TOWARD A 3D MARINE CADASTRE IN SUPPORT OF GOOD OCEAN GOVERNANCE

SAM NG'ANG'A, MICHAEL SUTHERLAND, SARA COCKBURN AND SUE NICHOLS

University of New Brunswick
Department of Geodesy and Geomatics Engineering
Canada

ABSTRACT

Jurisdictions that are contemplating the development of 3D Cadastres cannot afford to ignore the marine environment. Apart from its extreme importance as a resource, the use of the marine environment is volumetric by nature and involves the exercising of rights to the surface, water column, seabed, and subsoil.
This paper proposes a 3D marine cadastre model that can be used to support effective and efficient decision making associated with marine governance. It investigates some of the issues surrounding data modelling and data quality by reviewing the components of a marine cadastre. It concludes by highlighting some of the key issues in developing a marine cadastre.

INTRODUCTION

Coastal and marine areas are ever increasing in value to the welfare of countries, communities and regions. These areas provide natural, social and economic functions that contribute to increased quality of life. The oceans are instrumental in determining climate that beneficially affect all life on Earth [Payoyo, 1994]. Other natural functions include habitat for endangered species, species breeding and resting areas, water treatment, groundwater recharge, and flood attenuation. Some social and economic functions include tourism, commercial and recreational fishing, oil and gas development, and construction [Eckert, 1979; Prescott, 1985; Gomes, 1998].

Additionally these spaces are sources of wealth for humankind by providing [Eckert, 1979; Payoyo, 1994]:

- Sources of food from animals, plants and fish;
- Means of transportation;
- Means of communication (e.g. cables);
- Areas for implanting fixed navigational installations (e.g. lighthouses and piers);
- Areas for the dumping of waste materials;
- Areas for scientific research on Earth's basic physical and biological processes.

Coastal and marine environments are also very susceptible to the negative effects of factors ranging from geology and climate, to human terrestrial, coastal and marine activities. It is almost impossible to control geology and climate, and very difficult to avoid human impact on coastal and marine environments as these environments play such an integral role in the quality of human life. However, the current pattern of the use of coastal and marine spaces is not sustainable and there is an urgent need to make sustainability a fundamental norm in the use of these areas [Miles, 1998]. Good marine governance is therefore vital in the sustainable use of these environments.

OCEAN GOVERNANCE

Governance is about decision-making and steering, and the distribution of knowledge and power within an organized entity (e.g. a jurisdiction, government department etc.) as that entity pursues its goals and objectives [Centre on Governance, 2000; Paquet, 1994; Paquet, 1997; Rosell, 1999]. Accurate, up-to-date, complete and useful information regarding the resources that currently exist, the nature of the environment within which those resources exist, as well as on users' relationships to those resources is therefore always a requirement for effective governance of marine areas. Information on (but not limited to) living and non-living resources, marine contaminants, water quality, shoreline changes, seabed characteristics, bathymetry, spatial extents, and property rights, responsibilities and restrictions all contribute to the sustainable development and good governance of marine environments [Nichols, Monahan and Sutherland, 2000; Nichols and Monahan, 1999].

Information relative to a jurisdiction, regarding the effects of its private and public laws on the marine environment (e.g. spatial extents and their associated rights, responsibilities, and restrictions etc.) would be stored in a marine cadastre. Other relevant information such as regarding the physical and biological natures of the environment (among other things), may be stored in order to give the cadastre a multipurpose function. However, the importance of the marine environment to human existence makes it imperative that information models, used in a marine cadastre to represent a jurisdiction's relationships to the marine environment, represent the 3D reality as closely as possible so as to facilitate the enactment of good governance.

Internationally, the United Nations Convention on Law of the Sea (UNCLOS) has focused nations' interests on offshore resources by providing a legal mechanism whereby a nation can extend its claim as far seaward as the continental shelf. Because it explicitly deals with the rights, restrictions and responsibilities to the physical layers offshore, UNCLOS has created a complex three-dimensional mosaic of private and public interests. When a nation's coastal zone management programs, jurisdiction and administration issues are added on, a clear understanding of the nature and extent of associated spatial boundaries is crucial for cadastre-based decision making purposes.

THE MARINE CADASTRE

The multipurpose cadastre concept has been traditionally designed on a three dimensional spatial unit representing unique, homogeneous, contiguous interests [see McLaughlin, 1975; NRC, 1980; Moyer and Fisher, 1978]. In some senses the cadastre also represented a fourth dimension, time (e.g., time-shared interests). In the oceans where resources and activities, and therefore rights and restrictions, can co-exist in time and space and can move over time and space, the definition of a parcel is even more complex. Furthermore, it may not be the best unit of representation for all interests (such as the overlapping administrative units described above). Until another framework is proven more useful, the cadastral concept may help the initial exploration of ideas.

3D Issues surrounding the marine cadastre

For many years, the Common Law has regarded property rights as a "bundle of sticks" which consists of many strands, each representing a separate right in the property. [Kaiser Aetna v. U.S., 444 U.S. 164, 176 (1979); Black, 1990]. Traditionally, many of the strands or elements of the bundle have been held by a single person or legal entity at any given time. Today complicated zoning regulations, easements, leases, and other use rights complicate the traditional system. Some authors (e.g. Hoogsteden and Robertson, 1998,1999) have advocated the "unbundling" of these property rights in order to clarify today's complicated ownership scheme. Cadastre 2014 (3.2) promotes the division of rights into "legal land objects" as follows: "If a law defines phenomena, rights, or restrictions which are related to a fixed area or point of the surface of the earth, it defines a land object" [Bevin, 1999].

However, defining a land object based on the surface area of land it occupies does not present an accurate view of every right that may exist in that land. A three-dimensional definition of any given right, whether it is surface-based or not, renders a more accurate picture of the land parcel. For example, the right to explore for minerals may have an impact on the surface of the land, but it will also affect a three-dimensional cross-section of the parcel below the land's surface. Policy-makers would no doubt benefit from an understanding of the upper and lower bounds of the exploration rights, and how these may affect the environment or other property entitlements within the same parcel.

Nowhere is the need to unbundle rights in 3D form more pressing than in the world's oceans. This is true for several reasons. First, in a marine environment, individual ownership of a "parcel" is not the norm. Government ownership, public rights, and international law may usurp what private rights do exist in the water column, and may eliminate an individual's "right to exclude others from the property," which is traditionally considered one of the most treasured strands in a property owner's bundle of rights. [Kaiser Aetna v. U.S., 444 U.S. 164, 176 (1979); Loretto v. Teleprompter Manhattan CATV Corp. et al, 458 U.S. 419 (1982)]. This absence of the parcel in a marine setting, and the lack of an individual owner holding many simultaneous rights, makes a bundled portrayal of rights in a marine cadastre ineffective when it comes to decision-making. The distinct portrayal of these rights is essential for informed policy-making.

Secondly, few marine activities can be said to take place on the "surface" of the water. Nearly everything marine actually takes place in a volume of water. Most marine rights, such as aquaculture, mining, fishing, and mooring rights and even navigation have an inherently three-dimensional nature, which makes a two-dimensional definition of these rights legally inadequate. Where and how do these rights overlap? It is entirely possible that any two marine rights intersect not at the surface of the water, but at some point far below, in the water column or even within the seabed. In order to control and regulate marine activity, a more accurate portrayal of rights in the water column is required. This can only be achieved using a three-dimensional representation of these rights.

TECHNICAL ISSUES - BUILDING THE MARINE CADASTRE

In this section, we discuss the technical issues surrounding the construction of a marine cadastre. Referring to several authors [e.g. McLaughlin, 1975; National Research Council, 1980, 1983] the following major cadastre components have been identified:

1. A reference framework consisting of a geodetic network;
2. A series of large scale base maps including the procedures and standards for the production of base maps;
3. A series of registers that record interests in land parcels.
4. A cadastral overlay that delineates all cadastral parcels and displays a unique identifying number.

The geodetic reference framework

The geodetic reference framework permits the spatial referencing of all (land) data to identifiable positions on the earth's surface. It consists of monumented points whose locations have been accurately determined with respect to a mathematical framework. Three design issues need to be resolved in defining this framework [McLaughlin, 1975; National Research Council, 1980, 1983]:

- Type of Mathematical Map Projection to be used as the basis for the Geometric Framework;
- Density (Control Spacing) Requirements;
- Accuracy Requirements.

Information collected about marine spaces can be found in several different projections and datums. This is complicated by the different jurisdictions that marine spaces are divided into. For example, a legal boundary survey of an Aquaculture lease in New Brunswick will be carried out by a New Brunswick Land Surveyor and lease coordinates provided based on double stereographic projection and NAD83 datum. Oil and gas leases are on the other hand surveyed by Canada Lands Surveyors and coordinates provided based on Universal Transverse Mercator (UTM) projection and NAD 27 datum.

Conversion from one datum to another is generally a process that introduces error into the coordinates that are finally derived. When transforming directly from geodetic coordinates then the Molodensky datum transformation method is used. These datum transformation formulas produce results of sufficient accuracy only when local rather than mean datum shifts are available [Elema and Jong, 1999, Vanicek and Krakiwsky, 1982]. When converting from Cartesian coordinates, the Helmert transformation is used. This 7-parameter transformation assumes that the geodetic system has consistent scale and orientation throughout the network, which is not neccesarily the case. In most cases, the rotations and scale factor are considered zero, which leaves the three translations, reducing the Helmert transformation to a 3-parameter transformation [Elema and Jong, 1999].

Issues surrounding the accuracy requirements of the geodetic reference framework for marine applications are still being resolved. The GPS network is being used for marine positioning because it is deemed homogenous i.e. distances from the satellites (which are the reference stations) are considered to be the same for all points on the earth [Elema and Jong, 1999]. There are several different GPS positioning modes and accuracies that are currently being used to addres

The vertical reference framework

The vertical datum (or chart datum) used in nautical charts is of particular importance to the definition of geodetic height coordinates. Different definitions of chart datum's exist e.g. mean lower low water, mean low water, low water, lowest astronomical tide mean low water spring [Monahan and Nichols, 1999]. In general, the chart datum is usually based on some kind of a low water level. Perhaps nowhere in the world is this more apparent than in the Bay of Fundy in Atlantic Canada, which is said to have the greatest range between high and low water in the world and where many parts of the coastline are tidal flats. The difference between high and low water mark can be as much as 300 or 400 metres. The discrepancies may be significant when merging data sets that variously refer to "ordinary high water", "lowest low water astronomic tide", "mean water level", or no datum at all. Accentuating the problem is the fact that most mapped shorelines are not tide level-controlled, but an approximation from aerial photography or other surveys many years ago [Nichols et al, 1997, 2000, 2001].

The International Hydrographic Organisation (IHO) and the International Maritime Organisation (IMO) advocated in the 1980's that states should consider adopting the lowest astronomical tides as the chart datum [Elema and Jong, 1999, Groten, 1999]. This datum is obtained by obtaining tidal observation over a period of 18.4 years. The implication for any country that does not use this datum is that such a period will be needed to establish an acceptable datum in case of international boundary dispute resolution.

Heights obtained using GPS are related to the WGS 84 ellipsoid and do not necessarily have a geometrical meaning. Since one is interested in heights relative to the mean sea level then the difference between the ellipsoid and the reference surface (in our case the chart datum) is needed at every GPS point. It is assumed that the geoid corresponds to the mean sea level. In actual fact, the mean sea level coincides with the geoid, superimposed by the sea surface topography [Vanicek and Krakiwsky, 1982].

A Series of large scale base maps

Several authors [McLaughlin, 1975; National Research Council, 1980, 1983] have identified three primary issues that need to be considered when designing the base map component of a cadastre:

- data sources;
- data content; and,
- accuracy of the data.

These three issues depend on the purpose for which the base map is being assembled. For example, in the case of constructing a base map for the purpose of preparing a claim under the United Nations Convention on Law of the Sea (UNCLOS), several authors [e.g. Monahan et al., 1999, van de Poll et al., 1999] have indicated that navigation data, raw water depth (bathymetric data), field values of magnetic fields, calculated water depths, free-air gravity anomaly and magnetic anomaly should make up the data content of the base map.

The proposed data source for the base map is the International Hydrographic Office / Intergovernmental Oceanographic Commision (IHO/IOC) mapping information available as the General Bathymetric Chart of the Oceans (GEBCO). The accuracy of the data is as follows: 16 Mercator sheets cover the world from 72N to 72S, on a scale of 1:10 million at the equator, and two polar stereographic sheets cover the polar regions to 64N and 64S respectively, on a scale of 1:6 million [British Oceanographic Data Centre, 2001].

A series of registers that record interests

The register of interests in a marine cadastre will be used to describe interests in parcels once they are identified. The information is focussed on meeting specific needs of the users of the records, who in this case are the MPA users. An inventory of tenures that exist in the marine environment is important. At the same time, formal or informal laws that are the basis of these tenures need to be identified and their effect qualified and visualised.

The property rights model

Traditionally, relational database models, tying several tables together through table keys, have been used to catalogue the interests that exist in a marine cadastre. Newer data models such as the Object Oriented (OO) modelling concept are now being used.

OO modelling depends on classes, objects and relationships as the fundamental concepts. In marine cadastre modelling, we assume that there exists a marine parcel (or an alternative marine object) that is the focus of data collection, storage, and retrieval. Since queries will be based on the ability to identify what rights exist within the marine object, then it is imperative that all rights and interests that exist in the marine environment are captured.

It is possible to group interests according to living and non-living resources in the marine environment. However, this is contingent on a standard definition of what constitutes a resource. New technologies now allow us to not only see the water column (e.g., schools of fish) but also the seabed surface and the geological structure beneath the surface. Technologies for sidescan sonar, single beam echo-sounders, multibeam sonar and seismic surveys provide the tools for systematically exploring and describing ocean frontiers more clearly. In conjunction with sophisticated visualization software, the imagery allows users to view the living and non-living resources in the coastal and offshore areas. It is not difficult to see that these same technologies can be used to view the complexity of the associated rights, responsibilities and restrictions in the coastal and offshore areas.
Interests might be grouped according to the physical layers that make up the marine environment. If this is the case, then there needs to be an explicit regime that defines what interests exist on the water surface, water column, seabed, and subsurface. This might entail further grouping of these "physical interests" into 2 broad categories:

- **Focussing on the physical layers**: Nearly everything marine actually takes place in a *volume* of water. Most marine rights, such as aquaculture, mining, fishing, and mooring rights and even navigation have an inherently three-dimensional nature, which makes a two-dimensional definition of these rights legally inadequate. Where and how do these rights overlap? It is entirely possible that any two marine rights intersect not at the surface of the water, but at some point far below, in the water column or even within the seabed.
- **Focussing on the type of interests**: As has been discussed in a previous section, individual ownership of a "parcel" is not the norm in a marine environment. Other interests may usurp what private rights do exist in the marine parcel, and may eliminate an individual's "right to exclude others from the property."

We can be able to take a first attempt at visualising a data model for the marine cadastre based on the foregoing discussion. The marine parcel object:

1. **Is made up of 4 physical layers; water surface, water column, seabed and sub surface.** In OO terminology, this represents a whole-part relationship between the marine object and its components;
2. **Has living and non-living resources.** This represents a parent-child relationship between the marine object and the components that it might(or might not have);
3. **Has certain interests associated with it.** This represents another parent-child relationship between the marine object and the classes of interests;
   - Interests can be broadly classified as rights, restrictions or responsibilities that individuals have with respect to a marine object. This describes a parent-child relationship between the marine object and the interests;
   - These interests can further be categorised according to the type of laws that recognise their existence; formal, informal, customary, federal, provincial, municipal etc. This indicates a dependency relationship between the interests and the laws and a parent-child relationship between the law and the types of law.

Figure 1 shows the data model of the marine parcel object.

Creation and maintenance of cadastral overlays

The marine cadastral overlay will delimit the status of marine property ownership. The individual building block for the overlay is the marine cadastral parcel, an unambiguously defined unit of land within which unique property interests are recognised [National Research Council, 1980, 1983; McLaughlin, 1975; Larsson, 1991].

The process of creating a cadastral overlay

The National Research Council [1980] observes that a cadastral surveying system plays an important role in creating and maintaining a cadastral overlay. This system governs the creation and mutation of boundaries and is usually defined in one or more surveying and boundary statutes. These statutes govern most boundary surveys and usually specify the following information [National Research Council, 1980]:

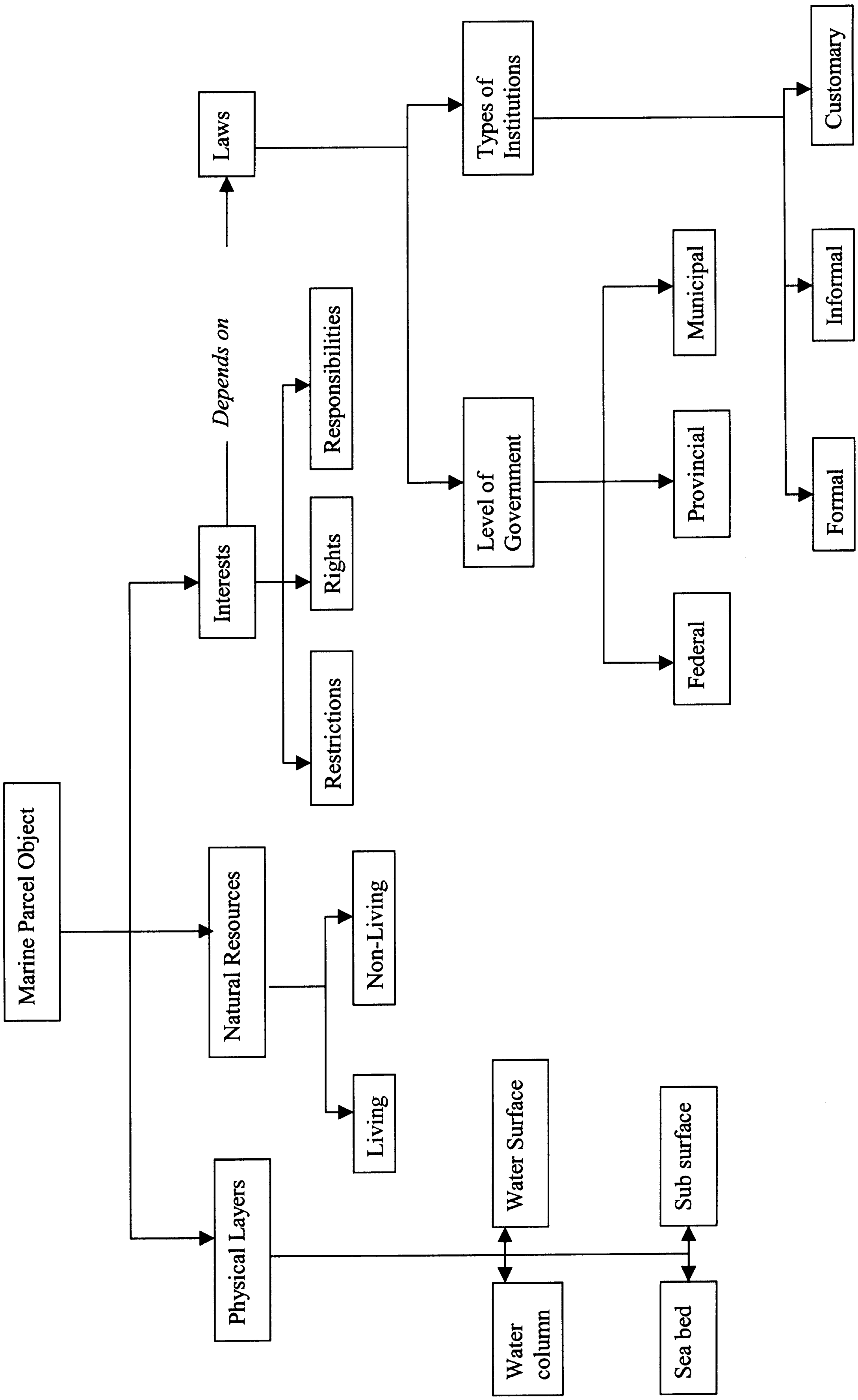

Figure 1: The marine parcel attribute data model.

- The geometric reference framework to which all information must be referred;
- The type and weighting of information that must be provided in evidence of the creation and mutation of a boundary;
- The standards of survey practice that must be met in providing this information;
- The authority vested in public survey administrator (e.g. the Director of Surveys) to examine and register the proposed boundary mutation;
- The right of judicial appeal from administrative decisions.

Several offshore boundary delineation schemes (or cadastral survey systems) exist. Oil and Gas exploration leases in Canada provide examples of a resource-based boundary delineation approach. The *Canada Oil and Gas Land Regulations* provide for the division of offshore Canada Lands (up to the Exclusive Economic zone) into grid areas. Each grid area is then divided into sections and then further subdivided into units. In addition to this general framework, survey plans must be submitted to the Surveyor General indicating:

- Position, direction and length of the boundaries of grid areas;
- Position of existing wells;
- Nature and position of monuments;
- Road allowances or rights of way.

Clearly, this boundary delineation scheme is only specific to Oil and Gas. Information about the rights to lay cables and pipelines might not be available. In fact, the licenses and leases are not specific in describing how these newly allocated rights affect existing rights such as navigation and fishing. Creation of a cadastral overlay using this information will lead to gaps (indicating areas where licenses and leases have not been allocated).

KEY ISSUES IN DEVELOPMENT OF A MARINE CADASTRE

In this section we highlight some of the important issues that need to be addressed in the development of a marine cadastre.

Governance issues

a) **Boundaries as a governance solution or a governance problem?** Surveyors generally approach the governance issue from the perspective that "good boundaries make good neighbours" and that clarity of boundaries will improve governance. Legal specialists on the other hand argue that the law only eliminates ambiguities when an issue occurs, i.e., boundary delimitation should be dispute-driven. Social scientists add to the complexity by arguing that boundaries of ocean spaces do not need to be drawn and instead the focus should be on co-management of resources.

b) **Multi-organizational and multi-disciplinary approaches required:** There are many stakeholders and a main function of governance is to improve the communication and collaboration among them. New models need to be designed for ensuring that planning and decision-making processes are inclusive. This is a radical shift from the department-mandate-driven and single-discipline-oriented approaches that are traditional in government and in research.

Legal issues

a) **Better understanding the distinctions in law between jurisdiction, administration, and ownership:** In non-legal discussions, the distinctions tend to be blurred. However, in the oceans the distinction is critical to understanding the complexity of government authorities with respect to control, ownership, and use of marine spaces and specific resources. There is a need to ensure exactly what kinds of rights and restrictions are being reflected in the cadastre. In Canada, for example, we began by thinking of single administrative boundaries for the provinces. As the research evolved we realize it is necessary to try to represent multiple administrative boundaries in the cadastre for various resources, areas, and uses.

Technical issues

a) **Need for standards:** A discussion on some of the technical issues surrounding the building of a marine cadastre has been presented. It is important to note that a broad range of standards is required to improve the accessibility and use of marine data. These standards included those for determining the geodetic reference framework, the base map, and the cadastral surveying system.

b) **Recognizing the limitations of technology**: A marine cadastre is not a technology solution. In fact the technology, although enabling us to visualize some of the issues more clearly, may inhibit our understanding as well. There are issues such as: a) loss of information through generalization; b) assumptions that a set of data must be accurate or complete because it is in digital format; c) a tendency to be overwhelmed by the colourful images rather than paying attention to the actual problem. What we need to do is use the technologies more wisely to better communicate the information we have (and its limitations) to a broader range of people.

ACKNOWLEDGEMENTS
The authors would like to gratefully acknowledge the Geomatics for Informed Decisions (GEOIDE) network for their financial support.

REFERENCES

Bevin, T. (1999): Cadastre 2014 Reforms in New Zealand. In the Coastal Cadastre: Onland, Offshore. Proceedings from the New Zealand Institute of Surveyors & FIG Commission VII Conference, Waitangi, New Zealand, p. 99-111.
Black, H.C. (1990): Black's Law Dictionary, 6th Edition (6th Edition by The Publisher's Editorial Staff – Coauthors J. R. Nolan and J. M. Nolan-Haley, Contributing Authors M.J. Connolly, S.C. Hicks, M.N. Alibrandi), West Publishing Company, St. Paul Minnesota.
Borissova, I., P.A. Symonds, R. Gallagher, B.C. Cotton and G. Hill (1999): "A Set of Integrated Tools based on Arcview for Defining the Outer Limit of Australia's Extended Continental Shelf". In Proceedings of the International Conference on Technical Aspects of Maritime Boundary Delineation and Delimitation, International Hydrographic Bureau, Monaco, September 8-9, pp 151-163.
British Oceanographic Data Centre-BODC (2001): The GEBCO Digital Data Atlas. http://www.bodc.ac.uk/frames/index2.html?/projects/gebco/index.html&2, accessed, September 2001.
Centre on Governance (2000): "What is governance?" Centre on Governance, University of Ottawa. http://www.governance.uottawa.ca/english/overview/o_definition, accessed November 2000.
Eckert, R. D. (1979): The Enclosure of Ocean Resources: Economics and the Law of the Sea. Hoover Institution Press, Stanford University, Stanford, California.
Elema, I. and K., de Jong (1999): The Law of the Sea in the North Sea. In Proceedings of the International Conference on Technical Aspects of Maritime Boundary Delineation and Delimitation, International Hydrographic Bureau, Monaco, September 8-9, pp 151-163.
Gomes, G. (1998): "The review of the NOAA National Coastal Zone Management Programs for Estuary and Coastal Wetland Protection." http://www.oceansconservation.com/iczm/gomes.htm. Accessed September 2000.
Groten, E. (1999): "Coastal Boundaries and Vertical Datums." In Proceedings of the International Conference on Technical Aspects of Maritime Boundary Delineation and Delimitation, International Hydrographic Bureau, Monaco, September 8-9, pp 103-109.

Holmes, C.(1999): The Relevance of MultiBeam Data in the Coastal Cadastre. In the Coastal Cadastre: Onland, Offshore. Proceedings from the New Zealand Institute of Surveyors & FIG Commission VII Conference, Waitangi, New Zealand, p. 45-52.
Hoogsteden, C.C., and W.A. Robertson (1998): On Land - Off Shore: Strategic Issues in Building a Seamless Cadastre for New Zealand. XXI International Congress Proceedings: Developing the Profession in a Developing World, International Federation of Surveyors, Commission 7, Cadastre and Land Management, p. 32-48, Brighton.
Hoogsteden, C.C., and W.A. Robertson (1999): Re-engineeering New Zealand's Cadastre: Strategic Issues in Building an Onland-Offshore Cadastre. GIM international,Vol. 13, No. 6, p. 7-9, June 1999.
Kaiser Aetna v. United States, 444 U.S. 164 (1979): Retrieved on September 14, 2001 from the FindLaw website on the World Wide Web.
http://caselaw.lp.findlaw.com/scripts/getcase.pl?navby=case&court=US&vol=444&invol=164
Loretto v. Teleprompter Manhattan CATV Corp., 458 U.S. 419 (1982): Fundamentals of Modern Real Property Law, Third Edition. Rabin, E.H., and R.R. Kwall. The Foundation Press, Inc., Westbury, New York. 1992.
McLaughlin, J.D.(1975): The Nature, Function and Design Concepts of Multipurpose Cadastres. Unpublished Ph.D. Dissertation in Civil and Environmental Engineering, Madison: University of Wisconsin,
Miles, E. L. (1998): "The concept of ocean governance: Evolution towards the 21st century and the principle of sustainable ocean use. Paper prepared for for SEAPOL workshop on ocean governance and system compliance in the Asia-Pacific context. Rayong, Thailand, 1997.
Monahan, D. and S., Nichols (1999): Fuzzy Boundaries in a Sea of Uncertainty: Canada's Offshore Boundaries. In The Coastal Cadastre - Onland, Offshore - Proceedings of the New Zealand Institute of Surveyors Annual Meeting, Bay of Islands, NZ, Oct 9-15, pp. 33-43.
Moyer, D.D. and K.P. Fisher (1973): Land Parcel Identifiers for Information Systems. Chicago: American Bar Association.
National Research Council (1980): Need for a Multipurpose Cadastre. Panel on a Multipurpose Cadastre, National Academy Press, Washington, D.C.
Nichols, S., D. Monahan and M. D. Sutherland (2000): "Good Governance of Canada's Offshore and Coastal Zone: Towards and understanding of the Maritime Boundary Issues." In *Geomatica*, Vol. 54, No. 4, pp. 415-424.
Nichols, S., I. Edwards, J. Dobbin, K. Komjathy, and S. Hanham (1997): Real Property Issues in the Marine Acquaculture Industry in New Brunswick. Fredericton, NB: Dept. of Fisheries and Acquaculture, 77 pp.
Nichols, S., M. Sutherland, S. Ng'ang'a, and D. Monahan (2001): Report on the proceedings of the Association of Canadian Land Surveyors Stakeholders Workshop on Canada Lands Offshore. Published by the Association of Canada Lands Surveyors.

Paquet, G. (1994): "Reinventing Governance." In Opinion Canada, Vol. 2, No. 2, April.

Paquet, G. (1997): "Alternative service delivery: Transforming the practices of governance." In *Alternative Service Delivery: Sharing governance in Canada.* Eds. Ford, R. and D. Zussman, KPMG, The Institute of Public Administration, University of Ottawa Libraries.

Payoyo, P. B. (1994): "Editor's introduction." In Ocean Governance: Sustainable development of the Seas. Ed. Payoyo, United Nations University Press, Tokyo - New York - Paris.

Prescott, J. R. V. (1985): The Maritime Political Boundaries of the World. Methuen, London - New York.

Rosell, S. A. (1999): Renewing Governance: Governing by learning in the information age. Oxford University Press.

Van de Poll, R., M. Halim,M. D'arcy, J. Harding,R. Macnab, and D. Monahan (1999): Integrated Procedures for Determining the Outer Limit of the Juridical Continental Shelf Beyond 2000 Nautical Miles. In Proceedings of the International Conference on Technical Aspects of Maritime Boundary Delineation and Delimitation, International Hydrographic Bureau, Monaco, September 8-9, pp 235-246.

Vanicek, P. and E.J. Krakiwsky (1982): Geodesy: The Concepts. North Holland Publishing Company, Amsterdam.

Wilkins, K., M. Sutherland, S. Nichols and G. Paquet (2001): Ocean Governance: Geomatics as a Technology of Collaboration. Presented at GEOIDE conference, 2001, Fredericton, NB, Canada, June 21-22.

LEGISLATION CITED

Canada Oil and Gas Land Regulations, C.R.C c 1518

ABOUT THE AUTHORS

Sam Ng'ang'a is a Ph.D. student in the Department of Geodesy and Geomatics Engineering of the University of New Brunswick and is developing software tools for visualizing 3D marine boundary information for coastal and ocean management.

Michael Sutherland is a Ph.D. student and Senior Research Assistant in Land Administration and Cadastral Systems in the Department of Geodesy and Geomatics Engineering of the University of New Brunswick and is developing global models regarding the need for marine boundary information in coastal and ocean governance.

Sara Cockburn has a law degree from Tulane Law school and is currently an M.Eng student in the Department of Geodesy and Geomatics Engineering of the University of New Brunswick. Her current research interests include UNCLOS, ocean boundaries and coastal zone management.

Dr. Sue Nichols is a professor in the Department of Geodesy and Geomatics Engineering concerned with property rights issues on land and at sea. She has also been involved in research on national spatial data infrastructures in the US and Canada since 1990. Department of Geodesy and Geomatics Engineering.

CONTACT ADDRESS

Name:	Sam Ng'ang'a
Name:	Michael Sutherland
Name:	Sara Cockburn
Name:	Sue Nichols
Institution	Department of Geodesy and Geomatics Engineering University of New Brunswick
Office address	P.O. Box 4400 Fredericton, NB, E3B 5A3 Canada
Telephone:	+1-506-447-3259
Telephone:	+1-506-451-6812
Telephone:	+1-506-451-6812
Telephone:	+1-506-453-5141
E-mail:	nganga@unb.ca
E-mail:	msutherl@unb.ca
E-mail:	t8wn@unb.ca
E-mail:	nichols@unb.ca