APPLICATION OF MANAGEMENT FRAMEWORKS IN COASTAL ZONE MANAGEMENT

The Award Winning Paper presented for the "Water Related Infrastructures" Competition 2000/2001 Sponsored by St. Anthony's Industries Group (Pvt) Ltd. Over 35 years of age.

by

S.S.L. Hettiarachchi and S.P. Samarawickrama

1. Background

Environmental degradation of the coastal zone is a major hazard faced by Sri Lanka an island state. The coastal region which is vital to the nation's economy comprises more than sixty administrative divisions within the maritime boundary. The population density and the distribution of urbanized lands are significantly higher in the coastal zone than in the interior and most of the larger towns are located within this region.

During the last two decades there has been increasing pressure for development in the coastal zone, particularly for tourism and recreational purposes, nearshore fisheries, fish farming, industrial development and housing. Communities have exploited the use of natural resources such as sand and coral on a commercial basis. Development pressures have also led to the adhoc reclamation of estuarial, lagoon and marsh waters and unrestricted disposal of untreated sewage leading to major pollution problems.

The coastal zone is also a dynamic environment and is subjected to coastal erosion, tidal flooding, inland flooding and landslides. Severe impacts of coastal erosion and flooding and the need to discharge inland floodwater have imposed increasing demands for coastal and flood protection and effective drainage of inland waters. The coastal erosion rates are very high around the island and this parameter is presently identified as the most important in determining coastal zone development work. The impacts of coastal erosion had also increased at alarming rates due to unplanned human intervention in the coastal zone.

Having recognised the magnitude of the problem the government authorities undertook remedial measures by formulating a well planned programme of action for the management of the coastal zone. These management strategies have been implemented since the early eighties and they have proved to be successful in controlling the degradation of the coastal zone and introducing planned development. Against the background of conflicting pressures of development and conservation it is relevant to investigate the introduction of improved strategies for the efficient management of the coastal zone.

2. Investigative Study for the Development of Management Frameworks-Scope of Study

The paper presents the results of a study to investigate the relevance and applicability of the use of management frameworks for the overall management and development of the coastal zone of Sri Lanka. It is expected that such an initiative will facilitate the adoption of a coordinated approach in engineering interventions for the management of sustainable multiple uses of the coastal zone, in particular the conservation of coastal aquatic systems.

The study commissioned two linked research tasks the aims of which were,

(i) To review the existing status with regard to mechanisms relevant to planning and management in the coastal zone.

(ii) To develop methods and tools forming an appropriate management framework for the environmental protection of the coastal zone of Sri Lanka with emphasis on coastal protection.

The first task was broadly classified into two sections, namely,

(i) Identification of existing coastal zone activities and assessing the impacts of natural resources exploitation and human interventions in the coastal zone.

(ii) Review of the existing status of planning and management of the coastal zone.

Eng. (Dr.) (Prof.) S S L Hettiarachchi, BSc Eng, PhD(London), DIC, AMIE(SL) is an Associate Professor in the Department of Civil Engineering at the University of Moratuwa.

Eng. (Dr.) S P Samarawickrama, BSc Eng, PhD (Lond), DIC, AMIE(SL), Presently Senior Lecturer, Department of Civil Engineering, University of Moratuwa.

The second task relates to the development of an appropriate management framework as a coherent, defined process applicable to a wide range of coastal zone activities and this task was broadly classified into four sections, namely,

(i) Identification of issues and parameters essential to a management framework in the Sri Lankan context including the level of detail and frequency of data collection associated with the principal variables.

(ii) Effective means of maintaining and managing different types of information leading to the preparation of coastal data bases.

(iii) Comparative analysis of the different types of management frameworks used in practice and the identification of an appropriate framework and its constituent components as applicable to Sri Lanka.

(iv) Establishment of the selected management framework by combining the above components into a coherent structure which will provide a clear executive procedure for the management of a wide range of coastal zone activities.

Pressure from human activities and unfavourable natural conditions have thus imposed adverse impacts on the coastal environment and in particular on coastal ecosystems. There exist strong and often conflicting pressures for exploitation of the coastal region with crucial economic and social implications. The coastal zone of Sri Lanka has provided and will continue to provide opportunities for economic development in a wide field of activities. Therefore such regions require management based on effective strategies which have been developed by considering all important aspects of the regions to be managed. In this context the investigation of the potential use of an appropriate management framework for its efficient management is justified.

3. Variables Essential to a Management Frame Work

The identification of the Issues and Parameters essential to a management framework is an important phase which has to be carried out based on detailed investigations. The coastline is an extremely complex and sensitive interface between the land and the sea, the behaviour of which is governed by both local and distant conditions. It responds in a most significant manner to any environmental change either natural or man made, and hence the study of the coastline requires a sound understanding of the changes in the coastal regime. This demands a detailed examination, at both local and regional scale, of the natural processes involved and the historical effects of man's intervention on the coastline and on the coastal zone in the broader geographical context. The presence of a large number of environmentally sensitive ecosystems along the coastal zone adds an important dimension to this exercise. To provide and understanding of a given regime or region, a large range of variables have to be considered. The inter-relationships among such a range of variables, all of which has a perceived contribution towards coastal erosion, are clearly complex. The selection of the relevant variables play of vital role in the development of an efficient management framework.

Coastal erosion has apparent and immediate consequences to man and society and is therefore often a principal concern in the administration of coastal districts. In engineering management of the coastal zone, the coastal stretch is often divided into, a number of coastal sections identified as 'coastal cells'. This division is based primarily on principal characteristics related to the coastal geomorphology and geophysical properties. The division also takes into consideration the nature and extent of the problems, economic values related to land use, the presence of existing protection works and administrative responsibilities. Within each 'coastal cell', coastal erosion and accretion can be understood, defined and explained in terms of the sediment balance (sediment budget) of a given cell. The establishment of coastal cells provide a sound foundation for work on the application of management frameworks for the environmental protection of the coastal zone.

The range of variables which are identified as Issues and Parameters is classified under the three categories namely Characteristics and Usage, Forcing and Response. This not only provides coverage of the relevant processes but also defines usage so that activities and possible conflicts can be considered when developing a management strategy.

Coastal Characteristics

This category identifies the main physical characteristics of the coastal zone including land and sea bed levels, shoreline types, reef locations and elevations, river mouths, road, rail and utility routes etc. This will include environmental components such as flora and fauna e.g. mangrove and the classification of sites of special interest in environmental terms. The essential quantifiable parameters have to be defined for each characteristic.

This sector will also require the delineation of coastal zones in which coast protection and other relevant engineering works have been undertaken, including river training and reservoir construction - which affect river discharge of both water and sediment onto the coast.

Coastal Usage

This category identifies and quantifies the wide range of activities which influence or are influenced by coastal processes; typical activities are fishing, agriculture, transportation - land and water based, industrial plant, public and private institutions, e.g. tourist resort facilities, utilities, residential areas, etc., including sand mining. These activities will also be related to zoning decisions of Central and Local Government.

The scale of these activities will be based on quantification parameters including socio-economic factors such as employment, turnover, contribution to GNP, and physical parameters such as waste production, treatment and disposal.

Coastal Forcing Parameters

These are identified as those processes which drive the coastal dynamics, such as winds, waves, tides and tidal currents and river discharges - quantified appropriately, for example in monsoon and non-monsoon conditions. Important forcing parameters are groundwater extraction and toxic waste input to groundwater.

Coastal Response Parameters

This sector will identify those quantifiable variables which describe the reaction of the coastline and its nearshore region to the forcing parameters. It will included, for example, properties of beaches, slope, sand sizes, shore-line locations and cliff recession, water table levels variations, groundwater quality and salinity intrusion.

It is recognized that this wide range of Issues and Parameters is not a static data set thus an important part of the definition process will be to consider the rates of change of these factors and their implications in relation to historical data and the need for continued or new monitoring activities. Hence Issues and Parameters should be updated on a routine basin.

4. Field Investigations to Assess Environmental Problems

Having conducted a detailed study on the management and development of the coastal zone, extensive field investigations were carried out on the western and southern provinces of Sri Lanka to identify further, existing coastal zone activities and to obtain supplementary information. There was a need to understand the existing coastal problems as well as those which may arise as a result of future development activities. These studies also enabled an assessment of the impacts of natural resources exploitation and human intervention in the coastal zone. This information plays a vital role in identifying the principal variables of the management framework. The important environmental problems in Sri Lanka's coastal zone are summarised as follows :

1. Coastal erosion, flooding and drainage
2. Unplanned human settlements
3. Construction of maritime structures which interact positively with the coastal waterfront
4. Construction of buildings and infrastructure within the dynamic coastal zone
5. Clearing of coastal vegetation
6. Coral mining
7. Sand mining
8. Discharge of sewage and wastewater
9. Discharge of industrial effluent
10. Agricultural run-off
11. Effects of sand bar formation across river and lagoon outlets, salt water intrusion and drainage
12. Reclamation of mangrove forests and coastal wetlands
13. Dredging of river estuaries
14. Siltation of lagoons and coastal aquatic systems
15. Discharge from ships
16. Oil slicks
17. Breaking of the reef for navigation
18. Over-fishing and collection of exotic fish
19. Fish farming
20. Dynamiting and use of explosives for fishing
21. Pollution of beaches and coastal aquatic bodies
22. Threatened wildlife

Against this background Sri Lanka also faces the challenges of possible impacts of global climate change and accelerated sea level rise over the next few decades. Sea level rise may aggravate existing environmental pressures and the impacts of coastal erosion, flooding, salt water intrusion and the degradation of coastal wetlands. Climate change will also have impacts on the wind patterns which in turn will influence the wave climate leading to the impacts identified earlier. Therefore the overall influence of global climate change and sea level rise is very complex and its impacts on the coastal zone should be clearly identified.

5. Identification of an Appropriate Management Framework

Several management frameworks for coastal zone development have been presented by researchers and practitioners in this field of study. In the context of the problems prevalent along the coastal zone of Sri Lanka, it was observed from a literature review that the manage-

ment frameworks developed by Fleming and Townend, as part of the Anglian Sea Defence Management Study in the U.K., provided a sound basis for the development of an appropriate management framework. Fleming and Townend (5,6,7,8,9) identified multiple stages of development evolving from a static to dynamic integrated framework applicable to a nation as a whole.

From a detailed review of the wide ranging problems of the coastal zone of Sri Lanka, where development projects are often in conflict with the conservation of the natural environmental system, it was identified that an Integrated Management Framework would be most appropriate for its overall management and development.

In the development of an Integrated Coastal Management Framework it is important to recognise the fact that coastal zone management is characterized by its integral nature due to three principal reasons. Firstly, an integral approach is necessary because of the interrelationship between coastal zone activities (in particular land use), coastal and flood protection measures and the routine management and control aspects of the coastal zone. Secondly, an integral approach is required due to widely varying disciplines and techniques that are involved in the analysis of coastal zone problems and their potential solutions. Thirdly, a certain degree of the spatial integration is necessary in view of the potential physical interactions between neighbourng coastal sections.

6. Development of an Integrated Management Framework

On the basis of field investigations a wide range of Issues and Parameters which were considered relevant to an Integrated Coastal Management Framework was identified. These were classified into three groups, namely, Coastal Characteristics and Usage including Jurisdiction, Coastal Forcing and Coastal Response. These Issues and Parameters form the Main Variables of the management framework.

This set of Issues and Parameters was applied to trial study areas on the southwest coast of Sri Lanka to test its applicability and relevance to real life situations. The locations of the field visits were selected to cover the range of,

1. Planning, development, conservation and management problems
2. Potential conflicts between these and other activities and
3. Environmental impact assessment of coastal zone development projects.

A complete list of the Issues and Parameters is presented in Table 1 as the Main Variables of the framework. These variables form a major constituent component of a fully operative and comprehensive Integrated Coastal Management Framework.

Given that the effectiveness of any management process is determined by the adequacy of the information upon which decisions are based, it is clearly important that the most essential variables should be updated on a routine basis. This means that whilst information on coastal characteristics will require periodic review, the more dynamic components will need to be collected as part of a structured monitoring programme. Such a programme will focus on forcing components and aspects of the coastal response. Tables 2 and 3 provide a typical scope for such a programme based on the need to collect relevant data without placing an undue burden on financial resources.

It is clear that the Issues and Parameters set described in Table 1 is extensive and previous experience has shown that the optimum method of application is via a series of inter-related data based software systems, namely, Referral and Relational data bases. The first will store data and present that data on demand in a form readily assimilated by the user, including maps, charts, tables and raw data access, with provision for updating. This data base is best developed using two separate record structures one for references and another for environmental data. The second will permit analysis of the data to determine the correlation and interaction between different parameters, for example, shoreline recession related to sand mining, or, changes in agricultural patterns related to saline intrusion. It is only by conducting this type of analyses that the influences of changes in a specific factor on the response of other factors can be quantified. This is the essence of environmental impact modelling-to determine the consequences of a proposed development on those parameters which describe environmental quality.

To achieve the above purpose, coastal processes and its modelling have to be incorporated in the framework by the use of a system of mathematical models. It is recognised that management/development strategies require both qualitative and quantitative information on the likely impact or efficiency of an existing or proposed scheme so that different engineering options can be evaluated objectively one against the other. Mathematical models enable this objective to be achieved by simulating existing conditions within the system of interest and by predicting, in quantitative terms, the consequences of natural changes and human intervention in these conditions.

Table 1 : Main Variables of the Management Framework

1 Coastal Characteristics Usage and Jurisdiction	2 Coastal Forcing	3 Coastal Response
1.1 Natural Environment	2.1. Wind	3.1 Erosion
1.1.1 morphology	2.2 Waves	3.2 Accretion
1.1.2 aquatic systems	2.3 Water levels	3.3 Flooding
1.1.3 ecology	2.4 Currents	3.4 Pollution
2.5 Rainfall	3.5 Water quality	
2.6 River discharge		
2.7 Temperature		
1.2 Community		
1.3 Communication (transport)		
1.4 Services		
1.5 Agriculture		
1.6 Industry		
1.7 Fisheries		
1.8 Trade		
1.9 Recreation		
1.10 Tourism		
1.11 Waste disposal		
1.12 Coastal works		
1.13 Sites of special interest		
1.14 Jurisdiction		

Table : 2 Data Requirement for Forcing Component

Description	Format	Frequency	Analysis	Use
Wind	velocity and direction	hourly	-offshore storm climate -inshore wave climate -extremes	to assess shoreline exposure
Waves	height period direction	every three hours	-offshore storm climate -inshore wave climate -extremes	to assess shoreline exposure
Water levels	height refer to datum	at least hourly	-tides -extremes -joint wave and water level analysis	required for inshore wave computations and allows the significance of storm surge to be identified
Tidal Prism	water levels, currents and volume	every 5-10 years	-estuary power curve	to define estuary dynamics and in the longer term to provide indication of changes in the hydraulic regime
River discharges	discharge	daily-	-hydrological analysis	to define river dynamics and for hydrological forecasting

Table : 3 Data Requirement for Reponse Component

Description	Format	Frequency	Analysis	Use
Aerial Survey	photographs	annual	foreshore and backshore levels	to identify key features, quantify change in both plan and cross-shore sense and to monitor both physical and ecological change
Hydrographic Survey	depths along profile lines	every 5-10 years	changes with time	establish limit of sediment exchange on shore face and provide detailed current bathymetry for coastal process studies
Land Survey	levels along profile lines	biannual	changes with time	allows changes in the beach to be studied and related to forcing data (Table 2)
Inspections	text records	biannual	changes with time	observations of beach features and coastal structures can be related to processes and key events to help establish patterns of shoreline behaviour

It was identified that the establishment of 'coastal cells' plays a vital role in the development and the application of management frameworks relating to the coastal zone. A preliminary study of the sediment transport for the southwest coast of Sri Lanka, based on shoreline cells, was undertaken as part of a technical assistance programme funded by German aid (10). The shoreline cells used in the investigation provide a sound foundation for the establishment of coastal cells for coastal zone classification to be used in an Integrated Coastal Management Framework. The shoreline cells could be expanded in the on-offshore directions to generate coastal cells which will cover a wider area both offshore and hinterland. The present narrow definition of the coastal zone in the geographic context, as specified in the Act, is inadequate and require re-definition for effective management.

In addition to the Main variables identified under Issues and Parameters, the associated Referral and Relational data bases and the Mathematical models for coastal processes, an Integrated Coastal Management Framework will also include as its components ;

- Legislative and coastal development approval procedures
- Factors influencing broad geographical area master - planning
- Management and policy options
- Processes to ensure that decisions on specific development proposals are compatible with an overall master plan
- Special nature of environmental standards and criteria and environmental impact assessment

An Integrated Coastal Management Framework is established by combing the principal constituent components into a coherent structure which will provide a clear executive procedure for the management of the coastal zone and in particular applicable to the evaluation, in socio-economic and environmental impact terms, of a wide range of coastal activities, both new developments and remedial measures. Figure 1 represents the important elements of an Integrated Coastal Management Framework in diagrammatic form.

The results of three investigations which were conducted in parallel were made use of to understand the important aspects relating to the potential use of an Integrated Coastal Management Framework.

The first project related to salt water exclusion and drainage and its impact on low lying coastal areas in the administrative district of Galle in the southern province (11). The project identified the benefits of such a framework in analysing problems (engineering, socio-economic and ecological) that are common to a given region consisting of several coastal cells.

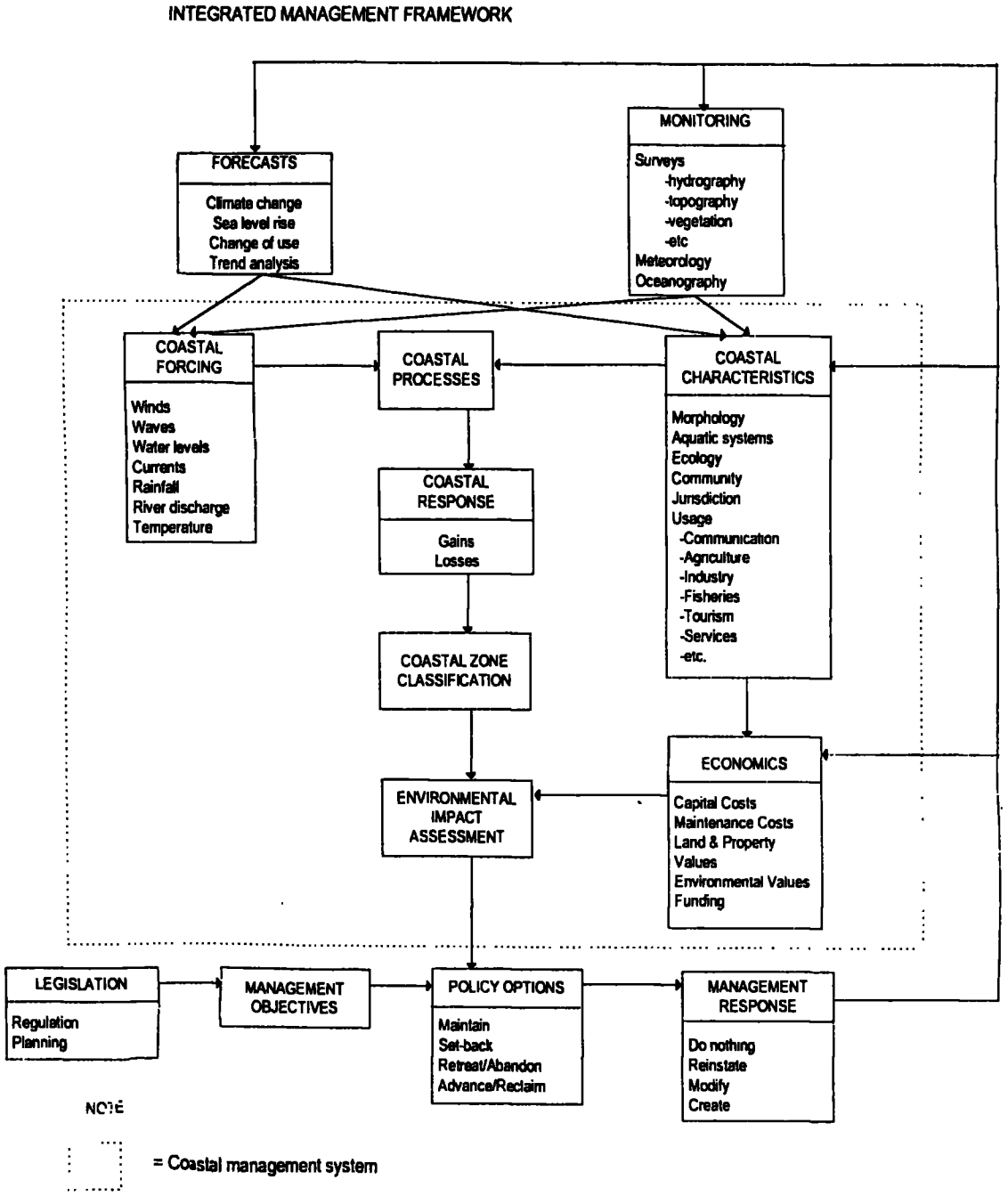

Figure 1 : Integrated management Frameqork

The second project related to water quality monitoring and modelling in the Kelani river and estuary which flows through a densely populated urban environment (12). The project illustrated the importance of monitoring systematically the water quality and developing a fully operative water quality model for a river to which a large number of industries discharge effluents. The modelling also enabled the establishment of a practicable set of ambient water quality standards for a segment of the river based on designated water use, existing levels of water quality and future levels of water practically achievable. The project also identified clearly that integrated mathematical modelling of coastal aquatic systems could be effectively incorporated in an integrated management framework.

The third project related to the hydraulic and environmental investigations of the Negombo lagoon, located in the western province (13). This project illustrated the benefits of such a framework in analysing problems within an environmentally sensitive ecosystem located within a single coastal cell. The Muthurajawela marsh and the Negombo lagoon is the only coastal wetland in the island for which are Integrated coastal resources management plan has been adopted. The study confirmed that engineering investigations can be incorporated into this plan, thereby contributing to a wider In-

tegrated coastal management framework of which natural resources management and engineering management are two important components. This study also provided information on data collection and its manipulation and on specific issues of development of data bases.

The three trial studies included investigations on impact of salt water intrusion on low lying agriculture, modelling of estuaries in the context of pollution management and engineering interventions for sustaining multiple uses of coastal wetlands. The results of all three investigations supported the establishment of an Integrated Coastal Management Framework and provided sufficient evidence that such a framework could be successfully implemented in an efficient manner. The studies clearly illustrated the manner in which mathematical modelling could be incorporated effectively as an active component within such a framework in order to evaluate measures to mitigate the adverse effects of environmental degradation arising from natural processes and/or human interventions. It was evident that modelling plays a vital role in optimization of a given scheme.

A summary of one of the investigations is given in the following section.

7. Case Study - Muthurajawela Marsh and Negombo Lagoon

The investigation identified the importance of the Muthurajawela marsh - Negombo lagoon wetland and its environment, on one hand as a unique eco-system rich in biodiversity and on the other hand as source of multiple resources being exploited by the stakeholders. The investigation established the need for the coastal aquatic system to be managed for sustaining multiple uses and for the community to be safeguarded against the adverse effects of their unconstrained action.

Investigations confirmed that unauthorized landfill, unplanned development along the waterfront, siltation, reduction of tidal exchange and flushing, discharge of industrial effluents and municipal waste and overall pollution of the environment are major problems affecting the Negombo Lagoon. These problems and their impacts have a close interrelationship with the hydraulic regime, which can be simulated by mathematical modelling. It also enables the prediction in quantitative terms the consequences of natural and man made changes in these conditions. In this context the investigation identified important findings relating to the dynamics of flow, sediment transportation and siltation. If the coastal fishery anchorage at the lagoon inlet is to be developed it would be necessary to extend the modelling work at identifying methods of improving the anchorage with minimum structural changes and least environmental impact to the unique eco-system.

The findings illustrated the relevance and applicability of mathematical models in the investigation of the hydraulic behaviour of lagoons and their environmental management (14). Mathematical models can be used effectively to study the impact of different hydraulic regimes and to predict likely changes, which will take place due to development activities and other action. In view of critical interactions which are likely to take place with neighbouring aquatic and terrestrial ecosystems it was evident that the management be carried out within a well formulated integrated framework.

The findings clearly support planned engineering interventions to sustain multiple uses of the lagoon. Failure to do so will affect the biodiversity of the eco-system and the resource users will be deprived of long-term sustainable benefits.

Figure 2 illustrates selected results from the mathematical modelling of the Negombo Lagoon. The accompanying definition sketch also illustrates the interactions of Coastal Management Cells and Special Area Management Cells within an Integrated Coastal Management Framework. It was evident that results from Special Area Management studies could be effectively integrated with Coastal Management Cells.

8. Recommendations for Furthers Studies

A review of coastal zone management activities in Sri Lanka identified a need to adopt a coordinated approach in engineering interventions for the management of sustainable uses of the coastal zone. This approach could be implemented by developing an Integrated Coastal Management Framework.

The advantages of an Integrated Coastal Management Framework include

* the provision to make maximum use of data/information available on the coastal zone for its integrated management.
* the ability to undertake strategic planning by which identification is made, well in advance, of data requirements for potential development projects of national interest and thereby planning and implementing required studies.
* the facility to monitor crucial environmental problems and hydraulic phenomena.
* the capability to handle emergency situations such as the predictions of the movement of oil spills and their control.

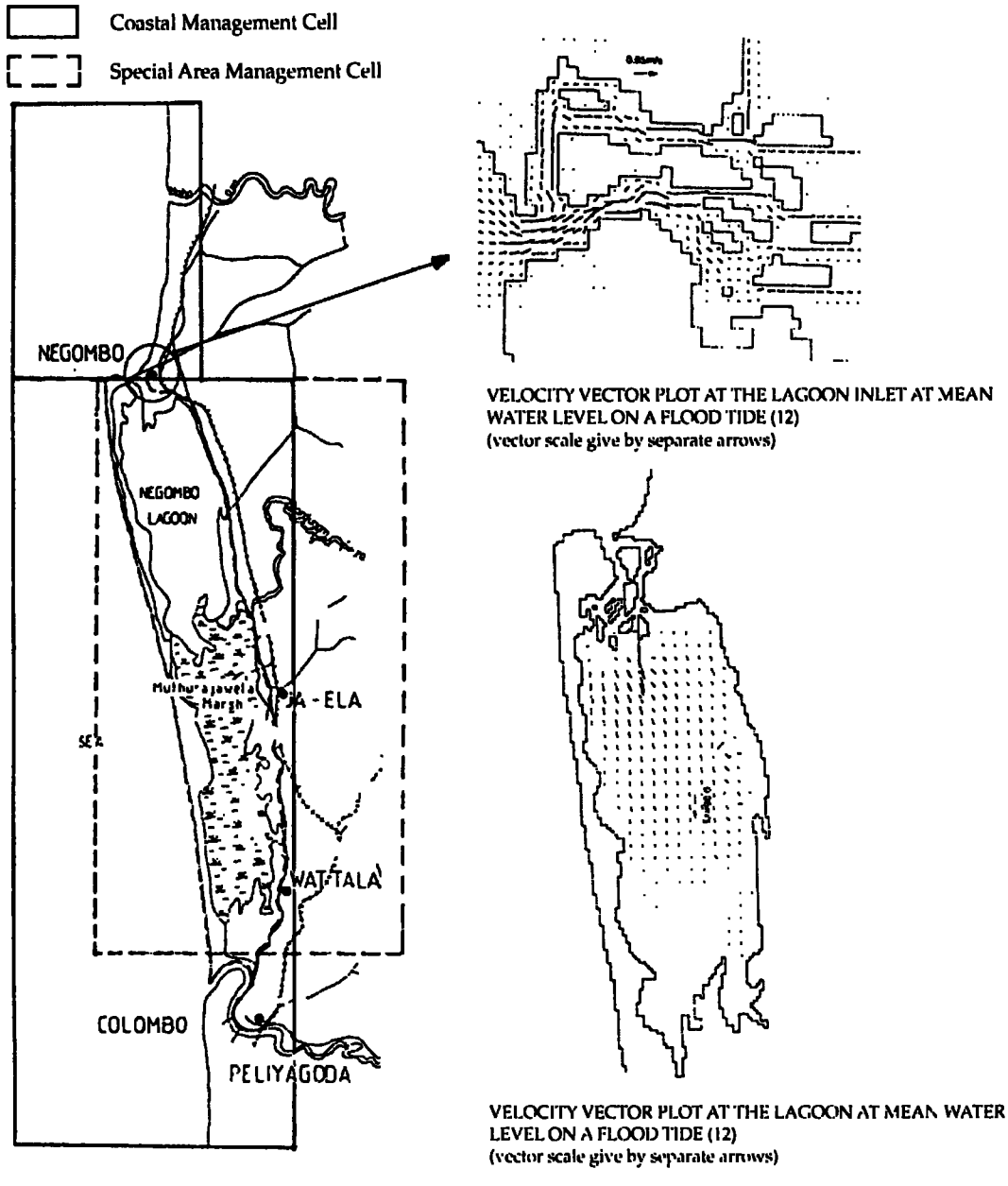

Figure 2 Modelling of the Negombo Lagoon

The implementation of a fully operative management framework is best carried out in three stages. The stages comprise, Planning and design of the framework, Performing trial studies to test the applicability and relevance and the Development of the framework by preparing the data bases together with the incorporation of the required mathematical models. This paper has presented studies relating to the first and second stages of the implementation of such a framework.

The results of the studies conducted have identified and listed the major constituent components of such a framework. The main variables have been applied to trial study areas to test and prove their applicability and relevance. The results of three coastal zone investigations have been examined and analysed to provide justification for the potential applicability and successful implementation of such a management framework.

On the basis of the findings of this study it is recommended that a fully operational Integrated Coastal Management Framework be developed for the environmental protection of the coastal zone of Sri Lanka. The following activities are recommended to achieve this objective.

1. To review critically the existing responsibilities of and procedures adopted by institutions in Sri Lanka for management, planning environmental impact and approval of development proposals in the

coastal zone. This review has to be conducted at inter-departmental level to identify the strengths and weaknesses in these sectors and report thereon, with proposals for modification where necessary.

2. On the basis of findings of this study to conduct further investigations on Issues and Parameters essential to an Integrated Coastal Management Framework in the Sri Lankan context. In particular, to test the validity of these Issues and Parameters by interaction with public and private sector interests.

3. To review and select appropriate data base software to provide a vehicle for the definition and quantification of these issues and parameters. To acquire that software and implement it in Sri Lanka, as part of an Integrated Coastal Management Framework, to a fully operational level including application manuals.

4. To apply the Integrated Coastal Management Framework to a region consisting of a few coastal cells to illustrate, as a sample case study, the beneficial uses of such a framework in operation. The case study should be representative in that the selected cells should include environmentally sensitive ecosystems such as wetlands and eroding coastlines subjected to unfavourable natural conditions and human intervention.

9. References

1. Coast Conservation Act No.57 of 1981. Parliament of the Democratic Socialist Republic of Sri Lanka, 1986.

2. Coastal Zone Management Plan. Coast Conservation Department of Sri Lanka, 1986.

3. Master Plan for Coastal Erosion Management. Coast Conservation Department of Sri Lanka, 1986.

4. Revised Coastal Zone Management Plan. Coast Conservation Department of Sri Lanka, 1997.

5. Fleming, C A. The Anglian Sea Defence Management Study. Proc. of Conf. Coastal Management, organised by the ICE, Thomas Telford, London, 1989.

6. Fleming, C A & Townend, I H. A coastal management data base for East Anglia. Proc. of Conf. Coastal Zone 89, organized by the ASCE, Charleston, SC, USA 1989.

7. Fleming, C A. The development of wider perspectives in coastal erosion control. Proc. of Symposium on Developments in Coastal Engineering, University of Bristol, UK 1991.

8. Townend, I H & Fleming, C A. Planning for Coastal Erosion. The Yearbook of the IWEM, 1994.

9. Townend, I H & Fleming, C A. Classification Techniques for Coastal Interpretation, Prof. of Conf. Eurocoast Littoral 94, Lisbon, Portugal, 1994.

10. Fittschen, T., Perera, J A S C & Scheffer, H J Sediment Transport Study for the Southwest Coast of Sri Lanka. CCD-GTZ Coast Conservation Project, 1992.

11. Hettiarachchi, S S L (editor). Study of Salt Water Exclusion and Drainage Schemes in the Galle District, Vols 1 & 2, Report of study funded by the Southern Province Rural Development Project. Dept. of Civil Engineering, University of Moratuwa, 1995.

12. Bhuvendralingam, S and Hettiarachchi, S S L. Kelani River - Water Quality Monitoring and Modelling, Report of study funded by the CEA and BKH Consulting Engineers. Dept. of Civil Engineering, University of Moratuwa, 1995.

13. Hettiarachchi, S S L. Sedimentation in the Negombo Lagoon Outlet, Report of study funded by the Wetland Conservation Project of the CEA. Dept. of Civil Engineering, University of Moratuwa, 1994.

14. Samarawickrama, S. P. and Holmes, P, Long-term Tide and Wave-Induced Sedimentation at a Lagoon Entrance, Paper forwarded to 28th International Conference on Coastal Engineering, 7-12 July 2002, Cardiff, Wales.