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Lecture Notes

Part 2

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CLIMATE CHANGE VULNERABILITY: LOCAL PERSPECTIVES

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Introduction

Cities are causes and victims of climate change. Many cities have developed along the coasts and they multiply out of control with resources used with thoughtless abandon. Cochin, the biggest city along the west coast of India after Bombay functions as the nerve centre of distribution of goods due to its proximity to the port. As elsewhere, Cochin too has expanded rapidly and heavily stressed from environmental perspectives. Cochin has good reason to be concerned as global climate change issues pose severe problems to its coast and coastal structures. This paper presents some results of the combined analysis of impact assessment studies of the coast and coastal structures around Cochin to address the anticipatory issues of the selected sea level rise scenarios.

Study Area, Methods

The area under study is about a 60 km coastal strip, where the shoreline is oriented in a NNW-SSE direction, which varies in its width from north to south. The bordering beaches are composed of fine sands and, in general, have low profile. Shore protection structures in the form of seawalls exist along the southern stretch. They are in a dilapidated condition at several reaches.

Beach transect data generated in the region has been analysed to determine the effects of projected sea level rise scenarios on the anticipatory sedimentary responses such as erosion. Besides the destruction through inundation and increased rates of erosion, sea level rise situations also increase the risk of flooding. In order to elucidate the responsible factors, analysis has been carried out to determine the effects of tropical cyclones in the study area. The present era of intense utilization of the coast and the corresponding demand for construction of coastal protection structures to stabilize the shore necessitates long-term development planning for sustainability. Moreover, knowledge of this dimension will be of considerable use in planning the development programmes including the designing of coastal protection structures. Considering also that the region is densely populated and supports a broad range of economic activities, the potential impact of sea level rise forms an important focus for such assessments.

Sea level rise scenarios

The future sea level changes to be expected are the function of our understanding of the past and present trends. Periodic assessments of the IPCC were designed to provide a comprehensive survey of the state of knowledge about climate change for use by national and international decision makers as the general projections on average global sea level rise, which is readily used in the present investigation as the projected sea level rise scenarios.

The historic sea level rise for Cochin is estimated to have been 2 cm in the last one century (Emery and Aubrey, 1989; Das and Radhakrishna, 1993). Assuming that the local effects remain essentially the same, global trends can be added to the local estimates to develop the total sea level rise projections for a given location. The scenarios of future sea level were obtained by adding the projected values for a given year to the local trend of 0.02 cm per year times the number of years from present.

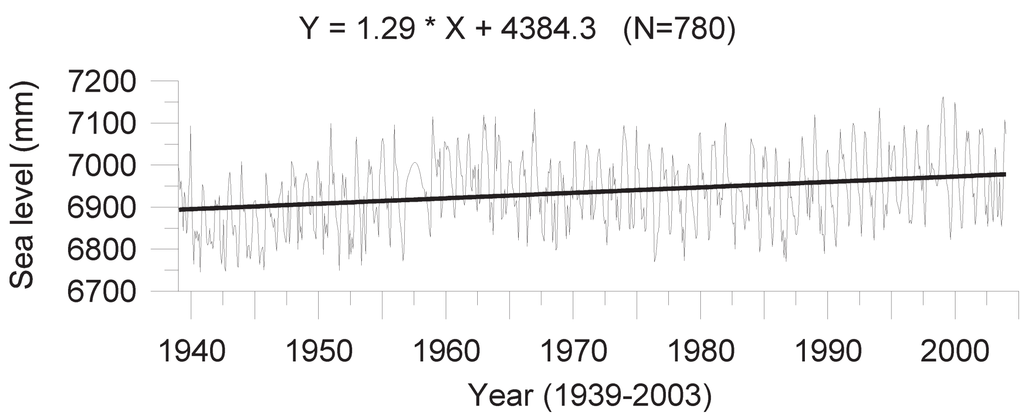
Data obtained from Cochin Port trust (CPT), Cochin and the global data bank of Permanent Service for Mean Sea Level (PSMSL) based at Bidson Observatory, UK for the tidal station at Cochin have been used to compute the monthly mean and long term seasonal trends of sea level. All data are referred to local datum.

Results

Interannual changes and the long-term seasonal cycle of tides

Daily mean sea level is computed from the average of hourly data extracted from the tidal records spanning up to year 2003 beginning with the year 1939. This averaging will significantly eliminate the influences of diurnal, semidiurnal and shorter tidal components in the data (Pugh, 1987). The monthly average, in turn, is effective in reducing all effects with period less than a month. The monthly means are computed from the daily means. Regression technique was used for the determination of trend equation (Spiegel, 1981) (Fig. 1).

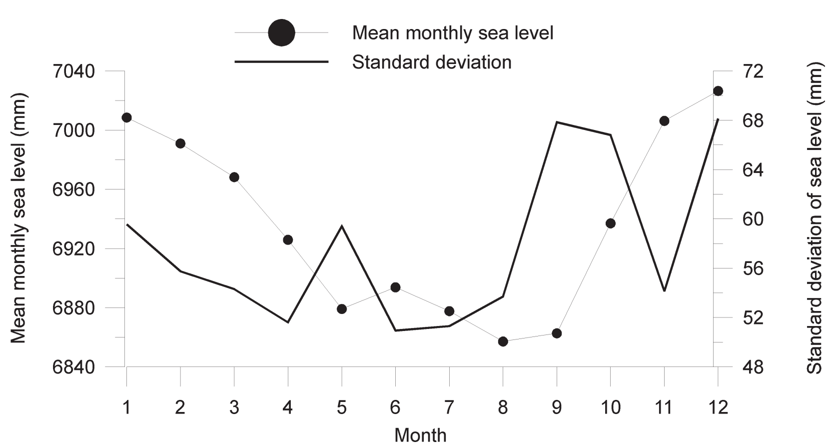
Fig. 1. Long term trend based on monthly mean sea level anomalies



Monthly mean sea level variations

The climatological seasonal cycle derived from the data has shown a range of about 17 cm, the increase from the lowest to highest occurring from August to December (Fig. 2). The sea level is found to be the lowest during the southwest monsoon, even though the rainfall and river discharges are maximum during this period. This can be explained in relation to the prevailing monsoonal forcings and associated upwelling in the region. During this period, the coastal region off Cochin experiences upwelling by which denser seawater is brought to the surface, which overrides the effects of river discharges.

Fig. 2. Mean monthly values and seasonal cycle of sea level at Cochin for 1939-2003



An increase in mean sea level will affect waves, currents and bottom pressure in the near shore region. In general, an increase in mean water depth will be accompanied by an increase in mean wave height, resulting in a more severe wave attack on the coast and a greater wave induced littoral drift. Though it is established that both the morphological and ecological systems of the coastal zones will be affected by a rise in mean sea level, relatively little is understood about wave-induced onshore transport processes.

The effects of future sea level rise on coastal processes and anticipatory sedimentary responses in the study region under various scenarios were examined. For this, the relationship between rising sea level and the rate of shoreline recession (Bruun, 1962), which was widely accepted for derivation of sandy coastlines, was applied (Dinesh Kumar, 2000). Two conditions of erosion were investigated for the study area, which are shoreline recession and associated erosion assuming the existence of a beach seaward of the seawall and erosion/scour at the seawall where there is no beach above mean low water. The erosion due to sea level rise for the region is estimated to be 7125 m^3 per year, implying an erosion rate of -- 0.3 x 10^6 m^3-- per year, which could be attributed to the effects of wave attack. Using the extreme conditions of wave height and sea level rise, future erosion potential is expected to increase by 15.3% by the year 2100. Thus the erosion due to wave attack for the low scenario of sea level would be expected to increase considerably. An estimate of the future erosion and shoreline recession rates and scenarios of future erosion at the existing coastal structures was also made. From the results obtained, it has been found that the effects of climate change and associated sea level rise scenarios will bring profound effect on the coast as well as coastal sedimentary environments, and the land loss along the coastline will be significant.

Inundation

Besides destruction through increased rates of erosion, sea level rise situations also increase the risk of flooding (Nicholls et al., 1999). A detailed study on the various sea level rise and tropical storm surge scenarios in the study area helped in determining the effects, which quantified the inland extent of permanent and episodic inundation that may be expected, if the retreat option to sea level rise is taken into consideration. A quantitative estimate of permanent and episodic land loss resulting from sea level rise and from tropical cyclone induced storm surges was made. Considering an average beach slope of 1 percent for the study region, together with a value of +2.0 mm/year (Das and Radhakrishna, 1993), and also assuming that effects of eustatic sea level changes are negligible in the vicinity, the amount of land that is vulnerable to both permanent and episodic flooding from storm surges was determined. For the purpose of comparison, the effects of the minimal tropical storm, minimal hurricane and maximum storm surge-producing hurricane in the current climate state have also been calculated.

Flooding would increase along the coast. A higher sea level would provide a base for storm surge build-up enabling a storm that occurs once in a few years to flood many areas that are flooded today only by storms with recurrence intervals of hundred years or more. The destruction or over wash of barrier lands by increases in sea level would destroy ocean front properties and leave inland properties vulnerable to storm waves. Higher water levels would reduce coastal drainage gradients. Reductions in these gradients would increase flooding attributable to rainstorms, promote saltwater intrusion into coastal aquifers and force water tables to rise and in some areas to emerge at the surface. Thus, the effects of sea level rise scenarios of land loss on the coastline in the study area are significant. The low dunes that overlook the beaches along the coast will provide no hindrance to inland flooding and the relatively shallow slope of the coast will result in significant loss of land as sea level rises and beaches erode and retreat inland. The unconsolidated sediments that make up the coastline will present no obstacle to erosion caused by the rising waters of the Arabian Sea. The higher wave energies (*i.e*., deeper water will allow larger waves to break onshore) will increase erosion. The monetary losses involved will be significant, as the amount of property inundated by the sea and the number of zones subject to temporary flooding will increase.

Modifications to existing structures

Storm events, raised water levels and associated impacts necessitate the designing of safe, stable and functional coastal structures. However, until recently most planning had taken place against a conceptual framework of relative environmental constancy. However, the adequacy of short term economic planning for achieving sustainable development has already been severely criticised (Weaver and Green, 1998). The change in perspective outlined above is now nowhere more important than in human use in the coastal zone. Designing a safe, stable and functional coastal structure requires water levels that may occur throughout the life of the structure. An assessment of the impact of low and high sea level rise scenarios on the coastal protection structures in the region was made. Depth limited breaking wave criteria (Anonymous, 1984) were used to estimate the design wave heights over the next century for the chosen sea level scenarios. The 50-year return interval water levels were used in conjunction with the scour depth estimates seaward of the seawall to establish the design conditions for any given year. The increases in beach erosion, assuming the existence of a beach as the source for eroded material were considered. Sea floor profile changes that would occur as a result of the sea level rise scenarios were described and it was found that erosion/scour at the toe will be accelerated when there is no beach seaward of the seawall (Dinesh Kumar, 2000). These changes were estimated for two conditions for each sea level rise scenarios by assuming no shore protection works beyond those currently existing and after the berm will have eroded back to the sea wall. As sea level rises, land and structure elevations that are currently not affected by water levels will begin to be inundated or overtopped, and the increased flooding will result directly from the increase in high tide levels as the sea level rises and from the increased frequency of which a certain elevation will be inundated by storm events. The crest of the seawall is at an elevation such that during a 50-year return interval event with present sea levels, approximately 60 percent of the waves will overtop the structure. The change in yearly probability of some damage, intermediate damage and serious damage to the existing sea wall was found to be a function of the projected sea level rise scenarios. In general, it was revealed that, if the study region is to remain in its present form, extensive coastal engineering projects, including the upgrading of the existing structures will have to be implemented for the accelerated sea level rise scenarios investigated. However, the costs of these measures would be significant.

Discussion

As explained, anticipated sea level rise, stemming from global climate warming will affect the coastal zones of Cochin through permanent inundation of low-lying areas with accelerated beach erosion and greater frequency of flooding events. Sea level rise would inevitably bring substantial losses from shoreline retreat and associated processes, and the indirect consequences may bring greater damages than the direct ones. The vegetation and life in the coastal environments are expected to be affected with harmful effects for the population in the region. Other conditions being equal, the more sensitive landscapes will suffer greater catastrophe. Damages to this coastal city cannot be observed in isolation because it is linked with other regions through economic and cultural ties. Changes will affect the hinterlands also and chain reactions may follow. Urban planning will be confronted with a number of anticipatory issues including adaptation strategies.

Further Reading

Bruun, P., 1962. Sea level rise as a cause of shore erosion. J. Waterways Harbours Div., Am. Soc. Civ. Engg., pp. 117-130.

Emery, K.O and Aubrey D.G. 1989. Tide gauges of India. *J Coast. Res*., 5, pp.489-500.

Das, P.K. and Radhakrishna, M. 1993. Trends and the pole tide in Indian tide gauge records. *Proc. Ind. Acad. Sci., (Earth Planet. Sci.)*, 102(1), pp. 175-183.

Dean,R.G.and Maurmeyer, E.M.1983. Models for beach profile responses. In : Handbook of Coastal Processes and Erosion, Komar, P.D., (ed.), CRC Press Inc., Boca Raton, Florida, pp. 151-165.

Dinesh Kumar, P.K. 2000. Studies on the impact of selected sea level rise scenarios on the coast and coastal structures around Cochin, Ph.D. Thesis, Mangalore University, India, 125 p.

Nicholls, R.J., Hoozemans, F.M.J., and Marchand, M. 1999. Increasing flood risk and wetland losses due to global sea level rise: Regional and global analyses. *Global Environmental Change,* 9, pp. S69-S87.

Pugh, D.T., 1987. Tides, Surges and Mean Sea Level: A Handbook for Engineers and Scientists, John Wiley and Sons, N.Y., 472 p