Tsunami Impacts on Coastal Ecosystems of Southern Sri Lanka

Photo: Rebecca Tharme

Photo: Mattias Rust

A closer look at coastal ecosystem damage as a result of the tsunami along the coast of Sri Lanka has provided much-needed impetus for integrated coastal zone management (ICZM) linked with integrated water resource management (IWRM). Mr. Sithara Atapattu and Ms. Rebecca Tharme of the International Water Management Institute (IWMI) explain.

By mid-January 2005, in the aftermath of the tsunami that devastated much of the coastline of Sri Lanka, disaster relief agencies had provided considerable humanitarian support to affected communities, and mapping of affected areas was well underway. The majority of attention and resources were directed at assessing and providing for the immediate needs of survivors. In most areas, removal of human remains and large-scale clearing of debris were completed.

Rapid On-site Assessments

The first environmental assessments of a range of coastal ecosystems along the south coast of Sri Lanka were initiated by various organizations, including IWMI, providing some preliminary observations on the nature and scale of the tsunami's impact on their biophysical character.

The degree of direct physical damage to wetland ecosystems was found to be incomparable to the devastation brought about to people and their livelihoods, and to settlement infrastructure. However, the assessments were necessarily rapid, limited in scope and reliant on once-off observations. It is anticipated that more comprehensive biophysical monitoring of change, in comparison with pre-tsunami baseline information for specific systems, may yield evidence of more pronounced detrimental effects.

The spatial extent, laterally and in terms of inland penetration, and intensity of impact on coastal ecosystems were highly variable and a complex function of multiple factors, from coastal bathymetry to ecosystem condition. As a result, it could not simply be assumed that where areas showed little or no sign of impact, it was attributable to a high degree of protection by natural systems. Overall, observations did suggest, however, that where natural ecosystems and their habitats were intact or in good condition, the impact of the waves was reduced, while in areas subject to intensive anthropogenic modification, impacts appeared greater in magnitude. In some places though, it appeared that nothing would have prevented the devastation that was incurred.

Thailand and Sri Lanka

Many stretches of the southern coastline are characterised by sand dune systems vegetated with indigenous and alien trees (e.g. Casuarina), shrubs and creepers. Impacts were less where the foredunes were elevated and stabilised with vegetation, forming an effective barrier protecting adjacent inland areas. There were areas where seawater had washed over low dunes or eroded gaps, damaging the dune system. In many areas, the natural cover of Pandanus and Ipomoea was reduced by up to 75% and marine turtle nesting sites were damaged, according to a survey by The World Conservation Union, IUCN, Sri Lanka. Coconut plantations and home gardens were also affected where they occurred near the beach.

Physical damage to coastal lagoons appeared relatively limited and patchy at first evaluation. It is likely that detailed follow-up assessments will show changes in ecological character from original condition across the many types of lagoons present in the south, from freshwater to hypersaline systems. Karagan Lagoon showed an increase in surface area, shifts in salinity concentrations and the short-term effects of high debris loads. In this lagoon, as in others, there was evidence of inputs of marine organisms, while mortalities of fresh- and brackish water fish and plants, due to elevated salinities or loss to the sea, was recorded in other cases.

Kalametiya Lagoon, situated within the Lunama-Kalametiya Sanctuary, a protected mangrove site, was markedly affected and transformed from a closed system pre-tsunami, separated from the sea by a sand bar, into an effectively open system to the sea – part of the sand bar was removed completely and the remaining low bar has the potential to be breached easily, especially a concern with the upcoming monsoon season starting in May (Photograph page 10 bottom). These changes are bound to have long-term ecological consequences. Moreover, as the lagoon was (and remains) an important fishing ground, there are serious livelihoods repercussions for the surviving members of the neighbouring villages.

Estuaries and lower rivers were conduits of water inland, with tsunami-induced waves travelling upstream in both large and small systems. Physical impact on one or both

banks typically was localised, with scouring of bank sediments and removal or damage of riparian vegetation. In systems structurally altered by bridges and road culverts, for example, impacts appeared enhanced, with the structures allowing accelerated passage of water into upstream marshes, rice fields and small-scale banana and young coconut plantations – flattening vegetation and leaving behind salt and sediments with potential future effects.

Mangrove ecosystems have been slightly or moderately affected in many areas where broad, multi-storey mixed stands of Avicennia, Ceriops and other species were in good condition, for example, along the lower reaches of the Madhu Ganga (River), a protected Ramsar site. At Kalametiya Mangrove Sanctuary, which is dominated by stands of Sonneratia, as in other locations, sections of mangrove forest acted as frontline buffers to the waves; large healthy trees were seen toppled by the tsunami as far inland as several hundred metres from the beach.

Coral Reefs Under Pressure

Coral reefs, which form as scattered fringing reefs around the coastline of Sri Lanka, are currently subject to tremendous pressures due to coral mining and the collection of ornamental fish and invertebrates. Coral reefs were further highly degraded by a bleaching event in 1998, which killed many reef areas. Some scientists argue that the hardest hit areas were those that experience the most coral mining. The reef system protected within Hikkaduwa National Park, which was severely degraded in 1998, escaped with minimal tsunami damage (localised debris impacts, some dislodgement of corals), whilst the vast majority of tourist boats and many shoreline buildings were destroyed. Prior coral bleaching did not seem to exacerbate the impact. Less is known as yet of the effects of the tsunami on coastal sea grass beds.

Large-scale impacts have occurred to coastal lagoon fisheries and agricultural lands which have triggered new livelihoods dynamics for fishers and farmers alike. Considerable attention is now focused, though multi-partner proposals, on restoring and/or providing alternative livelihoods options for coastal communities dependent on natural resources. Support for livelihoods needs to be not only acceptable for the local people, but also environmentally appropriate and controlled, to best cater for the altered patterns of resource use and access.

Future Coastal Zone Development

The impacts observed have several implications for rehabilitation and future development planning of the coastal zone. The south coast of Sri Lanka has evidently had poorly planned coastal developments to date. This situation has made the immediate coastal area extremely vulnerable to more frequent natural disasters than tsunamis, including cyclones and hurricanes. The Sri Lankan Government is looking at a way forward in terms of future development of the coastal zone, and a 100 metre buffer zone for coastal development, with 300 metres for certain high-risk areas of the coast, is being mooted at present. There are of course difficulties inherent in such an approach, including the issue of the potential relocation of towns and entire fishing communities at sites far removed from their current sources of livelihood.

There are numerous initiatives for coastal reconstruction underway involving international and local NGOs, local universities and government agencies. These rapidly evolving initiatives require practical environmental guidance, delivered through well-coordinated efforts. For instance, the Ramsar Convention on wetlands has convened a Ramsar Tsunami Reference Group comprising Wetlands International, the World Wildlife Fund (WWF), IUCN, BirdLife International and IWMI (http://www.wetlands.org/tsunami/). Its immediate priority is to coordinate ongoing rapid assessments of the affected areas and to bring together scientifically sound advice on wetlands in the Asia region, in order to assist governments in choosing the most effective response measures and to help inform settlement and re-development plans.

Currently in Sri Lanka, few aid-based plans for rehabilitation seem to pay sufficient attention to environmental concerns, either in the short-term or longer-term. There is a high risk of sites being located too close to ecologically sensitive or protected areas – such areas need to be delineated and prioritised as many people are rebuilding homes and businesses on the original sites and some new resettlements are already under construction.

Much debate has centred on the significance and role of natural coastal ecosystems in mitigating the impact of the tsunami. There has been recognition that natural and human landscapes need to be managed as an integrated system. In this regard, the disaster has provided much-needed impetus for integrated coastal zone management (ICZM) linked with integrated water resource management (IWRM), in Sri Lanka and elsewhere in the region.

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Sand dunes severely damaged by wave action, fishermen repairing boats and small-scale agricultural lands and wetland areas affected by the wave.

Tsunami-Induced Coral Reef and Coastal Ecosystem Damage in the Indian Ocean

Photo: Mattias Rast

Long-term damage to the coral reefs and coastal ecosystems in the tsunami-affected areas of south Asia is the subject of intensive study. Damage appears to vary from country to country, and even locally. Prof. Olof Linden of the World Maritime University provides an update.

Photo: Frida Lanshammar

The Sida-supported CORDIO (Coral Reef Degradation in the Indian Ocean) project has formed a network of coral reef experts and managers in 11 countries of the Indian Ocean. These experts are involved in coral reef monitoring, targeted research, management and policy issues, education and training, and research and development of alternative livelihoods for coastal communities that no longer can support themselves from traditional coastal activities such as fishing. These expert groups were already on "standby" when the tsunami took place and as a consequence could secure data regarding the impact of the tsunami on coastal ecosystems quite soon after the event. CORDIO-teams of marine biologists started assessments in Sri Lanka, India, Maldives, Seychelles and Kenya and were in the field within days after the catastrophe. Additional teams started diving in Thailand just four days after the event.

Thailand and Sri Lanka

In Thailand and Sri Lanka coral reefs at several hundred sites along the entire Andaman Sea coast of Thailand and the south, southwest and east coast of Sri Lanka were surveyed. The tsunami impact varied dramatically between sites, with damage ranging from almost unaffected in about 50% of the sites to severe. Extreme mechanical damage was seen on approximately 15 to 30% the sites. On the reefs of Trincomalee in eastern Sri Lanka, the damage was particularly bad. Here, nearly half the reef area was turned into fields of rubble and sand. More than 75% of the remaining reef has been severely damaged by large coral blocks and dead coral that have bulldozed the reef, tearing off the live coral and eroding the limestone foundation of the reef, particularly along the southern reef margin (Figure 1).

Virtually all remaining live corals have been damaged, and many Acropora colonies (Staghorn coral) were sheared. Among standing thickets, most branches were loose and moving with the swell. Many tabulate and massive corals had been uprooted and toppled over – even some Porites colonies (Brain coral) over 2 metres in diameter, and many colonies of less than 50 centimetres have been transported large distances. Signs of paling and bleaching were evident in remaining massive colonies, which may be caused by sediment stress and abrasion.

In many sites, damage was patchy, with scars in the reef ranging from less than one to several meters across, but often far apart. Large coral boulders that had been killed by the el Niño-related bleaching in 1998 had been turned over by the tsunami wave and caused the scars in the surrounding reef. Also, rubble that had been formed by dead coral from the 1998 bleaching had been shifted by the wave and was now partly covering large stands of Acropora coral reef.

Litter and debris from land included textiles, plastics, tree branches and logs, parts of boats and household items. Some smothering of corals was observed, but it appears to be primarily from re-suspended marine sediments rather than terrigenous matter. Damage to sea grass beds was minor and, where present, was mostly due to shifting rubble.

Although some impact on fish populations of the reef areas was noted during the acute phase, notably on small fish such as gobies, butterfly fish and wrasse, long-term studies are necessary to assess whether these impacts will be of significance. Notably, the problem of overfishing in the affected coastal areas is by far the most important issue in coastal management.

Severe beach erosion was observed both in the east and southwest, but the impact was patchy. Severe damage was observed where illegal coral mining in the sea has been rampant. While there was evidence that in places where mangroves and coastal vegetation were less disturbed, the energy of the tsunami dissipated more efficiently. Hence, additional information on how the tsunami was shaped, deflected, weakened or focused by bathymetry and shore profile is essential to draw more detailed conclusions.

India, Gulf of Mannar

Scientist surveyed 11 sites within the Tuticorin, Vembar, Keezhakkarai, Mandapam groups of islands and one mainland site in the Gulf of Mannar between January 4 and 10, 2005. No significant coral damage was recorded at any of the sites (Figure 2). Within the Tuticorin and Keezhakkarai Groups a few table corals (Acropora cytherea) were tilted and few branches of Acropora intermedia and A. nobilis were broken by the strong waves of the tsunami. In the Vembar and Keezhakkarai Groups, sea grass and seaweed entangled corals and had also been washed ashore. The gravel sand seafloor near the reefs was replaced by layer of fine sand about one centimetre thick, but was not smothering branching and massive corals. At the mainland site, the tsunami filled 25 to 30% of the cup-shaped colonies of Turbinaria sp., which dominate this reef, with 4 to 5 centimetres of fine sand. Except for a few displaced colonies, no damage was recorded within a 60 m^2 area that has been artificially restored by SDMRI using coral fragment transplanted on cement slabs. There was no sand deposition on this site and the faunal assemblages had not changed.

No impacts on the fish community were recorded at any site and no significant impact to sea grass beds was recorded at any of the sites surveyed.

On Thalaiyari Island in the Keezhakkarai Group, trees were uprooted as a result of soil erosion. Soil erosion was also noticed between the mainland and Krusadai Island in the Mandapam Group. It is worth mentioning that mining of both living and of dead corals in the reef areas of the Gulf of Mannar is extensive.

Andaman and Nicobar Islands

Reef Watch Marine Conservation carried out assessments of the impact of the tsunami on coastal marine biodiversity starting in late January 2005. The turtle nesting beaches of South Andaman, Little Andaman and the Nicobar Group of islands have almost disappeared as the tectonic activity that initiated the tsunami has caused the subduction of these islands by 1 to 4 metres. This will affect the reproductive potential of Leatherback, Green Sea, Hawksbill and Olive Ridely turtles which use these islands as nesting sites.

The tectonic movement also affected the coral reefs in Nicobar and south Andaman and resulted in a subduction so that the reefs suddenly were located up to 4 metres deeper in the water. The opposite was the case for the reefs of north Andaman, where some reefs were lifted 4 meters above their previous position. Other physical effects (breaking of branches) were caused by wood logs and other debris from land. In most of the reefs, the larger colonies of Porites were toppled. Previously the coral reefs in the area were dominated mainly by the genus Porites followed by Acropora. If there is substantial damage to Porites, then entire reefs in that particular region are likely to become unstable and may be unable to withstand further environmental stress.

Coral reefs in several areas in Nicobar and south Andaman (for example Jolly Buoys, Redskin and Alexandra) has been extensively damaged. In the reef flats sand and silt has been deposited on the coral reefs. Large coral colonies (larger than 2 metres in diameter) have been uprooted and scattered all over the reef, and coral colonies occurring on the reef edge have been pushed out to deeper water, perhaps up to 20 metres. Broken branches of Acropora and Hydnophora rigida have been scattered over the reef, the fish abundance and diversity decreased, and tree logs and other land-based debris originated is found over large parts of the reefs.

Seychelles

In the Seychelles coral reefs on coralline substrates such as on the northern islands clustered around Praslin (including Curieuse, La Digue, Felicite and the rocks of Isle Coco and St. Pierre) showed very high levels of damage (approaching 100%). The assessments showed that the reef framework in these areas was too loosely consolidated to be able to withstand the force of the tsunami wave. The consequence was very dramatic damage to the corals, which broke loose and turned over. A contributing factor was that the coral reef had been weakened by the extensive mortality during the 1998 El Niño and subsequent bioerosion. In these areas significant amounts of reef rubble was moved by the wave and deposited on live coral colonies. In contrast to the reefs on coralline substrates, the corals on the granitic seabed around Mahe showed much lower levels of impact, generally below 10%. The limited damage on Mahe is due to the shelter provided by the outer northern islands and dissipation of wave energy as the tsunami travelled over the greater distance of shallow water from the outer edge of the banks to Mahe.

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Photo: Rebecca Tharme

Kalametiya Lagoon, Sri Lanka, with remains of sand bar. The sensitive Mangrove vegetation has been seriously affected.

Photo: Mattias Rust

Cottages upturned by the waves.

More Reading on the Web

CORDIO, IUCN and scientists from different research institutions reported the initial impacts of the tsunami based on rapid assessments by scientists. "Rapid Assessment of Tsunami Damage to Coral Reefs in Sri Lanka: Interim Report 19 January 2005" by NARA/CORDIO/IUCN/GCRMN., and other reports, regular updates and tsunami-coral reef resource materials, can be obtained from the CORDIO (www.cordio.org) and IUCN (www.iucn.org) websites.

Long-term Implications of the Tsunami in Aceh, Indonesia

The northern tip of Sumatra in Indonesia, and the provincial capital of Banda Aceh in particular, bore the brunt of the 2004 tsunami. Dr. Sutardi Sutardi of Indonesia's Ministry of Public Works, and also Program Secretary of the Indonesia Water Partnership, examines the full impact of the event across several sectors, and what remains ahead.

Of all the countries in South and South-east Asia affected by the Asian tsunami, Indonesia was perhaps hardest hit. According to the National Board of Coordination for Disaster Management, as of March 7, 2005, more than 125,766 people are known to have lost their lives in Sumatra alone, with some 94,494 people still considered missing. Sadly, the true number of perished may never be know.

The northern tip of Sumatra and the provincial capital of Banda Aceh in particular bore the brunt of this tsunami. Satellite imagery shows that 49 km^2, or 80% of the built up area of Banda Aceh city, was either totally destroyed or extremely damaged. Outlying villages were likewise devastated; while loss of life there may not have been as severe, infrastructure, housing and livelihoods have been lost on a wide-scale.

Water Supply and Sanitation

Pre-disaster, water supply networks served about 35% of urban population and about 7% of rural population, while the rest were getting their water from shallow fresh water wells. In tsunami-affected areas, water supply networks (80% damaged) and water treatment plants and pumps (65%) were hard hit. Shallow freshwater wells for household use are now saline, with water table around 5 metres deep and contaminated by potentially infections sludge.

Water and sanitation impacts are a concern at temporary camps; there are no waste disposal collection or disposal system, and no proper storage facilities for food or water (small containers only good for 1–2 days supplies). Inadequate numbers of latrines is also a widespread concern. Obviously, long-term access to fresh, safe drinking water is a concern. Emergency measures by the local and national governments as well as the international community are providing safe water supply and proper sanitation for temporary camps and the affected people. The rehabilitation and reconstruction phases will be focused on rehabilitating the broken water supply and sanitation infrastructure, and possibly the extension of service to newly reconstructed areas/settlements.

Health

Significant quantities of waste have accumulated on land, in canals, and even been washed back to sea. Debris (including corpses) is still being deposited on beaches by tides. There is no guidance or procedures for appropriate solid waste disposal; waste is being dumped (in which its composition is not known) 5 to 10 kilometres inland from Banda Aceh along the roadsides. Some sites are near rivers or temporary settlements, with the focus being on speed and ease of deposition. Transportation for waste collection is inadequate, delaying clean-up and prolonging the infectious period. Hospital waste has been washed into open public areas; there is no organized collection or safe disposal of such materials.

There are fears of leakage of toxic materials (oil leaks, pesticides from warehouses and shops in and around Banda Aceh) and airborne transmission of infectious organism from dust and dry sludge, and during the collection and transportation of gathered wastes. Pollutants of many types are being transported and deposited in other areas causing problems to be transferred from one location to another. Open burning of solid waste and debris poses a serious health hazard.

Food

The tsunami and earthquake caused serious damage to irrigation structures, canals and embankments, and flood protection facilities along the river mouth. Many farmers report lost rice harvests, and rice paddies have been contaminated by salt water and sludge.

All irrigation systems near the coast of Aceh were severely damaged by the tsunami, where the damage was greater in secondary and tertiary canal systems than in headworks and main canals. The total irrigation area damaged is estimated at 28,000 ha in Aceh province (9.6% of the total irrigated area of 290,680 hectares) and about 3,700 ha (1.1% of total irrigated area of 327,224 ha) in North Sumatra province. Damage to irrigation systems and rice fields may cause a loss of about 143,000 ton of rice production per year. Two to three years may be needed to bring productivity back.

Public Infrastructure Damage

All flood control and coastal structures near the coast of Aceh were severely damaged by the tsunami, including up to 271 kilometres upstream within five major rivers. The Krueng Aceh River flowing in Banda Aceh was especially hard hit. Similarly, the tsunami damaged completely the seawall off the west coast.

The number and severity of destroyed public facilities are massive. Two major ports in Banda Aceh and Meulaboh are completely out of function. About 1,078 kilometres of road were destroyed and 181 bridges collapsed, hindering relief efforts. Similar conditions plague electricity and telecommunications service delivery, as well as the drainage system and urban water supply facilities. Damage to government offices and hospitals hindered a coordinated response during the first month of emergency relief.

Livelihoods

The livelihoods of hundreds of thousands of people have been affected. Examples include:

- An estimated 37,000 hectares of prawn/fish farms along the coast have been lost, diminishing investments and opportunities for small-scale businesses.
- Land tenure is now uncertain for many families who used to live in the coastal strip.
- Uncertainties regarding the future of rice farming, coconut plantations, fish farms and open sea fishing (due to damage of fishery equipments).
- Lost assets, belongings and livelihood security possibilities, especially along the coastal strip, all of which may result in higher dependency on natural resources.

Guidance is necessary to enable communities to be better informed of the likelihood of natural disasters happening, and to enable them to prepare better for future even-

Ecosystems and Groundwater Degradation

Many natural ecosystems (mangroves, coral reefs, near shore zones including fish farms, freshwater reservoirs and the coastal strip) have been heavily damaged, leaving them more vulnerable to possible future events such as high tides.

Due to wide-scale infusion of saline water and possible contaminants (e.g. from sewage) groundwater and shallow freshwater wells are now saline and contaminated by sludge. Observation of the shallow groundwater for provision of water supply for temporary shelters shows no obvious signs of improving; therefore water shortages are reported from some settlements. In this situation, the emergency restoration of domestic water supply through the drilling of deep wells, provision of portable water treatment plants and the repair of domestic water systems are required.

Core Principles for Spatial and Zoning Plan

Cities in coastal areas will need to be maintained with some adjustments on local aspects, protection from earthquakes and tsunami, and protection on conservation areas. Measures needed include:

- Construction of an arterial road from western to eastern parts of Aceh Province.
- Construction of an access road to link the southern and northern parts of Aceh.
- Development of buffer zones, fish farms and parks in locations not considered feasible for settlements from geological and environment points of view.
- Determination of environmental and building codes for zones with limited development, and building escape facilities for protection from earthquake and tsunami.
- Development of man-made constructions and natural/vegetation buffer zones in coastal areas.

Photo: Matrias Rust (small); SIWI (large)

tualities. Future resettlement plans – spatial planning issues, sanitation, water and waste collection/disposal facilities – need appropriate development.

Restoring Lives and Livelihoods

This process has begun with machine and labour intensive public works to remove thousands of corpses and to clean up waste materials, debris and sludge. Barracks have been provisioned and equipped with multipurpose spaces, water supply, sanitation and access via roads. Other needed measures:

- Provide the opportunity for families to rebuild their own homes with the support of construction materials and design standards and building codes.
- Support families and communities where displaced people have taken refuge.
- Provide transparent compensation, even if past experience shows that this is the area of greatest difficulty, legally speaking.
- Focus on land offices and dispute-resolution procedures, including institutions and staffing.

Restoring the Economy

Restoring the economy will require a number of measures, including (but not limited to):

- Recognise labour intensive infrastructure investment, and purchase and hire locally.
- Recapitalize household enterprises with grants rather than loans.
- Move quickly to re-establish banking services (including proof of identity procedures).

Recovery of Water Resources Infrastructure

The recovery of water resources infrastructure is critical, including domestic water supply and sanitation, irrigation, flood control and coastal protection. Three phases will be necessary: the emergency phase, rehabilitation phase and reconstruction phase.

The emergency phase, a six-month period starting immediately after the disaster, includes emergency restoring of water resources infrastructure. The focus is on supplying clean water to drink by means of drilling of deep tube wells, repairing domestic water supply systems and improving living conditions by drainage of wet areas.

Following the emergency phase, a 1.5-year long rehabilitation phase will be needed. Domestic water supply and sanitation facilities need to be rehabilitated up to pre-disaster levels of service. Flood control will need rehabilitation to minimise damage against possible future floods, and river structures/stretches must be normalized to at least a minimum level. Finally, rehabilitation of coastal structures to protect against tidal waters will be needed.

The reconstruction phase, a four-year period starting 2006, will need to see that domestic water supply and sanitation facilities have increased the coverage of service levels, targeted new settlement areas. Irrigation facilities will need to recover the function of irrigation systems to enable farmers to produce the paddy and other agricultural production to the existing commanding areas (before tsunami), and incentives and systems for sustainable maintenance need to be introduced. For flood control, flood management structures need to be reconstructed to the original condition, if not better, and public and private assets must be protected from possible flood damage in all river systems. Finally, coastlines must be secured against tidal waves in order to protect public and private assets at the original level or more based on spatial plan.

Photo: Mattias Rust

The recovery of water resources infrastructure is critical, including domestic water supply and sanitation. Here, a toilet is visible, partly covered with sand.

The general principles of the implementation program of the recovery plan in the water resources sector are as follows:

Rapid participatory damage and needs assessment: Emergency and recovery plans should be based on the rapid participatory field damage and needs assessment, and the recovery works should be based on the prioritisation drawn from the damage and needs assessment. Attention should be paid to prioritisation of those works that should be based on the needs of the local population.

Recovery plan: The prioritisation is given to: (a) improving the local working and living conditions ; (b) emphasizing labour intensive infrastructure recovery works to be carried out by local people, (c) maximum stimulus for revival of local economic activity.

Spatial Planning: Recovery of coastal protection facilities should depend on the condition of the area to be protected. Where the protection areas are devastated, or the coastal geography was changed and the local people have shifted, the recovery works should be carried out in consideration of the result of spatial planning.

Financial Challenges

A cost estimate for the recovery of public infrastructure (excluding private holdings) has been made based on a grouping of three sectors under the Ministry of Public Works. These are 1) Cipta Karya, consisting of water supply, sanitation, drainage facilities and construction of barracks; 2) Bina Marga, consisting of roads and bridges; and 3) Sumber Daya Air, consisting of irrigation, flood control and coastal protection facilities. Total funds required to recover three sectors of public infrastructure (including fund required for spatial planning) under the Ministry of Public Works alone is estimated at USD 827.5 billion.

This amount will stretch Indonesian financial capacity, since it is twice the annual budget for all three sectors for the entire country. Therefore, special arrangements in terms soft loans or grants from international donors is required to fund the recovery of public infrastructures. Otherwise, it the pace of development of public infrastructures for the rest of the country will be hindered.

Funds required for each phase and period of implementation plan are as follows:

- Emergency Phase: USD 89 billion
- Rehabilitation Phase: USD 143 billion
- Reconstruction Phase: USD 596 billion

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