J. Natn.Sci.Foundation Sri Lanka 2006 34(4): 169-175

FEATURE ARTICLE

Coastal engineering impacts of the Sethusamudram Ship Canal project

S.P. Samarawickrama[1], J. Gunawardene[2], S.S.L. Hettiarachchi[1*] and M. Mendis[1]

[1] *Department of Civil Engineering, University of Moratuwa, Katubedda.*
[2] *Lanka Hydraulic Institute, John Rodrigo Mawatha, Katubedda, Moratuwa.*

Submitted: 16 November 2006 ; Accepted: 27 November 2006

INTRODUCTION

The Sethusamudram Ship Canal connecting the Bay of Bengal to the Gulf of Mannar will be constructed by dredging a channel in the existing coastal waters either side of the Palk Bay. The canal will reduce the steaming distances between the east and west coast of India and will improve navigation within the territorial waters of India. It is a challenging project which will impose a range of impacts both in the short and long term on the coastal waters of both India and Sri Lanka. The canal has been designed as a two-way canal for vessels having a speed of 8 knots. The depth of the canal is to be maintained at -12 m CD (Chart Datum) with a bottom width of 300 m. Capital dredging quantity is estimated as 82.5 million cu. m and the maintenance dredging is estimated to be 2 million cu. m in the first year reducing to 1.4 million cu. m in 5 years and remaining constant thereafter. Figure 1 gives the proposed canal alignment indicating the areas to be dredged and Table 1 gives the capital dredging quantities.

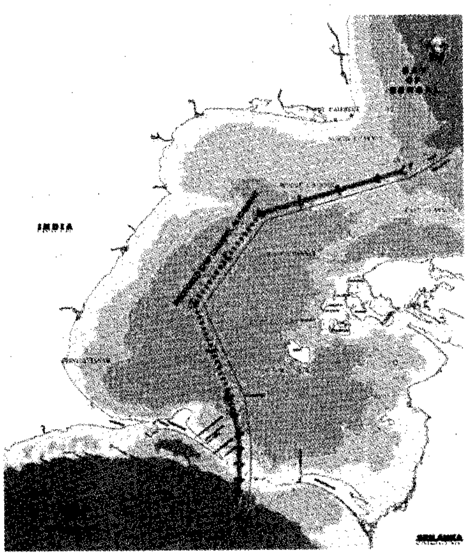


Figure 1: Proposed canal alignment

Table 1: Capital dredging quantities

Segment	Length (km)	Dredge quantity (million cu.m)
Adam's Bridge	35	48.0
Palk Bay	78	No dredging
Palk Strait	54	34.5
Total	167	82.5

Mathematical modelling is one of the principal tools of assessing and monitoring the impacts of coastal engineering projects. This paper presents the results from a mathematical modelling study which has been carried out as an initial assessment to investigate the impacts of the Sethusamudram Canal. The results provide a broad overview of the potential coastal engineering impacts of the proposed project. A series of nested MIKE21-HD models comprising Regional, Intermediate and Local models were constructed. The local model represents the Gulf of Mannar in detail with the use of new bathymetric data obtained from the Sri Lankan Navy. Detailed bathymetric data were available only for the Sri Lankan side and for the Indian side data were obtained from the Admiralty Charts and reports prepared by the Indian Authorities.

* Corresponding author

The scope of work for hydrodynamic and sediment transport modelling was to study the changes in hydrodynamics and sediment transport regimes in the vicinity of the **Adam's Bridge** with the application of MIKE21 – HD and ST models. The hydrodynamic modelling provides the changes in flow patterns due to the canal whereas the sediment transport modelling supports the assessment of coastal evolution with and without the Sethusamudram Canal. The scope of work for particle analysis modelling was to study the dispersion of dredged material released during dredging as well as disposal of dredged material.

The results from the study refer to the initial assessment via mathematical modelling using the existing and secondary data. The next stage of development would be refined modelling using specific data collected to define the coastal phenomena of this very hydrodynamically complex coastal region.

Hydrodynamic model setup

The nested grid set-up, on which the hydrodynamic modelling was performed, is indicated in Figure 2. The detailed modeling was carried out only for the Adam's Bridge area since the surrounding very shallow depths would most likely create high levels of change in comparison to the Palk Strait with the introduction of the Canal.

The Regional Model was set-up with a grid resolution of 1000 m ×1000 m and the size of the model was 200 km × 400 km. Stepping down from the Regional Model to the area of interest is implemented through an Intermediate Model with a grid resolution of 100 m × 100 m. The extent of the Intermediate Model is 60 km × 40 km. Boundary conditions for this Model were extracted from the Regional Model as Transfer Boundary conditions. This Model takes two different forms (with and without the canal) depending on the modelling options. Figure 3 illustrates the Intermediate Model with the Canal.

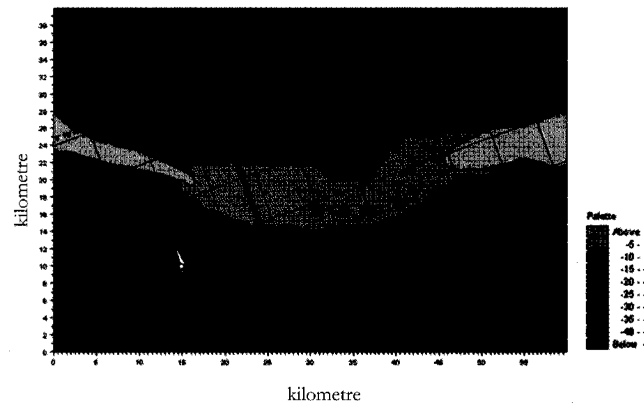


Figure 3: Intermediate model

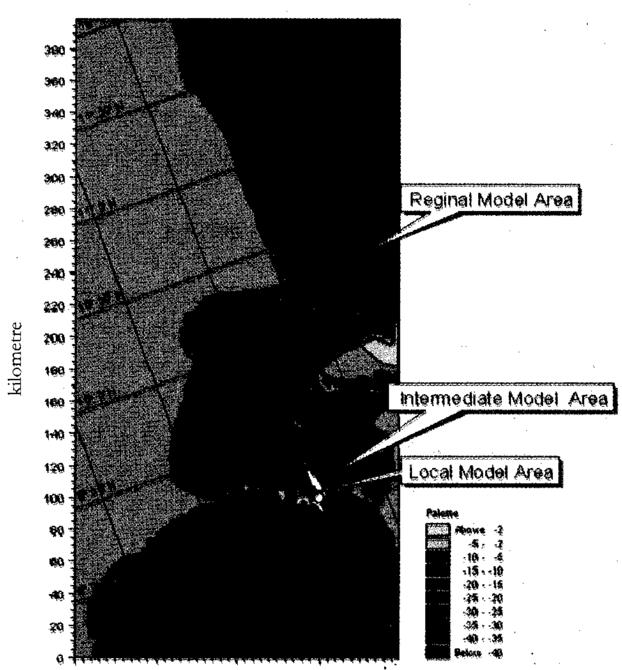


Figure 2: Nested grid set-up in the hydrodynamic modelling

The smallest hydrodynamic model created in this study is the Local Model with a grid size of 20 m × 20 m. The extent of the Local Model is 6 km × 10 km. Boundary conditions for this Model were extracted from the Intermediate Model as transfer boundary conditions. This Model takes two different forms (with and without the canal) depending on the modelling options.

Boundary conditions for hydrodynamic modelling

Accurate definition of the open sea tidal constituents at model boundaries is essential for the verification of the tidal propagation pattern in the area of interest. Southern boundary conditions were obtained by interpolating the generated tides of Kalpitiya and Tuticorin Port whereas for the northern boundary, generated tide at Cuddalore Port was used directly.

The wind information used for the present study was obtained from the Hydrodynamic Modelling and Ship Manoeuvering Studies.[8] This wind information for Bay of Bengal, north of Palk Strait and for Gulf of Mannar has been derived from the Alkyon database of ship reported data. Some comparison has been made in an earlier study between the wind statistics derived from the Alkyon database together with the measured winds at Nagapatinam and at Pamban and found to agree well.

Wave data collected off Vember in the Gulf of Mannar is available for a one year period. Current observations are available at four locations in the Gulf of Mannar. These data are for three seasons and for a duration of two days in each season. The project area comprises three distinct water bodies, namely Gulf of Mannar, Palk Strait and Bay of Bengal. It is very necessary that offshore wave measurements be carried out for a period of at least one year and near shore wave data for period of few months to cover these three water bodies. These data are necessary to obtain the driving boundary conditions and for the calibration and verification of the mathematical models. In addition, wind and current measurements have to be carried out at selected locations.

The Regional Model that covers a fairly large area has been forced by a uniform wind field due to lack of field data, which is far from the real situation. In particular the regional distribution of wind over the Arabian Sea and the Bay of Bengal that results in a major ocean current off the west coast of Sri Lanka cannot be modelled without the measured data. This current reverses seasonally and probably induces some circulation in the Gulf of Mannar.

By considering the location of the Sethusamudram project site which joins three distinct water bodies, namely Gulf of Mannar, Palk Strait and Bay of Bengal, it is recommended to have a long-term field investigation programme. In particular, the impact of the regional distribution of wind over the Arabian Sea and the Bay of Bengal that results in major ocean current off the west coast of Sri Lanka and other oceanographic impacts could only be understood by having long-term data sets.

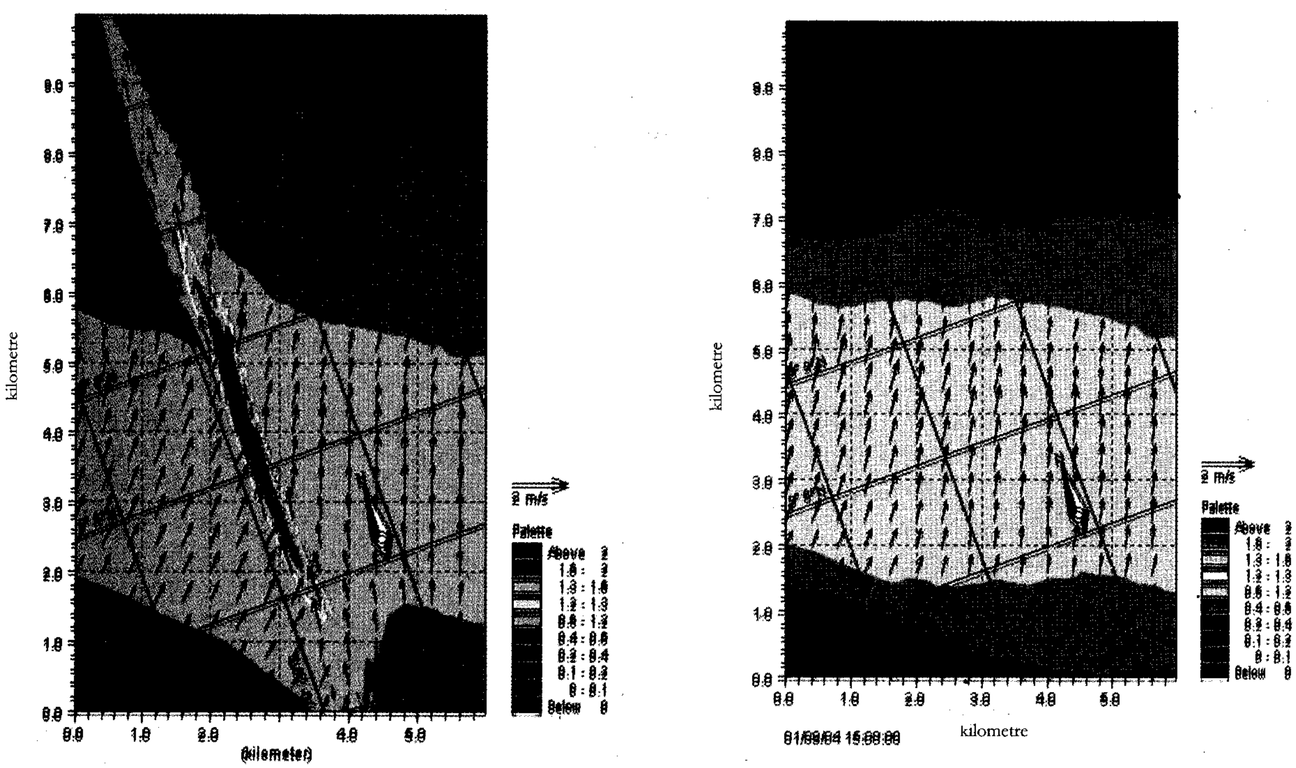
Hydrodynamic model results

Hydrodynamic modelling was carried out for different tide and wind configurations to determine the hydrodynamics of the project area for the existing conditions and with the proposed canal conditions. Figure 4 gives a comparison of the existing and with-canal conditions.

Following conclusions can be drawn from the modelling results.

South West Monsoon period

(i) Under the influence of strong wind (14.75 m/s) from SW, maximum current increases from 1.0 m/s to beyond 2.0 m/s.
(ii) For normal wind conditions (8.75 m/s) from SW, maximum current increases from 0.6–0.7 m/s to 1.4 m/s.
(iii) For strong and normal wind conditions from West, current patterns are very similar with slightly lower magnitudes when compared to wind from South West.



(a) Existing (b) With Canal

Figure 4: Tidal currents during Spring Tide - Wind speed of 14.75 m/s from South West - Maximum currents

(iv) Current patterns for spring and neap tidal conditions together with SW Monsoon wind conditions are very similar indicating the weak tidal influence under SW Monsoon wind conditions.
(v) There will be significant increase in current with the introduction of the Canal but these increases will be limited only to the canal area and the vicinity of the Canal.
(vi) There will be a 53% increase in volume exchange from Gulf of Mannar to Palk Strait under normal SW Monsoon wind conditions and 67% increase under strong SW Monsoon wind conditions.

North East Monsoon period

(i) Under the influence of strong wind (12.75 m/s) from NE, maximum current increases from 0.6-0.7 m/s to 1.4 m/s.
(ii) For normal wind conditions (6.25 m/s) from NE, maximum current increases from 0.4 m/s to 0.8 m/s.
(iii) There will be an increase in current with the introduction of the Canal but these increases will be limited only to the canal area and the vicinity of the canal.
(iv) There will be a 38% increase in volume exchange from Palk Strait to Gulf of Mannar under normal NE Monsoon wind conditions and 46% increase under strong NE Monsoon wind conditions.

Even though the change in current regime is limited to a smaller area in the vicinity of the Canal, the increase in volume exchange could lead to changes in temperature, salinity etc., Considering the ecological sensitivity of the area, these changes will have to be investigated through Advection Dispersion Modelling. Continuous and in-situ measurements of salinity, temperature *etc.,* at selected locations will have to be carried out together with the wind and current measurements for the calibration and verification of the Advection-Dispersion Model.

Zero impact solution of dredging and compensation filling will also have to be considered. Using compensation filling to achieve the desired balance between the increase of currents and changes in the net cross sectional area, water exchange between Gulf of Mannar and Palk Bay could be maintained at the existing level. In addition, this could be very useful for the possible future development of an Indo-Lanka Bridge. Zero-impact solution has been adopted successfully in the Oresund Link between Sweden and Denmark. This option has to be considered giving due consideration to all the environmental issues.

Sediment transport modelling

The modelling was carried out using available data and this has naturally led to certain limitations in the application of the model results.

Sediment transport in the Adam's Bridge area depends on:

- Alongshore transport of sediment
- Sediment transport along the dredged Canal
- Sediment that fall into the Canal from the sides

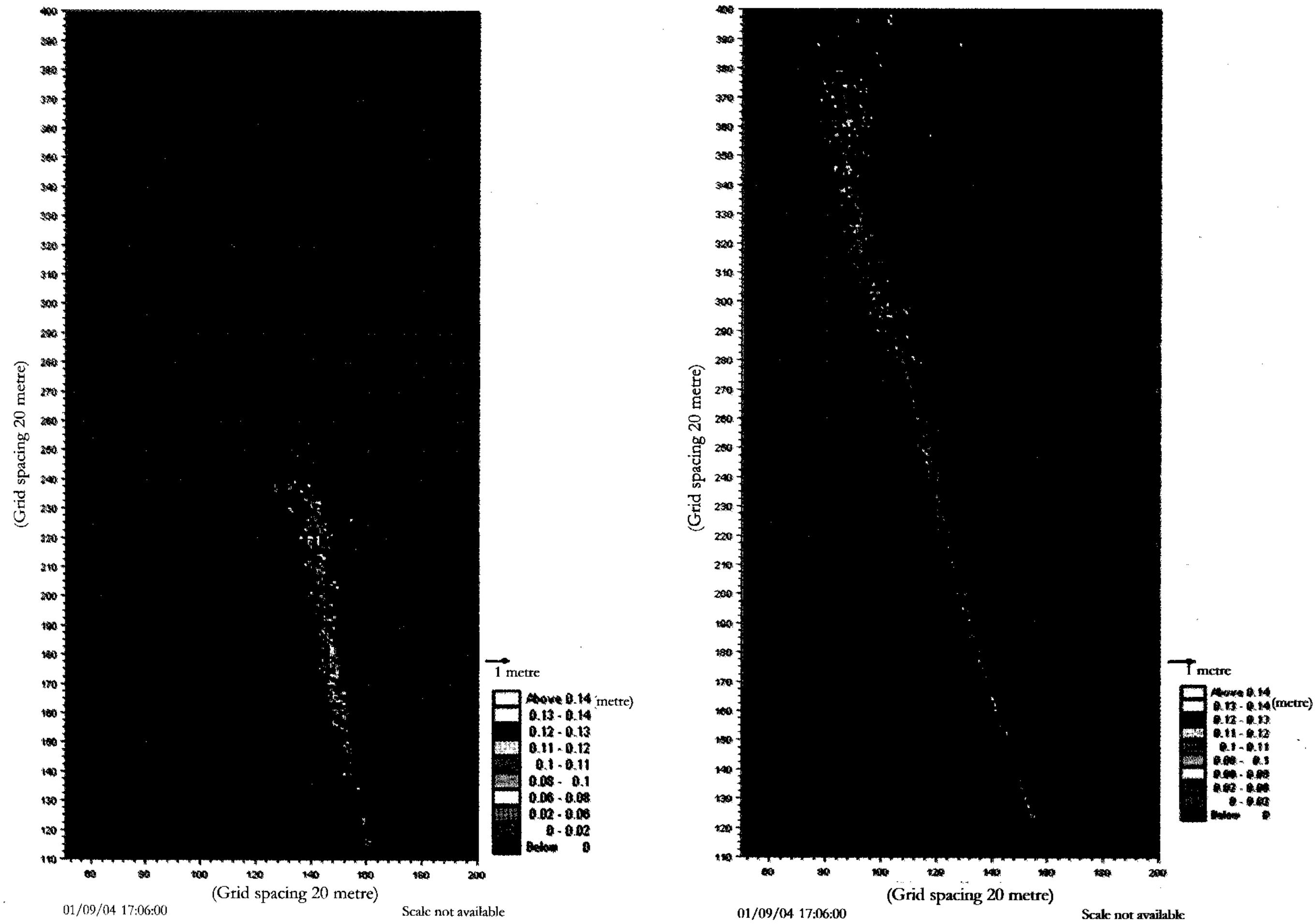
Present modelling covers the prediction of sediment transport along the dredged Canal due to the current. Sufficient long-term measurements of wave data are absolutely necessary to do an alongshore transport prediction in Adam's Bridge and to predict the quantity of sediment that falls into the Canal from the sides. Alongshore modelling is a critical component which should be implemented to understand the full impact of the Sethusamudram Canal project.

Under existing conditions, total gross sediment transport capacity could be estimated as 0.1 million cubic meters/year and with the introduction of the Canal this could increase to around 1.5-2.0 million cubic meters/year. The hydrodynamic modeling carried out indicates the significant drop in current magnitude on either side of the shallow area of the Adams Bridge. This would contribute to the formation of Flood and Ebb deltas within the Canal. Actual quantity of transport will depend on the supply of sediments to the canal entrance through alongshore sediment transport, south of the Adam's Bridge and the quantity of sediment which will fall into the Canal from the sides.

The estimate of 1.5-2.0 million cubic meters/year of dredging should be investigated further. It is most likely that the Canal may require a significant quantity of continuous dredging arising from siltation. Therefore it is recommended that the whole aspect on dredging be considered on a detailed scientific basis. A full appreciation of the sediment transport processes leading to sedimentation is desirable for the planning of long term maintenance and may also raise issues regarding the viability of the project as a whole.

Dredged material dispersion modelling

It is expected that Cutter Suction Dredgers (CSD) will be used for dredging the shallow portions upto a level of -8 m CD and Trailer Suction Dredgers (TSHD) will be used for dredging material below -8 m CD at the Adam's Bridge area.



(a) without the canal (b) with the canal

Figure 5: Dispersal of dredged mud (30 μm) during dredging 14.75 m/s wind from South West

Modelling without the Canal simulates the commencement of the dredging programme in the shallow water depths (-1 to -2 m CD). Results indicate that the dispersion of fine material (both sand and mud) is limited to a very small area due to the prevailing low velocities. Modelling with the Canal simulates the final stages of the dredging programme and the maintenance dredging, in deep water depths (-11 to -12m CD) using TSHDs. Results indicate the movement of dredged sediment along the Canal in the shallow region of the Adam's Bridge due to the high concentrated velocities. At the end of the shallow region the plumes begin to spread according to the velocity regime.

It should be noted that the dispersal modelling has been carried out allowing only few hours of spreading for selected scenarios. It was found that particles dispersed upto the model boundaries within a few hours. Therefore the selected local model area has to be extended in future modelling. Dispersal of dredged material during dredging has also been carried out according to a typical dredging plan applicable to this type of project. By considering all these factors, it is recommended that the whole aspect of dredged material dispersal modelling during dredging be carried out in detail according to the actual dredging plans to be adopted by the contractor. On the other hand several scenarios could be examined and the most appropriate scenario could be used to develop the dredging plan. This aspect is of considerable importance in developing the Environmental Management and Monitoring Plan as required for a project of this nature.

Figure 5 gives the dispersal of dredged mud at the beginning (without the Canal) of the dredging programme and at the end (with the Canal) of the dredging programme.

Modelling of dredged material dispersion during dumping was carried out for the dumping location in the Gulf of Mannar. Dispersion in the initial stages of dredging with CSDs will be higher when compared to later stages with the TSHDs as the CSDs involve direct pumping together with very fine particles. Results of the modelling carried out for fine particles of both mud and sand (30 μm) indicate that the dispersion is limited to a local area due to the existence of very small velocities in this deep region. Overall, dispersion is limited to an area of 1 km radius from the dumping location with a maximum of 1.5 km.

Remedial structures

Adam's Bridge is a dynamically stable coastal region and Figure 6 gives the complex-dynamic island system. The study carried out by the Indian Authorities has correctly suggested not to initiate the construction of any remedial structures in this dynamic regime at the beginning of the project . It has been further suggested that such structures could be planned after observing the behaviour of the Canal for the first few years which is accepted.

It is very important that more detailed investigations on potential structures and associated impacts be studied at this early stage. It is a good practice to develop a knowledge base on possible alternative structural systems that may be required to handle multiple impacts that may arise in the canal operation. The modification to the designs and construction (if necessary) could be done after observing the behaviour of the Canal during the first few years. Identifying possible alternatives and mitigating the adverse impacts are also important in terms of project design and environmental impact assessment and monitoring.

Before and during the construction of the Oresund Bridge/Tunnel Link between Denmark and Sweden, there were extensive modelling and monitoring to ensure that the impacts of the project (dredging and altering the cross-section of a narrow section of the outlet of the Baltic Sea) were kept within pre-determined limits. There is a need to develop a reliable model based on extensive field investigations and calibration/ verification. A methodology similar to the one used in modelling the impacts of Oresund Bridge/Tunnel should serve as a guideline for this project.

CONCLUSION

Considering the location of the Sethusamudram Project Site which joins three distinct water bodies, a long-term field investigation programe is recommended. In particular the impact of the regional distribution of wind over the Arabian Sea and the Bay of Bengal which results in major ocean current off the west coast of Sri Lanka and other oceanographic impacts could only be understood and modelled using long-term data sets. Due to lack of field measurements, the models could not be calibrated and verified to the extent normally carried out for a project of this nature. In view of this limitation the results of the present study, although not comprehensive, are indicative in character.

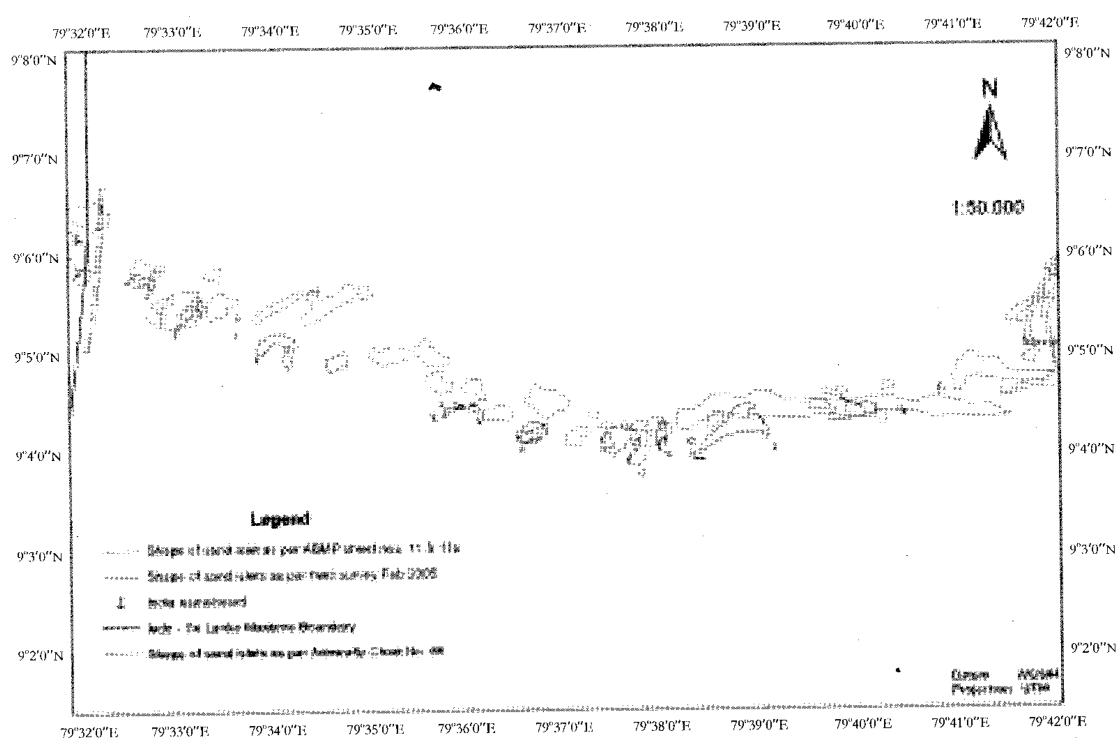


Figure 6: Changes to the Islands

Acknowledgement

Authors acknowledge the financial support given by the Sethusamudram Advisory Group of the Ministry of Foreign Affairs, Sri Lanka. Authors also acknowledge the support given by Mr. Malith Mendis, Dr. Ranjit Galappatti and Dr. K.P.P. Pathirana.

References

1. Institution of Civil Engineers (1991). Capital Dredging. *Proceedings of a conference,* 15-16 May. Institution of Civil Engineers, UK.
2. Lanka Hydraulic Institute (2005). Dispersal of Dredged Sediments Modelling. *Colombo Port Efficiency and Expansion Project.* Lanka Hydraulic Institute, John Rodrigo Mawatha, Katubedda, Moratuwa.
3. Lanka Hydraulic Institute (2004). Hydrodynamic Modelling. *Colombo Port Efficiency and Expansion Project.* Lanka Hydraulic Institute, John Rodrigo Mawatha, Katubedda, Moratuwa.
4. Lanka Hydraulic Institute (2005). Sediment Transport Modelling. *Colombo Port Efficiency and Expansion Project.* Lanka Hydraulic Institute, John Rodrigo Mawatha, Katubedda, Moratuwa.
5. Lanka Hydraulic Institute (2005). Water Quality Modelling. *Colombo Port Efficiency and Expansion Project.* Lanka Hydraulic Institute, John Rodrigo Mawatha, Katubedda, Moratuwa.
6. Wilson, S. (2005). Colombo South Harbour. *Detailed Engineering Report,* UK.
7. National Environmental Engineering Research Institute for Tuticorin Port Trust (2004). *Environmental Impact Assessment for Proposed Sethusamudram Ship Canal Project.* Tuticorin, India.
8. Indomer Coastal Hydraulics (Pvt) Ltd. for Tuticorin Port Trust (2005). *Hydrodynamic Modelling and Ship Manoeuvring Studies for the Sethusamudram Ship Canal Project. Part 1 & 2 – Hydrodynamic Modelling.* Tuticorin, India.
9. Indomer Coastal Hydraulics (Pvt) Ltd. for Tuticorin Port Trust (2005). *Hydrodynamic Modelling and Ship Manoeuvring Studies for the Sethusamudram Ship Canal Project. Part 3 – Nautical Feasibility Study.* Tuticorin, India.
10. Institution of Civil Engineers (1987). Maintenance Dredging. *Proceedings of a conference,* 20-21 May. Institution of Civil Engineers, UK.
11. L & T Ramboll Consulting Engineering Ltd. (2005). Preparation of DPR and evaluation of EIA study for Sethusamudram Ship Canal Project. *Final Detailed Project Report.* L & T Ramboll Consulting Engineers Ltd., India.