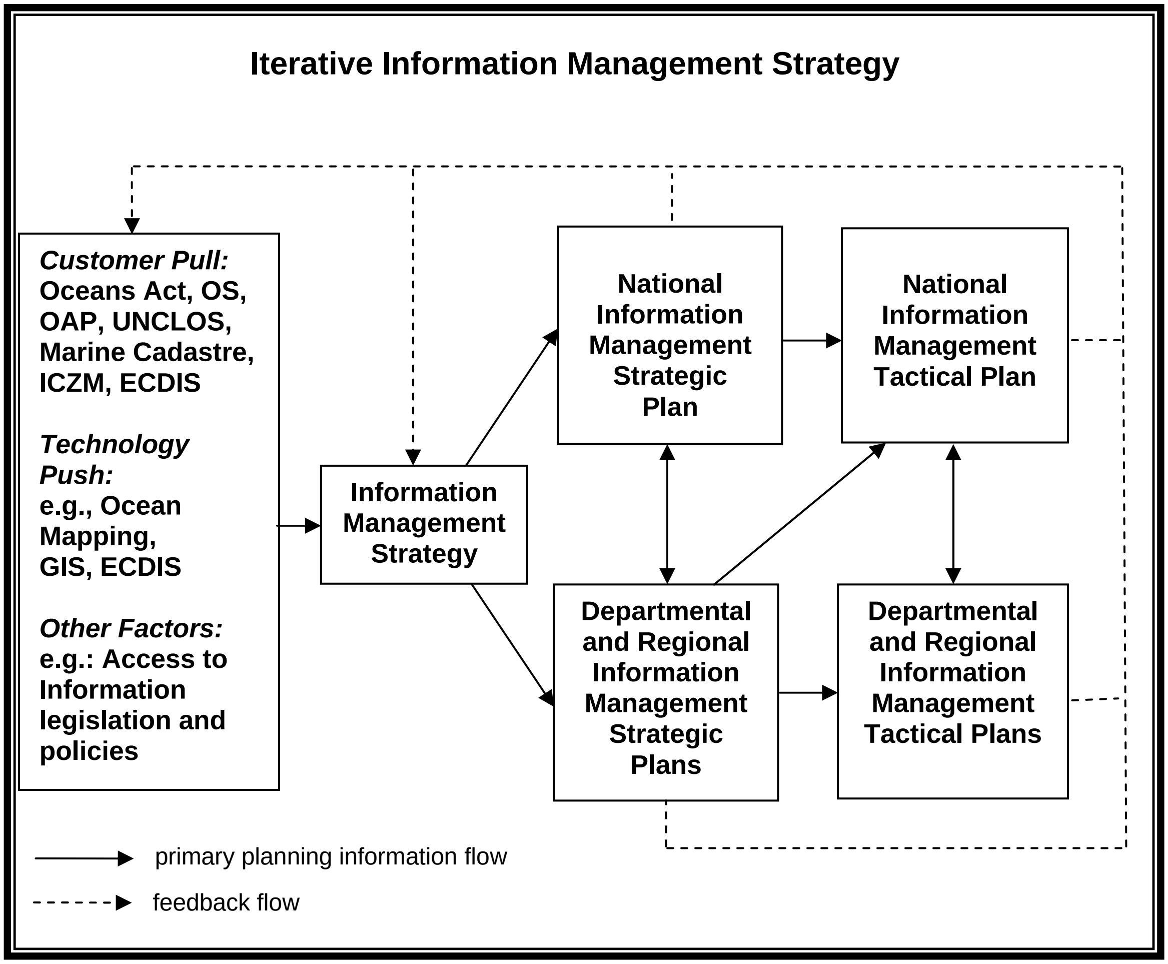


Figure 6.6: Iterative information management strategy
(after Wexelblat and Srinivasan, 1999)

Table 6.1: Benefits of Integration
(after Landsbergen and Wolken, 2001)

Arguments for Integration	**Accomplishments**
Effectiveness	Federal departments' mandates traditionally targeted specific problem areas. (E.g., safe navigation, environmental protection, and economic development.) Current challenges, however, go beyond jurisdictions and require integrated policy and program approaches. Leveraging information resources is key in responding to those challenges. E.g., the *Oceans Act* [1996] gives leading authority and not single authority to the Minister of DFO.
Efficiency	The manipulation and sharing of digital information can be made more economical with appropriate information management policies and strategic targeting of priorities. Transactions costs can be reduced and participation can be increased by developing integrated systems. (E.g., exploiting ocean mapping capabilities for all applicable projects.) (Technological interoperability is crucial but not sufficient.)
Responsiveness	Identifying and addressing problems is largely dependent on having access to the right information at the right time, without the threat of information overload. Integrating systems includes having access to information products generated by other experts.

Table 6.2: Barriers to Integration
(after Landsbergen and Wolken, 2001)

Arguments Against Integration	**Reasons**
Politics	Uncertainty about rights to information legislation. Fear of information misuse and liability. Fear of losing resources and power.
Organizational Issues	Lack of confidence in the quality of information provided by others. Lack of suitable information for specific needs. Little positive experience with interoperable systems. Limited useful inventory of information resources. Information not known to exist is difficult to share
Economics	Limited monetary resources without incentives to share. Building an integrated system costs more in the short term. Cost recovery is a pressing issue.
Technology	Incompatible hardware and software. Technology acquired before mission specified. Different data and information sharing arrangements between institutions.

1. The OAP provides for improved science and technological cooperation in the Placentia Bay area.

2. Strategic information management plan is not available, however developing a tactical information management plan and detailing the alignment and integration function of this plan to the OAP can help ensure a sustainable system.

3. Decision has been made regarding the initial stakeholder group, their data and information needs, the technological aspects of data and information collection and sharing.

4. Collaborative arrangements finalized. E.g., NRCan controls spatial data on seafloor. This data combined with changes in water column temperature, circulation can aid local government agencies overseeing aquaculture development. Environment Canada collects data on surface air temperature and weather patterns that combined with data on sea surface temperature is able to provide more accurate forecast over the Bay area.

5. Alignment requires data and information holders to identify areas of interests that benefit from collaboration.

6. Probable issues of integration:
   - how the information is managed, disseminated, visualized, and updated;
   - how the users access the information
     a. internet – scientists, government in real time;
     b. what are the other methods for those not having access to internet, e.g., fishers on open sea;
   - compatibility with information provided by buoys operated in other regions (for scientific comparisons);
   - reliability, consistency, security, and completeness related issues;
   - insufficient funding to complete the integration process.

Box 6: Modelling the integrated system

6.3.6 Launching the system and assessing the performance

At this phase an actual project or initiative is launched by adhering to the principles laid out in the information management strategy:

- The unit responsible for the design of the project or initiative makes decisions on the use of financial, technological, and human resources;
- Interfaces are being set up between decomposed tasks and agencies with relevant information resources;
- Data and information is being supplied in the agreed format for decision making, performing predetermined agendas;
- Information with metadata is stored for future use.

Assessing the performance of the information management strategy is key to secure funding for the sustainable operation of the system. The issues of accountability and transparency may appear as government slogans of the day, the management, or mismanagement of ocean and coastal resources and activities, however, bear significant consequences. Therefore, information management arrangements that do not meet the objectives and priorities of ocean management need to be re-evaluated. Box 7 concludes the Placentia Bay scenario with a summary of issues concerning system launching and performance assessment.

1. Decision on the number, location, and instrumentation of the buoys has been made.

2. Vendors and subcontractors have been identified.

3. The buoys, hardware and software as well as individuals responsible to manage the collected data and information are deployed.

4. As users access these information resources, it can be evaluated whether the proposed information management system is sufficient to provide improved information regarding the set requirements, such as safer navigation in foggy areas, forecasting fog, changes in water quality.

Box 7: Launching the system and assessing its performance

6.4 Evaluation of Design

Clarke [2001] points out that information technology and information systems do not guarantee a sustainable competitive advantage. Rather, it is the result of the way information is being used, and hence it is more of a human issue than a technological one.

In response to the Government of Canada's efforts of developing an advanced technology infrastructure to support its programs and priorities, Campbell et al. [2002] concludes that

> *[t]he Internet and other technologies are useless, however, if the needed information has not been created, cannot be found or is untrustworthy. It is the information infrastructure on which the achievement of GoC priorities ultimately depends. [Campbell et al., 2002]*

6.4.1 Summary of major design components

Efforts to build the aforementioned information infrastructure so far failed to sufficiently address the needs of the ocean and stakeholder communities. This research has found that prior approaches to the management of ocean and coastal information in the public sector or in publicly funded organizations are no longer able to promote:

- the objectives outlined in legislation and in key national ocean management policies;
- the technologies move beyond traditional boundaries as well;
- that information management is a basic component of integrated coastal management.

In response to these challenges the proposed process for formulating an information management strategy:

- provides a systems engineering approach to establishing an ocean and coastal information management strategic plan, as well as tactical plans; This approach has several advantages over the currently practiced ad hoc establishments of projects and initiatives as highlighted in Section 6.2;
- focuses on integration of information resources in order to increase the economy and quality of decision and policy making processes in all levels;
- harmonizes national level objectives with sectoral, regional, and local objectives;
- allows for upgrades in the system by offering an iterative loop between the subcomponents of the system.

6.4.2 Limitations of the design

Although the proposed information management strategy permits gradual implementation on a project or initiative basis, it is limited in scope to address the following issues:

- it involves changes in organizational culture and politics that often invokes resistance from employees and the organization as a whole;
- it is heavily dependent on long term participation and support of experts;
- significant improvements will not be achieved if only a fraction of the information producing organizations participate.

6.4.3 Implementation plan and potential barriers

6.4.3.1 Implementation as part of an overall ocean strategy development

The outlined process allows for implementation of projects and initiatives at different scales. The most advantageous implementation, however, would occur when it accompanies the development of the follow up to the first phase of the OAP [DFO, 2005b]. As described in Figure 6.5, an information management strategic plan should be developed in parallel to the ocean management strategic plan. A proficient information management strategy would help ensure that organizations tentatively willing to cooperate on ocean and coastal management objectives and would also:

- understand what information resources are needed to address the agreed upon objectives;
- create an inventory of the information holdings relevant to those objectives;
- be willing to share relevant information holdings;

- combine resources to fill the information gaps;
- provide for vertical and horizontal integration of priorities;
- uncover conflicting priorities and facilitate resolutions.

6.4.3.2 Barriers to implementation

The major areas representing a barrier to implement the proposed strategy are converging around the following three topics:

- failure to understand and appreciate the role of information management in the administration of ocean and coastal resources and activities;
- following this design initially takes more time and resources than not considering an information strategy at all, or developing one based on short term regional or sectoral interests. However, on the cost of failed initiatives a working solution could have already been financed;
- the collection and processing of ocean and coastal information is expensive and often involve legal liability as well. There needs to be an understanding of these issues before integration takes place.

This research recognizes that no information management strategy is able to provide a single solution to ocean and coastal management challenges, nor it is the purpose here. Rather its purpose is to add value to the existing networks of ocean and coastal information sharing arrangements that in turn benefit information providers and users.

6.5 A Potential Way Forward

Addressing the present ocean and coastal management priorities requires stepping over traditional roles and responsibilities. The complexity of the relevant institutional and legal framework has been emphasized throughout this thesis. The development of the Oceans Strategy [DFO, 2002] took over five years, engaging federal, provincial, territorial governments, industry, academics, First Nations, and NGOs, as legislated by the *Oceans Act* [1996]. It, however, did not lay the foundation for a permanent coordinating body entrusted with overseeing affairs falling under the mandate of the Oceans Strategy [DFO, 2002].

The *Oceans Act* [1996] requires the Minister of DFO to coordinate with other federal ministers, boards, and agencies in all matters affecting ocean and coastal waters. However, the implementation of an advisory or management body that would extend this coordinating function to include other stakeholders as well is only a recommendation [*Oceans Act*, 1996, Part II. 32].

This research has found that the timely and balanced implementation of modern ocean management objectives would greatly benefit from the establishment of a permanent advisory body, as suggested by the *Oceans Act* [1996]. Members of this advisory body would represent the wide range of disciplines involved in the management of ocean and coastal resources and activities across governments and from non-governmental entities. It would oversee the realization of objectives already identified, and prioritize upcoming integrated management issues in need of attention between the developments of national level policy documents (e.g., the establishment of Marine Protected Areas, developing a Marine Cadastre, addressing environmental concerns).

This advisory body would be assisted by working groups in charge of specific coordination topics. An Information Management Working Group would be responsible for applying the information management strategy developed in this thesis. The priority areas of application would be determined by the advisory body. The Working Group's responsibility starts with assessing the stakeholder needs and harmonizing the various objectives. It is then followed by addressing the subsequent strategy elements.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

> *Information alone will not necessarily lead to better … decisions. Nor is information a substitute for legal, economic, and political measures that must be taken to ensure appropriate development of … resources. But if the information resource is well-managed, it can provide three important advantages: decisions can be made with better knowledge of the consequences and options; a basis for more equitable decisions can be established through informed participation; and the consequences of the decisions can be monitored and enforced. [Nichols, 1992]*

7.1 Introduction

Fishing and ocean transportation have long standing traditions in Canada. At present, concerns on the ocean and coastal environment extend well beyond the problems of sustainable exploitation of living resources and improving the safety at sea. It has been acknowledged that the institutional and legal framework reinforcing the disconnected management of this environment will no longer be able to serve the nation's interests in the sustainable development of its ocean and coastal spaces. With the introduction of *Oceans Act* [1996] the management of ocean resources and activities are legislated to follow the principle of integrated management.

This research examined the information management components of national level decision and policy making in the realms of oceans and coasts. It has been pointed out that past mismanagement of information on ocean and coastal resources negatively affected this environment and the stakeholder community. It has been highlighted that without adjusting the management of ocean and coastal information to the pertinent ocean management objectives increases the probability of unsustainable information management projects while also has a negative effect on meeting the overall objectives.

7.2 Summary of Research Findings

The basis for this research originates from the increased recognition of the value of information in support of integrated approaches to land and inland water management [GeoConnections, 2007]. Information management, however, received limited attention during the formulation of ocean and coastal management strategies and policies and there is only limited reference in the CGDI to the ocean and coastal environment. This research highlighted that:

- ocean and coastal information management does not exist in a vacuum. It is part of a system. In order to map the requirements of information management, the existing information environment needs to be systematically evaluated;
- the complicated governance structure enfolding ocean and coastal management would be better supported by an information management framework that considers the vertical and horizontal connections;
- the new ocean and coastal management objectives are promoted without sufficiently assessing the various requirements, including information requirements. For example, the four key components of the OAP [DFO, 2005b] are all heavily invested in the collection and management of information and theoretically in the sharing of information. Yet, information management is considered as an isolated component;

- addressing ocean and coastal management objectives in timely and efficient manner requires the support of an information management strategy that reflects these objectives (e.g., cooperation, integration, collaboration, communication);
- geomatics technologies and concepts are capable of supporting an ocean and coastal information management framework. In turn, the further development of these technologies and concepts would benefit from resolving institutional problems impeding the practice of integrated ocean and coastal management;
- the existing information management framework supporting the work of the ocean and coastal stakeholder communities are region or sector specific with limited capabilities to support integrated management. The issues of cross-functionality and interoperability were not considered during the design phase of these projects. In addition, continuity is a problem, often leaving stakeholder communities without access to information resources;
- requirements for past end present information management initiatives have been defined narrowly, not allowing to changes that are inherent in the political as well as in the ocean and coastal environment;
- a systems engineering approach, modified to the needs of a large governmental project, is able to address the key requirements for a high level ocean and coastal information management strategy.

7.3 Major Contributions

This research has identified information management as an interconnection among the pillars of the OAP. This will help to ensure that decisions affecting segments of the ocean and coastal environment are not be made without considering other activities and decisions. It will also enable the identification of gaps and overlaps in information collection and management.

Based on the principles of systems engineering, this research provides a conceptual design for an ocean and coastal information management strategy. The proposed strategy:

- commences with cross-referencing requirements with objectives;
- supports the coordination of regional and sectoral initiatives with and within the overall strategy;
- allows for a gradual introduction of the information management strategy, based on the priority of objectives;
- considers all resources, including human, financial, and technological;
- builds on the established professional networks;
- establishes new arrangements for collaboration amongst the stakeholder groups;
- introduces interdepartmental and intergovernmental connections at the early phase of the implementation;
- addresses the interdependencies between system elements;
- views technology as a facilitator, but technology use is not the objective.

7.4 Summary of Recommendations

The following recommendations have been derived from this thesis:

- information management needs to be considered as an interconnection among the pillars of the OAP [DFO, 2005b] and not as an isolated element;

- there is a need to address the management of ocean and coastal information at the national level;
- ocean and coastal information resources need to be managed in a systematic manner;
- an information management strategy needs to be developed;
- the proposed design should be considered for the formulation of an ocean and coastal information management strategy;
- planned information management initiatives should coordinate efforts and harmonize objectives with the national level strategy;
- extensive data and information collection efforts (e.g., delimitation of the outer continental shelf) should be performed in accordance with the adopted information management strategy;
- a permanent advisory body with a mandate to aid top level government officials in coordinating and overseeing ocean management issues should be established;
- within the above advisory body a working group should be instituted with a mandate of information management;
- contributions from and requirements of the geomatics and hydrographic communities need to be considered.

7.5 Recommendations for Future Research

This research proposed a process to design an information management strategy. Further research is needed to refine the steps involved in this design. More specifically:

- finding a strategy to evaluate the existing information environment;

- developing a framework for the documentation of information management projects;
- systematically evaluating past information management initiatives to share lessons learned;
- performing cost/benefit analysis with regards to information management initiatives;
- finding a methodology to improve accountability;
- building a system that monitors the priorities and how these are being met;
- analyzing legislation and policies relevant to information management;
- extending the process for international cooperation.

7.6 Concluding Remarks

There is little debate on the necessity of paying attention to the ocean and coastal environment. The uncertainty lies in the questions of who, when, what, where, how, and how much. The factors influencing the answers to those questions include societal values and traditions, economic objectives, contributions from science, and politics as it attempts to balance the variety of interests.

Information, whether digital or based on traditional ecological knowledge, plays an important role in the making of those decisions. This research offers a systems engineering approach to address critical issues in the management of ocean and coastal information. However, as Sydenham [2003] notes:

> *Systems engineering is not just a set of rules that are slavishly applied but more about a way of thinking and attitude that is an extension of much of conventional engineering design practice. [Syndham, 2003]*

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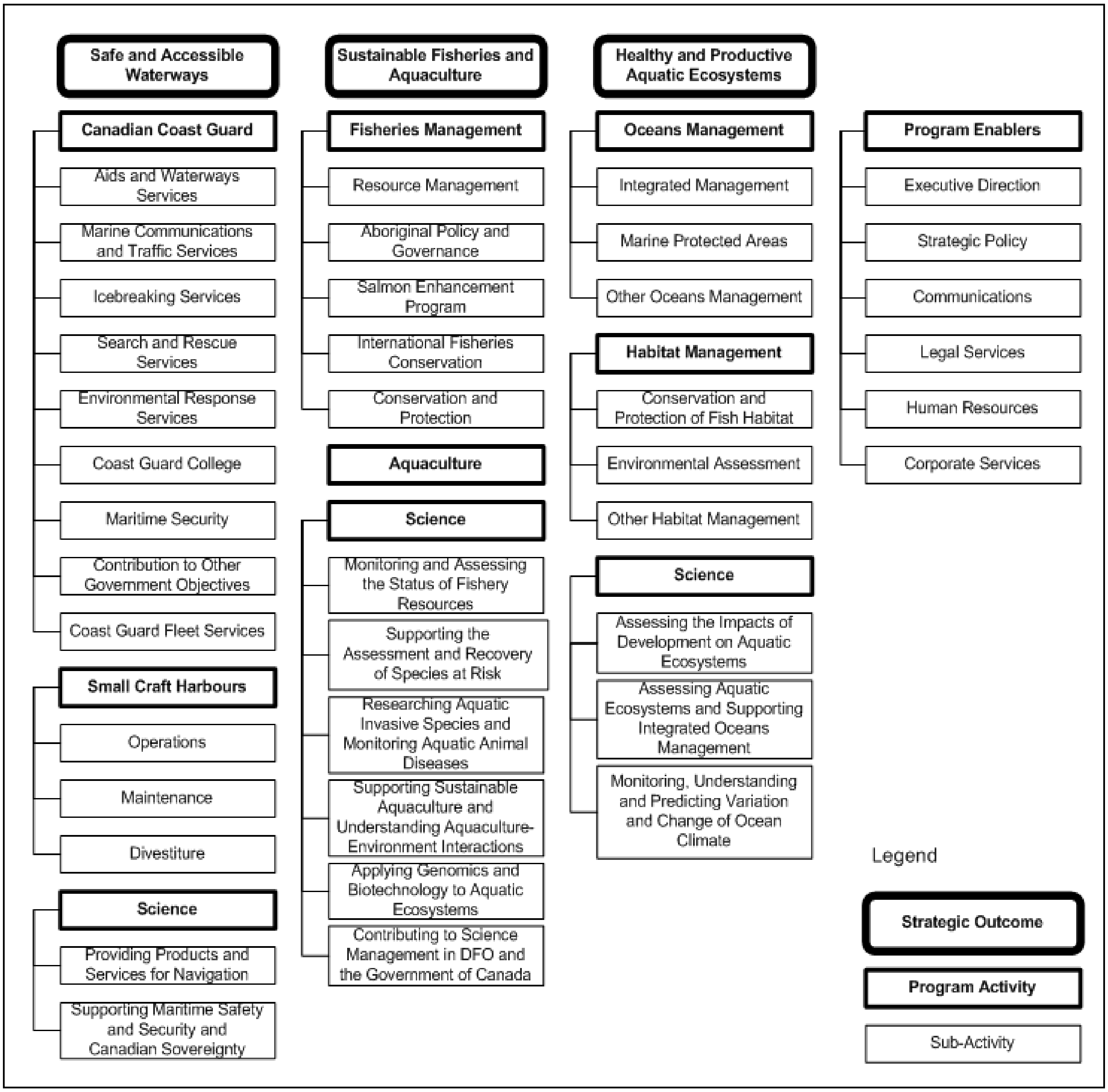
Navigable Waters Protection Act (R.S., 1985, c. N-22)

Oceans Act (1996, c. 31)

APPENDIX I

FISHERIES AND OCEANS CANADA
PROGRAM ACTIVITY ARCHITECTURE



Appendix 1: DFO's Program Activity Architecture[16] [DFO, 2006d]

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[16]http://www.tbs-sct.gc.ca/rpp/0607/fo-po/fo-po-PR_e.asp?printable=True

VITA

Candidate's full name: Katalin Komjathy

Universities attended (with dates and degrees obtained):

Bachelor of Business Administration, University of Miskolc, Miskolc, Hungary, 1991
Master of Business Administration, University of Miskolc, Miskolc, Hungary, 1993
Diploma in Technology Management and Entrepreneurship, University of New Brunswick, Fredericton, NB, Canada, 1995

Publications:

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