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An Integrated GIS for Shoreline Monitoring and Management

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Abstract: A coastal Geographic Information System (GIS) has been developed to support modernized coastal shoreline monitoring and management. The data in the study are diverse, including spatial data, time series data, socio-economic data, and aerial photographs. The spatial data are coastal shoreline locations, topographic data, parcel data, buoy locations and others. Time series data, such as wind and wave observations, were integrated with spatial data through the location of sensors. The GIS contains three subsystems: coastal shoreline erosion monitoring, coastal engineering management, and coastal data inventory. The results and experience gained from this are beneficial for similar application in other geographic area.

Keywords: GIS, coastal erosion, shoreline management

Introduction

Coastal zone for the aim of this paper, shall mean the area, on both side of the actual land water interface, where both territorial as well as marine environmental influences each other. In addition, interaction between various natural processes and human activity are important factors in the coastal area. The coastal zone shows high population density with large number of urban conglomeration and in consequence, a fast population growth. Also as a consequence, coastal zone are characterised by a high concentration of economic and, in particular, industrial activities with all the resulting problems of resource consumption, waste management and technological risk. On coastal water side, fisheries and aquaculture exploits a generally highly productive system. Very specific, and valuable as well as vulnerable, typical coastal ecosystems include estuaries, salt marshes, mangroves, coral reefs etc. Offshore activities such as oil and gas, as well as mining, are additional forms of exploitation of the coastal zone. In addition, the coastal zone is also the recipient of all water borne waste streams, primarily attributable to agriculture, its fertilizers and agrochemical, and all treated and untreated waste water the hinter land produce in their respective catchment. They all drained in to the coastal waters. Therefore, there is an urgent need for intelligent management of coastal zone.

GIS Technology and coastal management

Determining the accurate length of the coastline is important for such coastal zone management application as shoreline classification, monitoring erosion, mapping biological resources, habitat assessment and for the planning and response to nature (e.g. storm surges) and man made disasters (e.g. oil spills). Coastal zone management, by definition, is spatial management. Geo referenced spatial data is map data in a digital form which mean that each of the earth's features that are stored as spatial data has a unique geographic reference such as latitude and longitude. The increasing use of spatial data and GIS (Geographic Information System) by organizations and researchers is a valuable tool to help solve the planning and management issues in the coastal zone. There are many different Geographic Information Systems in use today and they tend to differ in certain aspects such as "how they link geographic location with information about those locations, the accuracy with which they specify geographic location, the level of analysis they perform and the way they present information as graphic drawing".

What is GIS?

At this point it is useful to consider exactly what Geographical Information System is (and what it is not). The definition of GIS are numerous but a useful one is that it is a data base system in which most of the data are spatially indexed and upon which a set of procedures operates in order to answer queries about the spatial entities in the data base. Thus it is an information system whose relation basis is co-ordinate data of the form X, Y, Z, a concept familiar to the surveyor. The function of an information system is to improve a user's ability to make decision in research, planning and management; a GIS is therefore essentially a management tool.

Why GIS for coastal zone management?

Since the coast all around the world are fast developing and firm management policies have to be established. However, for any management of the shore to be effective, it is necessary for the policies to be based on informed decision-making. This in turn requires ready access to appropriate, reliable and timely data and information, in suitable form for the task at hand. Since much of this information and data is likely to have spatial component, one branch of information technology with apparent potential for contributing significantly to coastal management in a number of ways. These include:

- ☑ The ability to handle much larger databases and to integrate and synthesise data from a much wider range of relevant criteria than might be achieved by manual methods. This in turn means that more balanced and coordinated management strategies may be developed for considerably longer lengths of coast.

- ☑ GIS encourages the development and use of standards for coastal data definition, collection and storage, which promotes compatibility of data and processing techniques between projects and departments, as well as ensuring consistency of approach at any one site over time.

- ☑ The use of a shared database (especially if the access is provided via a data network) also facilitates the updating of records, and the provision of a common set of data to the many different departments or offices that might typically be involved in management of a single stretch of coast. A shared database implies reduction or elimination of duplicated records, and thus the potential for significant economic savings as well as improved operational efficiency.

- ☑ Provides efficient data storage and retrieval facilities.

- ☑ GIS also offers the ability to model, test and compare alternate management scenarios, before a proposed strategy is imposed on the real-world system. Computer technology allows the consideration of much more complex simulations; their application to very much larger data bases: and also enables compression of temporal and spatial scales to more manageable dimensions.

Accuracy of GIS

Map accuracy is relatively a minor issue in cartography, and the map user are rarely aware of the problem. But when the same map is digitised and input to GIS, the mode of use changes. The new uses extend well beyond the domain for which the original map was intended and designed. Therefore, accuracy problem in GIS requires consideration of both object oriented and field oriented views of geographic variations. Moreover, the machines used to make measurement in GIS (Digital computers) are inherently more precise than the machine of conventional map analysis. Error analysis in spatial data base is very important with a direct bearing on the accuracy on GIS and hence require due consideration.

One of major requirements in the Digital Topographic Data Bases (DTDB) of a large country is consideration of a variety of features. Digital Stereo photogrammetry may be useful in extraction of cartographic features with a greater accuracy. The Digital Elevation data in the form of contours, thus digital monoplotting can be considered as a quicker method of plotting the data for maintenance of DTDB. Some of the other factors that also must be considered are:

- ☑ The type of spatial data
- ☑ The scale and resolution of the spatial data
- ☑ The type of map projection
- ☑ The measuring unit
- ☑ Horizontal and vertical datum for Geographic co-ordinates
- ☑ Metadata

Data and information requirements for coastal zone management

In order to be of any value, it is necessary that the information products output from a CZMs should correspond with the actual requirements of the various user communities. These information requirements include; given a number of potential users of coastal zone data and information, what are the main areas of common interest or significant diversity regarding both information desired, and the data needed to be processed in order to obtain that information. The various information required for achieving the goal of an effective management of the coastal zone could be categorised broadly under following headings.

Geographical data: an organised, planned and coherent coastal database should therefore a basic requirement of a good and constant management. Many of the data to be found within a coastal management database will be geographic in nature and can be called a Geographical data. It is a "data, which refers specially to features that describe the earth's surface". Geographical data has both location and attributes. We can define the where something is as the Spatial component of data, is the spatial or attribute component of data.

Table 1.1: Spatial Component of Data

Habitats	Coast	Transport
Estuaries	Sandy Beach	Roads(major)
Sea grass	Rocky beach	Roads (minor)
Macro algae	Rocky cliff	Major Ports
Inter-tidal	Inter-tidal	Harbours
Salt-marsh	Mangroves	Marinas
Mangroves	Salt marsh	Boat ramps
Waders	Others	Airports
Rookeries		Nav channel
Shellfish		Nav Markers
		Ferry routes

- ☑ Spatial data: It is an explicit spatial/ locational reference and can involve absolute or relative locations. These are often referred to as point, lines, areas, or surfaces or can refer to some attribute that is continuous (e.g. elevation), or discrete (e.g. Male/Female or soil categories).

- ☑ Attribute Data: Attribute data describes what is a some location and has some link between it and the spatial data.

For example: A map with country boundaries vs the same map with country names have a spatial dimension to them, and in many cases this spatial component can be harnessed as the common factor, which unites the disparate data elements into a coherent and integrated structure.

Table 1.2: Classification of Coastal Information Data

Seabed	Infrastructure	Restricted Zones
Bathymetry	Residential	National Parks
< 2 m	Industrial	Terrestrial
< 5 m	Commercial	Marine
< 10 m	Recreational	Cultural features
Inter tidal	Ports	Sacred sites
Spoil dump	Harbours	Risk to personnel
Others	Marinas	Navigation
	Mooring	Military
	Boat ramps	Zoning

Bottom Type	Intakes	Ecologically
Sand	Outfalls	sensitive area
Hard clay	Fresh water	Breeding &
Rock, mud	Power	spawning ground
shell	generation	Historical areas
Coral reefs	Hinterland	Heritage area
Others	Education	
	Medical facilities	
Benthic Flora		
Sea grass		
Seaweed		
Coral		

Classification of Coastal Information Data: Many coastal databases will, in potential or in reality, display many classic characteristics of databases found in GIS. As with any other GIS application, the data involved in creating a coastal GIS database fall into a number of distinct categories. Depending on the method of classification used, these include:

- ❖ Basic Geodetic or Planimetric Data: It establishes the geographic referencing system against which coastal entities or processes of interest may be placed.
- ❖ Topographic Data: It records the location and distribution of natural and cultural features(beaches, cliffs, dunes, roads, settlements, harbours, etc) within the landscape;
- ❖ Qualitative and Quantitative Attribute Data: It provides further information about the properties (size of sediments on beach, morphodynamic indices, tidal range, value of coastal properties, amount of shipping visiting selected ports, etc) of coastal entities and phenomena.
- ❖ Time series data: It allows temporal databases to be compiled (Langran,1990), and information to be gleaned about the variability of coastal entities , attributes and relationships in both space and time; and
- ❖ Metadata: It allows estimations to be made of currency, completeness, history, ownership, and reliability of information, derived from the system.

Sources of Coastal Information Data: As identified above, two types of data are input into a GIS, spatial and attribute. A wide variety of data sources exist for both spatial and attribute data.

Application areas for coastal zone management

Given the diversity of tasks facing the coastal manager and also the range of data processing functions that may exist in a typical GIS, there is a multiplicity of potential application areas for coastal GIS technology. Few generic areas of applications are as follows:

Coastal resource survey and management: Continuing expansion of human population increases pressure on the shore for living space, leisure and recreation, and a host of the purposes. At the same time, the oceans and coastal waters of the world are also important hunting grounds for a wide range of economic resources, of value to society. As these resources gradually depleted, there is a corresponding increase in the need to explore conservation measures on remaining sticks. GIS has considerable potential to assist in these tasks. Few examples are as follows:

- ❖ Within the leisure and recreation sectors, GIS has been used to assist in the development of new or improved infrastructure including development of new shore-based facilities such as marinas, and the management of recreation activities in the areas of fragile coastal dune systems.
- ❖ In the fishing and aquaculture industries, GIS may be used to find optimal locations for fish-farms, through the analysis of salinity, bathymetry, shelter, land uses, proximity to other facilities, etc.
- ❖ GIS is also a major technology within the mining and oil exploration industries, where it is harnessed to assist in the discovery, assessment and exploration of new mineral wealth.

Coastal change monitoring and analysis: The coastal zone is highly dynamic, and the scientist or manager increasing requires access to technologies that can represent these dynamics, particularly to evaluate and deal appropriately with changes in the geometry or the shore. Two main divisions of coastal change analysis may be recognised, namely monitoring and simulation modeling respectively.

In monitoring studies, the primary objective is to record what aspects of the coast are changing, and where and why these changes are taking place. Monitoring at its simplest involves recording what is present at one baseline instance in time, and then comparing this pattern with that of subsequent stages.

GIS has been applied at the coast in order to keep track of a wide range of natural and human-induced changes, including:

- ❖ Changes in the extent and ecology of wetlands
- ❖ Analysis of erosion and shoreline changes
- ❖ Assessment of potential and actual flood hazard and damage.
- ❖ The silting up of harbours and the effectiveness and impacts of mitigation efforts such as dredging.
- ❖ Monitoring the changes of land use in the coastal hinterlands, in particular the growing urbanization of the coastal fringe; and
- ❖ Monitoring the behaviour of oil spillages in coastal environments.

Modelling coastal process: While monitoring can help identify and evaluate changes that are taking place at the shore, effective management of the coastal zone occasionally requires intervention and manipulation of the processes, controls, feedback and interrelationships at work along, within and across the shore, in order to arrive at more desirable ends. Modeling and simulation of coastal phenomena are extremely valuable techniques for assessing the effectiveness and likely impacts of such intervention.

Traditional modeling of coastal phenomena has mostly relied on experiments with wave tanks and other large physical models. However, it is becoming increasingly common to us computer-based simulation modeling techniques wherever appropriate. Among the other benefits, computerised simulation has the potential to overcome scale limitations that may be present in a physical model; may avoid the need for physical destruction or alteration of materials under study; can provide greater degree of control over the temporal aspects of the simulation (including compression of long time periods into more manageable extent, temporary halting or even reversal of the model to examine specific aspects in greater detail; etc.); and may be much cheaper and more manageable than construction of a physical model. Furthermore, development of a successful computer simulation depends on the creation of a robust data model for representing the system variables within the GIS, and this in turn requires a meaningful conceptualisation of the phenomena under study. Thus, the process of setting up the simulation can, itself, promote greater awareness of the constituent and relationships at work within the coastal system.

A number of examples are documented in the literature, describing the use of GIS technology for modeling processes and events within the coastal zone. Typical applications include the use of GIS for assessing the threat of sea level rise on the coast of maine, and the likely responses of coastal sand dunes to such rise. Modeling of oil spills with a view to minimising their environmental impacts, modelling possible impacts of dredge spoil dumping, modeling for multiple use of estuarine waters, and assessment of possible sites for aquaculture development.

GIS for coastal decision-making and policy formulation: by combining rapid data retrieval with analytical and modeling functions, GIS has the ability to respond rapidly and flexibly to ad hoc 'what if type questions'. Thus, a well-designed coastal zone information system could be significant as a decision-support tool, to aid development of integrated and sustainable coastal management strategies.

Conclusion

GIS should be viewed as an opportunity for the marine community to advance in the field of coastal zone management. GIS represents the latest essential tools to solve the spatial data-handling problem. Proper use of GIS required the data knowledge of the salt grimed hydrographic surveyor, the map composition skills of the experienced cartographer, the data base management skill of the data processing person, the scientific insight of geographer, the computer knowledge of a system analyst, and the personnel and organisation skill of the manager. The coastal zone GIS are currently enjoying a major upsurge in the level of interest and there are grounds for optimism in believing that the significant advances in this direction is not too far away. It can be concluded that the use of GIS in coastal zone management is very useful.

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