Environmental Assessment Report

Summary Environmental Impact Assessment
Project Number: 40156
March 2010

India: Sustainable Coastal Protection and Management Investment Program

Prepared by the Goa Department of Water Resources, the Karnataka Ports and Inland Waterways Department, and the Maharashtra Maritime Board for the Asian Development Bank (ADB)

CURRENCY EQUIVALENTS
(as of 15 February 2010)

Currency Unit	–	Indian rupee/s (Re/Rs)
Re1.00	=	$0.02154
$1.00	=	Rs46.42

ABBREVIATIONS

CRZ	–	coastal regulation zone
EIA	–	environmental impact assessment
EMC	–	environmental management committee
EMP	–	environmental management plan
ICMAM	–	Integrated Coastal and Marine Area Management
km	–	kilometer
m	–	meter
mm	–	millimeter
m/s	–	meters per second
PMU	–	program management unit
TA	–	technical assistance

NOTES

(i) The fiscal year (FY) of the government begins on 1 April and ends on 31 March. FY before a calendar year denotes the year in which the fiscal year starts, e.g., FY2008 begins on 1 April 2008 and ends on 31 March 2009

(ii) In this report, "$" refers to US dollars.

CONTENTS

I. INTRODUCTION

1. The Sustainable Coastal Protection and Management Investment Program will address immediate coastal protection needs and coastal instability by implementing protection works in the states of Goa, Karnataka, and Maharashtra that are both economically viable and environmentally and socially appropriate. It will also support natural protection measures, such as developing dunes and seeding them with grass and planting mangrove or other trees for protection or shelter, besides promoting the broader aspects of coastal management, such as ensuring water quality, maintaining navigational entrances, dredging waterways, and training river and drain mouths. Institutional capacity will be developed to meet the long-term needs of sustainable coastal protection and management, and the private sector and communities will be encouraged to participate more in coastal protection and management. The approach to coastal protection and management will significantly change, in a well-planned and programmed transition from environmentally harmful protection works to environmentally appropriate and sustainable solutions.

2. The Ministry of Water Resources through the Central Water Commission will be the national coordinating agency and will be responsible to the national government for the project. The state executing agencies will be the Goa Water Resources Department, the Karnataka Ports and Inland Waterways Department, and the Maharashtra Maritime Board.

3. The first loan tranche (project 1) covers the detailed design of four subprojects (see map below).

Map of Project Area Showing Locations of Subproject Sites

10-0700 HR

4. This summary environmental impact assessment (EIA) report summarizes the EIAs for the four subprojects in project 1. Feasibility studies of the subprojects were done in 2008 and 2009 as part of project preparatory technical assistance (TA). Project 1 is a category A project requiring EIAs mainly because the coastal process is complex and the design of structures is based on model simulations. The risks and risk management must be clearly dealt with in project design. Alternatives must also be explored and analyzed to determine the advantages and disadvantages to stakeholders. Despite the category A classification, however, many interventions will be confined to improving the natural environment of the shoreline by stabilizing and restoring the natural beaches. The use of soft, environmentally appropriate technologies for erosion protection, including building artificial reefs, restoring and managing dunes, and planting mangrove and shelter belts, will be supported.

II. DESCRIPTION OF THE PROJECT

5. The coastal zone is a key part of India: about 20%–25% of the population lives within 50 kilometers (km) of the coast, 70% of these in the rural areas. The country has about 7,525 km of coastline—5,425 km along the nine national coastal states of the mainland and 2,100 km along the union territories. All the coastal states and territories are affected by coastal erosion. About 26% of the mainland coastline is seriously eroded, and much of the coastline is actively retreating. The rise in sea levels and the likely increase in frequency and intensity of storms will heighten erosion, with serious consequences for the economy and the environment in the coastal states. By the middle of the century the sea level in the Indian subcontinent will have risen 15–38 centimeters, according to projections. A rise of 1 meter (m) in sea level will displace 7.1 million people in India as 5,764 km^2 of land and 4,200 km of roads are lost.

6. Coastal erosion is due to both natural factors (such as storms and currents) and human actions (such as dam and harbor construction, riverbed quarrying, and inlet stabilization). In India, human activities have contributed to or caused much coastal erosion. These activities include dredging (reducing the sediment supply), river damming and sand mining, and the construction of littoral barriers such as groins, jetties, or ports. Seawall construction can cause beach scour. The loss of shoreline vegetation also affects erosion rates, as do sediment traps such as dredged navigational channels and wave process alterations caused by jetties and ports. The urbanization of the coast has worsened coastal erosion.

7. Coastal erosion ravages land, houses, infrastructure, and business opportunities and poses a high risk to human well-being, economic development, and ecological integrity. It diminishes coastal livelihoods, particularly among poor households, and ultimately coastal economies. Every year, 400 hectares of land, 75,000 hectares of crop areas, and 34,000 residential houses and industrial establishments are lost or damaged through coastal erosion. The impact will be much more widespread in the coming years as economic development proceeds. The rural poor coastal communities are the most vulnerable to the impact of erosion and poor coastal management. But many of India’s rapidly growing urban areas are also vulnerable. Mumbai, for example, spends about $2.5 million per km on capital works alone to protect some of its prime waterfront property.

8. Sustainable and alternative solutions for coastal protection are urgently needed as human activities and relative sea levels exert mounting pressure on the coastal zone. Continuing coastal erosion worldwide has inspired innovative techniques for effective and unobtrusive shoreline and nearshore control. There are increasingly more examples of softer options, such as beach nourishment, dune management, or artificial reefs, replacing or

modifying hard rock protection. India is also making the transition to softer solutions, but it is not an easy one and it requires large investment in planning and design. To start with, the design philosophy must change. The planning and design studies must include a comprehensive analysis of the causes and extent of erosion. The designs must be appropriate for the root causes of the erosion and must accommodate coastal processes in the solution rather than simply trying to mitigate the effects. India must change from its present piecemeal approach to a more comprehensive one based on participatory planning, better-designed and environmentally friendly coastal infrastructure, and accountability, with the long-term goals of minimizing costs and reaping economic benefits.

9. The impact of the investment program will be improved income and reduced poverty in the coastal communities of Goa, Karnataka, and Maharashtra that are covered by the subprojects. The impact will be measured by the rise in income in the communities, buoyed by the expansion in tourism and businesses; the reduction in poverty in the communities; and the rise in land value in the subproject areas. The outcome of the investment program will be the protection and management of shorelines in the three states, meeting the needs of stakeholders and the environment. The key performance target here is the protection and management of 150 km of coastline with the participation of community and private sector.

10. The projected outcome will be achieved through the following outputs: (i) sustainable plans for and management of shorelines, (ii) reduced coastal erosion and instability, and (iii) increased capacity for shoreline planning and development.

11. The four subprojects in the first loan tranche are summarized in Table 1. Coastal protection in India has been concerned primarily with rock protection to deal with the effects of erosion and not the causes. In other countries it is now understood that traditional methods of shoreline protection, using hard engineering structures such as groins, seawalls, and breakwaters, cannot be supported as long-term strategies. The current approach is to carry out comprehensive studies to identify the causes and extent of erosion, and to design softer solutions, such as beach nourishment, submerged reefs, and dune management where practicable. Subproject designs and plans are based on detailed field and numerical model studies of coastal processes and the cause of erosion at each subproject location.

Table 1: Summary of Subprojects

Scheme	Objective and Main Scope
Goa Coco beach	To restore the beach, which has suffered from almost complete erosion over recent years and is now almost entirely lost, resulting in a major collapse of local tourism and erosion risk to the hotels and land. 1. Construction of a semi-submerged breakwater off Mama point. This structure is designed to block the passage of waves into the bay. 2. Construction of a 125 meter concrete sand retention structure to retain the sand on the west side of the bay. 3. Beach nourishment of 180,000 m^3 to restore the beach to its original profile.
Goa Colva beach	The project will address erosion problems along a 6.5 km stretch of the 25 km Salcette beach. 1. Nalla training at Majorda and Utorda beaches. Erosion is primarily due to the uncontrolled flow of water from the Nalla, which migrates up and down the coast. 2. Dune restoration and management along 6.5 km of shore. Dunes can provide an effective buffer. Dune restoration involves scraping from the lower beach, dune

Scheme	Objective and Main Scope
	restoration, planting, and the construction of sand fences, boundary fences, and access pathways.
	3. Geotextile offshore reef construction at Colva. At the very-high-density tourism area at Colva, a multipurpose reef can provide additional protection as well as possible recreation activities such as surfing and snorkeling.
Karnataka Ullal	Long-term and sustainable erosion protection will be provided to prevent very severe erosion at Ullal and possible breaching of the spit. 1. Construction of two large reefs 600 m offshore and in 6 m depth of water. Construction of four nearshore berms. 2. Beach nourishment of 350,000 m^3 along the Ullal spit-sand to be sourced from the entrance and lower part of the Netravati river. 3. Shortening of the southern breakwater and extension of the northern breakwater. This would allow sediment from the Netravati river to be pushed southward and support the nourishment of the southern beach
Maharashtra Mirya bay	Community land and housing along the north part of the bay will be protected. The reinstatement of the beach will allow landing access to fishing boats and opportunities for tourism. The reef will provide habitat for fish and fish breeding. 1. Construction of offshore geotextile reef in the northern part of the bay. Single-layer, shore-perpendicular bags (volume: 10,060 m^3) will be used. Sand will be sourced from sand heaps near the harbor. 2. Beach nourishment of 450,000 m^3 to be placed on the beach and in shallow water inside the geotextile reef. Sand will be sourced from sand heaps, the harbor, and sand accumulated outside the harbor. The beach will provide a natural buffer against storms along the north and central part.

m= meter, km= kilometer, m^3= cubic meter
Source: PPTA and design reports

III. DESCRIPTION OF THE ENVIRONMENT

A. Context of Subprojects

12. The four subprojects are in four separate locations along the west coast of India. They have similar beach settings, but their environmental settings are different.

13. Coastline erosion has intensified in the states of Goa, Karnataka, and Maharashtra—the focus of the investment program. In these states, 50% of the 1,100 km coastline is facing erosion. According to proposals prepared in 2001 for the National Coastal Protection Project, about 530 km of coastline in these states is prone to erosion and 330 km needs protection. Along the west coast, beaches are under extreme pressure from economic development, urbanization, and population growth. At the current rate of seawall and other construction works along the shorelines, the beach could become almost extinct in the next 20 years. Coast protection at present involves the construction of rock walls (revetments) mainly through the dumping of rocks of mixed sizes (riprap).

14. The rural poor coastal communities are the most exposed to the hazardous impact of erosion. Dependence on coastal resources, lack of alternative livelihoods, and destitution draw them to the coastline despite threats from the sea. Coastal erosion hits such communities

hardest since it destroys their property and disrupts their livelihood. The impact of climate change and the associated rise in sea level is likely to worsen coastal erosion.

15. **Goa.** The 105 km coastline of Goa has wide, pristine beaches, sand dunes, and cliffs. About 11 km (10.5%) is subject to erosion. The coastal region of Goa has been subject to high development pressures, poor land-use planning, ineffective enforcement of regulations, and inappropriate coastal protection solutions.

16. **Karnataka.** Karnataka has a coastline of about 300 km, of which about 250 km (83%) is affected by erosion. So far about 57 km of seawalls have been constructed along the Karnataka coastline, but have failed in several cases because they were inappropriate coastal protection solutions, lacked maintenance, and used poor construction methods. Coastal protection is generally developed as an emergency measure and the range of possible interventions considered is limited to a few hard structural measures, such as seawalls and groins. Most seawall structures collapse 3–10 years after construction.

17. **Maharashtra.** Maharashtra has a coastline of 720 km, of which about 320 km (44%) is subject to erosion. Coastal erosion has been increased by the clearance of mangroves and associated vegetation along the shoreline, the construction of offshore and coastal infrastructure including fishing and commercial harbors, and inappropriate coastal protection solutions. Serious coastal erosion in the rural areas has made the coastal communities more vulnerable to natural disasters, such as cyclones, since their dwellings are along the fringes of the shoreline.

B. Environmental Settings of Subprojects

1. Physical Resources

a. Geomorphology

18. The west coast is characterized by flat seabed slopes (1:100 to 1:500) and a wide continental shelf of about 250 km (60 km to 340 km).

19. **Mirya subproject.** Of the 720 km coastline of the state of Maharashtra, sandy beaches account for only 17%; rocky coast forms 37% and mud flats, 46%. The general paucity of sandy beaches along Maharashtra's coast adds significance to the beaches in bays such as Mirya bay.

20. The shoreline of the bay is relatively steep; at about 200 m from shore the depth is more than 5 m. The majority of bed material is sand in the near-coast region. Sediment is supplied to the area from interaction between local rivers, land runoff, and coastal hydrodynamics. Estimated long-shore sediment transport rates show that the net transport along the west coast is mostly toward the south. How this attribute is related to the beach dynamics of Mirya bay is not known. Any significant supply is unlikely since the beach along the northern reaches of Mirya bay consists mostly of granular material, most likely from the erosion of the lateritic cliff.

21. Beach sand from the northern end near the cove is coarse material (sandy, gravelly sediment with granules). The percentage of granules in the sediment decreases and the proportions of sand increase along the beach from north to south, suggesting progressive erosion at the cove north of the bay and the southward drift of this eroded material.

22. **Coco subproject.** The coastline of Goa has continuous stretches of sandy beaches (occasionally interrupted by rocky promontories or headlands), which protrude as far as 2–3 km into the sea. The majority of the bed material is clay and silty-clay in the offshore; however, sand environments exist in the near-coast region.

23. Like most of the other estuarine beaches, Coco beach slopes gently landward from the waterline. The western-end waterline is marked by a laterite seawall put up to protect private property. Along the eastern edge there are natural laterite formations. Coco beach was a veneer of sand on a lateritic base until its recent loss. Sediment is supplied to the area from interaction between the Mandovi river and the coastal hydrodynamics. Sediment from Coco beach is predominantly sand, being slightly gravelly in the eroded area. Samples taken from the sandbar off Miramar in Mandovi estuary were predominantly sand. The beach sand was predominantly black, indicating the presence of iron and manganese ore spilled during transport on the Mandovi river.

24. **Colva subproject.** The stretch of sandy beach between Cansaulim in the north and Betul point in the south is popularly known as Colva beach, which includes Utorda and Majorda beaches. In general, the beach foreshore is wide and steep at its extreme ends. It has a gentle gradient and is backed by well-developed sand dunes. The original natural dune ecosystem was altered by structures, roads, and canals built as tourism developed in the area. In places where creeks (nallas) join the sea, the dunes are severely eroded and rise abruptly above the beach. During the monsoon finer sand is removed by wave action, resulting in a steeper profile for the beach nearer to the water. The nearshore coastal bathymetry off Colva beach, where the submerged reef will be built, is gently sloping, making the beach attractive to swimmers.

25. The linear stretch with a very wide beach between Velsao and Mobor is backed by the largest and longest strip of sand dunes in the entire coastal zone of Goa. The dunes are mostly within 500–600 m from the shore. The Utorda–Majorda–Consua–Betalbatim coastal zone is marked by long strips of sand dunes, some as high as 8 m, with associated vegetation. Coconut plantations are prominent. At several places in this stretch, the sand dunes have been flattened and destroyed. There is severe beach erosion near the Majorda beach resort.

26. **Ullal subproject.** The Mangalore area is covered mainly by tertiary and quaternary sediment. Outcrops of granite extend to the beach near the south end of Ulla (Someshwara) and in other places. Ullal beach is immediately south of the mouth of the Netravathi river. As is typical of most estuaries in Karnataka, sandbars have developed near the river mouth. Ullal beach is on a barrier spit, also a common feature at river mouths in the state because of the migration of coastal rivers. The beach is one of 90 beaches of varying aesthetic potential, and among 22 deemed unfit for use because of coastal erosion and other human activities.

27. Ullal beach, like most of the other eroding beaches, is comparatively steep, and is deeper still at the point where seawalls are causing scouring. The foreshore land accommodating human settlements and built areas rises abruptly above the beach.

28. At Ullal beach, the texture of beach sand varies from coarse to fine depending on the season and wave dynamics. Sediment is supplied to the area by interaction between the river and the coastal hydrodynamics. At a short distance from the shore the sediment is predominantly silt and clay.

b. Meteorology and Oceanography

29. India's west coast is visited by two storms a year on average. Unlike the east coast, where there are two distinct monsoons, the west coast experiences only the southwest monsoon (May–September). While high wave activity prevails during the southwest monsoon (June–September), the seas are relatively calm the rest of the year. The wave direction and energy during the monsoon season propagate at shore normal or perpendicular to the coast. Because of the monsoons, the waters off the west coast of India experience a wind stress that is strongly time dependent. Climatic ship drift data indicate that from April to October the long-shore surface current is equatorward along the west coast. There is also evidence of upwelling along the west coast, especially along the southern part. From November to January, during the inversion period, the equatorward long-shore wind stress is very weak. Data on monthly mean wind show that the long-shore component of wind stress, which is equatorward throughout the year, is weak in March. It begins to increase in April, reaches a peak value in July, and again declines by November. Strong tidal currents exist in the northern west coast of India. The west coast of India has a semidiurnal tidal range varying from about 1 m in the southern extents to 6 m in the north. The tide exhibits diurnal and semidiurnal bands. Strong tidal currents exist in the northern west coast of India. The measured current speed is found to vary from 1.4 meters per second (m/s) in the open ocean to 3.2 m/s in the Gulf of Khambhat.

30. **Mirya subproject.** Wave characteristics recorded north of Ratnagiri (off Dhabol at 14 m depth line) show wave heights (Hs) ranging from 0.4 m to 4.6 m. The wave height for a 100-year return period for Ratnagiri is 3.9 m. Mirya bay is particularly vulnerable to high-impact open-ocean swells especially during the monsoon period. The oceanographic pattern expressed within Mirya bay is inferred to be a trend from a southward drift during the southwest monsoon to a partial reversal during the non-monsoonal period.

31. In Maharashtra the currents are somewhat reduced compared with areas to the north such as the Gulf of Khambhat. Here the currents are mainly tidally induced during the summer months, whereas the magnitude of the current speed observed increases during the monsoon period because of increased precipitation and runoff. There is a significant difference in the dominating current direction during the two seasons. The majority of local currents are bound by varying physical and geologic conditions such as bathymetry. Local meteorologic conditions will also drive variable current cells.

32. **Coco subproject.** A study off Calangute beach to the north of Coco beach in November–May indicated significant wave heights of 10–75 centimeters. The direction of these waves, as determined from visual observations, was found to be west–northwest in November–March and southwest during the month of May. Wave data from data buoys indicate that the significant wave height off Goa varies from 1.0 m to 5.7 m. In general, significant wave heights greater than 2.5 m in May–September are typical of monsoon wave characteristics. Coco beach is partially protected from open ocean swells by the bay and estuary in which it is located.

33. Goa lies midway up the west coast, and the daily tidal amplitude varies from 2 m to 3 m. At Coco beach the tide is observed to range from 1.5 m to 2.2 m along the coast of Goa. The currents are mainly tidally induced during the summer months, whereas the magnitude of the current observed at the Mandovi river mouth increases during the monsoon period because of increased precipitation and runoff.

34. Studies indicate a predominant northward flow along the beach during the fair-weather season and a persistent zone of rip currents about 2 km south of Baga (north Goa). During the

pre-monsoon and monsoon months, littoral currents were found to be directed northward in some places and southward in other places along the beach, leading to numerous converging currents near the beach. The general patterns of these currents and the changes in their regimes have a bearing on the pattern of sediment distribution and sediment transport in the area. Because it is secluded Coco beach has negligible littoral drift compared with other beaches that face open seas.

35. Rivers in Goa are comparatively short, mainly rain fed, and with significant tidal influence. Mandovi is the largest. It originates in Parwa ghat, a section of the western ghats in Karnataka State, and traverses about 75 km before it joins the Arabian Sea. It is joined by a vast tributary system and is characterized by narrow bends, shallow depths, and several islands. At the mouth, between the Aguada and Cabo headlands, the Mandovi is 3.2 km wide; 4 km upstream the width is less than 1 km, forming a bay structure. Near the mouth of the river, within the bay, there are two shoaling zones: the Aguada bar and the Reis Magos bar.

36. **Colva subproject.** Wave statistics show a persistent west–southwest wave approach in the southwest monsoon season. As in Coco beach, wave data indicate that significant wave height off Goa varies from 1.0 m to 5.7 m, and in general heights greater than 2.5 m in May–September are typical of monsoon wave characteristics. Along Goa coast the daily tidal amplitude varies from 2 m to 3 m.

37. During the pre-monsoon and monsoon months, littoral currents are directed northward in some places and southward in other places along the beach, leading to numerous converging currents near the beach. The general patterns of these currents and the changes in their regimes have a bearing on the pattern of sediment distribution and sediment transport in the area.

38. **Ullal subproject.** Karnataka lies in the southern half of the west coast. The daily tidal amplitude varies from 1 m to 2 m and at Ullal beach the tide may vary from 1.0 m to 1.5 m. Tides may not have any major role in coastal erosion but, along with the dynamics of currents and waves, their role in the system is significant. High tides during storms or large wave events may have a more important effect on the shoreline.

39. In summer, seawater intrusion is up to a distance of 20 km in the Netravati river and up to 15 km up the Gurupur river, which joins the Netravathi river at its mouth.

40. The current speed observed and reported off Mangalore coast during May at a depth of 9 m was 0.05–0.40 m/s and the direction was 180°–360°.

41. Being located in the southern half of the west coast, Mangalore receives maximum exposure to the southwest monsoon. Most rain falls in June–September. The monthly rainfall pattern in the past 10 years indicates that the maximum rainfall occurs in July.

2. Ecological Resources

42. No terrestrial or marine protected areas are within the subproject areas. No endangered species in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species have been reported, and there are no records of turtles nesting on the subproject beaches. No national parks, wildlife sanctuaries, or important bird areas are found in the immediate vicinity.

43. **Mirya subproject.** Benthic samples showed intertidal beach sand from Mirya bay to be poorly populated by benthic organisms. Diversity was also poor—not more than four groups were recorded from any place. The severe wave action and coarse sand at Mirya bay make the intertidal area inhospitable, resulting in a low density of benthic fauna (infauna and epifauna). A large amount of shells and shell fragments in the sediment indicate large gastropod and bivalve populations in deeper regions and offshore. Sediment in Mirya bay itself is finer in texture and the milder water currents support richer fauna, especially burrowing organisms.

44. Species landed by Mirya bay fishers include ribbonfish, carangids, sciaenids, squids, perches, silver bellies, halfbeaks, fullbeaks, puffer fish, thryssa, catfish, pomfrets, prawns, and crabs. Mirya bay fishers engage in traditional fishing using seine nets, gill nets, and drift nets. The peak fishing season is July–October. The main contributors to the fish catch are small and medium-size pelagic fish, which are not confined to the bay ecosystem. Within Mirya bay traditional methods using shore seines and gill nets are the most important for subsistence fishing. Traditional canoes operate small gill nets from the northern end of the bay. Mirya bay is traditionally a shore (beach) seine operation center. The number of units operating has declined over the years as the beach area, which is essential to their operation, has declined.

45. Although some mangroves, salt marshes, and mudflats exist in the Ratnagiri district, there are none at the subproject site. Those that do exist in the area are far enough from the area of construction to be unaffected.

46. **Coco subproject.** Benthic samples taken from Coco beach in August indicate that the intertidal beach sand is poorly populated. True sediment dwellers are poorly represented in the biota of the intertidal beach sand because of the presence of fine mineral particles in significant quantities. Further, there is high content of organic debris, which renders the sediment inhospitable to several organisms. Coco beach seems to have lost the built-in mechanism to acquire richness and diversity of benthic organisms, as favorable conditions are lacking. The sediment from the sandbar off Miramar sampled in October was also poorly populated. The dynamic currents and coarser grain size do not favor the establishment of richer fauna there.

47. Overall, water quality in the Mandovi estuary is healthy. Nutrient concentrations are low during dry periods but increase during the monsoon. Past studies reflected nutrient enrichment in areas close to mine ore rejects, especially during the peak southwest monsoon, and normal concentrations beyond these zones, indicating that the effect is localized. Also, past modeling studies showed that treated sewage discharged by the sewage treatment plant of Panaji city had no impact on Mandovi water quality beyond 250 m from the outfall point because of the persistence of good flushing conditions.

48. At Coco beach, the major fish species landed are penaeid prawns, Indian mackerel, carangids, and oil sardines. Around 92 active fishers are engaged in fishing, especially in fair weather. Gill nets, drift nets, and seine nets are operated from this center. The peak fishing period is August–November.

49. Mangroves are present upstream of the Mandovi estuary, but not near this beach.

50. **Colva subproject.** The severe wave action and coarse sand during the monsoon are not favorable to a variety of benthic organisms. Overall, the biodiversity observed is low in species and communities. True sediment dwellers are poorly represented in the biota of the intertidal beach sand because of the grain size and the surf dynamics. Sediment in the sea off

Colva hosts a richer fauna compared with intertidal beach sediment. The finer texture and the milder water currents support richer fauna, especially burrowing organisms.

51. Sand dunes along the beach have a variety of native and exotic plants, which help to bind the sand and increase dune stability.

52. **Ullal subproject.** An important feature of the beach ecosystem at Ullal is the changing condition of the beach. Sand is partially lost in the monsoonal scour and then replenished during the non-monsoon period. Having evolved over a long period of time, the beach has lost its dynamic stability through the extreme erosion of monsoon waves and disruptions in the sediment budget caused by interventions such as breakwaters and seawalls. Thus, the material (sand) cycle in the beach has almost lost its equilibrium and the beach system is in unidirectional degradation.

53. Among benthic fauna, true sediment dwellers are poorly represented in the biota of the intertidal beach sand of Ullal beach. The benthic biota in coastal waters is seasonal because of seasonal changes in sediment characteristics and hydrodynamics. Ullal beach seems to have lost the built-in mechanism to acquire richness and diversity of benthic organisms, as favorable conditions are lacking.

54. Ullal used to be a major traditional fish landing center with many fishing activities and a variety of craft and gears. The beach was wide enough to accommodate Rampan (large shore-seine) operation, which ceased after purse seines were introduced in the 1970s. Since 2005 the landing center has been used by only a few boats during the fair-weather period; the rest of the boats have migrated elsewhere.

3. Social, Economic, and Cultural Conditions

55. **Mirya subproject.** The major resource and land uses in the Mirya bay area are (i) traditional fishing in the bay waters, (ii) navigation related to commercial marine fishing, (iii) housing and homestead agriculture in the two villages of Bathy Mirya and Jakie Mirya, (iv) the fishery harbor and associated activities, and (v) activities associated with the commercial cement industry at the breakwater and pier south of the Mirkarwada Fishery Harbor.

56. The subproject is in Ratnagiri Taluka and spreads over Mirya Gram Panchayat and Mikawada Ward No. 19 of the Ratnagiri Town Municipal Council. Mirya Panchayat is predominantly rural, while Mirkawada is part of an urban area. According to local residents of Mirya bay, a beach width of about 50 m has eroded along the bay. The erosion of this beach has primarily affected traditional fishers. The accumulation of sand near Mirkarwada fishing harbor affects the navigation of a large number of fishing vessels and the effective operation of the fishing harbor. This is an important fishing port in the region south of Mumbai, and fishing and related trade contribute substantially to the economy of Ratnagiri town.

57. Fishing and related occupations, such as boat industry, fish drying, and marketing of fresh and dried fish, are the livelihoods of about 70% of the population in the Mirya bay area. The majority of the people in the Mirkarwada ward survive on fishing and related activities.

58. **Coco subproject.** The major resource and land uses at Coco beach and the adjoining nearshore and foreshore areas are (i) beach tourism; (ii) traditional fishing; (iii) water sports; (iv) housing, homestead agriculture, and animal husbandry; and (v) fish landing and related

activities. Local residents live on the seafront alongside hotels and small tourist and fishers' shacks. Further inland are forests, paddy fields, and cattle grazing areas, all with commercial value.

59. Coco beach lies within Nerul Gram Panchayat of Bardez Taluka. The two predominant economic activities are tourism and fishing. Some families undertake agriculture on a stretch of paddy fields near Coco beach. Beach erosion has confined fishers to a narrow area, making it difficult for them to launch and land their boats.

60. Coco beach is well known as an attractive beach and is frequented by a large number of tourists, mainly from abroad. Because of its sheltered location the beach is used extensively as a base for boat trips including whale watching. The significant decline in the number of tourists has made enterprises unviable. A large number of workers are employed in tourism.

61. **Colva subproject.** The major resource and land uses at the Colva, Utorda, and Marjoda beaches and the adjoining nearshore and foreshore areas are (i) beach tourism; (ii) traditional fishing (in the Colva area); (iii) water sports; and (iv) housing, homestead agriculture, and animal husbandry. The beaches are popular with domestic and international tourists. There are two hotels at Utorda, and one at Majorda. These two locations seem to be popular mostly with international tourists; there are local villages but no urban development. There is also one hotel at Betalbatim. Colva, which has a small town and many hotels and tourist facilities, is one of the most popular beach locations in Goa among domestic tourists. Other types of tourist business operating on the beach are various boat rides and water sports. In addition, there are many hawkers selling clothes, souvenirs, and other knickknacks.

62. Colva, Utorda, and Majorda are parts of a continuous stretch of 25-km-long beach in Salcette Taluka of South Goa district. The main sources of livelihood are tourism, trade, and employment associated with tourism and fishing. A large percentage of households are employed in trade linked with resorts, hotels, shacks, and other service establishments. Some shacks employ people from abroad, in addition to interstate migrants and local people.

63. The Colva stretch of beach is very important to the tourism industry in Goa. Nearly 25% of all domestic visitors and more than half of all foreign tourists in the state visit Colva beach.

64. **Ullal subproject.** The major resource and land uses at Ullal beach and the adjoining nearshore and foreshore areas are (i) fish processing; (ii) traditional fishing; (iii) housing, homestead agriculture, and animal husbandry; and (iv) fish landing and associated activities.

65. Ullal, in the Dakshina Kannada district of Karnataka, is a suburban settlement south of Mangalore, typically developed for housing with community facilities like schools, hospitals, and places of worship. Fish meal and fish oil extraction plants are located along the northern part of the beachfront. To the south, residential plots, ice plants, and processing units are located along the seafront. Farther south are open beach (fish landing center), a resort, and several other institutions and settlements. The township is toward the eastern side, and beyond the town limits paddy fields, grazing land, forestland, and coconut groves are found.

66. Ullal beach used to be an attraction for people of Mangalore. The beach was quite wide and was a popular traditional fishing center. Soon after breakwaters were built at the mouth of the Netravati–Gurpuru river in 1994, however, the beach south of the southern breakwater started eroding. Government agencies started dumping granite boulders to form a seawall as a protective measure. But the erosion problem only worsened.

67. The villages severely affected by beach erosion extend along Ullal beach from Kotepura in the north to the Mukkacheri and Someshwara in the south. In Kaiko, one of the affected areas, several houses that were recently destroyed by wave action are still visible. Some portions of the walls built earlier are sinking, forcing agencies to dump more boulders. According to the local people, many past attempts to build rock walls on the beach did not succeed. Almost all of the coconut palms that provided protection to homes as well as nuts for consumption have been uprooted or badly damaged. Some households have abandoned their homes after these were severely damaged and sought shelter elsewhere.

68. Vessel navigation through the mouth of the Netravati river to the Old Mangalore Port (Bunder) has been a problem for years. The development of the fisheries harbor in the Gurupur river, by the side of the old Bunder, spurred excessive vessel traffic. Several boats grounded on the sandbars that occasionally formed at the mouth of the river. The government department concerned built the breakwaters in an attempt to solve the problem.

IV. ALTERNATIVES

69. **Project locations.** The project terms of reference required the selection of one or two subprojects per state for detailed studies and design. The selection was based on a range of issues that went beyond coastal protection and into matters such as socioeconomic circumstances, state preferences, erosion status, data availability, ability to demonstrate alternative coastal protection solutions, and interdepartmental aspirations.

A. Proposed Technologies

70. The solutions developed to meet the specific needs of each subproject location are summarized in Table 2.

Table 2: Summary of Features Proposed for the Subprojects

Proposed Feature	Mirya	Coco	Colva	Ullal
Offshore submerged reefs	✓		✓	✓
Onshore berms				✓
Beach nourishment	✓	✓		✓
Concrete retention box		✓		
Dune restoration and management			✓	
Nalla (stream) training			✓	
Semi-submerged breakwater (wave)		✓		
Breakwater realignment (river)				✓

Source: PPTA and designed reports

71. The transition to softer solutions is relatively new to India but has been achieved in other countries. In many areas softer options such as beach nourishment, dune management, or submerged structures below mean sea level have replaced or modified hard rock protection. In Italy, for example, where seawalls, detached breakwaters, and groins have modified the coastal landscape, created downdrift erosion, and prevented the full recreational use of the beach, besides being costly to maintain, has adopted soft shore protection over the last few decades. The measures include beach nourishment, beach draining, the use of geotextile bags and tubes, and the construction of submerged breakwaters, submerged groins, permeable groins, and

artificial shoals. More recently, multifunctional coastal protection options have been gaining greater acceptance. On the Gold Coast (Australia) and on Mount Maunganui (New Zealand), for example, artificial offshore submerged reefs have been built for coastal protection, recreation, and marine ecology improvement. Beach nourishment projects are most often undertaken in conjunction with some form of sand retention device such as groins (e.g., Poole bay, England), submerged reefs (e.g., Narrowneck on the Gold Coast in Australia), or detached breakwaters (e.g., East Anglia, England). This combination of coastal protection methods lowers the costs of nourishment (since the material stays in place for a greater period of time), addresses the availability constraints of source materials, and is more sustainable.

1. Reefs

72. A multipurpose reef is an innovation that provides multiple benefits, particularly coastal protection and surfing waves. Other benefits may include sheltered waters inshore for safer swimming or improved marine ecology on the reef. The key purpose of the reef as detailed for the subprojects is coastal protection. Other technologies considered were linear and T-groins, and shore-parallel reefs and rock seawalls. The offshore reefs and nearshore berms at Ullal are designed to reduce the amount of fill lost alongshore or offshore. The reefs and the berms are positioned in such a way as to avoid any undesirable effects, including accelerated erosion at adjacent down-coast beaches.

73. **Geotextiles versus rock materials: Environmental issues.** Most rock quarries in India are in protected forest areas, and recent environmental laws have put major limitations on the quarrying of rock. Quarry permissions for rock, especially large rocks (heavier than 1 ton), are not easily available. Rock and tetrapod options would require, besides diver support, heavy barge cranes, whose sourcing is quite problematic in India. The transportation of large volumes of rock also entails environmental issues. Discussions with government officials indicate that communities or nongovernment organizations are very likely to object to the disruption and environmental impact of extensive rock extraction and movement. Because of the environmental issues relating to rock quarrying, the Ministry of Environment and Forests requires minimized use of rocks as construction materials in coastal and harbor work wherever possible. The environmental considerations for the two types of materials are compared in Table 3.

Table 3: Geotextile Options and Rock and Tetrapod Options Compared

Aspect	Sand-Filled Geotextile Tubes	Rocks and Tetrapods
Logistics and environment during construction	Low impact	Concerns about getting permission to extract such large volumes of rock. Some risk of social objection to heavy truck movements.
Resistance to storms	Less-well-documented information	Long track record and well-researched empirical formula for design. Maximum weight 5–7 tons. Some risk of slipping.
Fisheries	Greater fish biomass attractive to fishers. Nets would not be harmed.	Some advantages for crustaceans. Would cause snagging of nets and could be perceived badly by fishers.
Marine environment	Once covered in weed and sand, appearance similar to that of natural structures. Seaside sand deposit reduces forces on bags and creates natural front face.	Reef footprint three times larger than that of the geotextile reef. Tetrapod less ecologically friendly than geotextile alternative—would support a lower biomass than geotextiles.
Tourism	Potential for tourism and recreation	Limited tourist potential
Maintenance and sustainability	Uses high specifications and properly designed structures. Life expectancy can be long.	Proven track record. But some risk of slips and breakage of tetrapod legs. Tetrapod construction must be of very high quality to ensure sustainable structures.
Project objectives and perspective	High and very much in line with overall project objectives	Not in line with general project objective of supporting new technologies
Costs	About the same as those for rock and tetrapod structures. Future increases in national capacity should offer further price advantages over rock and tetrapod structures.	Long-term indications of reduced availability of rocks and increase In prices

Source: PPTA and designed reports

2. Berm and Concrete Box Retention Structures

74. For the final design of one subproject (Ullal), 15 different berm shapes were considered and modeled. At Coco beach, a long geotextile berm was considered for use as a retention structure. However, the risk of damage at that location was felt to be high, so a much smaller concrete rock retention structure was chosen instead. A second, smaller geotextile berm was also removed from the design to allow sand to move to a bordering beach area.

3. Beach Nourishment

75. Beach nourishment practices include pumping nourishment material onto a beach, and piling material at a high watermark or a low watermark or as a berm to allow waves to move

material onto the beach and create a natural profile. Beach nourishment is gradually becoming one of the main methods used for coastal protection.

76. The various sand sources were assessed and the results considered in subproject design. An analysis of possible contaminants is included in each subproject EIA.

4. Breakwaters

77. At Ullal, the breakwater-altered designs were tested through evolution numerical modeling. The feasibility study concluded that the recommended design would facilitate the natural bypass of sand, and direct sand from the river south to supplement the littoral drift from the northern beach. The modifications were deemed cost effective, with minimal works required. The shortening of the south wall would make expensive maintenance unnecessary. The new north wall would minimize works to repair the damaged head of the northern breakwater.

78. At Coco beach, the design team recommended that a low-crested breakwater made of rocks be built because a rock structure at that location would be natural looking and sustainable.

5. Dune Restoration and Management

79. **Dune construction and stabilization.** In regions where sediment is transported by the wind, dunes are usually constructed by placing wooden fences strategically along the back of the beach. The fences disrupt the airflow, thereby promoting sediment deposition, generally on both sides of the fence. Closely associated with dune construction is dune stabilization, to secure bare sand surface in the dunes and repair gaps in coastal dune ridges. Both fences and vegetation are often used to stabilize dunes.

80. The Colva feasibility study, done under a project preparatory TA, considered dune management alone to be insufficient to tackle the problems. The initial design included sand-filled geotextile tubes as a dune core. The geotextile tubes would address dune management by (i) providing a geotextile dune core that would prevent dune erosion and breaching, and (ii) helping to channel water flow across the beach during the monsoon. The risk of turbulence along the seaward edge of the geotextile tubes proposed for use as a dune core was, however, identified in a later technical review and discussion with stakeholders, and so the geotextile tubes were not included in the final design.

81. **Beach scraping.** Beach scraping is the transfer of sand from the lower beach to the upper beach (within the beach system), usually by mechanical equipment, to redistribute the sand to parts of the beach above the tide level. Beach scraping can be used to speed up the rebuilding of the dune system after a storm event. The amount of scraping must be kept to an environmentally acceptable volume. Over-excavation could affect marine fauna and alter the stability of the beach. For the beaches at Colva scraping should not exceed a depth of 0.25 m over a width of 20 m from the low-tide level. To build up larger dunes the beach scraping should be done over several seasons.

B. With the Project and Without

82. The subprojects would prevent losses that would otherwise occur without the project. To assess the expected quantifiable benefits of the subprojects, with- and without-project scenarios were compared. Most benefits accrue from the prevention of land, building, and infrastructure

losses occurring in the without-project scenarios. All subprojects are assumed to have an economic life of 25 years. Quantified benefits arising from the prevention of erosion and damage are based on the probability of occurrence and accrue from the start of the subproject. Other benefits, notably from tourism, begin to accrue from the second or third year after the start of construction. Under the with-project scenario, the soft engineering solutions will prevent further degradation of the coastline, while enabling the beach to regain stability through natural processes. Reversing the environmental degradation ensures that

(i) fisheries are protected;
(ii) beaches from which boats can be launched locally are improved or maintained;
(iii) natural littoral drift is uninterrupted; and
(iv) the environment is improved through the use of submerged reef structures in coastal defense and protected areas, and through dune restoration and management.

83. The benefits of the proposed interventions on the beaches will accrue from the positive impact of preventing erosion by correcting the sediment cycle. The economy will benefit from the prevention of loss of property and from the savings on the recurring cost of coastal protection. The beach improvements will help restore the traditional fisheries operations and also open up opportunities for beach tourism.

V. ANTICIPATED ENVIRONMENTAL IMPACT AND MITIGATION MEASURES

A. Physical Resources

1. Air Quality

84. Air quality will be affected during construction by emissions from vessels, equipment, and land vehicles in work activities at work locations. If the conditions at subproject work areas during or shortly after construction are dry and windy, wind-borne dust may occur. Sediment from dredge areas is likely to contain a small proportion of fine sediment.

85. No effects on air quality are expected during the post-construction maintenance of reefs, berms, and beach nourishment areas, apart from small emissions during short inspection visits by responsible authorities or during the repair of any damage. The visits are expected to be of relatively short duration compared with the initial construction activities.

86. **Mitigation measures.** Possible mitigation measures include (i) turning off engines and generators when not in use; (ii) ensuring that equipment conforms to international standards; (iii) regularly or routinely servicing all construction vehicles and machinery; and (iv) immediately replacing defective equipment and removing it from the work site.

87. Dust emissions from construction sites can be controlled (i) by suppressing dust through regular sprinkling (morning and evening) with water; (ii) halting work during excessive onshore winds; and (iii) immediately dealing with social complaints as they are expressed.

88. **Residual effects.** The effects on air quality are expected to be small in volume and geographic extent. Emissions will occur during most of the construction season, but will be of relatively short duration in any one location. Potential effects can be minimized through the use

of standard mitigation measures. Concentrations of particulates and gases will rapidly return to pre-construction conditions once the activity stops.

2. Noise

89. Noise will occur when vessels or barges bring dredged sand to the beach nourishment areas, and equipment or pumps distribute sand along the shore. Vessels and equipment will be used in reef, berm, and breakwater construction, and vehicles and equipment will be used in beach scraping, dune restoration, and creek (nalla) training. Additional, though smaller, noise sources will include land vehicles used to move materials and equipment between staging areas and work-area access points. But the noise from the vehicles will be mainly engine noise and not the high-impact noise associated with marine pile-drivers. The noise will occur periodically over more than one non-monsoon construction season at some subproject locations.

90. **Mitigation measures.** Possible mitigation measures include (i) identifying work timing windows or appropriate hours of equipment operation acceptable to the community through consultation, (ii) maintaining minimum noise levels near dwellings and businesses, (iii) checking daily to lessen excessive noise especially out of daylight hours, and (iv) addressing complaints regarding noise immediately.

91. Noise can be minimized by (i) turning off engines and generators when not in use; (ii) ensuring equipment conformity to international standards; (iii) fitting all vehicles used in construction with silencers; and (iv) immediately replacing defective equipment and removing it from the site.

92. During the feasibility study consultation residents in the vicinity of some subprojects said they wanted to have the erosion problem dealt with as quickly as possible to prevent further damage to dwellings, and declared their openness to extending work hours to shorten the overall construction period.

93. **Residual effects.** Noise will occur at reef, berm, breakwater, and beach nourishment locations during seasonal (non-monsoon) construction periods (over three non-monsoon seasons at some locations), dune restoration and creek-training locations, and sand extraction and dredging sites. However, the noise at any single work location will not be sustained and will shift as work is completed. Noise levels can be minimized through the use of standard mitigation measures. The effects on communities can be minimized through public consultation regarding appropriate hours of construction activity. Noise levels will return to pre-construction conditions once the activity ends. No significant effects of project-related noise are anticipated.

3. Shoreline Currents

94. Artificial reefs can alter local current patterns, producing effects such as rip currents and downstream beach erosion. Reduced currents can lead to the formation of sediment bridges connecting reefs to beaches (tombolos), which in turn can reduce the amount of sediment transported to down-current beaches and thereby cause the erosion of those areas. Compression of flows can lead to stronger currents and scour of the shoreline and seabed in the gap if the reef is placed too close to the beach.

95. **Mitigation measures.** The effects of reefs and other structures on currents were considered during the development of the reef designs and placement. Detailed numerical

modeling was used to evaluate and guide the choice of structure features and placement locations. The factors considered included depth, distance offshore, length, width, and shape. A key element of the design studies was avoiding negative effects on the beach system, particularly in relation to beach erosion or rip currents.

96. Reefs will be placed well offshore to get maximum benefit by creating wide shadow zones. This also ensures that currents are not reinforced in the gap between the reefs and the shore by compression of flows. The reefs will reduce, but not totally eliminate, wave energy in their lee to induce sedimentation and thus widen the beaches so that they provide natural protection for the shorelines. Allowance for some wave energy in the reef shadow zone ensures that sand can still move downstream and thereby eliminate downstream effects.

97. **Residual effects.** Significant adverse effects on currents are not expected, but changes in current patterns are to be monitored and evaluated for several years after the reefs are installed. Appropriate measures will be considered and taken if significant adverse effects are observed.

4. Erosion of Beaches

98. In addition to the influence of altered currents on potential downstream beach erosion, reduced sediment flow in the early stages of salient formation could induce the erosion of downstream beaches.

99. There is a risk of unexpected events such as storm surges and undesirable impact on coastal erosion because of the complexity of nature and the difficulty of acquiring accurate data.

a. Mitigation Measures

100. The effects of structures on currents and the potential for the formation of tombolos or downstream beach erosion were considered during the development of the reef designs and placement. Numerical modeling was used to evaluate and guide the choice of reef features and placement locations. Factors that would help to avoid the negative effects on the beach system, particularly in relation to beach erosion or rip currents, were considered.

101. A suite of models was used during the design stage to identify structure placement locations and features that would minimize the potential for downstream erosion. The models were (i) a sophisticated model for predicting wave dynamics; (ii) a model for predicting shoreline adjustment; and (iii) a coupled wave transformation, circulation, and sediment transformation model for beaches. Model predictions and simulations used to aid in the design of structures were based on a combination of global and domestic data sets. Long-term wave and tidal data from global data sources were compared with local data sets and field data, and used to calibrate models. Modeling was carried out and validated against historic data to analyze the effects of previous works and to predict the outcomes of the subprojects. The models examined changes in current speed and direction during different tidal cycles. To incorporate sensitivity to the effects of a rise in sea level into flow modeling the existing situation and the proposed shoreline for a scenario with a rise in sea level were simulated.

102. **Uncertainty and sensitivity in predicting environmental impact.** The design team indicated confidence to be at least 90% for design parameter output predictions such as those for currents and waves. The team assessed the potential size of extreme wave events and storm surges (values and background appendixes are presented in the subproject design

reports, 30 November 2009). For waves, the team used multiyear data from National Oceanic and Atmospheric Administration (NOAA) WaveWatch 3 model sites off the west coast of India to extract a 10-year hind-cast analysis of extreme wave conditions, and calculated expected worst-case wave heights and velocities for inshore waters at depths found at the subproject locations. The long-term hind-cast data from the offshore data set were compared with shorter-term data collected at a depth of 25 m by the Integrated Coastal and Marine Area Management (ICMAM) for comparable dates. The hind-cast data showed a high degree of correlation ($r^2 = 0.78$) with ICMAM data, meaning that the long-term hind-cast records are highly useful in understanding the local wave climate.

103. To support modeling, detailed bathymetric surveys were conducted. Data were placed on grids at 4 m resolution. Tides were included so that depth variations and translation of the surf zone across the steep beach face during the tidal period were incorporated. Tidal data were based on long-term data extracted from a world tide model created using about 15 years of intensive satellite measurements, local hydrographic data, and field sea level measurements. Model simulations included conditions that occur in all seasons and the time of flood or high tides for 20 years.

104. The team examined the possible size of storm surges and the effect on subproject designs. The design team found that storm surges to the south of northern Maharashtra have not been the subject of study apparently because the conditions for generating large surges are by and large not suitable, in contrast to the conditions in areas to the north, in Gujarat and north of Mumbai, and because the storm surge is likely to be small. The design team looked at the possible size of a storm surge associated with a large cyclone and found the designs to be able to accommodate the projected sizes (0.5 m) in the subprojects. Accordingly, such surges would have no effect on the project structure that would have an undesirable impact on coastal erosion.

105. Globally, the sea level is forecast to rise over the next 100 years. The anticipated rise depends on latitude and local geologic conditions. For example, the relative rise is smaller on continents where the coasts are emerging or accreting. In Australia, the state governments have set guidelines that anticipate a rise of 0.9–1.0 m by the year 2100. In India, the anticipated rise in sea level is only 1.7 millimeters (mm) per year in Cochin, or only 0.17 m over the next 100 years, but is 25 mm per year in Mumbai, a rise of some 2.5 m over 100 years. For subproject design a middle value was used in accordance with global communities—a 1 m rise by 2100.

106. The final designs were completed after review, first by a panel of three international experts and then separately by an independent expert.

107. **Risk of unexpected or undesirable environmental impact.** The risk of unexpected or undesirable impact on coastal erosion exists, but information provided by the design team suggests that the likelihood of such an occurrence is very low. The confidence of 90% indicated by the design team for design factors such as waves and currents was relatively high and variations of output values within the 90% confidence range are not expected to affect subproject structures and cause undesirable effects on erosion.

108. **Risk management.** Although the risk of undesirable impact from unexpected events appears to be low, design personnel indicated that, in a worst-case situation, geotextile structures could be removed fairly easily compared with rock structures—geotextile tubes can be split, sand spilled, and tubes readily removed by crane or barge. Other actions are possible

for less serious situations, such as using more sediment for beach re-nourishment if small amounts of beach erosion are observed after an unexpected event.

109. The planned placement of sediment (beach nourishment) is intended to initiate sediment deposition on the eroded portion of beaches and to offset the early retention by reefs and berms of sediment moving to adjacent beaches so that those beaches are supplied with sediment.

b. Residual Effects

110. The proposed designs and locations of reefs are expected to avoid changes in currents that would induce beach erosion. Significant adverse effects on currents are not expected but changes in current patterns are to be monitored and evaluated for several years after the reefs and berms are installed. Appropriate measures, including the removal of geotextile reefs, will be taken if significant adverse impact is observed.

111. The proposed designs and locations of reefs are also expected to avoid the erosion of beaches. Significant adverse effects on nearby beaches are not expected, but the physical features of the beaches are to be monitored and evaluated for several years after the reefs and berms are installed. Appropriate measures, including the removal of geotextile reefs, will be taken if significant adverse impact is observed.

5. Sediment Quality and Quantity

112. Project design indicates the use of sediment from river mouths in or near harbors (Coco beach and Ullal) and at Mirya bay, a nearby coastal fishing harbor for beach nourishment and geotextile tube filling. The exact locations and volumes of sediment will be determined on the basis of samples to be collected from the target area, and analyzed to identify the locations where the particle size and quality are appropriate.

113. Exploratory samples collected from target areas during the project feasibility studies were tested for four heavy metals (mercury, arsenic, lead, and cadmium) selected for use as indicators of contamination. The findings presented in the project feasibility studies generally show mercury and cadmium to be below detection levels, and arsenic and lead to be below the standards now in use in North America (those standards were used because India has no prescribed standards or levels for the heavy-metal content of sediment).

114. The types of other possible contaminants and the spatial variability of contaminants in bottom sediment within the proposed target area are not yet known. Accordingly, the effect of such contaminants on sediment and water quality, ecological conditions, and human health are uncertain. Information about possible contaminants in the dredging area and specifically in the locations where sediment will be extracted will have to be developed in detail to accurately identify the possible effects on sediment and water quality along the proposed beach nourishment areas and downstream areas.

115. The types and concentrations of contaminants in the bottom sediment of river mouths are influenced by upstream activities, commercial activities and outfalls, and the uses of the water among the general population. Also, the physical properties of the sediment, such as particle size, influence sediment chemistry. Generally, coarse-grained sediment (such as sand, the target material for subproject use) has a lower potential for accumulating contaminants than fine-grained sediment (such as silt). Fine sediment potentially has higher concentrations of, and

serves as a sink for contaminants because a given volume of fine-grained sediment has a relatively greater total surface area for the adsorption of contaminants than coarser sediment.

116. The removal of substantial amounts of sediment from source areas for use in nourishing beaches or restoring dunes could alter the sediment balance and other environmental conditions in the source area.

117. **Mitigation measures.** Sourcing plans for the acquisition of sediment from river mouths and harbors to be placed along the proposed beach nourishment areas must incorporate a sampling and analysis program to identify the concentrations of potential contaminants. The sampling program and choice of compounds to be analyzed must be based on a review and synthesis of historical data, and potential sources and types of potential contaminants. This is likely to mean an expanded suite of parameters to test, beyond the four metals analyzed in the exploratory sampling during the feasibility studies. Compounds such as oil and grease, additional metals, and pesticides may be included together with additional parameters to support the interpretation of laboratory results for selected contaminants of concern. The program must identify acceptable thresholds based on international standards for each potential contaminant of concern.

118. In concept, high concentrations of potential contaminants may be largely avoided because the design requirements for beach nourishment call for the selection of materials with coarse particle sizes and the avoidance of smaller particles. As noted, high levels of contaminants are usually associated with fine material such as silts and clays, which will be avoided to meet project design needs.

119. Potential sources of sediment with high sand content and suitable for use as beach nourishment will be rejected if they have contaminants above the thresholds of acceptability defined for the contaminants of concern identified in the sediment quality sampling and analysis program.

120. Bottom sediment in the proposed target area may contain solid waste material. If pre-dredging samples indicate a high concentration of solid waste in selected bottom areas, a strategy will be needed for its removal and proper disposal before the sediment is placed in the beach nourishment area. If such material is observed after the sediment is placed on the beach a beach clean-up may be in order.

121. The locations and quantities of sediment to be extracted from beach scraping, dredging, and other source areas are based on amounts that can be removed without altering the sediment balance in the source area over the long term.

122. **Residual effects.** The quality of the source sediment is not yet known. If potential contaminants in source sediment are adequately assessed and sediment with high levels of contaminants is avoided, no significant effects on beach sediment quality are anticipated.

6. Water Quality

123. During construction, water quality near work areas could be affected by

(i) turbidity during sediment placement in target areas along beaches as fine sediment is flushed from coarser sand material, during possible spills of sediment near the beach nourishment area or during the filling of geotextile tubes used for reefs and berms, and during or shortly after the beach-scraping of beach sand for use in dune restoration;

(ii) contaminants flushed from sediment after it is placed at target locations on the beach, during the filling of geotextile tubes in reefs or berms, or during sediment spills; and

(iii) leaks or spills of operational material such as fuels, oils, or hydraulic fluids.

124. Turbidity could impair the photosynthesis of phytoplankton and other flora, the feeding and migratory behavior of fish and invertebrates, and aesthetic attributes potentially important to tourist activity at some beach areas. By design, the project will select bottom sediment that is made up largely of coarser sand material. For subprojects involving beach nourishment, high turbidity is expected after the initial sand placement and possibly after the first period of heavy waves as fine sediment is removed from coarser fractions. The high turbidity is expected to be of short duration, however, with concentrations of fine material declining as those particles settle out of the water column in lower-energy areas away from the immediate shoreline.

125. Sediment having high concentrations of potential contaminants will not be used for placement on the beach or in reef or berm geotextile tubes. Currently, the types of contaminants that may be present in bottom sediment to be used for beach nourishment are not fully known. In general, contaminants have the potential to be toxic to organisms, to interrupt food webs and the migration of fish and other organisms, and to affect human health. If present in sediment placed on the beach such compounds are likely to be rapidly flushed from the sand material together with fine sediment.

126. Fuels, oils, and hydraulic fluids also have the potential to affect ecological resources and human health. Their effects would depend on the amount of material released and the degree of exposure of organisms and humans.

a. Mitigation Measures

127. **Potential contaminants.** The selection of bottom sediment to be used for beach nourishment and for reef and berm filling will be based in part on the identification of potential contaminants and the acceptable limits for allowing the use of sediment containing those contaminants.

128. **Turbidity.** The selection of bottom sediment to be used for beach nourishment and for reef and berm filling will also be based in part on the presence of mainly larger particle sizes and small proportions of fine material such as fine sand, silt, and clay.

129. **Sediment spills.** Equipment inspection and repair will be undertaken and documented routinely before and during sediment transfer from transport containers or vessels to the beaches, reefs, and berms.

130. **Fuels, oils, and hydraulic fluids.** Protocols for routine equipment inspection, repair, maintenance, and fueling will be required before the start of work, and practices during work must be documented. Contingency plans to be used in the event of spills will also be required beforehand, and spill containment and clean-up equipment must be present during all fueling and fluid replacement or top-up activities. Vessels and equipment should be fueled at shore mooring locations where spill containment equipment is present before the start of fueling.

131. Routine discharges are unlikely because of the nature of the proposal. If there are accidental spills, contingency plans should be initiated immediately.

b. Residual Effects

132. Water will be temporarily turbid along the shoreline after dredged sediment is placed in the beach nourishment areas, in berm geotextile tubes, and after beach scraping and in the vicinity of reefs when geotextile tubes are filled. Periods of high turbidity are expected to be of relatively short duration and geographic extent, with a return to background levels dependent on the amount of fine material in the sediment, and prevailing water or climate conditions. Periods of high wave energy along the shoreline could induce additional flushing of fine material at that time.

133. Possible contaminants in sediment should be identified before extraction by dredging or other means from source areas. No effects should be evident if sediment having contaminants is avoided during dredging or extraction. Standard measures for preventing, containing, and cleaning up possible leaks or accidental spills of fuels, oils, or hydraulic fluids are available and should be in place before the start of construction.

134. The effects on water quality are not expected to be significant if the proposed mitigation measures are used.

7. River Flows

135. At Ullal, the placement of breakwater structures at the river mouth has the potential to alter river flow and cause flooding upstream. The proposed design will maintain the same gap between the north and south breakwaters and is not expected to affect river flow, though there may be a small amount of constriction during the construction of the realignment at the Bengre spit training wall. Sandbars in the river delta, at the Netravathi–Gurupur confluence, may shift with slight changes of flow at the river mouth. The removal of sand from the sandbar in Netravathi river may also cause a small change in flow in the vicinity.

136. At Coco beach, the artificial breakwater and retention structures could alter river flows and local current patterns, causing changes in local bathymetry. The construction of the breakwater and concrete retention structures is not expected to obstruct the passage of water from the Sinqireum–Neerul river. The proposed sand retention and nourishment will allow the river delta to remain intact. No difference in seabed levels between the 2008 bathymetry and the condition with the proposed works is expected to the south or east of the Coco beach location. A small creek flows across the middle of the beach; the proposed beach nourishment will not obstruct the flow of that creek.

137. **Mitigation measures.** In the construction of breakwater works for the Ullal project steps will be taken to ensure that the river mouth is at no time excessively constricted, though dredging at the mouth could be done if necessary to allow the free flow of water up and down during the tidal and other cycles. Activities will be carried out within a short period so that the new breakwater system is in place before the peak flow of the river during the monsoon. The distance of the river between the breakwaters will be kept the same to preserve the current water flow and navigation.

138. At Coco beach, the effects of the structures on currents and river flows were considered during the development of the structure designs. Numerical modeling was used to evaluate and guide the choice of features and placement locations. Factors considered included depth, distance offshore, length, width, shape, and potential negative effects on local bathymetry and river flows. The breakwater will provide shoreline protection within the bay by blocking wave energy and rotating waves to minimize erosion.

139. **Residual effects.** No significant adverse effects on Netravathi river flow (Ullal) or on currents at Coco beach are anticipated.

B. Ecological Resources

1. Marine Biota and Habitat

140. **Effect of sediment for beach nourishment, reef and berm filling, and breakwater placement on benthic organisms.** The placement of sediment for beach nourishment, and for reefs, berms, and other retention structures and breakwaters will smother intertidal and sub-tidal benthic biota and temporarily impair food-web relationships and possibly local food production of harvestable species. The effect on beach nourishment areas will be short lived as the benthic population will begin reestablishing once the sediment placement stops.

141. Baseline information has not been collected to characterize fish and invertebrate use of the proposed project areas for breeding or other purposes. The large, uniform beach areas suggest that the areas are not a unique habitat for breeding or other life-stage activities. The areas comprise exposed, rough environments with bottom sediment being highly abrasive sand to gravel in some areas. Taxa that move inshore seasonally to breed or rear is likely to avoid areas influenced by work activities, as eggs deposited on the sea bottom could be smothered.

142. At locations offshore where submerged reefs are proposed (Mirya, Colva, and Ullal) sand-dwelling benthos will be smothered and the sand-bottom habitat will be replaced by a potentially reef-like habitat. Submerged reef structures have been shown to provide shelter from the impact of waves and currents, as well as substrata for the growth of epiflora and fauna. The structures offer the potential to enhance marine life with the increase in surface area provided by the geotextiles and the creation of reef habitat suitable for breeding by some species, and will form the basis for new fish and invertebrate assemblage, possibly strengthening local fisheries.

143. The project feasibility study studies indicated that locally available benthic fauna identified at project sites have short generation times, indicating in turn the strong likelihood of rapid reestablishment in case these fauna are affected by sediment spillage during the installation of the submerged reef structures. The effects of benthic smothering are expected to be short lived considering the short generation times of these organisms and the prevailing littoral transport of larvae of these organisms. Recolonization of the benthic fauna is expected within several months. Beach-scraping activities (Colva beach) will remove a surface layer of benthos near dune restoration locations.

144. **Effects of beach scraping.** The effects of beach scraping on benthic communities will also be short lived, as benthic populations will begin reestablishing once the scraping stops.

145. **Effects of water quality changes.** The temporary increase in turbidity has the potential to reduce photosynthetic activity and impair plankton production, feeding activity, and migration and behavior patterns. These effects could cause a short-term reduction in the production of harvestable species. Alongshore and cross-shore currents will carry sediment from the site to the surrounding region. The littoral transport of sediment in the area is minimal during the non-monsoon period. The zone of high turbidity is expected to extend less than 1–2 km at that time before the sediment settles out of the water column.

146. The project activities could cause the release of chemicals along the beach, including contaminants in sediment from dredging locations, fuels, oils, and hydraulic fluids. Measures that will minimize the potential release of these compounds are described above. These materials could be directly toxic to organisms and could interfere with food webs, migration and behavior patterns, and the catch of harvestable species.

147. **Effects of sediment dredging and extraction.** Details of the proposed methods and timing of sediment dredging and extraction are not yet known. The dredging will remove sediment from bottom areas in river mouths (near Coco beach and Ullal) and the fish harbor at Mirya bay, and create temporary sediment plumes. The activities will involve the movement of vessels and equipment to and from work sites over the work period.

148. Dredging will remove benthic biota and temporarily impair food-web relationships and possibly the local food production of harvestable species. The effect will be short lived, however, as the reestablishment of the benthic population will begin with the cessation of sediment removal. The feasibility studies indicated that benthic fauna identified at project sites have short generation times, indicating in turn the strong likelihood of rapid reestablishment.

149. Dredging activities include underwater noise and surface lighting that could affect the seasonal use of the dredge area for activities such as breeding or migration.

150. As noted above, the temporary increase in turbidity may reduce photosynthetic activity and impair plankton production, feeding activity, and migration and behavior patterns, and cause a short-term reduction in the production of harvestable species. Currents will carry sediment from the site to nearby areas. Sediment plumes moving with prevailing tidal cycles and river flow could affect habitat and organisms elsewhere in the coastal area.

151. The dredging activities could cause the release of chemicals, including contaminants in sediment at dredging locations or in fuels, oils, or hydraulic fluids. These materials have the potential to be directly toxic to organisms and to interfere with food webs, migration and behavior patterns, and the catch of harvestable species.

152. **Mitigation measures.** Measures that will minimize the release of sediment and chemical compounds during the placement of sediment in the beach nourishment areas and during the construction and filling of the reefs and berms are described above.

153. Fish and invertebrate taxa using the beach areas are not known. The characterization of the fish and invertebrate communities, especially mobile species, would enable the types and timing of likely use to be identified, and the timing of construction activity refined to minimize possible effects. Additional information on the proposed dredging and breakwater construction activities at the river mouths (Ullal and Coco beach) is needed for the development of mitigation measures.

154. The project activities are to be completed as quickly as possible. At reef and berm locations, the sand-bottom habitat will be replaced by a potentially reef-like habitat and new fish and invertebrate assemblages.

155. The reefs and berms, if deemed no longer necessary, lend themselves to decommissioning through the splitting open of the geotextile bags, the release of sand in those bags, and the removal of fabric. All this suggests that the benthic smothering effects would be reversible if the bags were removed.

156. **Residual effects.** The project is likely to cause the localized reduction of benthic and plantonic production in the beach nourishment and beach-scraping areas during the construction period, with effects lasting for several months, after which the benthic biological conditions typical of sand habitats are anticipated to be reestablished. The benthic habitat in relatively small areas under the proposed reefs will be replaced by a reef-like habitat as biological colonization of the reefs and berms takes place. Follow-up studies to verify that reefs are providing the expected habitat, fish and invertebrate assemblages, and possible fisheries enhancement will require the collection of pre-construction baseline data. Measures can be applied to minimize the potential effects of dredging and other construction activities, but additional information on the proposed activities will be needed to develop effective mitigation measures. Long-term significant effects are not anticipated if appropriate mitigation measures are developed and adhered to.

157. If measures to prevent the release of potentially harmful chemicals are implemented, adverse effects on marine life are not likely. Adverse effects on marine life in the beach areas are expected to be limited to the duration of the construction activities and to occur over the relatively small construction area, with turbidity temporarily affecting a broader area. Significant adverse effects on marine life are not anticipated.

2. Terrestrial Biota and Habitat

158. Small areas of land are likely to be needed during construction for equipment access points or material and equipment storage or staging. The project needs are as yet uncertain; they will be identified on the basis of the contractors' proposals during tendering. The subprojects are mainly located in areas of human habitation and activity, including tourism and, at one location (Ullal), light industry. Adverse effects on terrestrial habitat are unlikely. Dune restoration and management activities at Colva are directed at ameliorating degraded conditions on the dunes and will improve habitat features.

159. **Mitigation measures.** If vegetated areas must be cleared, the conditions in the project area indicate that any disturbance of local habitats is likely to be rectified. Replanting and therefore stabilization of the environment, including replacement of any native plant species, should be possible.

160. **Residual effects.** Although land needs are still uncertain, there is likely to be little effect on terrestrial habitat; effects can be mitigated if needed. No significant adverse effects are anticipated.

C. Social, Economic, and Cultural Conditions

1. Navigation

161. During construction, the navigation of small vessels near the beach areas could be affected by the movement of vessels or barges bringing dredged sand to be placed on beach nourishment locations and to fill the geotextile reefs and berms, pipelines conveying sediment from vessels carrying dredged sediment to deposition areas along the beach, vessels used for reef and breakwater placement, and the reef, berm, and other breakwater structures once they are installed. There is wide sea room around the proposed work areas so risks of collision or impaired movement of local boats are low.

162. After construction the reefs and berms will be in place. There is potential for disturbance to the navigation of fishing boats near submerged reefs. But there is ample sea room, and most coastal traffic would move outside the line of the reefs and impairment of local boat traffic is not likely.

163. **Mitigation measures.** Navigation aids such as buoys could be used to show the location of submerged reefs but have not been used in other areas where similar artificial reefs have been installed. In those locations, wave patterns signal the presence of a structure submerged just below surface (similar to a natural reef). This topic was discussed during public consultation meetings and will be discussed in future meetings including those to be held before the start of construction. Future consultations will involve awareness building so that stakeholders know the final locations of the proposed reefs and associated construction activities, and they can give their input regarding the need for markers such as buoys.

164. **Residual effects.** Significant adverse effects on navigation are not anticipated. The locations of the submerged reefs and their effects on navigation will be included in further consultation sessions to be held during project implementation.

2. Fishing Activity

165. Traditional fishing from shore has been greatly curtailed by the loss of usable beach areas due to erosion. Construction activities along remaining beach areas have the potential to disrupt possible shore fishing as work takes place at different locations along the beaches, though the amount of fishing activity at some subproject sites is now very small. Fishers living in Ullal are now confined to the Mangalore harbor area and mainly fish on grounds well to seaward of the proposed reef area.

166. Small fishing vessels moving along the shore from other areas would be subject to navigational effects during construction and after construction, as described above. Larger trawl vessels that fish off Ullal do so mainly in deeper water but would have to avoid the reefs during construction and after construction if they were to operate closer to shore.

167. During the construction of the reefs and berms and during beach nourishment, some disturbance to the navigation of fishing boats may occur mainly because large dredging vessels will be required to bring sediment to the sites.

168. The installation of the offshore reefs has the potential to cause localized and short-term disruption of fishing practicies. The installation of each reef should take less than 20 days per

reef, excluding weather downtime. The area of each reef is very small compared with the length of the beach. Fishing vessels are not likely to be disrupted by activities in these small areas.

169. **Mitigation measures.** During construction, some areas will have to be restricted to ensure the safety of the local people and site workers. The areas will be visible to fishing vessels while work vessels and equipment are present. Consultation meetings will be held before construction to inform stakeholders of planned activities and to discuss the type and scheduling.

170. After construction, the potential effects on fishing activity relate mainly to vessel operation near the submerged reefs. Possible mitigation measures related to navigation are presented above.

171. **Residual effects.** Significant adverse effects on fishing activity are not anticipated. The locations of the submerged reefs and the effects on fishing activity will be included in further consultation sessions to be held during project implementation.

3. Local Land Traffic

172. During construction there will be periodic movement of equipment and supplies by land to storage and site-access areas. The main material to be used during these activities—sediment for beach nourishment and for reef and berm filling—will be transported by vesselsor barges. The number of vehicles and trips required during construction will be identified during the tendering; however, these requirements and their effects on land traffic are not expected to be large.

173. **Mitigation measures.** Construction-related activities, including the movement of equipment and supplies, will be discussed with stakeholders during consultations before construction. Project needs related to access points, staging areas, and land traffic will be discussed at that time, together with community input regarding the timing of activities and any local traffic control needs.

174. **Residual effects.** No significant adverse effects on local traffic are anticipated.

4. Tourism

175. During construction, local tourist entities may be periodically affected by air quality changes, noise, local traffic, and water quality changes (high turbidity) along the shoreline. These effects will be temporary. The high turbidity may extend for several kilometers and persist for a number of days after activity ceases depending on the amount of fine material contained in the sediment used for beach nourishment.

176. During the operation stage, berms will be visible along the shore and changes in wave patterns will be visible offshore where the submerged reefs are situated. The berms will eventually blend with the beach as areas in the cups formed by the berms fill and the beach extends seaward.

177. **Mitigation measures.** Consultation meetings will be held before construction to inform stakeholders of planned activities and to discuss their type and scheduling.

178. Measures that will mitigate the possible effects of high turbidity and degraded water quality are described above.

179. **Residual effects.** The main residual effect on tourism will be periods during construction when high turbidity will be visible in water along the beach. The turbidity may extend for several kilometers and last for a number of days once work activity ceases. Significant adverse effects on tourism along the beach are not anticipated.

5. Safety and Human health

180. Factors that could affect human health during construction include reduced air quality, noise, accidents or malfunctions, and reduced sand and water quality. Factors that could affect safety are accidents or malfunctions, increased land traffic, navigational mishaps, and equipment activities at the beach nourishment areas, as well as in the reef, berm, and other breakwater areas and dune restoration work areas.

181. **Mitigation measures.** During equipment operation and construction, some areas will have to be restricted and clearly marked to ensure the safety of local people and site workers.

182. Possible measures that will mitigate the potential effects on air quality, noise level, sand and water quality, land traffic, and navigation are described in preceding subsections. Mitigation related to accidents and malfunctions is described in section D below.

183. **Residual effects.** Measures must be implemented to protect human safety and health. Significant adverse effects are not anticipated if the measures are adhered to.

6. Livelihoods

184. The project is not expected to adversely affect livelihood during or after construction. Possible local effects during construction on fishing vessel movement or equipment use, fish production (the short-term reduction in benthic and planktonic food organisms is not likely to be detectable in the catch), and tourism are not likely to be manifested in loss of livelihood.

185. **Mitigation measures.** Additional mitigation measures to protect livelihoods do not appear necessary.

186. **Residual effects.** Significant adverse effects on livelihoods are not anticipated.

D. Accidents and Malfunctions

187. Possible accidents and malfunctions that could have adverse environmental effects during construction include fuel, oil, and lubricant spills; fires or explosions; sand spills; and vessel collisions. Fuel, oil, or lubricant spills could affect water quality, ecological resources, and human health. Fires and explosions could affect air quality and human health. Spills of sediment could affect water quality mainly by increasing turbidity along the shore. Vessel collisions could lead to economic losses and human injury or fatality.

188. **Mitigation measures.** Measures can be taken to prevent these accidents and malfunctions. In addition, contingency plans can be prepared to contain and clean up spills of fuels, oils, lubricants, and sediment if an event occurs.

189. **Residual effects.** Significant adverse effects of accidents or malfunctions are not anticipated as long as preventive safeguards are in place and contingency plans prepared and implemented if found necessary.

E. Compliance with the Government of India's Coastal Regulation Zone

190. Coastal regulation zone (CRZ) maps have been prepared in order to highlight regions in which regulations may apply to individual subprojects. Areas of particular concern to this project are CRZ I (between the low-tide line and the high-tide line) and CRZ III (area above the high-tide line to 200 m inshore). Since the proposed subproject designs are either below the low-tide line or part of a greater shoreline protection and management scheme, the activities are deemed permissible in reference to certain notifications. None of the subproject areas are ecologically sensitive, given the definitions of CRZ I, and the disturbances caused by the project implementation will be short term and will not affect the ecological resilience of the subproject areas.

F. Cumulative Effects of the Project

191. The subprojects are located at substantial distance from one another along the west coast. The various activities during construction and operation are not expected to cumulatively affect valued resource components as long as planned mitigation measures are adhered to. The project activities are likely to add incrementally to effects from other sources in their respective areas over the construction period (such as local increases in noise and exhaust fumes) but are not expected to have adverse effects on valued resource components within their respective regions once construction ends.

G. Climate Change Implications

192. During construction, vessels, equipment, and land vehicles will emit exhaust fumes containing greenhouse gases. High turbidity in some areas (mainly where sediment is placed on beaches to nourish them) will potentially reduce photosynthetic activity and carbon uptake. These effects will be temporary, occurring for short periods during more than one work season (non-monsoon period) in several subproject locations. The amounts of greenhouse gas and reduced carbon sequestration are not expected to be large. Effects are not expected after the construction period. Dune revegetation in some areas may aid carbon sequestration, though the effects would be small and local.

193. Globally, the sea level is forecast to rise over the next 100 years. The anticipated rise depends on latitude and local geologic conditions. For example, the relative rise is smaller on continents where the coasts are emerging or accreting. In Australia, the state governments have set guidelines that anticipate a rise of 0.9–1.0 m by the year 2100. In India, the anticipated rise in sea level is only 1.7 mm per year in Cochin, or only 0.17 m over the next 100 years, but is 25 mm per year in Mumbai, a rise of some 2.5 m over 100 years. For the purposes of this project, a middle value was used in accordance with global communities—a 1 m rise by 2100.

194. As an example, the reef at Ullal is designed to emerge at low tide. The present crest level before settlement is +1.9 m above the chart data. In most global reef designs, the crest is placed much deeper, at 0.5–1.0 m below the chart data. Thus, the design crest level at Ullal is very conservative (placing the crest at a level that is well above the chart data). The crest level

was chosen for a range of reasons, including concerns about settlement, which led to the selection of a higher reef crest to build in a safety factor. This same safety factor means that the reef is expected to function well up to 2100 with the assumption of a 1.0 m sea level rise due to climate change. Reef studies at various locations have shown that the crest can be up to 2 m below chart data before the reef starts to be inefficient. Of course, this level depends on the local wave climate. The level of the crest must be no deeper than the height of the storm waves, which at Ullal averages around a 3 m significant height. The reef level at Mirya is –0.2 m (chart data) and at the Colva central section between –0.1 and –0.3 m (chart data). At these sites settlement is likely to be minimal and even with climate change of +1.0 m the reefs would function without loss of efficiency.

VI. ECONOMIC ASSESSMENT

195. Economic and financial analyses were conducted for the four subprojects included under project 1 of the investment program. The subprojects will prevent osses that would otherwise occur without the project. The investment and ongoing maintenance costs of the subprojects were weighed against these benefits. The main direct financial and economic impact of the project will be the protection of land, buildings, and infrastructure from future damage caused by coastal erosion and monsoon storms. The protected land will also augment the incomes and livelihoods of urban and rural households and businesses on the coastline. Tourism, rural farm and fishing households, ports, and factories and their owners, operators, and workers will benefit from the subprojects. Removing erosion risk will help encourage future investment in the coastal zone.

196. In addition to land protection, the project will support the long-term sustainability of the beaches. Previous protection programs have neglected the beaches and in many cases have caused increased degradation. The use of the new technologies and soft protection measures proposed under the project will sustain and enhance the beach areas. The beaches are key contributors to the economies in the tourist areas and essential for artisanal fishers. The tourism potential of much of the coastal area is high and the long-term economic and environmental benefits of sustaining the beaches through the project interventions will be very significant. The subprojects will lead to the avoidance of resettlement costs that the state governments would be likely to incur if no action were taken to prevent the ongoing erosion processes. The projects have been assessed on the basis of the more simply quantified benefits, which are enough to provide an adequate rate of return. The project implementation will also generate additional benefits that have not been quantified, such as (i) indirect impact on employment, economic activity, and future investment; (ii) improved security for households, businesses, and farms; (iii) indirect benefits for the environment; and (iv) long-term benefits that may accrue from institutional and knowledge upgrading.

197. Project interventions will maintain the status quo or restore the pre-erosion situation. The financial impact on the beneficiaries is therefore limited and will occur only in some contexts. Where an eroded beach will be restored, there will be a restoration of income for tourism establishments that lost business because of the erosion of the beach, and new businesses may also be opened. At some locations where future erosion is prevented, there will be no financial effect on businesses or other beneficiaries. Some interventions will reduce future government expenditures; these interventions will have a potential impact on government expenditures by reducing future requirements for infrastructure replacement and the resettlement of affected populations.

198. The results of the economic analysis show that the four subprojects have economic internal rates of return of 15.2% for the Ullal subproject, 18.9% for the Mirya subproject, 15.4% for the Coco subproject, and 28.7% for the Colva subproject. The last-named project has a low cost per kilometer of beach protected with high potential impact on tourism if the long-term erosion processes along this popular tourist destination are not allowed to continue. Switching values show the subprojects at Mirya bay, Coco beach, and Colva beach to be robust to variations in total investment costs and total benefits. But the subproject at Ullal is more susceptible to variations in costs and benefits; this is partly a reflection of the high project cost in this case. Sensitivity analysis of benefit categories and other key variables shows that individual variables by themselves generally have little impact on the economic indicators. Economic risks to the viability of these subprojects are low, the major risk being large cost overruns.

VII. ENVIRONMENTAL MANAGEMENT PLAN

199. Although environmental issues are similar among subprojects, the four widely dispersed locations (in three different states) of subprojects means that individual environmental management plans (EMPs) are required to meet specific needs at each location. Each EMP aims to ensure that adverse impact is prevented or properly mitigated, and identifies mitigation, monitoring, and institutional measures to be taken during subproject design, construction, and operation. The EMP also identifies the parties responsible for implementing each action.

200. An environmental assessment and review framework, based on stakeholder consultations and on guidelines of the Asian Development Bank and the Government of India, has been prepared for the subprojects.

A. Impact To Be Mitigated

201. The environmental impact that could occur during project the pre-construction, construction, and post-construction stages (operation and maintenance) and the measures that would mitigate the potential impact are presented in Appendix 1. Potential adverse effects during the construction stage include temporary and localized effects on air quality, noise levels, beach sand quality, water quality, marine and estuarine biota and habitat, terrestrial biota and habitat, nearshore fishing activity and navigation, vehicle traffic, tourist activity, and safety of beach users. Measures have been identified to prevent or minimize these effects. Potential adverse effects during operation and maintenance include the erosion of beaches (if the structures do not perform as planned or unexpected events occur, with associated effects on land, buildings, and economic activity), as well as effects on the marine habitat and biota, fishing activity, and navigation. These possible effects were important considerations during the design stage and are mitigated mainly through site-specific design features such as placement location, depth, size, and shape.

B. Impact Mitigation Activities

1. Implementation Arrangements and Responsibilities

202. Program management units (PMUs) will be established in each state executing agency (Goa Department of Water Resources, Karnataka Department of Ports and Inland Waterways, and Maharashtra Maritime Board). Each state PMU will be responsible for implementing the

environmental mitigation measures and monitoring programs for subprojects in their respective states. The staffing of each state PMU will include representatives from the state executing agency, staff from the state environment agencies, and representatives from the state CRZ committee. The PMU also will include local representatives from the office of panchayats, the local district council, and the panchayat that will be responsible for establishing a shoreline management organization.

203. A senior environmentalist will be assigned to each PMU to supervise the implementation of the EMP, monitor compliance with planned mitigation measures and monitoring programs, and coordinate other environmental aspects of the subprojects. The environmentalist will be recruited or will be seconded from the state environment department. Other tasks of the environmentalist will include the provision of support for (i) the preparation of environmental assessments for tranche 2 and 3 subprojects; and (ii) the process of securing environmental clearance for subprojects.

204. The PMU will directly hold a support budget to engage specialist and survey staff from national institutes or from the private sector to provide technical support, monitoring, and field surveys as required.

205. Mitigation measures are to be implemented for all subproject activity stages (pre-construction, construction, operation), including multiple work seasons where planned for some subprojects. Measures are to be implemented at all locations where subproject-related activities are planned (reef, beach nourishment, and sediment extraction locations in Mirya; beach nourishment, breakwater, and sediment dredging locations in Coco beach; dune restoration and management, stream-training, beach-scraping, and reef locations in Colva beach; beach nourishment, reef and berm and other breakwater, and dredging locations in Ullal beach), including areas where on-land support activities will take place (such as construction work areas).

C. Environmental Monitoring Plan

206. Environmental monitoring plans that identify the impact to be monitored and the planned monitoring activities have been prepared for each of the four subprojects under project 1. Monitoring is planned for the construction period, to monitor pre-construction and construction activities, and for the post-construction stage, to monitor the effectiveness of the structure designs and locations and prevent impact on relevant environmental features in each subproject area such as the erosion of beaches, and adverse impact on fishing activity and navigation. The monitoring plans include all locations where subproject activities will take place and identify the parameters to be measured, the measurements to be made, the measurement locations and frequency, and institutional responsibilities.

207. Environmental monitoring will be organized through an environmental management committee (EMC) to be convened in each state by the state executing agency. The state executing agencies will be key as intermediaries of matters between the EMC, the stakeholders, the local community, and the contractor.

D. Implementation Cost

208. Loan funding has been assigned for monitoring and evaluation, including environmental management and monitoring. The estimated budget for the implementation of the environmental

management plan for both the construction and operation phases of the four subprojects is $282,000. In addition, funds have been made available for the training of the EMCs through the training program. Provision for the environmental assessment of tranche 2 and 3 has been included in the design consultancies.

VIII. PUBLIC CONSULTATION AND DISCLOSURE

209. Public consultation and disclosure was completed during the project preparatory TA in each of the subproject areas. Individual subproject stakeholder meetings were held to disseminate the proposed project designs at three critical stages of the project: (i) initial discussions and draft proposal, (ii) interim stage during the design stage, and (iii) and the final draft stage. Breakout groups proved useful in discussing the particulars of the designs and enabling individuals to question and debate. Stakeholder views and concerns were taken into account, assessed by the TA, and incorporated into the proposed designs. The specifics of these meetings are given in the subproject feasibility reports. Public participation and inclusion will be an important aspect in the continuation of the subproject implementation, and continued stakeholder meetings should be held during every stage of the investment program.

210. The foremost requirement of the EMC is to provide a platform for all stakeholders to meet regularly to discuss and resolve issues. The outputs of the meetings will be directed at the removal of obstructions that may impede the progress of project implementation. The EMC will consist of members from the community and other stakeholders in the project.

211. A respected community leader will chair the committee. The place of meeting will be a convenient location accessible with ease to all “resource use” categories including the grassroots level. This committee will meet monthly during the preparation and implementation of the project. A formal awareness program will establish a foundation for the functioning of the EMC, and will include

- (i) changing the way that coastal protection is perceived;
- (ii) understanding the site, functions, and impact of the available coastal protection and management options;
- (iii) viewing coastal protection as an investment in a valuable asset base;
- (iv) exploring the potential for generating the maximum possible returns from the investments (e.g. community income generation activities);
- (v) adopting a systematic approach based on long-term planning and action;
- (vi) creating understanding that the environmental impact must be well predicted and taken seriously during planning;
- (vii) understanding that early interventions can be more cost effective;
- (viii) ensuring that interventions are maintained and sustained; and
- (ix) ensuring that the EIA or initial environmental examination (IEE), EMP, and monitoring aspects are well understood and modified as necessary to acquire mutual cooperation.

212. The learning component will derive substantially both from the functioning of the EMC and from participatory monitoring. The monitoring will include a technical component that will provide scientific information to the EMC. All monitoring tasks will be assigned accordingly to appropriate technical agencies. The PMU will be responsible for hiring an appropriate technical agency to carry out the technical activities; the organization could be a state or national institute

or private organization. The PMU, through direct government funds and loan funds, will finance the technical support organization. The PMU will provide funds for the functioning of the EMC and the monitoring activities on the basis of a budget request to be submitted by the EMC.

213. A community- and stakeholder-based shoreline management organization will be established at an early stage to take on the responsibility and management of the completed project.

IX. CONCLUSION

A. Gains That Justify Project Implementation

214. The subproject designs are intended to prevent further degradation of the coastline, while providing a situation whereby the beach can regain stability through natural processes. The benefits of the proposed interventions on the beaches will accrue from preventing erosion by correcting the sediment cycle. The economy will benefit from preventing loss of property and saving on the recurring cost of coastal protection. The enhanced beaches will help regain traditional fisheries operations (Mirya bay, Coco beach, and Ullal), help the tourist sector to recover losses and prevent further losses (Coco beach, Colva beach, and Ullal), and create new opportunities for beach tourism. Additional benefits could include the possible enhancement of fisheries.

215. Erosion-related problems cause significant loss of opportunities to society as well as irrevocable loss of beachfront properties. Substantial amounts of resources may be needed to recover loss at a future date if the current trend is allowed to continue.

B. Minimization of Adverse Effects

216. Potential adverse effects during the construction phase, which will take place over several non-monsoon seasons, can be mitigated and significant residual effects are not anticipated.

217. Potential long-term effects of proposed structures (offshore submerged reefs, berms, concrete retention boxes, submerged breakwaters, and river-mouth breakwaters) were considered during the design stage and measures included to minimize possible adverse effects. Potential adverse effects on current and wave conditions and erosion of beaches were considered, and detailed numerical modeling was used to aid the selection of designs and locations to avoid those effects. The risks of unexpected or undesirable impact on coastal erosion, and possible risk management measures, were considered.

218. Potential long-term effects of breakwater realignment at the mouth of Netravathi river near Ullal on upstream flooding and sediment movement along the coast were considered during the design stage and measures to minimize effects incorporated in designs.

219. Environmental management plans (EMPs) will address the possible effects during construction and operation phases. Additional information to be obtained during an early stage of implementation to support the development of the EMPs includes

(i) details on planned sediment dredging and extraction activities in the mouth or estuary of the Netravathi river (Ullal) and Mandovi river (Coco beach) and near the fish harbor at Mirya bay, and supplementary assessment of potential effects;
(ii) details on planned breakwater realignment activities and supplementary assessment of potential effects (Ullal);
(iii) additional information on possible contaminants in the planned sediment sources to be used for beach nourishment and filling geotextile tubes (Mirya bay, Coco beach, and Ullal);
(iv) characterization of fish and invertebrate communities in all subproject areas using existing published and unpublished information to aid the identification of possible refinements in activities and schedules;
(v) details on planned sand-scraping and transportation activities and supplementary assessment of potential effects (Colva); and
(vi) design of a follow-up study to confirm expected reef habitat benefits and possible enhancement of nearby fisheries (Mirya bay, Colva beach, and Ullal), and if necessary collection of pre-construction baseline data.

220. The present national environmental capacity to analyze the impact of development projects on the coastal dynamics and supervise mitigation and monitoring programs is quite limited. One of the project objectives is to upgrade the capacity of the government and private sector consultants to support the preparation of professional environmental impact reports.

C. Use of Irreplaceable Resources

221. The subprojects will use very small amounts of hydrocarbons for the manufacture of fabric for geotextile containers and as fuel and oil to operate vessels, vehicles, and equipment.

D. Provisions for Follow-Up Surveillance and Monitoring

222. Monitoring programs will be implemented during the construction and post-construction phases. Long-term follow-up surveillance and monitoring is expected to include the examination of

(i) long-term effects on beach formation;
(ii) change in the effectiveness of retention structures;
(iii) effectiveness of reefs as new habitat for fisheries enhancement; and
(iv) effectiveness of dune restoration and management efforts.

SUMMARY OF MITIGATION MEASURES

Project Stage	Project Activity	Potential Environmental Impact	Proposed Mitigation Measures	Institutional Responsibilities
Pre-construction	**Site preparation:** material and equipment staging areas and beach access locations	Possible removal of terrestrial habitat	Sites rehabilitated before contractor leaves site upon completion of construction activities. Planting and stabilization of site, including replacement of any native plant species.	PMU Contractor
Construction	**Mirya, Colva, Ullal:** Offshore reef construction Temporary pipeline installation, operation and removal Vessel movement to and from reef work area Berm construction Semi-submerged Breakwater construction	**Physical**		
		Air quality Reduction in air quality from exhaust fumes and dust at on-land construction sites	Adherence to national emission and ambient air quality standards Engines and generators turned off when not in use Equipment conforms to international standards. Dust suppression by regular sprinkling (i.e., morning and evening) or other means. Possibly, halt work during excessive onshore winds. Verbal social complaints dealt with immediately and efficiently.	PMU Contractor
		Noise Increased noise levels	Adherence to national noise standards Engines and generators turned off when not in use Equipment conforms to international standards. Vehicles and engines fitted with silencers Daily checks and remedy of potential sources of excessive noise especially out of daylight hours. Complaints regarding noise dealt with professionally and with respect	PMU Contractor
		Water quality	Supervision of all operation procedures to minimize	PMU

Project Stage	Project Activity	Potential Environmental Impact	Proposed Mitigation Measures	Institutional Responsibilities
		High turbidity during reef filling Possible leaks or spills—sediment, fuels, oil, other fluids	spillage of sand Contingency plans for accidental oil, fuel, and sediment spills should be initiated immediately	Contractor
		Biological		
		Marine biota and habitat Reefs and berms will cover soft-sediment benthic habitat and biota High turbidity and sediment settlement temporarily impair photosynthesis and biological production in adjacent offshore areas Possible leaks or spills—sediment, fuels, oil, other fluids	Develop mitigation components based on a review and characterization of fish and invertebrates that occur in the nearshore area including seasonal or migratory species and sensitive times and locations Reef structure is expected to be colonized by biota offsetting smothering of soft-sediment biota.	PMU Contractor
			Minimize sediment release during construction to reduce affected area outside immediate reef-site area Implement contingency plans if spills of sediment, fuels, oil, or other fluids occur	PMU Contractor
		Social, economic, and cultural		
		Safety and human health Reduced safety of beach users	Public consultation to identify locations, times, and types of potential safety risks, and develop site-specific advisories and safety measures All equipment, waste, and construction material debris must be inspected and removed daily from site.	PMU Contractor
		Tourism Beach amenity and recreational use	Public consultation to identify locations, times, and types of potential safety risks, and develop site-specific advisories and safety measures	PMU Contractor

Project Stage	Project Activity	Potential Environmental Impact	Proposed Mitigation Measures	Institutional Responsibilities
		disturbed	All equipment, waste, and construction material debris must be removed daily from the site.	
		Fishing activity Disturb traditional fishing activity	Public consultation to identify locations, times, and types of potential conflict, and develop site-specific measures to minimize disruption of boat launching and fishing activity	PMU Contractor
		Navigation Local navigation	Vessel movement and equipment operation to be carried out in consultation with stakeholders to avoid interference with navigation	PMU Contractor
	Mirya, Coco, Ullal: Transport of dredged sediment to beach nourishment site Temporary pipeline installation, operation, and removal Sediment placement at site (beach nourishment)	**Physical**		
		Air quality Increase in exhaust fumes Possible dust emission (wind-spraying from vessels)	Adherence to national air quality standards Engines and generators turned off when not in use Equipment conforms to international standards. Dust suppression by regular sprinkling (i.e., morning and evening) or other means. Halt work during excessive onshore winds. Verbal social complaints dealt with immediately and efficiently.	PMU Contractor
		Noise Increased noise levels as vessels operate near shore	Adherence to national noise standards Engines and generators turned off when not in use Equipment conforms to international standards. Vehicles and engines fitted with silencers Daily checks and remedy of potential sources of excessive noise especially out of daylight hours. Complaints regarding noise dealt with professionally and with respect	PMU Contractor
		Sediment quality Chemical contaminants in sand	Adherence to international sediment quality standards Chemical testing of sand source before use—compounds to be tested in samples are to be based on initial assessment	PMU Contracted

Project Stage	Project Activity	Potential Environmental Impact	Proposed Mitigation Measures	Institutional Responsibilities
		used to nourish beach area Solid waste in dredged-material	of potential contaminants of concern (e.g., oils and grease, PAH compounds, pesticides from upstream locations, heavy metals) in target area Removal of solid waste if present in dredged sediment	specialists PMU Contractor
		Water quality High turbidity during sediment placement Possible turbidity from onshore activity Oil discharge during vessel and equipment operation Contaminants in sand Possible spills of fluids (e.g., oils, fuels) and sediment	Adherence to national water quality standards Supervision of all operation procedures to minimize spillage of sand and oil or fuel Soil erosion is to be considered with all onshore activities. Since the majority of large scale construction is offshore it is unlikely this will be an issue. Sediment is to be screened for potential contaminants and not used if present above thresholds identified in international standards Accidental spills contingency plans should be initiated immediately	PMU Contractor
		Biological		
		Terrestrial biota and habitat Onshore biota or habitat Removal of habitat for site access or material and equipment staging	Any disturbance to local habitats should be rectified before contractor leaves site. Planting and therefore stabilization of the environment, replacement of any native plant species. Sand piles or protruding abnormalities to be leveled	PMU Contractor
		Marine biota and habitat Sediment for beach nourishment will cover soft-sediment benthic habitat and biota	Develop mitigation components on the basis of a review and characterization of fish and invertebrates that occur in nearshore areas including seasonal or migratory species and sensitive times and locations. Newly placed sediment is expected to be colonized by benthic biota and return to pre-nourishment condition within	PMU Contractor

Project Stage	Project Activity	Potential Environmental Impact	Proposed Mitigation Measures	Institutional Responsibilities
		High turbidity and sediment settlement temporarily impair photosynthesis and biological production in adjacent offshore areas	several months.	
			Minimize sediment release during construction to reduce affected area outside sites of beach sand nourishment Implement contingency plans if spills of sediment occurs	PMU Contractor
		Social, economic, and cultural		
		Navigation Local navigation and fishing	Barge movement and dumping operation may be carried out in consultation with stakeholders to avoid interference with regular fishing	PMU Contractor
		Tourism Beach amenity and recreational use disturbed	Public consultation to identify locations, times, and types of potential safety risks, and develop site-specific advisories and safety measures All equipment, waste, and construction materials debris must be removed daily from the site.	PMU Contractor
		Safety and human health Reduced safety of beach users	Public consultation to identify locations, times, and types of potential safety risks, and develop sites-specific advisories and safety measures All equipment, waste, and construction material debris must be inspected and/or removed daily from site.	PMU Contractor
		Fishing activity Disturb traditional fishing activity	Public consultation to identify locations, times, and types of potential conflict, and develop site-specific measures to minimize disruption of traditional beach seining and boat use	PMU Contractor
	Colva: Dune restoration and management beach scraping Nalla training	**Physical**		
		Air quality Reduction in air quality from exhaust fumes and dust	Adherence to national standards that apply to emissions for the types of vessels, vehicles and equipment proposed by contractor for construction and adherence to national ambient air quality standards Engines and generators turned off when not in use	PMU Contractor

Project Stage	Project Activity	Potential Environmental Impact	Proposed Mitigation Measures	Institutional Responsibilities
			Equipment conforms to international standards. Dust suppression, e.g., regular sprinkling (i.e., morning and evening) of water at the construction site If necessary, halt work during excessive onshore winds (decision would be with contractor based on conditions). Verbal social complaints dealt with immediately and efficiently.	
		Noise Increased noise levels	Adherence to national noise standards Engines and generators turned off when not in use Equipment conforms to international standards. Vehicles and engines fitted with silencers Daily checks and remedy of potential sources of excessive noise especially out of daylight hours. Complaints regarding noise dealt with professionally and with respect	PMU Contractor
		Water quality Turbidity during construction Leaks or spills of fluids (fuel, oil, hydraulic fluids) during vessel and equipment operation	Adherence to national water quality standards Supervision of all operation procedures to minimize spillage of sand and oil and fuel Soil erosion is to be considered with all onshore activities. Contingency plans for accidental oil, fuel, and sediment spills should be initiated immediately	PMU Contractor
		Biological		
		Marine biota and habitat Beach scraping will remove benthic habitat	Develop mitigation components such as construction timing windows based on a review and characterization of fish or invertebrates that occur in nearshore area including seasonal or migratory species and sensitive times and locations	PMU Contractor

Project Stage	Project Activity	Potential Environmental Impact	Proposed Mitigation Measures	Institutional Responsibilities
		and biota Material spills (e.g., oils, fuels, sediment) would likely affect nearby biota	Implement contingency plans if spills of sediment, fuels, or other material occurs	PMU Contractor
		Terrestrial biota and habitat Removal of habitat for site access or material or equipment staging	If terrestrial habitat is altered during construction to provide storage room or site access, habitats should be rehabilitated before the contractor leaves the site. Planting and stabilization of the environment, including replacement of any native plant species, to be undertaken.	PMU Contractor
		Social, economic, and cultural		
		Navigation Impairment of navigation	Vessel or barge movement and breakwater construction carried out in consultation with stakeholders to avoid interference with nearshore navigation.	PMU Contractor
		Fishing activity Impairment of fishing activity	Consultation with fishers to identify acceptable timing	PMU Contractor
		Vehicle traffic Potential road accidents	Public consultation to identify times and types of potential conflict, develop timing windows for truck traffic and measures to advise public and truck drivers regarding road safety requirements	PMU Contractor
		Safety and human health Reduced safety of beach users	Public consultation to identify locations, times, and types of potential safety risks, and develop site-specific advisories and safety measures All equipment, waste, and construction material debris must be inspected and removed daily from site.	PMU Contractor
		Tourism Beach amenity and recreational use	Public consultation to identify locations, times, and types of potential safety risks, and develop site-specific advisories and safety measures All equipment, waste, and construction material debris	PMU Contractor

Project Stage	Project Activity	Potential Environmental Impact	Proposed Mitigation Measures	Institutional Responsibilities
		disturbed	must be removed daily from the site.	
	Mirya, Coco, Ullal: Dredging of bottom sediment from fish harbor and river mouths Extraction of sand from sand-trap and stockpile areas Transport of sediment to beach nourishment site	**Physical**		
		Air quality Increase in fumes Possible dust emission (wind-spraying from vessels and work sites)	Adherence to national air quality standards Engines and generators turned off when not in use Equipment conforms to international standards. Dust suppression by regular sprinkling (i.e., morning and evening) or other means. Halt work during excessive onshore winds. Verbal social complaints dealt with immediately and efficiently.	PMU Contractor
		Noise Increased noise levels as vessels operate near shore	Adherence to national noise standards Engines and generators turned off when not in use Equipment conforms to international standards. Vehicles and engines fitted with silencers Daily checks and remedy of potential sources of excessive noise especially out of daylight hours. Complaints regarding noise dealt with professionally and with respect	PMU Contractor
		Water quality Release of possible contaminants from sediment Possible high turbidity during work activities Possible leaks or accidental spills of oils, fuels or hydraulic fluids	Supervision of all operation procedures to minimize release of sediment or fluids Contingency plans for accidental spills should be initiated immediately Soil erosion is to be considered with all onshore activities.	PMU Contractor

Project Stage	Project Activity	Potential Environmental Impact	Proposed Mitigation Measures	Institutional Responsibilities
		Biological		
		Marine habitat and biota Possible effects on marine biota of multiple construction activities	Develop mitigation components based on a review and characterization of fish or invertebrates that occur in nearshore area including seasonal or migratory species and sensitive times and locations	PMU
		Social, economic, and cultural		
		Navigation Local navigation	Vessel movement and equipment operation to be carried out in consultation with stakeholders to avoid interference with navigation	PMU Contractor
		Fishing activity Disturb fishing activity	Consultation with fishers to identify mutually acceptable times	PMU Contractor
	Ullal: Breakwater realignment—mouth of Netravathi river	**Physical**		
		Air quality Increase in exhaust fumes	Adherence to national air quality standards Engines and generators turned off when not in use Equipment conforms to international standards. Verbal social complaints dealt with immediately and efficiently.	PMU Contractor
		Noise Increased noise levels	Adherence to national air quality standards Engines and generators turned off when not in use Equipment conforms to international standards. Vehicles and engines fitted with silencers Daily checks and remedy of potential sources of excessive noise especially out of daylight hours. Complaints regarding noise dealt with professionally and with respect	PMU Contractor

Project Stage	Project Activity	Potential Environmental Impact	Proposed Mitigation Measures	Institutional Responsibilities
		Water quality Possible high turbidity during work activities Possible leaks or accidental spills of oils, fuels or hydraulic fluids	Supervision of all operation procedures to minimize release of sediment or fluids Contingency plans for accidental spills should be initiated immediately Soil erosion is to be considered with all onshore activities.	PMU Contractor
		Biological		
		Terrestrial biota and habitat Removal of habitat for site access or material or equipment staging	Any disturbance to local habitats should be rectified before the contractor leaves the site. Planting and therefore stabilization of the environment, replacement of any native plant species. Trees that have been removed for land based works	PMU Contractor
		Marine biota and habitat Possible effects on marine biota of multiple construction activities	Develop environmental management components based on a review and characterization of marine biota that occur in river mouth or estuary including migratory species and sensitive times and locations.	PMU
		Social, economic, and cultural		
		Navigation Impairment of local navigation	Vessel movement and equipment operation to be carried out in consultation with stakeholders to avoid interference with navigation	PMU Contractor
Operation and Maintenance	**Colva:** Maintenance of restored dunes and trained nallas	**Physical**		
		Air quality Increase in fumes and dust	Adherence to national air quality and emission standards Engines and generators turned off when not in use Equipment conforms to international standards. Dust suppression, e.g., regular sprinkling (i.e., morning and evening) of water at the construction site	PMU

Project Stage	Project Activity	Potential Environmental Impact	Proposed Mitigation Measures	Institutional Responsibilities
			If necessary, halt work during excessive onshore winds (decision would be with contractor based on conditions). Verbal social complaints dealt with immediately and efficiently.	
		Noise Increased noise levels as vessels operate near shore	Adherence to national noise standards Engines and generators turned off when not in use Equipment conforms to international standards. Vehicles and engines fitted with silencers Daily checks and remedy of potential sources of excessive noise especially out of daylight hours. Complaints regarding noise dealt with professionally and with respect	PMU
		Water quality High turbidity during work activities Leaks or accidental spills of oils, fuels, or hydraulic fluids	Supervision of all operation procedures to minimize release of sediment or fluids Contingency plans for accidental spills should be initiated immediately	PMU
		Biological		
		Terrestrial habitat and biota Possible effects if temporary vehicle access areas are needed	If terrestrial habitat is altered before or during construction to provide site access, habitats should be rehabilitated before contractor leaves site.	PMU
		Social, economic, and cultural		
		Tourism, safety, and health	Public consultation to identify locations, times, and types of potential safety risks, and develop site-specific advisories	PMU

Project Stage	Project Activity	Potential Environmental Impact	Proposed Mitigation Measures	Institutional Responsibilities
		Beach amenity and recreational use disturbed	and safety measures All equipment, waste, and construction material debris must be removed daily from the site.	
		Fishing activity	Consultation with fishers to identify mutually acceptable times	PMU
	Mirya, Colva, Ullal: Reef maintenance and effectiveness	**Physical**		
		Erosion of beaches Beach formation—impairment of sediment movement, inducing erosion in downstream beaches	Detailed modeling was used during the design stage to determine location and design features Design is expected to create wave shadow salient and not cause beach erosion No further mitigation is planned, but possible downstream erosion to be monitored	PMU
		Change in effectiveness of retention structures (reefs and berms) Induces erosion or diminishes storm buffer of beaches	Structures planned to be effective for improving conditions at target site without diminishing storm buffer along other beaches No further mitigation is planned, but possible change in effectiveness to be monitored	PMU
		Biological		
		Marine habitat and biota Long-term effect on offshore biota	Reef structure is expected to be colonized by biota offsetting smothering of soft-sediment biota. No further mitigation is planned, but biological changes at reef location to be monitored	PMU
		Social, economic, and cultural		
		Storm buffer effectiveness Buffer diminishes along beaches as a	Results of numerical modeling to support design and location decisions are expected to improve conditions at target site without diminishing storm buffer along other beaches	PMU

Project Stage	Project Activity	Potential Environmental Impact	Proposed Mitigation Measures	Institutional Responsibilities
		result of erosion, resulting in structural and economic loss	No further mitigation is planned, but possible downstream erosion to be monitored	
		Navigation Long-term effect on nearshore navigation	Regular stakeholder meetings to discuss social and environmental concerns including navigation issues	PMU
	Ullal: Netravathi river mouth breakwater alignment	**Physical**		
		Water flow Potential flooding upstream	Alignment designed to keep gap between breakwater walls the same as current distance No further mitigation is planned but breakwater effects on flooding are to be monitored.	PMU
		Sediment movement Inhibition of southern sediment-flow Accumulation of river sand at mouth	Northern breakwater is aligned in a southwestern direction and southern breakwater is shortened to enable southward movement of sediment. No further mitigation is planned but breakwater effects on flooding are to be monitored.	PMU
			Sand that currently forms off river mouth and periodically inhibits navigation is in new designs expected to accumulate in deeper water off river mouth No further mitigation is planned but breakwater effects on flooding are to be monitored.	PMU
		Social, economic, and cultural		
		Navigation	Navigation periodically impaired by sand accumulations at river mouth is expected to improve though annual dredging at end of each monsoon is recommended No further mitigation is planned but breakwater effects on flooding are to be monitored.	PMU

PMU=Program Management Unit, PAH= Polycyclic Aromatic Hyrdrocarbon
Source: EIA reports