Environment and Reconstruction in Aceh:

Two years after the tsunami

UNEP

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The Director, DCPI
United Nations Environment Programme
PO Box 30552, Nairobi, Kenya
Tel: +254 (0)20 762 1234
Fax: +254 (0)20 762 3927
E-mail: uneppub@unep.org
Web: http://www.unep.org

Design and Layout: Rachel Dolores
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List of Abbreviations

ADB	Asian Development Bank
BGR	German Federal Institute for Geosciences and Natural Resources
BRR	Badan Rehabilitasi dan Rekonstruksi
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organization of the United Nations
FP	United Nations Population Fund
GIS	Geographical Information System
GTZ-SLGSR	Deutsche Gesellschaft für Technische Zusammenarbeit-Support for Local Governance for Sustainable Reconstruction
KLH	Kementerian Lingkungan Hidup
IUCN	World Conservation Union
MDF	Multi-Donor Fund for Aceh and Nias
MPA	Marine Protected Area
NAD	Nanggröe Aceh Darussalam
NGO	Non-governmental organisation
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
SEF	Strategic Environmental Framework
TRWMP	Tsunami Recovery Waste Management Programme
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAID-ESP	United States Agency for International Development - Environmental Services Program
WB	World Bank
WHO	World Health Organization

Executive Summary

Overview

This report assesses environmental conditions in Indonesia's Nanggröe Aceh Darussalam province (Aceh) and Nias, in the province of North Sumatra, two years after the tsunami that occurred in the Indian Ocean on 26 December 2004. The report arrives at a pivotal moment, as the reconstruction process is being re-evaluated from a number of critical perspectives.

In retrospect, it is clear that environmental concerns were not sufficiently incorporated into strategic planning at the outset of the reconstruction process, and that as a result, reconstruction efforts have contributed to further degradation of Aceh's environment in the months since the tsunami. This report identifies the key issues and provides recommendations to strengthen reconstruction efforts, help the region achieve sustainable development and reduce risks from future potential disasters.

This document is divided into three chapters. The first analyses 'green' issues related to ecosystems and biodiversity; the second focuses on the 'brown' issues linked to human development and infrastructure; and the third examines the region's institutional capacity to implement environmental reconstruction and recovery. In addition to the findings, the report contains a series of recommendations and – as annexes – specific project concepts.

The green assessment: ecosystem and biodiversity health

The green assessment team identified three major areas of interest.

Leuser-Ulu Masen Ecosystem endangered. The Leuser-Ulu Masen ecosystem is the largest and most intact natural forest area and biodiversity resource surviving in Sumatra, and one of the most important such reserves in the world. These forests, which have been classified as having maximum environmental sensitivity, safeguard environmental services that sustain lives and livelihoods throughout Aceh. Given that approximately 60 percent of the land in Aceh is under natural forest in the Leuser-Ulu Masen ecosystem, an average of 0.6 ha of land per person remains, only slightly more than the 0.4 ha per person that was farmed before the tsunami. However, significant damage to the forests would expose people in Aceh to hardships that are all too familiar elsewhere in Indonesia: increasingly erratic water supplies, increasing vulnerability to flash flooding and landslides, increasing erosion and siltation of downstream irrigation and drainage channels, as well as silt deposition on coral reefs that would diminish the productivity of fisheries. Such damage would sacrifice biodiversity resources that are of great potential financial value to the people of Aceh. The key concern is whether the government and people of Aceh will be able to protect these forests in the face of logging, mining, road and plantation concessions sponsored by others with short-term interests, in order to ensure the equitable, sustainable and profitable use of this unique resource for local benefit over the long term.

Destructive fishing practices. Efforts to restore pre-tsunami fisheries production in the waters around Aceh are flawed. Indeed, over-fishing and destructive fishing methods were widespread before the tsunami. Most large breeding fish had already been caught, and productive benthic ecosystems had been damaged. Rather than restoring pre-tsunami conditions, therefore, 'building back better' in the fisheries sector requires a different approach. Marine protected areas (MPAs) should be established at the kabupaten level, so that breeding fish can safely achieve a large size and maximum reproductive output. The creation of MPAs should also be combined with educational and other interventions aimed at increasing compliance with regulations prohibiting destructive fishing activities.

Damage to coastal ecosystems. It is necessary to restore the coastal ecosystems – especially mangroves – that were extensively damaged before the tsunami and were further impacted by the event. The continued use of an aquaculture model based on bare mud and fishponds that are managed with intensive labour, energy and chemical inputs, and that are highly vulnerable to sea-borne calamity, is a particular matter of concern. A mangrove aquaculture model could be introduced instead, through local dialogue and direct exchange between communities in Aceh and communities elsewhere in Indonesia where successful mature mangrove aquaculture systems have been established. These systems have proven to require fewer inputs and be more environmentally secure and productive. Lessons learnt from an analysis of the fates of 30 million mangrove seedlings planted in Aceh since the tsunami shed further light on the merits of this approach and how it may be implemented.

The brown assessment: environmental aspects of reconstruction

The brown assessment found that although many current environmental problems already existed before 2004, the reconstruction process itself is clearly having significant impacts on the environment. The team identified several major issues of concern.

Contaminated groundwater. In many tsunami-affected areas, shallow groundwater – a major source of drinking water – is still brackish and contaminated with faecal bacteria. Alternative drinking water sources are urgently required. Newly built houses must be provided with adequate sanitation systems to minimize future groundwater contamination. Water from deep aquifer systems is mostly of good quality and should be considered a major long-term drinking water source. There are, however, some indications of saltwater intrusion and possible contamination with faecal bacteria, perhaps as a consequence of inadequate drilling techniques. It is of utmost importance to monitor water quantity and quality in these aquifers, and to limit water extraction to sustainable levels. In some cases, the water from deeper aquifers contains high concentrations of heavy metals, particularly arsenic, that require further monitoring and partial treatment.

Soil degradation. Due to the tsunami, a thick sediment layer covers approximately 1,000 ha of agricultural land. Some areas remain saline, requiring improved land drainage. As the restoration of these areas can be very expensive, alternative land use practices should be considered (e.g. animal husbandry).

Sand and gravel extraction. Widely uncontrolled extraction of sand and gravel from rivers is expected to change river flow patterns and to increase the rivers' scouring force, threatening damage to major infrastructure along the rivers. Riverbed quarrying should be reduced to a minimum. Alternative sand and gravel deposits away from riverbeds should be explored and developed.

Undisposed waste. Large quantities of tsunami and household waste still need to be cleaned up. Waste is clogging drainage systems and posing a major public health risk. Waste collection and disposal facilities are deficient, and hazardous waste is scarcely taken into account. The collection and treatment of waste, particularly hazardous waste, should be improved and safe waste disposal facilities created.

Improper siting of houses. The locations chosen for the reconstruction of houses are not always appropriate. Houses are sometimes built in highly disaster-prone or environmentally sensitive areas, or in areas where the water table is very close to the surface. Such mistakes could be minimized by using a simple checklist enumerating important siting criteria, and by taking into account spatial planning instruments (e.g. maps of high-risk areas).

Inadequate sanitation. Inadequate or inexistent sanitation facilities in reconstructed houses are a major source of surface and groundwater pollution, particularly in areas with very shallow water tables. Houses should always be built with adequate sanitation systems that minimize water pollution; simple soak-aways should not be allowed. The minimum requirement for individual houses should be properly constructed, for example dual chamber septic tanks from which overflows discharge onto leach fields situated a safe distance from wells. Where possible, small water treatment plants should be constructed for groups of houses and larger settlements. The sustainable long-term management of these systems is required, as is a major awareness campaign: most people currently seem unaware of the risks posed by inadequate sanitation and unfamiliar with the operation and maintenance of sanitation systems.

Unsustainable building materials. The excessive use of burnt clay bricks in the reconstruction of houses – together with the fact that brick kilns use mainly energy-inefficient production techniques – creates a very significant demand for fuelwood. This fuelwood often comes from illegal logging operations. At least a portion of the bricks should be replaced with alternative construction materials (e.g. hollow concrete blocks), and efforts should be made to improve the energy efficiency of the kilns.

Environmental institutional capacities

Weak environmental impact assessment process: The current process for assessing the anticipated environmental impacts of reconstruction projects is deficient at both the strategic and the operational levels. This is probably largely due to the limited resources and capacity of the Provincial Environment Agency (Bapedalda NAD) to carry out the required environmental impact assessments (EIAs). Bapedalda's capacities must be improved significantly and swiftly. Additional short-term external help may be needed to meet shifting demand. At present, several types of projects with potentially negative environmental impacts are not subject to the EIA process. The screening criteria for deciding which reconstruction projects require EIAs should be revised, and adequate tools, including processing checklists, should be elaborated at once. Even when EIAs are not required legally, the environmental aspects of projects like the reconstruction of houses could be taken into account using environmental impact checklists. Aid agencies also need to improve their own EIA capacities, while the province should develop a more strategic approach to environmental decision-making and undertake strategic environmental assessments of reconstruction and development plans.

Environmental monitoring: Environmental monitoring is an essential tool for environmental management. The province's monitoring capacities must be improved. Additional laboratory equipment, a GIS-based environmental information system and capacity development are needed.

Information and coordination: Due to the magnitude and complexity of the reconstruction process, information management, coordination and communication among stakeholders are priority issues. Specific strategies for different aspects of environmental management (e.g. waste management or monitoring) would improve coordination and facilitate the monitoring and evaluation of the reconstruction process.

Introduction

The setting

The Indonesian province of Nanggröe Aceh Darussalam (Aceh) occupies the northern tip of the island of Sumatra and lies between 2-4o N and 95-98o E. The province has an area of 57,365.57 km^2, and a population of approximately 4,010,860. Aceh is divided into four municipalities (or Kota) – Banda Aceh, Langsa, Lhokseumawe, and Sabang – and 17 districts (or Kabupaten), each of which is further divided into sub-districts (or Kecamatan) (Table 1).

Table 1: Districts and Sub-Districts of Nanggröe Aceh Darussalam

District (Kabupaten)	Sub-District (Kecamatan)
Aceh Barat	Johan Pahlawan, Arongan Lambalek, Woyla Barat, Kawai XVI, Meureubo, Pantai Ceureumen
Aceh Barat Daya	Manggeng, Tangan-tangan, Susoh, Kuala Batee, Babah Rot
Aceh Besar	Lhoong, Lhok Nga/Leupeung, Leupeung, Seulimeum, Mesjid Raya, Darussalam, Baitussalam, Simpang Tiga, Darul Imarah, Peukan Bada, Pulo Aceh
Aceh Jaya	Teunom, Panga, Krueng Sabee, Setia Bakti, Sampoinet, Jaya
Aceh Selatan	Trumon, Trumon Timur, Bakongan, Bakongan Timur, Kluet Selatan, Kluet Timur, Kluet Utara, Pasie Raja, Kluent Tengah, Tapak Tuan, Sama Dua, Sawang, Meukek, Labuhan Haji Barat
Aceh Singkil	Singkil, Singkil Utara, Kota Baharu
Aceh Tengah	
Aceh Tenggara	
Aceh Timur	Birem Bayeun, Rantau Selamat, Sungai Raya, Peureulak, Peureulak Timur, Peureulak Barat, Rantau Peureulak, Idi Rayeuk, Banda Alam, Idi Tunong, Darul Aman, Nurussalam, Julok, Pante Beudari, Simpang Ulim, Madat
Aceh Tamiang	Seruway, Bendahara, Manyek Payed
Aceh Utara	Syamtalira Bayu, Tanah Jambo Aye, Seuneubon, Baktiya, Baktia Barat, Lhok Sukon, Samudera, Syamtalira Alon, Tanah Pasir, Dewantara, Muara Batu
Bener Meriah	
Bireun	Samalanga, Pandrah, Jeuniaeb, Peudada, Juli, Jeumpa, Jangka, Peusangan, Gandapura
Gayo Lues	
Kota Banda Aceh	Meuraxa, Jaya Baru, Baiturrahman, Lueng Bata, Kuta Alam, Kuta Raja, Syaih Kuala, Ulee Karang
Kota Langsa	Langsa Timur, Langsa Kota
Kota Lhokseumawe	Blang Mangat, Muara Dua, Banda Sakti
Kota Sabang	Sukajaya, Sukakarya
Nagan Raya	Darul Makmur, Kuala
Pidie	Meureudu, Meurah Dua, Bandar Dua, Jangka Buya, Ulim, Trienggadeng, Panteraja, Bandar Baru, Glumpang Tiga, Glumpang Baro, Mutiara Barat, Kembang Tanjung, Simpang Tiga, Kota Sigli, Pidie, Batee, Muara Tiga
Simeulue	Alafan, Simeulue Barat, Salang, Simeulue Tangah, Teluk Dalam, Simeulue Timur, Teupah Barat, Teupah Selatan

The Indian Ocean tsunami

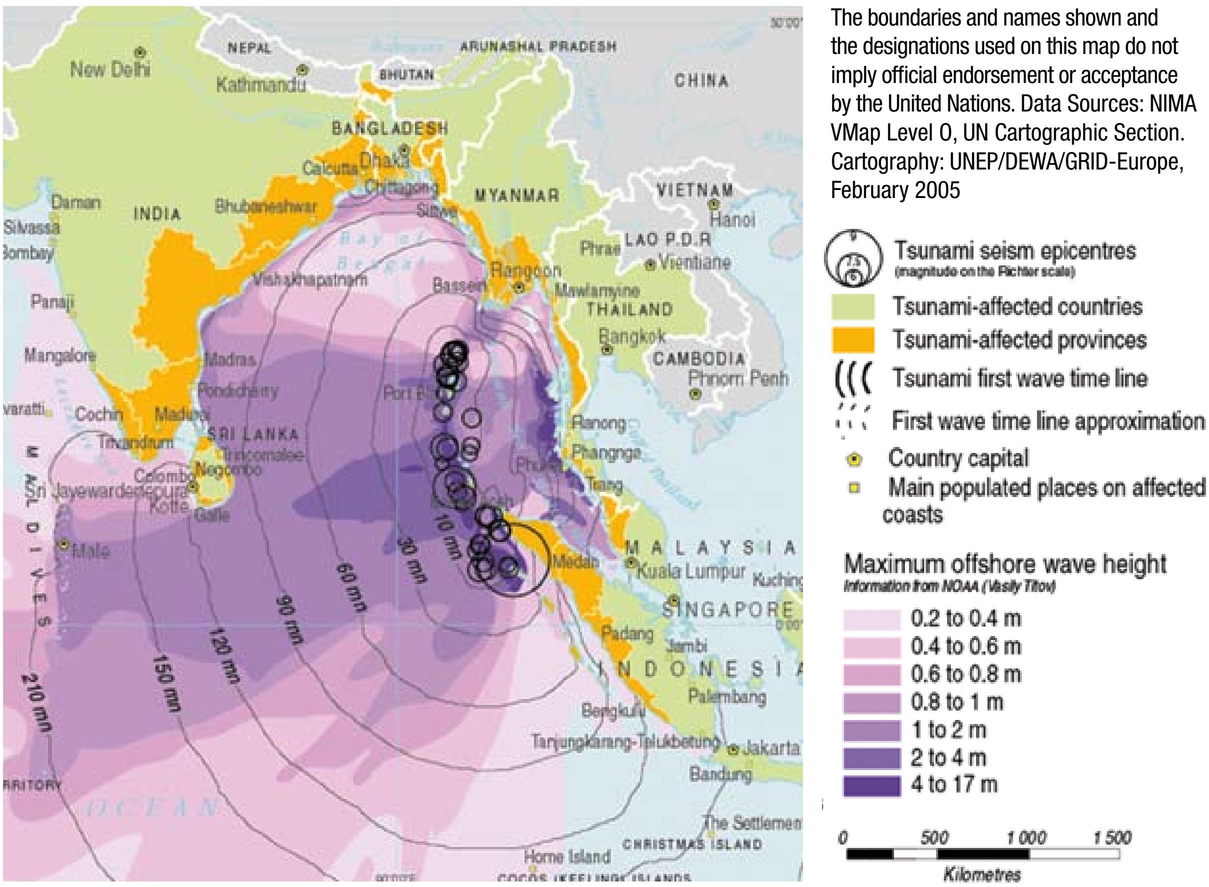
The Indian Ocean earthquake and tsunami in December 2004 had far-reaching effects in Western Indonesia. The impacts were particularly severe in Aceh, where 167,000 were reported dead or missing, and 127,000 houses were destroyed with a similar number damaged. On the island of Nias, in the province of North Sumatra, 850 were killed and 83,900 houses destroyed or damaged.

In addition to this human tragedy, the earthquake and tsunami caused tremendous social, economic and environmental devastation. Most of Aceh's coastal areas, public infrastructure and social facilities such as schools, health centres, and government buildings were destroyed. Livelihoods were severely impacted through damage to agricultural areas, disrupted fishing activities, loss of land titles, reduced water quality, pollution from solid and liquid waste and breakdown of sanitation and sewage facilities. Mid and long-term environmental impacts include substantial amounts of mixed solid waste, damage to coral reefs, loss of fertile soil, damage to vegetation (including beach forests and mangroves), salt intrusion, and environmental degradation resulting from the relocation and rehabilitation of affected populations, including overexploitation of natural resources.

The relief and recovery process

Shortly after the tsunami an unprecedented aid operation was begun. Hundreds of national and international aid agencies from more than 130 countries contributed to a massive emergency aid programme.

Over time, emergency relief operations gave way to rehabilitation and reconstruction. In April 2005 the Government of Indonesia issued a 'Master Plan' to guide the rehabilitation and reconstruction of communities in Aceh and Nias. At the same time, the President of Indonesia established the Badan Rehabilitasi dan Rekonstruksi (BRR), also known as the Agency for the Rehabilitation and Reconstruction of Aceh and Nias, to coordinate the rehabilitation and reconstruction process.



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Data Sources: NIMA VMap Level 0, UN Cartographic Section. Cartography: UNEP/DEWA/GRID-Europe, February 2005

Figure 1: Map of Aceh (showing districts and main towns, major terrain features and forest cover)

The main goals of the process have been necessarily humanitarian, ensuring that basic human needs are being met while creating a framework for social and economic progress in the region. At the same time, however, the major environmental damage created by the earthquake, the tsunami and the reconstruction process itself has been widely recognized. In order to 'build back better' and ensure sustainable development and an acceptable quality of life for local communities, environmental conditions must be greatly improved.

The assessment process

With this report, the United Nations Environment Programme (UNEP) aims to highlight priority environmental concerns and recommended actions that will strengthen reconstruction efforts and improve living conditions in Aceh and Nias.

The report is based on desk studies, field missions and extensive consultation with UNEP's partners in the Government of Indonesia, the international donor community and civil society. UNEP experts collaborated with a working group from Syiah Kuala University in Banda Aceh and a team of experts from Wetlands International Indonesia Programme to gather and analyze existing environmental data on the region. UNEP verified these data and collected additional data during field missions to Banda Aceh and its surroundings in September and October 2006. The assessment process benefited greatly from the inputs of the many aid agencies involved in the reconstruction process in Aceh. Without their knowledge and their willingness to share their experiences, this study would not have been possible.

This report, which has been peer reviewed by representatives of key agencies, summarizes the assessment teams' key findings and recommendations. The report arrives at a pivotal moment, as the reconstruction process is being reassessed with a view toward learning and applying lessons that will strengthen ongoing and future reconstruction efforts.

UNEP prepared this report in cooperation with the BRR, Kementerian Lingkungan Hidup (KLH, or Ministry of Environment) and various other expert institutions in the framework of UNEP's Post-Tsunami Environmental Recovery Programme. The Government of Norway, and the United Nations Office for the Coordination of Humanitarian Assistance (OCHA) financially supported this effort.

Report structure

This report consolidates the findings of three separate assessment teams, each with their own distinct approach and voice. As such, the report consists of three principal chapters. Each chapter analyzes a key set of environmental challenges – 'green' issues, pertaining to ecosystem and biodiversity health; 'brown' issues, pertaining to the environmental challenges of reconstruction; and, finally, an overview of the key institutions and actors involved in Aceh's environmental reconstruction. The green and brown assessment chapters each contain conclusions and recommendations that follow directly from the findings contained in those chapters. The body of the report is followed by annexes that contain, among other things, a number of specific green and brown strategic project concepts.

Chapter 1

The green assessment: the health of ecosystems and biodiversity

Background

The following chapter contains UNEP's findings and recommendations relating to the status of ecosystems and biodiversity in Aceh and Nias.[1]

a.Land resources

Status

Aceh lies in the moist equatorial zone and has a mean annual rainfall of 1,500-5,000 mm, depending on location and rain-shadow effects. The province is drier in the north and west, and wetter in the south and east, and in the mountains. The geology is largely granitic and volcanic, but there are significant areas of limestone (karst) in the north. Farm products include wet rice, which may be irrigated or rain fed, and mixed gardens of fruit trees and vegetable crops. Many areas are suitable for coconut, cocoa, coffee and other pan-tropical crops. There is a clear distinction between the flat coastal plain and the steeper upland areas, which are more suitable for tree crops. Leaving aside the approximately 60 percent of Aceh that is under natural forest in the Leuser-Ulu Masen ecosystem, there remains an average of about 0.6 ha per person, slightly more than the 0.4 ha per person than was being farmed before the tsunami (Table 2).

Table 2: Agricultural land areas before the tsunami

	Agricultural land use (hectares)		
Kota/ Kabupaten	**Wet rice land**	**Rain-fed land**	**Home gardens**
Sabang	10	403	0
Banda Aceh	586	4,890	4,221
Aceh Besar	30,421	61,779	23,104
Pidie	38,796	48,966	16,056
Bireun	22,948	91,317	17,172
Aceh Utara	38,831	301,484	42,425
Lhokseumawe	1,768	49,138	6,967
Aceh Tengah	19,516	41,445	4,502
Aceh Timur	35,746	75,285	28,023
Langsa	1,925	19,518	7,265
Aceh Tamiang	20,022	44,613	16,606
Aceh Tenggara	17,224	10,393	1,220
Gayo Lues	8,215	7,526	833
Aceh Jaya	9,294	13,837	1,197
Aceh Barat	21,551	37,970	3,076
Nagan Raya	16,698	17,269	1,424
Simeulue	19,330	10,925	3,545
Aceh Selatan	23,814	77,520	28,404
Aceh Singkil	13,433	21,235	17,155
Aceh Barat Daya	16,269	47,512	17,409
Total	**356,397**	**983,025**	**240,604**

The tsunami disaster at the end of 2004 damaged approximately 61,816 ha of agricultural land. The damage was caused by deposits of salt and marine mud (including approximately 5 million m3 on 1,000 ha of farmland along the west coast), the spreading of waste and building rubble, and by the breaking of irrigation and drainage systems, with impacts on the areas farmed and agricultural production (Tables 3 and 4).

1 This chapter's findings draw on materials assembled by various sources, such as the NGO Wetlands International Indonesia Programme (WI-IP) under contract to UNEP, including their studies of province-wide ecosystem and biodiversity data, and lessons learnt from post-tsunami mangrove planting activities, as well as its long-term work in Central Java. Detailed discussions and peer review inputs were provided by colleagues familiar with key aspects of ecosystem and biodiversity management in Aceh, including experts engaged by the Food and Agriculture Organisation of the United Nations (FAO) (coral reefs, fisheries), Asian Development Bank (ADB) (sensitivity mapping), UN Population Fund (FPA) (gender issues), Fauna & Flora International (management of Ulu Masen Ecosystem) and Leuser International Foundation (management of Leuser Ecosystem). UNEP's findings are also informed by its own activities in Aceh since the tsunami, including its involvement with international disaster risk reduction and disaster preparedness, and by its knowledge of global experiences in such fields as biodiversity prospecting and the marketing of biodiversity-related educational services. The findings in this chapter are intended to complement those of the Environmental Outlook Report prepared for Bapedalda NAD & GTZ-SLGSR (2006), which is intended to serve as the basis for an Environmental Action Plan that would include the creation of an Environmental Forum, an effective environmental monitoring system, environmental quality targets, and activities for raising environmental awareness.

Table 3: Tsunami impact on areas farmed				
	Total land area (ha)		Damaged land (ha)	
Kota/ Kabupaten	Irrigated	Rain-fed	Irrigated	Rain-fed
Banda Aceh	511	575	75	50
Aceh Besar	30,421	120,266	6,855	9,465
Aceh Jaya	9,294	14,305	8,800	3,068
Aceh Barat	7,789	9,421	2,970	1,114
Nagan Raya	5,709	8,793	3,960	1,560
Aceh Barat Daya	16,450	98,599	3,080	4,758
Pidie	36,566	288,455	2,860	3,072
Bireuen	22,948	167,173	2,118	567
Aceh Utara	39,184	290,502	1,224	612
Aceh Timur	35,746	122,745	2,119	0
Simeulue	19,330	10,943	3,410	79
Total	**223,948**	**1,131,777**	**37,471**	**24,345**

Table 4: Agricultural production in Aceh in 2005						
	Production by food plant (tonne)					
Kota/ Kabupaten	Wet rice	Dry rice	Maize	Soybean	Ground-nut	Green beans
Sabang	0	181	34	8	35	12
Banda Aceh	391	0	5	0	0	0
Aceh Besar	132,884	631	541	128	518	622
Pidie	191,531	390	1,460	1,918	3,864	724
Bireun	139,553	209	2,532	20,916	404	1,523
Aceh Utara	216,989	85	5,290	3,246	670	456
Lhokseumawe	4,585	0	167	110	29	18
Aceh Tengah	25,773	559	558	83	146	10
Aceh Timur	119,399	288	1,090	461	154	352
Langsa	8,519	0	21	0	43	13
Aceh Tamiang	62,877	153	2,847	2,366	201	90
Aceh Tenggara	88,011	0	71,286	189	150	112
Gayo Lues	42,775	0	128	103	115	14
Aceh Jaya	13,844	0	107	20	109	63
Aceh Barat	65,666	0	413	66	2,221	40
Nagan Raya	111,457	484	1,536	525	1,864	361
Simeulue	9,906	0	47	1	34	11
Aceh Selatan	85,607	8	1,150	199	1,006	260
Aceh Singkil	16,065	5,048	1,884	124	321	119
Aceh Barat Daya	55,807	41	2,662	434	3,590	46
Bener Meriah	11,500	398	669	170	124	9
Total	**1,403,139**	**8,475**	**94,427**	**31,067**	**15,598**	**4,855**

Key Issues

Tsunami-related impacts

Several institutions have undertaken agricultural rehabilitation efforts, but these have been mainly limited to land clearing. These efforts are being evaluated and monitored, in several cases using the demonstration-plot approach. Soil fertility remains affected in many areas. This problem could be corrected using agricultural technology to recover land productivity in areas of high salinity and acidity.

The restoration of supporting infrastructure is also urgently needed to accelerate land rehabilitation. Farmers are still contending with damaged irrigation and drainage channels, tidal flooding, and limited transportation facilities. Blocked land drainage is a particularly serious problem, because it can lead to water logging, salt retention and the intensification and spread of mosquito-borne diseases such as dengue, malaria and filariasis.

Farmers' economic recovery can be helped by providing support to restart farming activities, followed by guidance on the proper management of tsunami-affected land and on market- and environment-oriented farm management. Coordination among institutions involved in land rehabilitation efforts should be intensified to improve the effectiveness and impact of their programmes.

General issues

Land issues in Aceh are comparable with those in other locations in Indonesia's outer islands. The chief similarities lie in the climate and the nature of crops grown, in the terrain, with limited amounts of flat land, and in the geology, with a mixture of limestone, granites and some volcanic overlay. Differences include the soils, which are relatively fertile compared with, e.g., Kalimantan, but are vulnerable to water logging.

Social differences, however, are marked. Because of the conflict, Aceh largely avoided major transmigration schemes, which elsewhere introduced large numbers of Javanese, Maduranese and Balinese to extensive settlements in newly cleared forest areas. The conflict also discouraged private resettlement as well as commercial logging and plantation operations. People in Aceh do not hunt much and do not traditionally shiftcultivation of hill rice, which has done much to clear and fragment hill forest in the outer islands.

Because so little damage has so far been done to the upland forests, the high rainfall is not associated with significant soil erosion and downstream sedimentation, which are major causes of coral reef mortality elsewhere. Nor are there catastrophic landslides, although occasional floods occur due to poor drainage and high water tables in many areas. With adequate cultivated land for its population, land issues are, for now, likely to be limited to the possible over-use of pesticides and perhaps fertilisers, coastal salt intrusion (aggravated or caused by shifts in the terrain as a result of earthquakes) and localised erosion where slopes are bare during rainy periods.

Indicators

Monitoring land use would enable the detection and mitigation of changes detrimental to livelihoods, public health and ecosystems. Indicators of interest would include:

- use of nitrogen, phosphorus and potassium fertilisers in each drainage basin;
- total immobile contaminant loads on land areas;
- changes in status of known highly contaminated sites;
- amounts and kinds of pesticide application;
- implementation of integrated pest management (IPM) activities;
- implementation of agrochemical risk reduction activities;
- areas converted to agriculture from other land uses, including deforestation, urbanisation, infrastructure and hydropower reservoirs;
- areas subject to erosion; and
- farming areas under organic or near-organic management.

b. Forest ecosystems and biodiversity

The Sumatran context

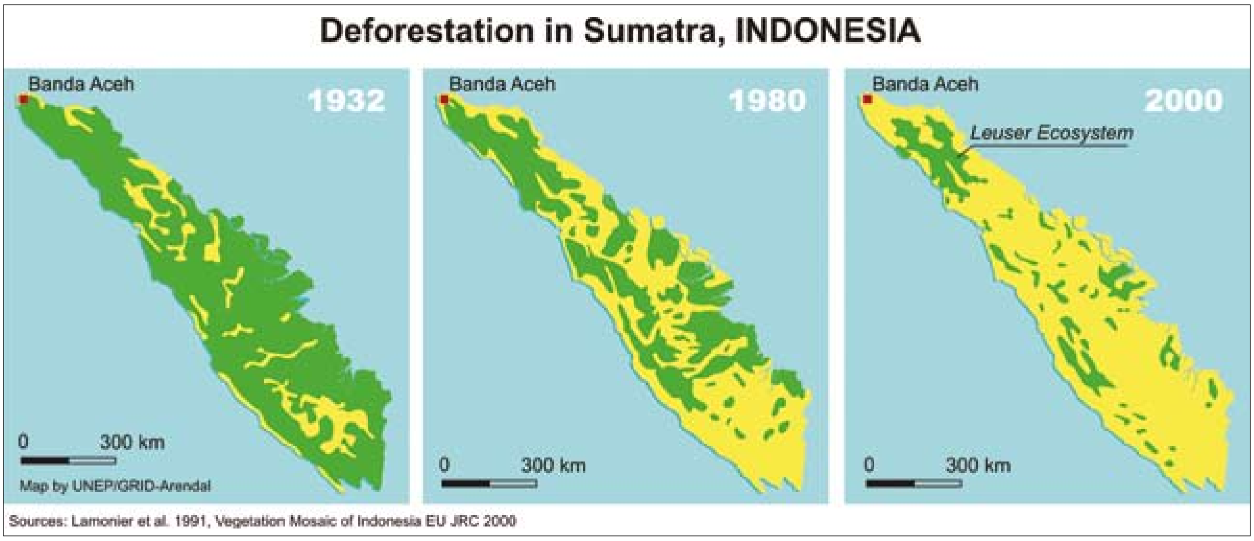
The island of Sumatra is part of a distinctive bio-geographical region known as Sundaland. Sundaland was wholly exposed by low sea levels during cool, dry periods over the last 100,000 years. In warmer, wetter times, as now, Sundaland is divided into the main land masses of Malaya, Borneo, Java and Sumatra. These areas generally have much in common, sharing many species and ecosystem types. Java, however, is a bit more distinct, because it was partly isolated by a large river system even when the beds of the South China Sea and Java Sea were dry. The entire region is very rich in species. In some locations, especially in Malaya and Sumatra, moist forests survived dry periods, allowing evolution to continue uninterrupted, with species-rich forests re-colonising other areas as wet conditions returned. Table 5 summarises data on species richness and endemism in Sumatra. The table shows that 10-11 percent of Sumatra's non-flying wild species (i.e. excluding birds, which move relatively freely among islands) are found nowhere else on Earth. Many more species are found only within the confines of Sundaland.

The native vegetation of Sundaland mainly comprises tropical rain forest, which varies greatly with altitude, soil type and drainage. Most of these forests have been damaged by logging and fires (which often go together, because logged forests can become very dry and flammable during periods of drought) or were cleared for plantations and farms during the last century. Figure 2 (page 16) shows the contraction of natural forest cover on

Table 5: Species richness and endemism in Sumatra

	Birds	Mammals	Reptiles	Fresh-water fish	Selected plant taxa
Native species	465	194	217	272	820
Endemic species	2%	10%	11%	11%	11%

Figure 2: Deforestation in Sumatra, 1932-2000



Sumatra during the 1932-2000 period, a process that is continuing throughout the region.

The result is that Sundaland's once undisturbed natural forests are now very largely restricted to isolated fragments that often have survived because they were officially protected. The region's remaining forests are frequently surrounded by forests that have been logged and are fire prone, farmland or plantations.

Most native species are adapted to life in continuously moist forests. As a result, many cannot survive the environmental changes associated with logging, and virtually none can survive in non-forest habitats or plantations of exotic trees such as oil palm (Eleais guineaensis), rubber (Hevea brasiliensis) or pulp wood acacia (Acacia mangium). The survival of Sundaland's unique fauna and flora thus depends on the continued existence of natural forest landscapes large enough to provide moist conditions and continuous enough to sustain large populations of the organisms concerned.

In this context, the importance of Aceh's conservation landscapes can easily be appreciated. There are only three such large areas in Sumatra: the Leuser-Ulu Masen ecosystem (land area ca 34,000 km2, mostly intact, including the Gunung Leuser National Park, GLNP, of about 8,000 km2), the Kerinci Seblat National Park (KSNP, land area ca 15,000 km2, much of it subject to illegal logging and poaching), and the Bukit Barisan Selatan National Park (BBSNP, land area ca 3,600 km2, which is extensively encroached). In 2004, the GLNP, KSNP and BBSNP mountain cluster was designated a World Heritage Site, reflecting its collective global importance for biodiversity conservation.

Aside from a few smaller reserves, such as Way Kambas and Bukit Tigapuluh, most other forests in Sumatra have been badly damaged or lost entirely, putting an even higher burden on the three parks to maintain the survival of Sumatra's astonishing but severely endangered biodiversity. Among them, the Leuser-Ulu Masen ecosystem stands out by virtue of its size, continuity and intactness. The area is also exceptional because of its extraordinary dominance of the province's land area (close to 60 percent), standing as a potential long-term guarantor of Aceh's biodiversity resources as well as the ecosystem services that Aceh will need in the future if it is to achieve sustainable development.

The Leuser-Ulu Masen ecosystems

Biodiversity

The Leuser and Ulu Masen ecosystems together contain the richest surviving assemblage of biodiversity in Southeast Asia.

The Leuser Ecosystem, 27,000 km2 in extent, stretches from the sandy beaches bordering the Indian Ocean, across the breadth of Sumatra almost to the mangrove swamps bordering the

Malacca Straits (Griffith, 2005). It includes two great mountain ranges reaching over 3,000 m in altitude. These ranges are separated by a rift valley through which two large rivers flow – the Tripa to the northwest, and the Alas to the south. The rivers flow into the Indian Ocean after passing through extensive freshwater peat swamps that are home to the world's densest populations of the critically endangered Sumatran orangutan *(Pongo abelii)*.

The Ulu Masen ecosystem lies within four districts of Aceh (Aceh Besar, Aceh Jaya, Aceh Barat and Pidie). The mainly forested area of around 7,000 km2 comprises a number of habitat types,

Figure 3: Key biodiversity areas in Aceh, the Ulu Masen and Leuser Ecosystems

including various forms of lowland to montane rain forest, swamp forest, and, in the north, forest growing on limestone (karst) terrain.

The Leuser-Ulu Masen area is the last place where there are viable, or potentially viable, populations of the Sumatran elephant (*Elephas maximus sumatranus*), orangutan, tiger (*Panthera tigris sumatrae*) and the critically endangered two-horned rhinoceros (*Dicerorhinus sumatrensis*), and the only place where all these species are found together. The area is also home to populations of tapir (*Tapirus indicus*), sun-bear (*Helarctos malayanus*) red hunting dog (*Cuon alpinus*), and a full complement of typical Western Sundaland primate species, including gibbons (*Hylobates agilis*), siamang (*Symphalangus syndactylus*), and cercopithecine and colobine monkeys. The rest of the biota is extraordinarily rich, with over 1,000 vertebrate species, thousands of higher plants, and an unknown but very large number (hundreds of thousands) of invertebrate species, many of them yet to be discovered. Such richness makes the area ideal for recreation, education and both basic and applied research. Taking all available sources of information into account, the areas of maximum biodiversity value tend to lie in the ecosystem's peripheral and lowland areas (Figure 3, page 17).

Ecological services

The forests of the Ulu Masen ecosystem provide vital environmental services to the people of northern Aceh. They control the hydrology of the area and the major watersheds of the Krueng (River) Aceh and Krueng Teunom, plus numerous smaller catchments, which provide water for the majority of northern Aceh's inhabitants. Forests help stabilize the steep slopes found in much of the area, preventing landslides. They also help control the climate of northern Aceh, ensuring the supply of rain needed to support agriculture.

The Leuser forests, like those of Ulu Masen, provide valuable ecological services needed for Aceh's recovery, including water supply, flood prevention, erosion mitigation, and climate regulation. Detailed economic valuations of the Leuser forests (van Beukering et al. 2001) concluded that these ecological services were worth several hundred million dollars annually. The net economic benefit of conservation relative to deforestation over a 30-year period was estimated to be over US$ 5.4 billion, with most of the benefits flowing to communities in the downstream environment. For these various reasons, the ADB-BRR Earthquake & Tsunami Emergency Support Project has classified the Leuser-Ulu Masen ecosystems as having maximum environmental sensitivity (ADB & BRR 2006). The deep green shaded portions of the map in Figure 4 indicate the area's high environmental sensitivity.

Conservation history

The name Leuser comes from the Gayo language word *leusoh*, meaning 'veiled in clouds', referring to the high mountains of the area, which possess mythic significance. Most of the Leuser area was promoted for conservation by the leaders of the traditional peoples in that part of Sumatra since as early as 1927. For six years, the local leaders lobbied the Dutch colonial authorities to have the great forests of Leuser conserved in perpetuity. Eventually, some 8,000 km2 was set aside, approximating the present Gunung Leuser National Park, but this excluded most of the valuable lowland forests and coastal plains.

This deep appreciation of the value of Aceh's natural forests later manifested itself in cooperation with efforts to extend conservation management to the much larger Leuser and Ulu Masen ecosystems as a whole.

In 1980, a Ministerial Decree confirmed the Gunung Leuser National Park and its immediate buffer zone at 900,000 ha. Another decree in 1995 extended the Leuser Ecosystem to 1.75 million ha, before a Presidential Decree in 1998 ratified its area at 2.7 million ha. A EU-supported Integrated Conservation and Development Project (ICDP) for Lowland Rainforests in Aceh operated during 1992-2004. The ICDP was followed by establishment of the Leuser Development Programme (LDP) and the Leuser International Foundation (LIF), which were expressly aimed at conserving the Leuser Ecosystem.

Grants from the Multi-Donor Trust Fund allocated US$ 9.81 million over 4.5 years for the Leuser Ecosystem (managed by LIF), and US$ 7.72 million for the Ulu Masen Ecosystem (managed by Fauna & Flora International, FFI). The goal of the grants was to protect the areas' critical environmental resources and services. The grants support activities aimed at:

- creating an effective, multi-stakeholder management framework for ecosystem protection and for strengthening the monitoring and protection institutions for each ecosystem;
- assisting the spatial planning process, supporting the livelihoods of local communities helping to rehabilitate the forests and ecosystems, and raising awareness and improving education regarding environmental and conservation issues; and

Figure 4: Environmental sensitivity map of Aceh

Source: ADB-BRR Earthquake & Tsunami Emergency Support Project 2006

- supporting good governance and strengthening financial oversights and safeguards.

Trends

Hostilities in Aceh have acted as a powerful brake on forces that might otherwise have destroyed much of the province's forest and biodiversity resources. Military activity in the forested areas strongly discouraged the working of legal timber concessions, mineral exploration, illegal logging, road building and farming. Prior to late 2004, there was a deadlock between the opposing sides. The tsunami, however, caused so much damage and upheaval that it allowed negotiating positions to change and created a new opportunity for peace. A settlement was agreed during 2005 and formalised into law in 2006.

The whole situation remains very complex and dynamic at the political level. Since the agreement, the central government has begun to approve road-building plans, logging concessions, mineral exploration and plantation development (particularly for oil palm) in Aceh's forested areas. Among these projects are eight logging concessions in the Leuser Ecosystem and five in Ulu Masen. These actions are generally opposed by the provincial government, which will make them hard (though not necessarily impossible) to implement. Another trend resulting from the peace process has been an increase in small-scale illegal logging and farming in forested areas. Meanwhile, some district governments have attempted to initiate road building projects, including through protected areas. At this stage, these projects are primarily aimed at promoting transport links between settlements, rather than opening up forests for exploitation.

Key issues

Resource management decisions

Aceh's forests and biodiversity are poised on a cusp of human decisions. In one direction lies the rapid slide to destruction that has befallen most other Sumatran, Indonesian and Southeast Asian ecosystems. In the other is conservation of these extraordinary resources for the benefit of future generations. The choice between these paths is imminent. The cessation of hostilities in Aceh has greatly heightened the vulnerability of the forests, and the biodiversity they contain, to logging, mining, road building and agricultural clearance. Factors tending towards destruction include the enormous national and regional demand for timber, minerals and plantation products, and the local opportunities offered by illegal logging and farming, especially to unemployed people including ex-combatants who are now re-entering society. Powerful vested interests would gain short-term profit from road building and opening up natural resources to human access and use at the expense of the forests and the biodiversity they contain.

On the other hand, there is a brief window of opportunity for other, more positive, factors to prevail. The people of Aceh, being generally devout Muslims, are not enthusiastic hunters of wildlife, partly because of dietary rules and partly because their faith opposes the needless destruction of Creation (Abou Bakr et al., 1983). There are also relatively few residents (slightly more than four million) relative to the size of the land area and forest resources. New autonomy provisions allow for greater local control over the use of natural resources. In principle, these provisions permit Aceh to determine for itself whether or not to liquidate its biodiversity resources in favour of logging, roads and plantations. There is a longstanding tradition in Aceh of conserving forest areas and an understanding of the risks of drought, flood and landslide that accompany forest clearance. The key issue that needs to be clarified in this context is whether the Aceh government or the Indonesian government has the final authority to determine the fate of Aceh's natural resources.

Biodiversity as a resource

A related strategic issue is the extent to which citizens in Aceh perceive biodiversity as a resource in itself that requires careful management and sustainable use, as distinct from more traditional approaches to extracting resources from ecosystems (such as land, timber, rattan, etc.) or the more recent interest in the environmental services provided by ecosystems (e.g., water catchment functions). This is a key conservation issue. Concentrating only on the management of ecosystem *outputs* may achieve a degraded but functional outcome with much loss of biodiversity. Maximising the return from conservation requires valuing, and working out ways to use sustainably the complete range of biological resources available. This, in turn, requires investing in an inter-connected process involving:

- **saving biodiversity** (e.g., the design, protective management, financing, use, planning, staffing and inter-sectoral significance of protected areas and protected area systems; the management of genetic resources, species, populations and ecosystems outside protected areas; the suppression of alien invasive species, fires and other factors that threaten wild species populations; and relevant legislation and policies);
- **studying biodiversity** (e.g., research and inventory work involving the collection of information of any kind related to any aspect of genetic resources, species, populations and ecosystems, and the organization and use of that information);
- **teaching about biodiversity** (e.g., using information about biodiversity for an educational purpose whether commercialized or not); and
- **using biodiversity sustainably** (e.g., for agriculture, medicine, bio-prospecting, ecotourism, natural history film-making and journalism).

These steps have been well explored worldwide, although aspects of using biodiversity have only come to be appreciated in the 1990s, with the advent of the technology to support bio-prospecting and contractual arrangements for equitable partnerships between biodiversity owners and bio-prospecting corporations (ten Kate & Laird, 1999). It can be imagined that Aceh will one day achieve clear ownership of its biodiversity resources, which are some of the world's most important and valuable. . If Aceh can establish ownership and control, and preserve its resources, it would be in an excellent position to mobilise the investment needed to use the resources wisely for the benefit of its people (Annex 1, Concept 1; Annex 2, Enterprise field 2).

Environmental services

The regular supply of high-quality water is a fundamental economic need. Clean, reliable water supplies are among the most valuable exports of forest areas. Water supplies, however, are acutely sensitive to the way in which catchment forests are managed. The total amount of water that flows from an area depends mainly on the amount that falls on it during the preceding period. Whether the water that emerges from a basin comes as a steady flow or in the form of floods alternating with droughts, however, depends on the ecology of the forest system growing on the catchment. Intact forests moderate seasonal and storm effects, and generally lend consistency to water delivery. They also supply water with very low sediment loads by preventing soil erosion.

This smoothness and purity of supply can be assigned value, and its consumers can be charged for that value at realistic prices. The minimum realistic price is the real cost of maintaining the catchment, including the opportunity cost of not damaging it. If logging is seen as the main alternative to keeping a catchment intact, then lost timber revenues should be reflected in the price of water. Water is often under-priced or even free. This approach is not sustainable in the face of increasing supply shortages and development pressures on watersheds. Many people in Aceh, and in Sumatra as a whole, are aware of the link between deforestation and the loss of water catchment services, such as an increased risk of landslides, flooding and supply shortages. Nevertheless, it would be helpful to document the economic value of the services provided by forests, in order to better inform and strengthen the degree of caution applied to decisions whether to log or otherwise clear forests. This might also provide a rationale for introducing a pricing system for water services. For example, charges to housing developments and irrigation or hydropower schemes could help finance conservation efforts upstream. Leadership and administrative changes will be required to establish a realistic water pricing system. When such a system is achieved, however, the long-term benefits to the entire society can be enormous.

Environmental education

The extent of public understanding of ecology and environmental economics in Aceh is presently unknown and should be assessed. Meanwhile, it can be observed that ignorance of the true value and potential of forest ecosystems and biodiversity is typically a contributory factor in their destruction, as it allows wrong decisions to be made and prevents correct decisions from receiving public support. Another outcome is the inequitable distribution of costs and benefits. Those who might lose something from a decision to protect resources (such as the opportunity to farm there) may perceive no corresponding benefits resulting from that decision. A more complete understanding of resource management decisions will increase the probability that the public will accept those decisions and comply with them. Increasing public awareness of the economic potential of biodiversity would also encourage a willingness to conserve resources and explore ways to obtain sustainable benefits from their use.

Among other things, awareness is also fundamental to disaster risk reduction and disaster preparedness. Local stakeholders can improve their environmental security by analysing their vulnerabilities to various kinds of disasters, by taking such actions as restoring protective ecosystems, and by agreeing on responsibilities and courses of action before, during and after disasters. For example, coastal ecosystems are known to be highly productive ecologically, and thus capable of supporting the livelihoods of millions of people. They are also known to be robust to several kinds of environmental shocks, especially high-energy sea-borne events associated with storms. Research since the tsunami indicates that the restoration of coastal ecosystems should be based on adequate local knowledge and participation. Environmental education should be integral to all aspects of disaster preparedness. Participatory education processes[2] enable communities to understand their physical and social environments, their vulnerabilities and their opportunities to improve their security in the face of future potential calamities.

Indicators

Biodiversity

The general natural history of Aceh can be inferred from studies conducted elsewhere in Sumatra. Much research has been done on vertebrates and higher plants at sites in the Leuser ecosystem. There is a lack of detailed knowledge, however, regarding the taxonomy, ecology and populations of most wild species in Aceh. This would need to be corrected through systematic inventory and monitoring work over many years, if some of the chief indicators of biodiversity status are to be used in Aceh. These include indicators based on the Living Planet Index or Wild Bird Index approaches, which report on trends in multiple populations of species and are powerful headline indicators of ecological health.

A more targeted approach might be used by monitoring selected species that are considered ecologically important or particularly sensitive to disturbance, or both, with an operational preference for those that can easily be detected (e.g. gibbons, hornbills). Another theme would be the use of species with particular physiological characteristics, to allow monitoring of physical conditions. It is easy, for example, to use the abundance of water-permeable, macroscopic and terrestrial (WAPMAT) species as indicators of prevailing moisture conditions in a forest, which is suggestive both of fire risk and of rain forest health. In practice, this need involve no more than counting the proportion of trees with large growths of moss on their lower trunks, which has proven to be a sensitive indicator of microclimate in Malaysia (Caldecott, 1997).

Proxy indicators of biodiversity may be of more immediate use in Aceh. These might include trends in forest loss, such as area converted to farmland or plantation, or damage, such as the extent and density of logging roads, as detected by field patrols or remote imagery. Alternatively, the identification of critical ecosystems and their allocation to protection categories of forest use could also be used. In an area like the Leuser-Ulu Masen ecosystem, such monitoring might be expected to show the stabilisation of damage and loss around an increasing number of intact and

2 See, e.g., the processes used in the European Commission's DIPECHO and UNEP's APELL programmes.

protected core areas within the landscape as a whole. The degree of connectedness among core areas would then also become an important aspect to monitor. Finally, measures of annual investment in biodiversity management can also be used as a proxy indicator of biodiversity trends.

Ecological services

Monitorable indicators of water catchment security include the proportion of catchment area under intact, natural forest, and/or under forest that is protected. Because everywhere is a water catchment for somewhere, however, prioritisation is needed to identify catchments of special concern. This is usually established according to the needs and value of downstream users of catchment services, with human settlements and valuable irrigation, hydropower, industrial or other installations given priority. In Malaysia, for example, the states classify catchments into one of three categories: Class A, B or C. Class A catchments are the least important and are open for low-impact logging. By contrast, logging is not recommended in Class B and C catchments or other areas identified by city and town administrations as essential for their own water supplies (which may be missed in data compiled at the state level). Definitive maps will be needed in order to identify, protect and monitor critical water catchments.

c. Coastal ecosystems

Status overview

The tsunami impacted coastal and estuarine settlements and ecosystems across virtually the entire coastline of Aceh, especially in the Aceh Besar, Aceh Jaya and Nagan Raya districts. It penetrated inland for an average of 2 km in the west, 500 m in the east and, in some locations, surged up rivers as far as 6 km. At up to 10-20 m in height, the tsunami's power so close to the earthquake's epicentre was sufficient to destroy tens of thousands of hectares of normally robust mangrove forests and damage sea grass beds, coral reefs and beach forests (Table 6). The surge destroyed 20 percent of the area's seaweed farming facilities and 40 percent of its fish ponds (tambak). Before the tsunami, the fish ponds occupied about 36,600 ha in 11 coastal districts, most having been established in areas previously forested with mangroves.

Table 6: Coastal wetlands thought to need rehabilitation in tsunami-affected districts and cities, by area in hectares and priority (** is highest, *** is high, ** is medium, * is low)**

(Source: Wetlands International Indonesia Programme)

	Seagrass		Mangrove		Coral reef		Beach forest	
District/City	**Area**	**Priority**	**Area**	**Priority**	**Area**	**Priority**	**Area**	**Priority**
Simeulue	?	****	1,000	****	?	****	?	****
Aceh Singkil	0	-	0	-	0	-	0	-
Aceh Selatan	0	-	0	-	0	-	0	-
Aceh Timur	0	-	20,000	*	0	-	?	*
Aceh Barat	?	****	10,000	***	?	****	?	****
Aceh Besar	?	****	25,000	****	?	****	?	****
Pidie	?	****	17,000	****	?	?	?	****
Bireuen	?	**	15,000	**	?	?	?	**
Aceh Utara	?	*	10,000	**	?	?	?	**
Aceh Barat Daya	?	**	1,000	**	?	*	?	***
Aceh Tamiang	0	-	0	-	-	-	?	*
Nagan Raya	?	**	7,000	**	?	**	?	**
Aceh Jaya	?	****	10,000	****	?	****	?	****
Banda Aceh	?	****	500	****	0	-	?	****
Langsa	0	-	1,000	*	0	-	?	*
Lhokseumawe	0	-	1,000	**	0	-	?	*
Total (excl. Sabang)	-		118,500		-		-	
Sabang	?	****	?	****	?	****	?	****

According to 2005 assessments by Wetlands International, most of Aceh's west coast had subsided to some extent, and the shoreline had moved inland by 100-200 m in many areas. Subsidence and uplift also affected the islands of Nias and Simeulue (Figure 5, page 24).

Coral reefs and capture fisheries

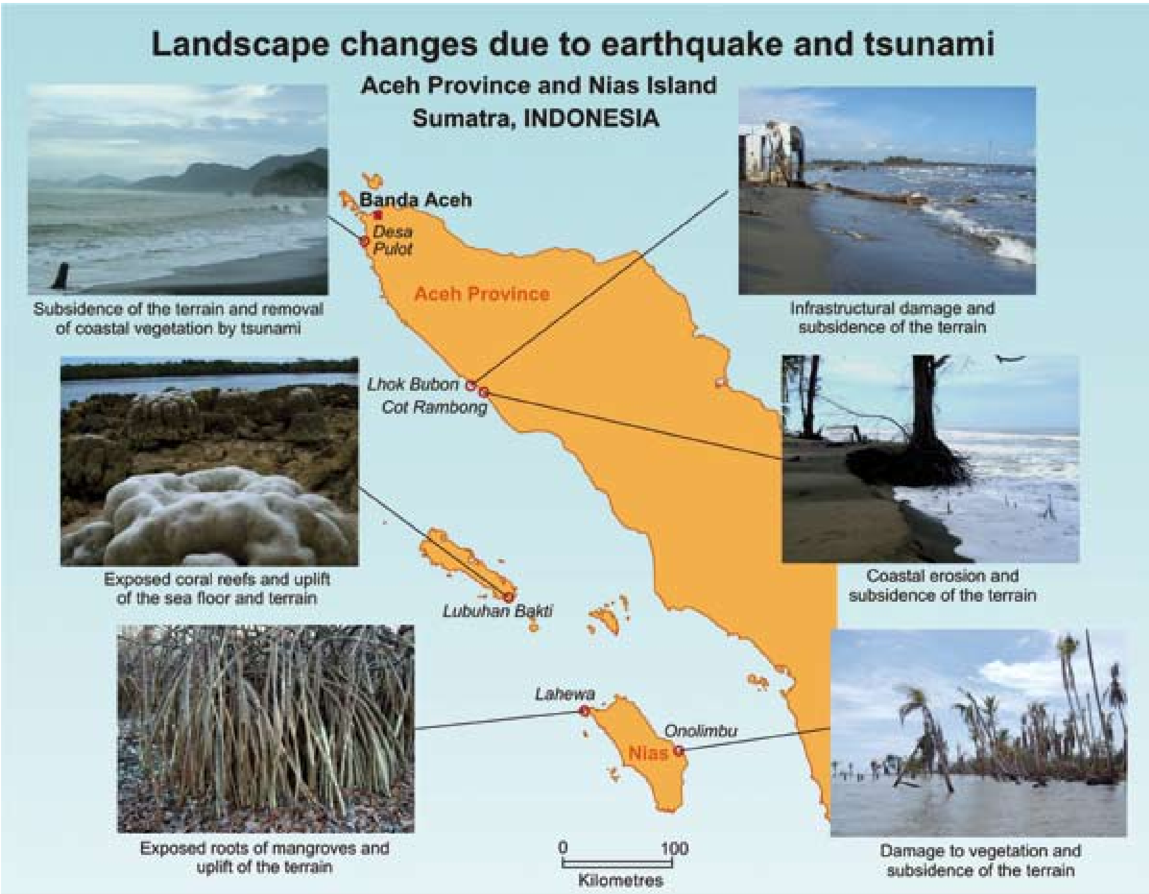
Significant damage was done to coral reefs in Nias and Simeulue, where topographic change had elevated some reefs above the water. As revealed by detailed studies in 2007 by scientists from the Wildlife Conservation Society and the Australian Research Council Centre of Excellence for Coral Reef Studies, the impact was particularly severe in Simeulue. Here the earthquake raised the whole island by up to 1.2 m, exposing most of the coral reefs ringing the island over most of its 264 km coastline. This resulted in the deaths of thousands of hectares of coral reefs, part of one of the biggest coral die-offs ever documented. Elsewhere, for example at Lhampuuk in Aceh Besar, coral death was more localised, amounting to 1.2 ha. Initially, there were fears that as much as 30 percent of the estimated 97,250 ha of coral reefs in Aceh waters had been badly damaged by the tsunami. More recent assessments, however, suggest that there was very little damage below about five metres depth. Shallower corals were damaged directly by the tsunami and by the powerful surge and backwash of water, silt and debris. Much debris remains trapped in reef formations at all depths.

The key to coral reef restoration is most likely to be found in removing as much debris as possible and relying on natural processes for regrowth. In addition, marine protected areas should be used to provide sanctuary for spawning fish populations and other reef organisms, while protecting the reefs from destructive fishing practices. There have been proposals and costly efforts to restore reefs by transplanting corals and by constructing various kinds of artificial reefs, including massive concrete structures. These ideas reflect a wish to restore fishery production to pre-tsunami levels, but they ignore several important factors:

- the pre-tsunami fishery was probably being badly over-exploited, as indicated by anecdotal evidence of changing fish species composition (in favour of lower-value fish), smaller average size of caught fish, declining catch rates, and data for 1980 and 2005 showing a 70 percent decline in demersal fish populations;

- the pre- and post-tsunami fishery did and does partly use destructive fishing methods (dynamite, cyanide, muro-ami, trawling), causing chronic damage to the benthic environment, including coral reefs; and

Figure 5: Landscape change in Aceh and Nias due to earthquake and tsunami



Photos are kindly provided by: **Wetlands International Indonesia Programme**

- as a tropical fishery, the key limiting factor to fishery production in Aceh is almost certainly not availability of structural habitat (which artificial reefs attempt to address) but rather the recruitment of new individuals (Rudolf Hermes, personal communication), a point central to the issues that need to be addressed in Aceh (see, e.g., Annex 1, Concept 2).

Mangroves and fish ponds

The east coast of Aceh is a continuation of the muddy coastline of east Sumatra, where conditions in the inter-tidal zone are excellent for the growth of mangrove vegetation. The west coast of Aceh is mostly sandy beach, but there are also small patches of mangrove in the districts of Aceh Jaya, Aceh Barat and Aceh Singkil. This distinctive ecosystem is dominated by tree species that can tolerate tidally flooded saline mud, including members of the families Avicenniaceae (*Avicennia marina, A. officinalis, A. alba, A. lannata*), Rhizophoraceae (*Rhizophora mucronata, R. apiculata, R. stylosa, Bruguiera gymnorrhiza, B. parviflora, Ceriops tagal, C. decandra*), Combretaceae (*Lumnitzera littorea, L. racemosa*), and Sonneratiaceae (*Sonneratia alba, S. caseolaris*). The community, then, is somewhat diverse taxonomically and in nature is also zoned. Some species do best in seaward locations (i.e., *Sonneratia alba*, and certain species of *Avicennia* and *Rhizophora*), others in the middle zone (mainly *Rhizophoraceae*), and still others in the landward zone, where there is the least saline exposure and mangrove associates, such as members of the Myrsinaceae (*Aegiceras cornoculatum*) and Meliaceae (*Xylocarpus rumphii, X. granatum*), can be found. The landward zone mangrove transforms into terrestrial forest.

Mangroves are extraordinarily productive ecosystems. They occur in areas where the mixing of nutrients from sea and land supports vast numbers of breeding and maturing fish, molluscs, holothurians and crustaceans. The result is that mangrove forests can yield an annual direct harvest per hectare of 100 kg of fish, 20 kg of shrimp, 15 kg of crabmeat, 200 kg of mollusc, 40 kg of sea cucumber, and another 400 kg of species that breed in mangroves and mature elsewhere, such as on coral reefs (ADB, cited in Pye-Smith & Feyerabend, 1994). More than 70 other uses for mangrove products have been documented worldwide, ranging from palm sugar and honey to tannin and water-resistant poles (Hamilton & Snedaker, 1984). For these reasons, mangroves help support the livelihoods of millions of coastal dwellers. Mangroves are also physically sturdy and complex, with stilt roots and other structures that help to absorb wave energy. Healthy mangrove ecosystems help moderate the force of wind-generated waves, and thus are important in limiting coastal erosion and storm damage (UNEP-WCMC, 2006).

Estimates of the area of intact mangrove that existed in Aceh before the tsunami vary, with figures ranging from 54,000-60,000 ha published in the 1980s and 1990s (e.g. Rusila Noor et al., 1999). By 2000, however, the Ministry of Forestry reported that the total area was only about 30,000 ha. Aquaculturalists prefer to establish new ponds in standing mangroves. This enables them to sell the wood and makes the new ponds more productive. The establishment of 36,600 ha of fishponds before the tsunami, therefore, is consistent with the decline of intact mangrove cover. There is some uncertainty in these figures, but the tsunami reportedly damaged approximately 32,000 ha of mangrove (Table 7).

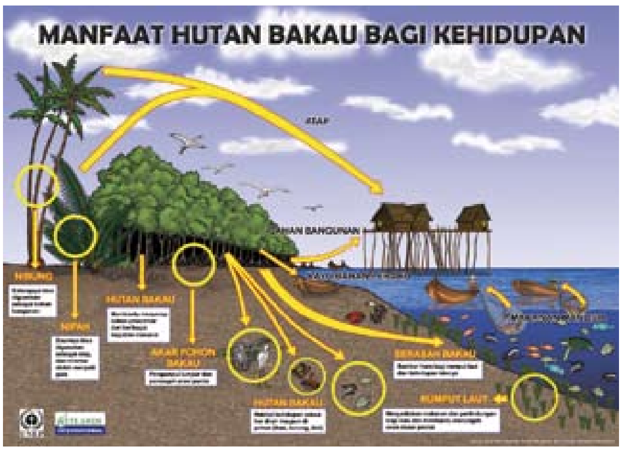


Table 7: Extent of tsunami damage to mangroves in Aceh	
District	**Area damaged (Ha)**
Banda Aceh	111.3
Lhoksumawe	308.6
Aceh Jaya	67.6
Aceh Selatan	0
Aceh Singkil	1,460.4
Aceh Tamiang	16,095.0
Aceh Timur	10,453.6
Aceh Utara	0
Aceh Bireun	0
Nagan Raya	0
Pidie	32.3
Aceh Barat Daya	2.7
Aceh Barat	361.6
Aceh Besar	53.9
Simeulue	3,056.9
Total	**32,003.9**

The aquaculture ponds that had partly replaced intact mangroves in Aceh suffered badly from the tsunami. The tsunami swamped and destroyed ponds, aerating equipment, dikes, water gates, etc., affecting an estimated 40 percent or more of the pond area in Aceh and 100 percent of it in Banda Aceh, Aceh Barat, Aceh Besar and Kota Abang (Table 8).

Table 8: Tsunami damage to aquaculture ponds in Aceh (source: Fisheries and Marine Affairs Department, 2005)		
District	**Pond area (ha) before tsunami**	**Damaged pond area (ha)**
Banda Aceh	724	724
Aceh Selatan	25	10
Aceh Timur	7,822	2,347
Aceh Utara	10,520	4,208
Pidie	5,056	2,573
Aceh Barat	289	289
Aceh Besar	1,006	1,006
Kota Sabang	28	28
Langsa	2,122	424
Total	**27,592**	**11,609**
N.B. No data are available for Lhoksumawe, Aceh Jaya, Aceh Singkil, Aceh Tamiang, Aceh Bireun, Nagan Raya, Aceh Barat Daya, and Simeulue, which between them had had about 9,000 ha of ponds.		

Overall, the tsunami caused a 68 percent reduction in average pond productivity per hectare in the districts for which comparable data are available – from 514 kg in 2004 to 163 kg in 2005 (Table 9).

Table 9: Brackish water pond production, 2004 and 2005, in Pidie, Sabang and Langsa			
Year	**Production (tonnes)**	**Area (ha)**	**Production (tonnes/ha)**
2004	3,701	7,206	0.514
2005	687	4,228	0.163

By September 2006, approximately 5,000 ha of the damaged aquaculture ponds had been repaired. Much effort went into planting mangrove seedlings in the same areas over the same period. In all, a total of almost 30 million seedlings are estimated to have been planted on 27,500 ha in Aceh since the tsunami (Cahyo Wibisono & Suryadiputra, 2006). The mangroves, however, were often planted in damaged pond areas before the ponds were repaired, and the heavy machinery used in repair work destroyed many of them. Other mangrove planting areas were later destroyed through the construction of infrastructure, suggesting a lack of coordination among various reconstruction actors. The need for better coordination of the sequencing and siting of planting is one of a number of lessons drawn through a UNEP-supported study of the post-tsunami mangrove replanting efforts in Aceh (Cahyo Wibisono & Suryadiputra, 2006). Other valuable conclusions of the study were that:

- short-term, project-based, cash-for-work schemes in which local people are used as paid labourers, with limited supervision, training or education, tend to result in little after care and high seedling mortality rates;
- with 95 percent of planted seedlings being Rhizophora (mostly *R. mucronata*), the resulting mangrove monocultures lack structural and taxonomic diversity and zonation, which may render them vulnerable to environmental shocks and disease;
- importing seeds and seedlings from Java to relieve local supply shortages meant that 35-50 percent died in shipping and the rest were stressed and weakened;
- the use of mature and qualified seeds and seedlings is essential to ensure high survival rates after planting;
- the choice of sites for nurseries is important to seedling production, the best sites being tidal, flat and sheltered from the wind;

- the use of growth media with too little mud content causes seedlings to die;
- a 1-2 month 'hardening off' period is needed before planting, during which the seedlings are progressively deprived of fresh water and shade;
- seedlings were often planted in the wrong sites, i.e., in areas that were sandy or prone to drying out, and in high-energy locations vulnerable to currents and wind;
- planting in privately owned areas without owner permission may result in seedlings being removed later;
- seedlings can be killed or weakened by technical errors, including planting at the wrong time of day (morning and evening being preferable), transporting seedlings with bare roots, and planting seedlings still in their plastic polybags; and
- attacks by pests – especially barnacles, crabs and mud shrimps – can be a major source of mortality for young seedlings.

The net result of these challenges and errors was that around half the planted mangroves did not survive. In addition to the need for stakeholder coordination, the study concluded that other major priorities include full, long-term community participation in all stages of the process and its planning, awareness of the correct techniques, sites and species for planting (Table 10), and recognition of the key indicators of good sites (i.e., mud skippers) and bad ones (i.e., barnacles). Educational and awareness-raising activities are, therefore, extremely important (see Annex 1, Concept 3). The diversification of species and cultivars planted should also be encouraged.

Aceh has approximately 274,000 hectares of peat swamp (Table 11), located along the west coast of Aceh Selatan (169,000 ha) and Aceh Barat (105,000 ha). Peat swamps have unique features associated with waterlogging, which inhibits decomposition, and acid conditions. Characteristic species in Aceh include jelutung rawa (*Dyera lowii*), pulai rawa (*Alstonia pneumatophora*), terentang (*Campnosperma macrophylla*), and laban (*Vitex pubescens*). Aceh's peat swamps are home to the world's densest population of the critically endangered Sumatran orangutan and are of extreme significance for their conservation. Peat swamps can dry out and become highly flammable in prolonged droughts or if their drainage is facilitated (e.g., by logging canals), making forest fires a major threat, along with palm oil plantation development.

Nias and Simeulue

Nias in North Sumatra is the largest (at 5,450 km2) and steepest, while Simeulue in Aceh is the northernmost (at 2°19'3"–2°26'41"N), of a line of islands parallel to the west coast of Sumatra. This line continues southwards to include the Mentawai archipelago in West Sumatra. All of these islands are culturally and biologically distinctive, being relatively isolated from Sumatra. Indeed, a deep marine trench has separated the Mentawais from Sumatra for hundreds of thousands of years. As a result, they possess numerous endemic species, including four primates, and a unique indigenous culture.

The population of Nias is predominantly Christian and has special cultural traits such as a caring attitude towards plants[3]. The island's mangroves are richer in species than those found in Aceh or Simeulue. A total of 55 bird species are endemic to Nias, Simeulue and nearby islands, including the Simeulue Scops owl (*Otus umbra*) and the critically endangered silvery pigeon (*Columba*

3 A number of traditional stories tell that the *fosi* tree has supernatural powers and can read the future of the people of Nias.

Table 10: Planting site requirements for different mangroves

Genus	Substrate	Location	Hydrology	Salinity
Rhizophora	Shallow to deeply muddy	Along the dikes of fish ponds, along rivers, muddy beaches	Slightly tidal	Moderate
Ceriops	Shallow to moderately muddy	Muddy beaches	Slightly tidal	Moderate
Bruguiera	Shallow to moderately muddy	Near rivers	Slightly tidal with fresh water inputs	Low
Sonneratia	Shallow muddy beach	Open muddy beaches, along rivers, around estuaries	Slightly tidal	Low
Avicennia	Muddy sand beach	Open beach	Always flooded by sea water	High

Table 11: Depth of peat formations in Aceh (from Cahyo Wibisono & Suryadiputra, 2006)			
		Area of peat (hectares)	
Soil types	**Depth of peat formation**	**Aceh Barat**	**Aceh Selatan**
Hemists/ Saprists	Deep	31,107	40,150
Hemists/ Saprists/ Mineral	Moderate	47,852	96,900
Hemists/ Saprists/ Mineral	Shallow	4,591	15,181
Hemists/ Saprists/ Mineral	Very shallow	21,867	16,403
	Total	**105,417**	**168,634**

argentina). A number of other endangered or vulnerable species are found on one or other island or both, including Wallace's hawk-eagle (*Spizaetus nanus*), and the large green pigeon (*Treron capellei*). As is also true among the peoples of the Mentawais, the starch staple on Simeulue has traditionally been provided by swamp sago alms (*Metroxylon sagu*) rather than rice. Nias was relatively unaffected by the 2004 tsunami but was severely impacted by the 2005 earthquake, which caused extensive damage and loss of life. The pattern of damage in Nias differed greatly from that seen in tsunami-affected areas. Whether buildings were destroyed, damaged or unharmed depended on the vagaries of earthquake vibrations and the varied quality of construction.

The earthquake also caused changes to the geography of Nias. In the north, large stretches of coastal lands were suddenly raised up to two metres further above sea level, lifting coral reefs high above the water. Such changes occurred in Lahewa District, including near the villages of Lahewa, Moaw, Toyolawa and Lafau.

Uplifting also seriously impacted the mangroves along the muddy east coast of Nias. Almost all the mangroves have dried out and many have died because they are no longer in areas flooded with seawater. Some mangroves have survived despite the uplifting, however, because their roots are still in contact with brackish, tidal river water. In other areas of the east and southeast the opposite occurred: the land sank towards or below sea level. As a result, in Bozihona and Onolimbu villages, coconut groves are now below water, and some residential land was lost as the shoreline advanced by up to 200 m.

Simeulue was battered by the tsunami but suffered little loss of life. The local people, who are well acquainted with earthquakes and tsunamis through traditional stories, immediately fled inland when they expected a tsunami (*semong* in the local language). Like Nias, the earthquake uplifted parts of the island by up to two m, exposing coral reefs and mangrove roots to the air (e.g., Labuhan Bakti village), and caused subsidence in places.

The Ministry of Fisheries and Marine Affairs (DKP) reported that in 2003 Simeulue district had almost 2,800 ha of intact mangroves. Most of the mangroves were located in Sinabang Bay, Teluk Dalam Bay, Sibigo Bay and Salang Bay. By 2005, the cumulative impacts of the tsunami and island uplift had reduced that area to only about 1,150 ha.

Issues

Coral reefs and fisheries

A classic sign of over-fishing such as prevailed in Aceh before the tsunami is the loss of large fishes. For many species (e.g., snappers, Lutjanidae) a single large fish can produce 1-2 orders of magnitude (10-100 times) more eggs than a small one. Promoting fisheries recovery should include MPAs, where breeding fishes can grow large in safety. MPAs would also provide spawning areas for corals and other reef organisms, thereby pumping eggs and larvae into the plankton swarm and encouraging recolonisation over large areas. The most effective way to 'building back better' in Aceh's fisheries sector would be to: establish numerous MPAs at the district level (districts having legal out to the four nautical mile line); engage in dialogue with communities and traditional authorities to increase compliance with regulations prohibiting destructive fishing methods; and exclude fishing boats, especially trawlers, which do not originate in Aceh.

Mangroves and fish ponds

Organizational and technical lessons have been learnt from the loss of 15 million mangrove seedlings planted in Aceh after the tsunami. Tens of thousands of hectares of muddy coastline and fish ponds remain denuded and vulnerable, and require extensive re-vegetation with mangroves. Progress toward creating a secure, sustainable and productive mangrove-dominated aquaculture landscape can be achieved by disseminating awareness-raising materials, such as posters and leaflets, and by exposing community stakeholders directly to communities and locations where mature mangroves have been successfully established in and around fish ponds. Participating communities can learn from one another. When the advantages of proper planting and maintenance are realised, communities will have the skills and the motivation to organise themselves and achieve results that will benefit them directly.

Issues in Nias and Simeulue

Wholesale changes in an island's topography pose special challenges for recovery and rehabilitation. The site will never be the same again: new areas have been exposed, others submerged. Both events affect land tenure and local sites of residence. In order to clarify who owns what land and to identify new opportunities and constraints, the islands will need digital terrain mapping and cadastral surveying. These and other future activities should take into account the environmental sensitivity of the islands and their high endemism rates.

Indicators

Reefs & fisheries

A strategy for fisheries recovery and sustainability based on creating MPAs and promoting compliance with rules on destructive fishing methods would lend itself to the following indicators:

- broad and inclusive public dialogue about the future of fisheries in Aceh;
- dialogue and collaboration with traditional authorities, such as Panglima Laut;
- dialogue and collaboration with Bupatis and kabupaten (district) authorities and dinas (local public services);
- creation, mapping and signing of MPAs by kabupaten authorities with the consent of local residents;
- assessment of the management effectiveness of MPAs, based on interviews and monitoring reports by NGOs and kepala desa (village heads);
- progress against destructive fishing methods, based on the number of fishers educated, informational and educational materials disseminated, and declining incidents of the use of dynamite, cyanide, muro-ami and trawling;
- number of trawl exclusion devices positioned in selected locations; and
- actions against outside trawlers (including agreement with Jakarta about licencing).

Mangroves and fish ponds

Progress towards introducing to Aceh a complete community-based mangrove aquaculture model for use in fish pond areas could be assessed using the following indicators:

- number of visits and visitors from Aceh to appropriate study areas elsewhere in Indonesia;
- number of events and participants in other educational and awareness-raising processes;
- formation and operational records of local NGOs and community-based organizations (CBOs) concerned with mangrove aquaculture for sustainable livelihoods;
- mangrove nurseries established, and number of seedlings of different mangrove species produced;
- linear km of banks and bunds planted and maintained;
- number and survival rate of mangroves planted, by species;
- spawning activity and population trends among fish associated with replanted areas;
- labour, energy and chemical inputs per unit of aquaculture production; and
- production figures for prawn, fish and seaweed.

Conclusions and recommendations

Headline indicators

Land resources

- areas, amounts and kinds of pesticides and fertiliser applied
- areas converted to agriculture from other land uses

Biodiversity

- identification of critical ecosystems and their allocation to protection categories of forest use
- annual investment in biodiversity management

Environmental services

- identification and mapping of critical water catchments
- proportion of critical catchment areas within intact, natural forest and/or forest that is protected

Reefs & fisheries

- creation, mapping and signing of MPAs by kabupaten authorities with the consent of local people
- progress against destructive fishing methods, based on the number of fishers educated, materials disseminated, and declining incidents of the use of dynamite, cyanide, muro-ami and trawling

Mangroves and fish ponds

- formation and operational records of local NGOs and CBOs concerned with mangrove aquaculture for sustainable livelihoods
- mangrove nurseries established, number of seedlings of different mangrove species produced, and linear km of banks and bunds planted and maintained.

Strategic choices

Aceh stands at a major historical point of choice between different futures. In one direction is the kind of development process that has most often occurred in the outer islands of Indonesia: the extension of logging into large areas of the remaining forest, conversion of much of the forest to oil palm plantations, and mining wherever commercial quantities of ore are discovered. In this model, selected areas would be set aside for protection, but these would become increasingly dry and vulnerable to fires from nearby farmlands, logged forests and plantations. The environmental consequences for local people would be severe, and there would be a wholesale loss of wild species and the opportunity to use them in the future. In another direction, however, lies the possibility of using the province's abundant natural ecosystems and biodiversity resources in a careful and creative manner for the benefit of current and future generations. This direction offers the promise of long-term and permanent benefits for the region's communities. If this different path were to be chosen, it is hoped that the government and people of Aceh could count on the international community's continued investments and support.

Chapter 2.

The brown assessment: environmental aspects of reconstruction

This chapter contains UNEP's findings and recommendations regarding environmental issues involving the reconstruction of developed areas and infrastructure.

a. Water resources

In post-tsunami Aceh the availability of sufficient clean water remains a major problem. This issue requires immediate attention, as people need water for drinking, cooking and personal hygiene on a daily basis. Most people in Aceh depend on shallow wells for their water supply. The tsunami impacted many of these drinking water sources, particularly those located close to the affected coastline. Damage from the earthquake may also have caused hazardous substances to contaminate important water resources. The following subsection provides an overview of the extent of damage to water resources.

Water availability and use

The climate in Aceh province is tropical with mean annual rainfall ranging from about 1,500 mm in the north and north-west up to about 5,000 mm in the central mountain areas (IWACO 1993, quoted by Ploether & Siemon, 2006). Mean annual rainfall in Banda Aceh is approximately 1,600 mm, with the maximum volume reached during the wet season from September to January (Table 12). Reportedly, very few households in Aceh directly capture and use rainwater. Instead, most water supplies come from rivers or groundwater sources.

As the geological setting throughout Aceh province is highly variable (Figure 6, page 32), groundwater recharge potential varies accordingly, with the highest potential for groundwater development around Banda Aceh, Sigli and, on the west coast, between Calang and Meulaboh (Figure 7, page 33).

The German Federal Institute for Geosciences and Natural Resources (BGR) carried out an helicopter-borne geophysical investigation and a hydrogeological reconnaissance survey (HELP Aceh, HELicopter Project Aceh) of these high-potential areas between August and October 2005, compiling data on the hydrogeological setting and water quality (Siemon et al., 2006; Ploethner & Siemon, 2006).

One of the most important areas for water supply in Aceh is the Krueng Aceh watershed, which serves as the main source of water for Banda Aceh and Aceh Besar districts (Bapedalda NAD & GTZ-SLGSR, 2006). In the lower watershed (downstream of Indrapuri), i.e., in the area around Banda Aceh, there are two distinct aquifer systems, one shallow, the other deep (Ploethner & Siemon, 2006). The top 20 m, which comprise the shallow aquifer system, are recharged by rainfall. This system is the major source of domestic water supplies in this region, mainly through shallow wells. In the late 1970's, the water table in this area was 2-4 m below ground level (Farr & Djaeni, 1975; Lawrence & Djaeni, 1977), with seasonal fluctuations of between 1-2 m and an average estimated annual groundwater recharge of about 200 mm. This is in line with the findings from 130 shallow wells that were investigated in Banda Aceh in February 2005. The wells were found to average 5 m deep at an average depth to groundwater of 2.1 m (Planete Urgence, 2005).

After the tsunami, dozens of wells were drilled to exploit the deep aquifer system, which was not affected by the tsunami. The deep aquifer system is multi-layered, with few sand-gravel horizons below thick clays (Ploethner & Siemon, 2006). The main deep freshwater aquifer is about 3-15 m thick and is located approximately 75-140 m below ground level. This aquifer is thought to be recharged mainly from the surrounding mountain areas, which comprise karst in the southwest and volcanic rocks

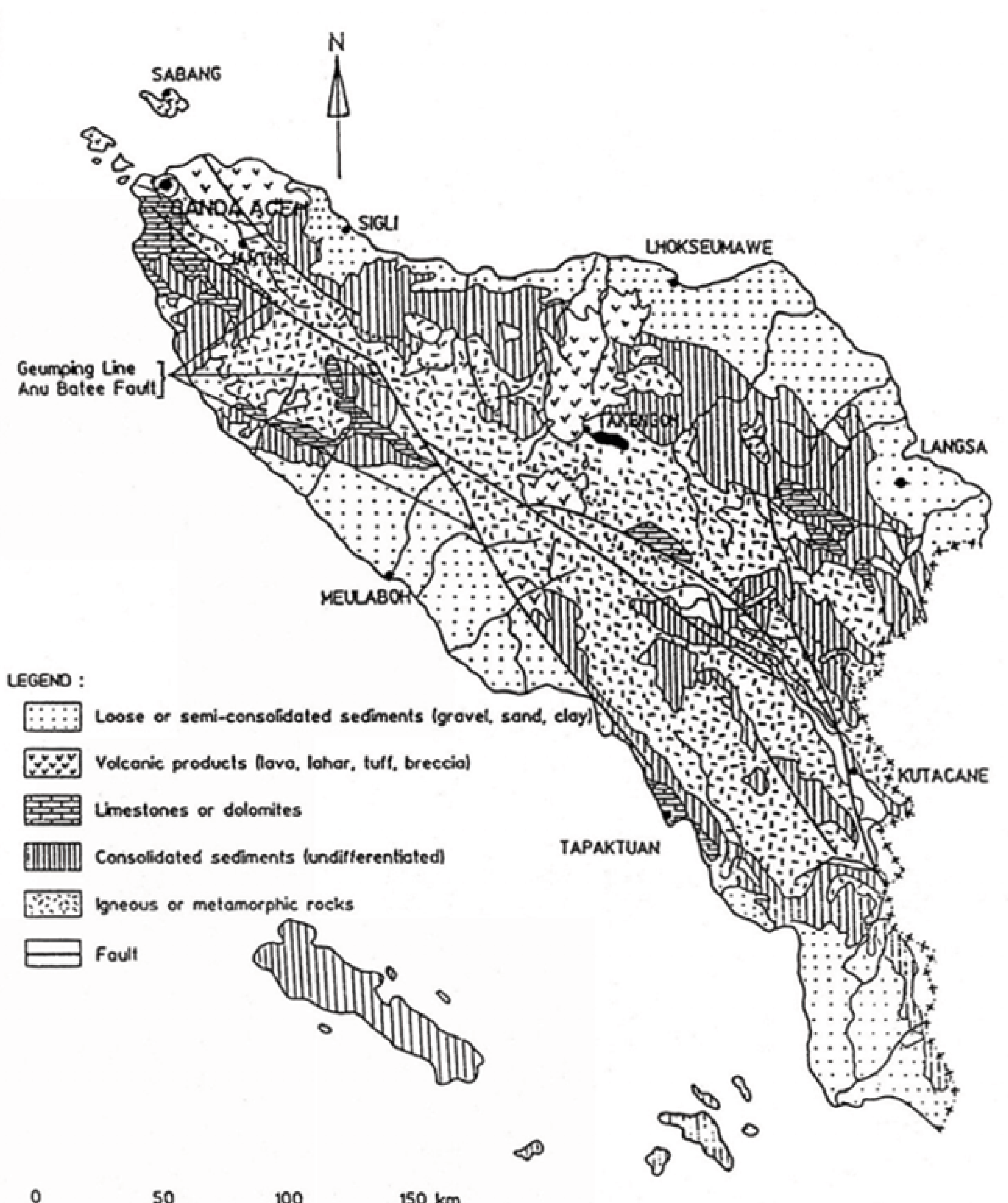
Table 12: Mean monthly precipitation in mm at Banda Aceh Airport (Source: www.worldclimate.com; data from 1115 months between 1879 and 1989).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
153	93	101	118	149	85	91	99	152	177	186	205	1608

in the northeast. Recently, another deep aquifer began to be exploited at a depth of about 180 m in Kajhu and Cot Paya (Ploethner & Siemon, 2006).

Another important source of fresh water are karst springs located southwest of Banda Aceh, e.g., at Mata Ie (Ploethner & Siemon, 2006). At present, only a small part of this water is used for water supply. BGR, however, has emphasized the significant potential these karst springs might have to accommodate the demand for fresh water along Aceh's tsunami-affected northwest coast.

Figure 6: Scan plot of the simplified geological map of Aceh Province (Ploethner & Siemon, 2006, Vol. C-1, p. 9; redrawn from IWACO 1993).



Drinking water in Banda Aceh and its surroundings comes primarily from wells dug into the shallow aquifer mentioned above. The local waterworks, PDAM Tirta Montala pipes filtered and chlorinated water from the Aceh River, but serves only about 9 percent of the area's population (Bapedalda NAD & GTZ-SLGSR, 2006). In several locations, water from local springs is captured and piped. This is the case, for example, in the karst area southwest of Banda Aceh.

As in the Banda Aceh area, the alluvium in the coastal plain around Sigli (Pidie District) can be separated into shallow and deep aquifer systems. The top 10-20 m can be considered the shallow aquifer system, which is recharged by rainfall. This aquifer is still the main source of domestic water supply via shallow dug wells. The water table ranges from about 0.5-3 m below ground level (Eberle et al., 2006)

The deep aquifer system is separated from the shallow system by approximately 40-50 m of clay. The majority of boreholes drilled in the coastal plain around Sigli have total depths of 60 to 70 m, tapping artesian water just below the clay sediments. This water is probably recharged from the surrounding hills.

Water supply in the Meulaboh Embayment comes mainly from shallow or medium-deep unconsolidated to semi-consolidated porous aquifers, or from river water (Ploethner & Siemon, 2006). The groundwater table in this area is only around 1-2 m below ground level. Approximately 60-66 m below ground level are sandy horizons that form a multi-layer aquifer. The local waterworks and the Swiss Agency for Development and Cooperation (SDC) have tapped this aquifer with wells up to 175 m deep.

Significant quantities of water are needed for rice production during the 'dry season'. This water is normally taken from rivers and conveyed to the fields through a system of open irrigation canals.

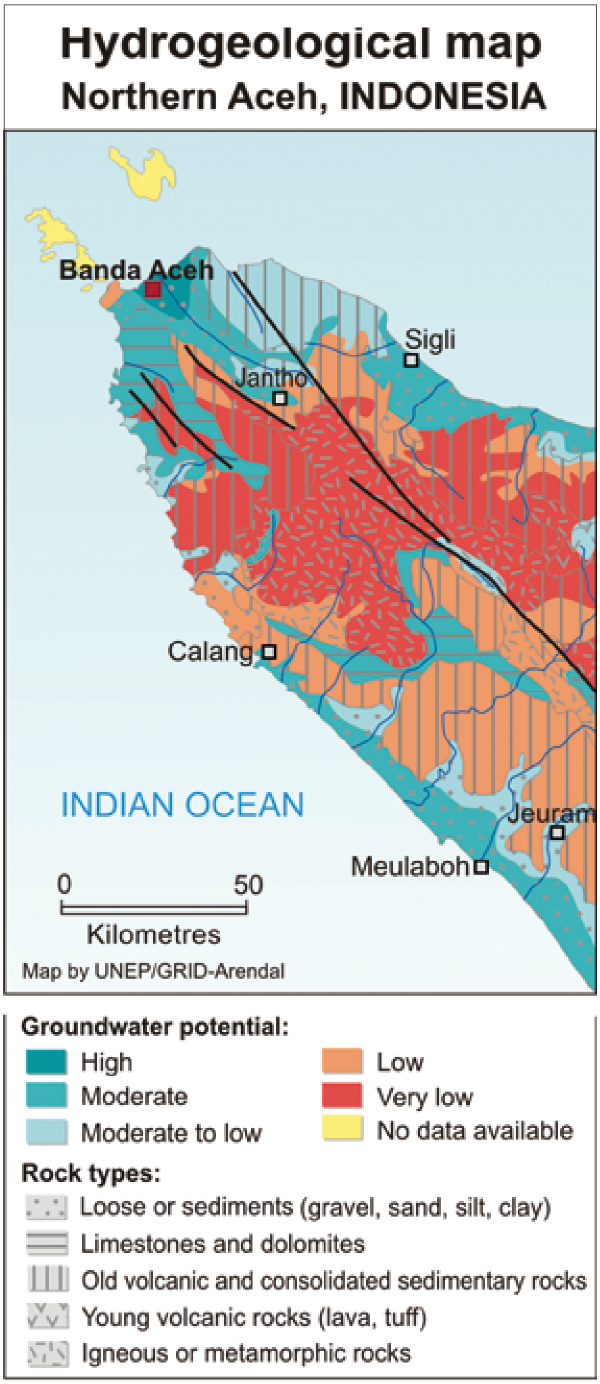
Industrial water use is still not very significant in Aceh. The fertilizer plant in Krueng Geukuh Village (Aceh Utara district) is one of the most important water users.

Major environmental problems involving water resources

Water quantity

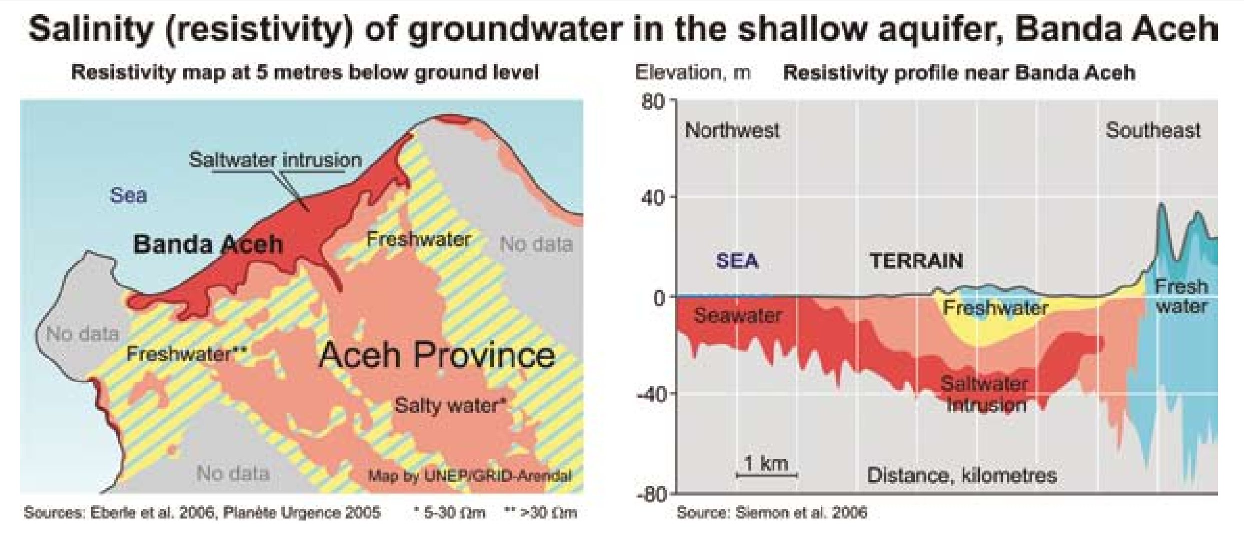
Due to abundant rainfall, Aceh Province currently has sufficient water quantities. Where upland watersheds are badly managed and extensive

Figure 7: Extract from the Hydrogeological Map of Indonesia, scale 1:1,000,000, showing different levels of groundwater potential (Ploethner & Siemon, 2006, Vol. C-2, p.13; information compiled by Setiadi, 2004).



Source: Ploethner & Siemon 2006

Figure 8: Resistivity map at 5 m below ground level (average depth of shallow wells), produced by BGR for the Banda Aceh area, and well sites monitored for electrical conductivity of groundwater, by Planete Urgence (130 shallow wells) or BGR (6 shallow and 11 deep wells). Pink and red-coloured areas on shore can be regarded as affected by salt water (from Siemon et al., 2006).



forest areas are cut down, however, soil water retention could be reduced significantly, resulting in lower surface water discharge during dry periods and possible flash floods during the rainy season.

Water quality

Water quality deterioration is one of the key environmental problems in Aceh Province. The degradation of water quality has a number of causes, including salination of fresh water resources; wastewater from private households, enterprises or industrial activities; sand/gravel extraction; agricultural and fisheries activities; and disaster-related spills.

Salination of fresh water resources

The tsunami flushed large quantities of saline water and sediments onto lowland coastal areas, sometimes reaching several km inland. Many wells were filled with saltwater. Because salt was washed into the soils, many wells continue to be recharged with salty or brackish water.

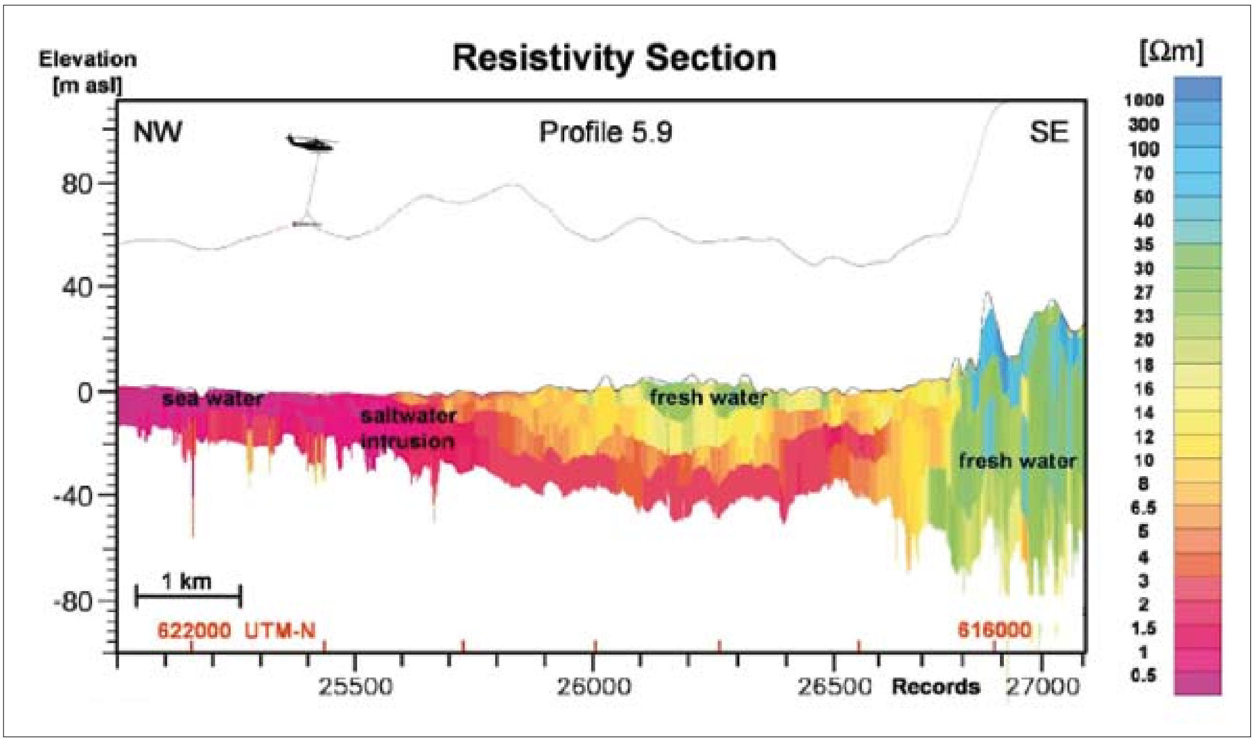
Shallow wells are the major drinking water source for the majority of Aceh's population. After the tsunami, most of the coastal population suffered from freshwater shortages. Many continue to receive their freshwater from aid agencies using tank vehicles.

Throughout 2005, many of the shallow wells dug into the surface aquifers around Banda Aceh, the Meulaboh Embayment and the coastal plain around Sigli, within the affected coastal belt of about 2-3 km and even further inland along estuaries, continued to produce brackish water, with electrical conductivity levels sometimes exceeding 10,000°S/cm (Ploethner& Siemon, 2006; Eberle et al., 2006; Planete Urgence, 2005). Using helicopter-borne geophysical methods, BGR was able to map the areas with high saltwater concentrations in the shallow aquifer with a high degree of precision (see Figure 8). This method also permitted the identification of locations highly likely to have enough freshwater to sustain development (Figure 9).

In order to supply the affected population with freshwater, many emergency wells have been drilled, mainly down into the deep aquifer systems. In the Banda Aceh Embayment these wells are usually tapping good quality groundwater at depths of about 150-200 m, according to analyses UNICEF and BGR analyses (Ploethner & Siemon, 2006). Care has to be taken not to overexploit the deep aquifer system. Overexploitation would probably cause seawater intrusion and potentially irreversible damage to these aquifers. Due to their proximity to the affected areas, karst springs could provide a reasonable alternative, as suggested by BGR (Ploethner & Siemon, 2006).

The United States Agency for International Development's Environmental Services Program

Figure 9: Resistivity profile near Banda Aceh showing areas with freshwater lenses (Siemon et al. 2006).



(USAID-ESP) conducted a scoping study of water resources development in the entire catchment of the Aceh River and the west coast of Aceh Province (Ploethner & Siemon, 2006). This study's findings will likely be of significant value to future water resource planning.

As of October 2005, according to BGR, 26 boreholes had been drilled in the coastal plain around Sigli, tapping water from the artesian deep aquifer systems. All of these wells were located within 2-3 km of the coast (Eberle et al., 2006). Once again, however, excessive groundwater abstraction raises the risk of saltwater intrusion into the aquifer system. In the town of Sigli, for instance, the French Red Cross found high salinity in a well drilled about 2 km from the coast. In order to avoid overexploitation of this aquifer system and potentially irreversible damage from saltwater intrusion, further investigation and monitoring of the fresh/saline water interface is needed. Freshwater losses due to uncontrolled flow from the artesian wells should be avoided by installing shut-off valves (Eberle et al., 2006).

Another problem in the Sigli area is that BGR's reconnaissance survey found arsenic in excess of permissible levels in 10 percent of the water samples from the deep aquifer system analysed (Eberle et al., 2006).[4] Efficient monitoring of water quality in this area is essential.

On the west coast, between Calang and Meulaboh, many shallow wells in areas close to the coast and directly affected by the tsunami are still producing brackish water (PT. Blantickindo Aneka, 2006). In 2005, many small diameter wells were jetted or drilled, mainly to depths from 40-100 m (Ploethner & Siemon, 2006), in order to provide the coastal population with fresh water. BGR and UNICEF took a number of samples (28 and 21, respectively) from these wells and found that most were producing fresh water. Water from several of these deep wells, however, contained high concentrations of arsenic, iron, manganese and ammonia (Ploethner & Siemon, 2006). In the area around Meulaboh, elevated arsenic concentrations seem to be related to the presence of peat, lignite or coal horizons above 60 m. Because arsenic is usually co-precipitated with iron, simple water treatment systems with an oxidation and filtration step should be implemented.

4 For drinking water, the World Health Organization recommends a maximum of 0.01 mg/litre (10 parts per billion).

Household and industrial/business wastewater

Contamination of water supplies from wastewater is of obvious concern. Wastewater commonly contains bacteria that provoke gastro-intestinal diseases. Indeed, the tap water in Banda Aceh is seriously contaminated with coliform bacteria. Although the number of city residents suffering from gastro-intestinal diseases is not particularly high, this is because the population boils water prior to consuming it. Wastewater also contains nutrients, organic compounds and/or toxic substances that degrade water quality and kill waterborne organisms.

In Aceh province, with its four million inhabitants, there is not a single treatment plant for household wastewater. Most private households have seepage pits or some sort of septic tank for black water coming from the toilet. If these tanks are closed at the bottom, as septic tanks are supposed to be, the overflows either run into the surrounding soil or drain off through surface storm water drainage systems, which are also collecting the households' grey water. In many cases, however, the tanks do not have a bottom and simply function as soak-aways. In either case, a great deal of effluent is infiltrating into shallow groundwater and contaminating drinking water sources, mainly nearby shallow wells. To some extent, the effluent is also discharged into standing surface water bodies, which are abundant in Banda Aceh and elsewhere. Poor maintenance of septic tanks and/or damage caused by the earthquake and tsunami of December 2004 (or earlier earthquakes) is reported to have increased the extent to which ground and surface waters are being contaminated by wastewater.

Most of the more than 100,000 houses built or planned for the tsunami-affected population are supposed to be provided with individual septic tanks. As the groundwater in Banda Aceh and many other affected places is very close to the surface, however, the soils surrounding the septic tanks will hardly filter the effluent before it enters the shallow groundwater. The problem will worsen if these tanks are badly maintained or damaged by subsequent earthquakes. There is, therefore, a very significant risk that the new sanitation systems installed during reconstruction will pollute shallow groundwater unless they are designed, built and maintained properly.

The magnitude of this threat is evident in the results of hundreds of water samples taken from shallow wells, rivers and standing surface water bodies, coastal waters, and even tap water supplied by the water works in Banda Aceh. The vast majority of samples analysed, for example, by MenLH & Bapedalda NAD (2005), PT. Blantickindo Aneka (2006), Arifin et al. (2006) and many others showed significant bacteriological pollution from coliforms, especially *E. coli*, clearly indicating faecal contamination. Many studies, however, also demonstrate that such bacteriological pollution existed before the tsunami.

The available data still do not offer a clear picture of the extent of microbial contamination in the deep aquifer systems. Some evidence confirms that even deep wells are contaminated with total coliforms, but not with *E. coli* (Ploethner & Siemon, 2006). The same authors concede, however, that the contamination might come from the tanks where the samples had been taken, rather than

Figure 10: Soil and groundwater contamination from oil and oil derivatives at a garage site in Banda Aceh. Photo: Petra van den Hengel

from the wells. Arifin et al. (2006) found significant bacterial contamination in two deep wells in Aceh Barat, possibly having spread from shallow aquifers during drilling activities.

Another source of ground and surface water contamination can be effluents from small enterprises, like slaughterhouses or restaurants, which discharge water containing large quantities of degradable organic substances. These effluents, together with the wastewater coming from private households, are the main causes of the generally high chemical and biological oxygen demands in the area's surface and coastal waters, and for their high degree of eutrophication (Arifin et al., 2006).

Contamination of ground and surface waters with oil and oil products is to be expected from petrol stations, garages and car wash facilities. This risk increases greatly if these facilities have been damaged by the earthquake or tsunami. To date, no data have been available on the extent of this contamination pathway. GTZ-SLGSR, however, has conducted a detailed survey on the contamination of soils and groundwater caused by the large number of garages and car wash facilities in Banda Aceh (Van den Hengel, 2006). (Figure 10).

No studies have been conducted into the extent of pollution in Aceh from laundry and dry-cleaning facilities, volatile organic compounds, pharmaceutical substances coming from households, hospital sewage or chromium from tanneries.

Sand and gravel extraction

Sand and gravel has been extracted throughout the province to meet the demand for construction material. Most of these materials are being taken from riverbeds, particularly from the Aceh River. At least five companies have been extracting sand and gravel on a large scale within only one km of the Aceh River south of Jantho (Bapedalda NAD & GTZ-SLGSR, 2006). This extraction of gravel and larger-sized matter removes significant portions of the riverbed and can be expected to influence the river's hydraulic regime significantly. Increased water flow velocity, scouring of the river bottom and bank erosion is expected to increase considerably. This, in turn, can cause severe damage to riverbanks and infrastructure, e.g., by undermining bridge foundations. At the same time the extraction process stirs up large quantities of fine matter, which are then washed away as suspended particles. Both effects – increased riverbed and bank erosion and the re-suspension of fine material – increase surface water contamination with suspended particles. This contamination, in turn, can affect fishing activities and coral reefs. In general, it is very difficult to assess the magnitude of these problems. At present, for example, there are virtually no data regarding increases in suspended solids and turbidity in river waters or increased sedimentation at river mouths.

Pesticides

Pesticides are used for plant production in agriculture, e.g., in paddy fields, and for the production of shrimps in 'tambaks'. No data are available to verify whether ground or surface water resources have been significantly affected by pesticide use.

Oil spills

According to UNEP (2005), only a few industrial sites were damaged by the tsunami. Amongst them are the Pertamina oil depots in Krueng Raya Bay/Banda Aceh and Meulaboh. About 8,000 m3 of oil was reportedly spilled in the depot in Banda Aceh. No information was available regarding possible soil and groundwater contamination from these spills.

b. Soil and mineral resources

Agriculture is the main source of income for the Acehnese population. One of the main production factors for most of the agricultural activities is soil. The tsunami wave is reported to have inundated more than 200,000 hectares of land in Aceh, including about 90,000 hectares of paddy fields, remaining up to six days on the affected fields (Iskandar et al., 2006). The impact of this inundation raised great concerns for agricultural output, particularly rice production, which is the backbone of the province's agricultural activities and the main food staple.

Apart from being an indispensable production factor for agricultural activities, soil also plays an important role in the reconstruction process. Clay-rich soils and sediments are essential for the production of clay bricks. Soil also has many other important functions, including, protecting groundwater resources by retaining potentially hazardous substances.

Aceh province is very rich in mineral resources. Of minor value per unit weight, but of prime importance for the post-tsunami reconstruction process, are materials like stones, gravel and sand. These mineral resources are limited, however, and their extraction can cause severe environmental impacts beyond the effects on water resources referred to above.

Major environmental problems related to soil and mineral resources

Agricultural land use

The tsunami damaged more than 60,000 hectares of agricultural land in Aceh (FAO, 2005). The main forms of damage to soil resources were described as de-surfacing of the landscape as a result of erosion and sedimentation, deposition of salt sediments, accumulation of debris, infiltration of salt water and depletion of soil fertility.

In October 2005, the ADB carried out a soil survey to define the magnitude of the problem, analyzing approximately 200 soil samples from representative irrigation schemes in Aceh Besar, Aceh Jaya, Aceh Timur, Aceh Utara, Bireuen, Pidie and Singkil. The main problem encountered was generally low soil fertility, mostly related to magnesium and copper deficiencies. The study did not find severe problems with soil salinity or high sodium concentrations (Hutcheon, 2006). Such problems were limited to areas with bad drainage conditions, for example, due to the obstruction of drainage systems by tsunami debris or sedimentation. The salt in these fields cannot be leached by rainfall or irrigation, so salinity will remain high.

Salt sediment deposits deeper than about 30 cm are very hard to plough in and mix with the original topsoil. If the sediments are less fertile than surrounding soils (e.g., very sandy), they will reduce the overall fertility of affected fields. According to ADB, approximately 1,000 ha of agricultural land on Aceh's west coast are suffering from sediment deposition at such depths. Soil restoration is very difficult in these areas, which can be regarded as the most heavily affected agricultural land.

Soil surveys conducted by Walhi (2005) and PT Blantickindo Aneka (2006) investigated the presence of heavy metals. Walhi analysed 93 samples in five affected districts. PT Blantickindo Aneka collected results from 10 different districts. Both studies found levels of cadmium and chromium that were elevated but not indicative of a serious problem. Walhi found substantially higher levels than did PT Blantickindo Aneka's. The latter study attributed this deviation to leaching losses between 2005 and 2006. Leaching, however, would not be so significant, particularly as the soils are mainly non-acidic. Questions about the accuracy of these study results suggest the need for further research.

There is no data available on the extent of pesticide contamination in soils. Because pesticides normally degrade fairly rapidly in topsoil containing organic matter, it is assumed that this is a problem of minor importance.

Mining and quarrying activities

The reconstruction process requires large quantities of stones, gravel, sand and clay. One small house uses an average of 10,000 bricks. The reconstruction of 120,000 houses (the requirement estimated by BRR) will, therefore, use 1.2 billion clay bricks, together with large quantities of stones, gravel and sand for foundations and concrete production.

Materials are typically extracted near the sites where they will be used. Gravel and sand are mainly extracted from riverbeds, particularly along the Aceh River, with a clear focus on Aceh Besar District (Supangkat & Hendratno, 2006). Indeed, after the tsunami, there was a sharp increase in licenses given for sand and gravel quarries in Aceh Besar (Krist, 2006). It is assumed that there is also a significant amount of illegal extraction, but the actual magnitude of the problem is not known.

The extraction of clay for brick production is mainly performed by small-scale operations that are using local clay deposits, often from agricultural fields. In many cases, the topsoil of paddy fields is removed to provide the raw material for the brick production. There is no information available on the location and extent of clay extraction or on possible reclamation activities.

c. Air quality

Not being an issue very closely related to post-tsunami reconstruction, air pollution has received little attention from the institutions and agencies involved in reconstruction. Air quality in most parts of Aceh Province and around Banda Aceh benefits from the existence of relatively high wind speeds throughout the year and the relatively limited impact of automobiles, industry and biomass burning. As a result, most people in Aceh do not generally perceive air pollution to be a major problem.

No long-term air quality monitoring systems exist in Aceh. Legislation requiring environmental impact assessments (EIAs, known as AMDALs locally) for major construction projects has given rise to a few short-term air quality studies. Measurements typically have been made only for a few days. Bapedalda Provinsi NAD's mobile air quality measurement equipment, however, was destroyed during the tsunami.

Indonesia's air quality standards are set forth in Government Regulation No. 41 Thn 1999. Parameters of concern are mainly dust concentrations (Total Suspended Particles, TSP, and/or PM10), SO2, NOX, CO, and Pb. Acceptable concentrations for these compounds are given for time periods ranging from one hour to one year.

Threats to air quality

There is very little industrial activity in Aceh, making this contamination pathway unlikely to be of major importance at this time. Relevant point sources could be the fertilizer plant at PT Pupuk Iskandar Muda Lhokseumawe and the PT Andala Cement Factory, located approximately 10 km southwest of Banda Aceh. The cement factory was severely damaged by the tsunami and is still not working. It has been reconstructed, however, and has a planned capacity of approximately 1.3 million tons of cement per year. Other point sources are power plants, which in Aceh usually burn fuel oil, and the waste incinerator at Banda Aceh's main hospital. Burned hospital waste can be a significant source of dioxin emissions, particularly if combustion temperatures are low.

The leading sources of diffuse air pollution in Aceh are vehicles, particularly in urban centres, slash-and-burn small-scale agriculture, forest fires for clearing land for plantations or other large-scale development activities, smoke from inadequate cooking facilities causing indoor air pollution, the backyard burning of waste, and construction activities.

Vehicle traffic reportedly increased significantly in Banda Aceh after the tsunami, very likely due to the presence of a large number of national and international institutions and aid agencies. During rush hours, the traffic in Banda Aceh is very dense. Major problems with traffic-related air pollution stem from the use of leaded fuel and the high number of two-stroke cycle motorbikes.

Forest fires, which are started to clear land and in small-scale slash-and-burn agriculture, can be major sources of air pollution. This issue is reportedly not a priority concern in Aceh at present.

Little is known about the extent of indoor air pollution caused by inadequate cooking stoves. It is not, however, regarded as a problem of major importance.

Solid waste from urban areas and villages is typically burned at dumpsites outside of town. Similarly, the burning of household waste in backyards is commonplace (Fig. 6), in part because the waste collection system does not reach significant parts of the population, but also because it is a generally accepted practice.

Construction activities increase dust concentrations in ambient air during dry periods. In addition, because the brick kilns used to produce bricks for construction are mainly run on fuel wood, brick production contributes dust, SO2, NOX, CO and CO2 emissions to the atmosphere, and fluorine is normally released when the clay is cooked.

Ozone-depleting chloro-fluorocarbons (CFCs), widely used as refrigerants, are greenhouse gases that contribute to global climate change. Among the tsunami waste was refrigeration equipment (e.g., refrigerators, air conditioning equipment) that likely released CFCs into the atmosphere after the tsunami and during the waste collection. Indonesia has ratified the Vienna Convention and Montreal Protocol and its amendments, which oblige the country to control the use of ozone-depleting substances. UNDP has reportedly been providing important support to Indonesia in this area.

Figure 11: Backyard burning of household waste in Banda Aceh.

Air quality data

Very few data are available regarding air quality in Aceh. Existing data come mainly from short-term point measurements for EIA studies and are of unknown quality. Very limited results have been reported for the cities of Banda Aceh and Sabang, and for the districts of Aceh Besar, Pidie, Aceh Utara, Aceh Barat and Aceh Jaya (Arafin et al., 2006). These measurements, some of which were taken prior to the tsunami and some after, do not really provide a clear picture of air quality in the province. The data, however, show little difference in air quality before and after the tsunami, and air quality parameters generally exceed permitted levels in very few cases. Overall, air pollution would not appear to be a priority environmental concern in Aceh at present.

d. Solid waste management

The earthquake and tsunami created an unimaginable quantity of debris and waste. According to estimates, approximately 300,000 - 400,000 m3 existed in Banda Aceh alone (UNDP, 2006). The problem was compounded by the fact that many people working in waste management were killed by the tsunami, and many refuse collection vehicles were destroyed. Taken together, waste management has been regarded as one of the most significant environmental challenges facing Aceh since the earthquake and tsunami (UNEP, 2005).

Numerous aid agencies have created initiatives to address Aceh's waste problem, amongst them UNDP, USAID-ESP and GTZ-SLGSR. Most activities related to waste management are concentrated in urban areas such as Banda Aceh, Aceh Besar and Pidie.

Probably the most important waste-related project is the Tsunami Recovery Waste Management Programme (TRWMP). The Programme was begun in March 2005 by UNDP in partnership with BRR and local governments in Banda Aceh, Aceh Barat/Nagan Raya, Pidie and Aceh Jaya. The main objectives of the TRWMP, which is funded primarily by the Multi Donor Fund for Aceh and Nias (MDF), are to build government capacity and create immediate employment and longer-term livelihoods in waste management. At the same time, the Programme will benefit the environment through collection, recovery and recycling of waste materials for use in rehabilitation and reconstruction, and through safe disposal of residual wastes (UNDP, 2006). The TRWMP has collected, recovered and partly recycled significant quantities of tsunami waste, particularly in Banda Aceh. It is now focusing increasingly on municipal solid waste collection and disposal, which has been a major problem in Aceh since long before the tsunami. One estimate has put per capita waste generation at 2.7 l/day (or 0.6 kg/day), about 75-85 percent of which is biodegradable and less than 9 percent of which is recyclable (Neff, 2006).

Major environmental problems related to solid waste management

Waste impacts

Although very little hard data exists, an enormous amount of visual evidence makes clear that waste is having very negative effects on Aceh's environment. Huge amounts of tsunami and 'normal' municipal solid waste are clogging drainage canals. Standing, contaminated water is posing threats to human health, particularly playing children, and surface and groundwater bodies.

Little is known about the extent of hazardous substances in the waste, which includes batteries, oil and oil derivatives, and medical waste from hospitals. These substances may have contaminated soil, ground and surface water, and could have affected human health through direct contact. A great number of the over 120,000 houses destroyed probably contained construction materials that included carcinogenic asbestos. UNEP identified high concentrations of Chrysotile (white asbestos) in roof material found in rubble from Banda Aceh.

Waste management

Waste collection and disposal is managed at the local level, usually by the sanitation department (Dinas Kebersihan). There are no waste authorities in the sub-districts (Neff, 2006). Waste collection efforts are mainly focused on households, shopping areas and markets in high-density, urban areas. Collection rates are estimated to be below 50 percent in Aceh and Sigli, with practically no collection at all in rural areas (Neff, 2006).

Collected waste is normally dumped outside of the towns or villages in open dump sites, where it is partially burnt, causing air pollution. Waste from Banda Aceh is dumped at Gampong Jawa, the waste from Meulaboh in Lapang, and Sigli's waste on the road outside of town (at km 23). None of these dumpsites satisfy the basic requirements of a sanitary landfill.

Although there is not yet a single sanitary landfill in Aceh, the planning process for the first one was recently initiated. On behalf of Bapedalda and UNDP, GTZ has been identifying suitable sites for the construction of a sanitary landfill for Banda Aceh and Aceh Besar. Two sites have been identified and are currently under detailed investigation. It is anticipated that the new landfill will replace the Gampong Jawa dumpsite in the next few years. UNDP has estimated that the landfill will cost US$10 million. Additional 'improved dump sites' are under construction by UNDP (UNDP, 2006).

A great deal of the waste from private homes and virtually all the waste in rural areas is buried or burnt in backyards. Waste recycling is mainly done by small private enterprises. Only the TRWMP has been recycling waste on a large scale: wood was recovered for the production of furniture or use as fuel for brick kilns, and building rubble was used for road construction (UNDP, 2006; Figure 12).

Almost no information is available on the management of hospital waste or other hazardous materials. Laboratories carrying out environmental analyses were found to be using inadequate waste disposal methods.

e. Reconstruction of private houses

Reconstruction of the over 120,000 houses destroyed is a top priority issue within the post-tsunami reconstruction process (Government of Indonesia, 2005). (http://e-aceh-nias.org/media_center/fact_sheet.aspxf). According to BRR, as of 15 September 2006, 27 NGOs and international

Figure 12: Wood recycling at Gampong Jawa dumpsite as part of the Tsunami Recovery Waste Management Programme.

aid agencies had pledged to reconstruct a total of over 83,100 houses. At present, approximately 28 percent of this total has been built.

Major environmental problems related to house construction

The construction of new houses can have significant negative impacts on the environment through either inadequate location and design of houses and settlements and/or the use of unsustainably produced construction materials.

Inadequate location and design of houses and settlements

The construction of 120,000 houses will require the use of a large surface area. Siting these houses may result in the loss of fertile agricultural soils or the sealing of significant surface areas, thus increasing surface runoff and soil erosion. If contaminated sites are chosen inadvertently, human health will be at risk. Locations where the groundwater table is very close to the surface are likely to prevent the proper functioning of most sanitation systems, causing groundwater contamination. Houses are built on unstable ground (e.g., very sandy areas) will easily be damaged by future earthquakes. If houses are sited in tsunami-prone areas, future tsunamis could cause further destruction. If the houses are damaged again, they will have to be reconstructed again, once more using up valuable natural and financial resources. It was beyond the scope of this study to look at these aspects of reconstruction. There is evidence, however, that some of the locations where reconstruction is being performed appear to be inappropriate for the reasons cited above.

The design and construction quality of housing can also have very significant environmental consequences. Particularly important is the adequacy of sanitation systems. Before the tsunami, sanitation was already a major problem in Banda Aceh. Due to the area's flat land and high groundwater levels it is difficult to install properly working sewage systems. Poorly maintained individual septic tanks (mostly without absorption beds) have caused significant public health and environmental problems by contaminating groundwater and drinking water supplies. With proper planning, post-tsunami reconstruction efforts offer a unique opportunity to remedy this significant problem. During the reconstruction period, whole settlements with hundreds of houses are being constructed at the same time, instead of one by one, as was the case before the tsunami. Most reconstruction projects, however, appear to be planning for individual household septic tanks rather than creating environmentally effective community sanitation systems.

It has been reported that a significant number of newly constructed houses lack essential infrastructure, such as water supply or sanitation. Most houses are being built with a constructed area of only 36 m2, in accordance with BRR recommendations. Families are reported to have begun modifying theses houses. In some cases, families may abandon these houses altogether to build larger or better homes elsewhere. Similarly, if houses are built using low-quality building materials or techniques, and if basic recommendations for earthquake-resistant construction are not taken into account, subsequent earthquakes will cause major damage and harm. These scenarios, which are avoidable, would entail further social disruption, environmental degradation and natural resource use.

Use of unsustainably produced construction materials

Estimates by FAO and ADB suggest that housing construction will require approximately 1 million tonnes of cement, 3.6 million m3 of sand, 1.1 billion fired clay bricks, 508,000 m3 of concrete blocks, 87,000 m3 of plywood, 370,000 m3 of sawn timber and 945,000 m3 of fuel wood for brick kiln firing (ADB, 2006). To meet the need for fuel wood for brick making alone, about 10,000 hectares of forest would have to be logged. These estimates are limited to the immediate plans to build 120,000 houses and do not include the materials required to construct other types of buildings, such as schools, mosques, hospitals and commercial buildings, or to modify houses after they have been completed.

A key concern is the use of fuel wood for brick manufacturing. According to the UNDP Construction Boom Analysis there are 1,412 small brick-making businesses in Aceh, most of which are using very basic kiln systems (Figure 13) that

Figure 13: Typical brick kiln with low efficiency in the use of fuel wood (Photo: Niclas Svenningsen).

have low levels of energy efficiency and often produce bricks of inferior quality.

Alternatives to the use of burnt clay bricks have been evaluated by several aid agencies, including FAO and ADB. Because brick kilning requires so much fuel wood, the use of bricks for infill walls is estimated to consume 2.5 times more timber than would the direct use of timber to build these same walls (ADB, 2006). As shown by ADB (using data from FAO), replacing a part of the clay bricks with sawn timber (for the infill walls) or hollow concrete blocks would reduce the overall timber requirement significantly (Table 13).

Timber logging is often done illegally, is a main threat to biological diversity, contributes to global climate change and causes major problems for soil and water management. Every opportunity should be used to minimize timber logging for reconstruction activities.

No studies are known to exist with respect to the environmental impact of the clay extraction itself. As a fertile agricultural topsoil containing significant amounts of organic matter, however, clay is a very valuable and nonrenewable resource. Humus-rich topsoil filters and retains many substances, such as pesticides, that are potentially hazardous for the groundwater. Clay for the bricks is normally taken from local clay sources close to the kilns, mostly from paddy fields. According to ADB, however, the clay is sometimes transported to the kilns over distances of up to 20 km, requiring additional energy consumption.

The environmental problems resulting from the river extraction of sand and gravel have been outlined above. It has been reported that some hard rock extraction is occurring in protected areas. Because small enterprises sometimes lack equipment suitable for grading the extracted material, they tend to extract much more material than is actually needed for construction.

In general, there is a lack of quality control of the materials used in construction. This can result in sub-standard buildings, particularly when concrete and mortar is manufactured with aggregates containing salt, which undermines the binding characteristics of the products.

f. Spatial planning and environmental impact assessment

Spatial planning and EIAs are very important tools for environmental management, especially in a reconstruction setting. Sound spatial planning can prevent the construction of houses in areas at high risk of being affected by natural hazards or where construction would degrade the environment. Spatial planning is also vitally important when siting key infrastructure (e.g., roads, harbours) or potentially polluting economic activities.

Table 13: Estimated reconstruction material requirements for different construction scenarios using alternative mixes of construction materials (ADB, 2006).

Construction material	Unit	Scenario 1	Scenario 2	Scenario 3
Clay bricks	bricks	1,050,000,000	286,000,000	286,000,000
Hollow concrete blocks	m^3	508,053	394,543	956,868
Sawn timber	m^3	368,747	482,539	368,747
Plywood	m^3	87,285	87,285	87,285
Fuel wood for brick kilning	m^3	945,000	257,400	257,400

Two important instruments present a framework for spatial planning in Aceh. The first is the Revised Master/Spatial Plan for 2005-2015 that was prepared by the regional planning agency Bappeda (Badan Perencanaan Pembanguna Daerah) in 2003, before the tsunami. The second is the 'Master plan for the rehabilitation and reconstruction of the regions and communities of the Province of Nanggröe Aceh Darussalam and the Islands of Nias, Province of North Sumatra' (the 'Master Plan'), which the Government of Indonesia issued in April 2005 to orient the reconstruction process.

Another important tool for environmental management is EIA, which is called AMDAL (Analisis Mengenai Dampak Lingkungan in Bahasa Indonesian). While spatial planning provides an overall framework for economic and social activities, EIAs allow detailed scrutiny of the possible environmental impacts of specific projects and activities (e.g., the development of a settlement or the construction of a factory).

A slightly shortened AMDAL procedure was introduced by Ministerial Decree 308/05 (PerMenLH 308/05) to alleviate concerns that the full EIA process, which is complex and time consuming, would prevent rapid reconstruction. According to Decree 308/05, the potential environmental impacts of all rehabilitation and reconstruction projects must be assessed in two steps. The provincial Bapedalda, supported by the entity that wants to implement the project, must screen all projects and identify those requiring a more detailed environmental investigation pursuant to the procedures described in Decree 308/05. Appendix 1 of Decree 308/05 specifies the types of projects that must normally undergo a detailed Environmental Impact Study (EIS). The Provincial Governor, however, has the right to make the final decision on this issue. All projects subject to the 308/05-AMDAL procedures are processed by the provincial Bapedalda, which conducts the scoping process with the agency that is proposing the project.

Major findings and problems

The spatial plan currently in force has not adequately taken into account environmentally sensitive areas and areas at high risk of being affected by natural hazards. Recently, however, positive steps been taken. ADB and BRR have presented an environmental sensitivity map indicating which areas should be preserved, mainly for nature conservation purposes, and GTZ-SLGSR has presented thematic maps on disaster risk that are to be taken into account in spatial planning.

A general problem with spatial planning is that it is done primarily on a large scale. This sometimes makes a spatial plan difficult to apply to specific project decisions. In addition, local stakeholders are frequently unaware of planning decisions made on the regional level. A particularly great planning challenge stems from the fact that houses are being reconstructed in areas that are likely to be affected by natural hazards again in the future. The Master Plan suggests that residential houses should be setoff from the shoreline by a minimum distance of 500 m, which is intended to serve as a buffer against possible tsunami waves. For reasons of land tenure, amongst others, people nevertheless tend to ignore spatial plans and build their homes where they were previously located. Those eager to construct tambaks very close to the coastline have also ignored spatial plans.

The main problem related to EIA is probably that a large number of 308/05-AMDALs have to be processed within a short time by a provincial Bapedalda that lacks the resources and tools to cope with this work. This challenge is made worse by the fact that aid agencies that are not always prepared to contribute to this difficult job in an efficient way.

The first step of the 308/05-AMDAL, the screening process, can also limit the application of environmental assessments. For example, if EIAs are only required for housing projects on more than 50 hectares (as required by Appendix 1 of PerMenLH 308/05, for big city areas), most housing projects will not be assessed, because most do not meet this threshold requirement. Similar limitations apply to river quarrying and other project types.

g. Environmental monitoring

Environmental management efforts cannot succeed without reliable information about environmental quality. Such information is normally obtained from regular monitoring programmes. This study assessed Aceh's capacities to monitor the environment. Special emphasis was placed on laboratory capacities in Banda Aceh.

Major findings and problems

Much of the equipment required for routine environmental compliance monitoring is available in Banda Aceh. Several laboratories have significant environmental monitoring capacities. Most of them, however, suffered extensive damage during the earthquake or tsunami. The instruments available at the moment in five of the best-equipped laboratories, much of it new, are summarized in Appendix IV.

Amongst the most important laboratories likely to be involved in environmental monitoring are:

- Labaratorium Lingkoungan of Bapedalda Propinsi NAD
- Industrial Laboratory Centre Banda Aceh (LABBA)
- Public Health Laboratory, UPTD
- Faculty of Chemical Engineering, UNSYIAH

By far the biggest and most experienced of the laboratories in Banda Aceh is the Industrial Laboratory Centre Banda Aceh (LABBA), which is also the province's only accredited laboratory (SNI 17025:2000, adopted from ISO 17025:1999).

Bapedalda NAD is the main institution responsible for testing for compliance with environmental standards and guidelines issued by the Indonesian government. As such, Bapedalda NAD's laboratory is intended to play a special role. Although this laboratory is planning to have good quality equipment soon, it is not yet fully operational and, as such, was not included in Appendix IV. Bapedalda NAD's mobile laboratory is currently being renovated and refurbished, and a boat is available for sampling surface waters and sediment.

In general, UNEP identified the following specific limitations with respect to local monitoring capacities:

- At present, there is mainly expertise in the analysis of inorganic analytes and basic microbiological parameters in water (total bacterial count, coliform, *E. coli*). Although instrumentation is available for the analysis of organic contaminants by means of GC, GC/MS and HPLC, and for other bacterial analyses (e.g., by a mini API system), there is a lack of expertise in the application of these techniques to organic analysis. Technical personnel would need to be trained to perform most of these analyses.
- Some additional equipment would be needed in order to conduct analyses of the pesticides or other organic pollutants listed in the World Health Organisation's drinking water guidelines (WHO, 2004), i.e., at least a Soxhlet Extractor, ECD and other detectors for GC, and a head-space analyser for GC and GC/MS.
- There is no PM10 monitor (for detecting the smallest, most dangerous air pollution particles) or stationary air quality monitoring.
- There is almost no sampling equipment for soil and sediment. There is also almost no experience with respect to soil analysis for heavy metals, pesticides and other organic pollutants. As a result, there is practically no soil monitoring at all.
- There is no instrumentation available for emergency response, in case of accidental releases of pollutants. When it is rebuilt Bapedalda NAD's mobile laboratory will be equipped only with instrumentation for water quality monitoring. There are currently no portable or hand-held air pollutant monitors that could be used in case of an emergency.
- The safety features of most of the laboratories are inadequate, and there are virtually no safety manuals, safety committees or safety officers. Safety regulations are either nonexistent or disregarded.
- There are serious shortcomings with respect to quality control/quality assurance (QC/QA). Only one laboratory has accreditation.
- There is very little cooperation and networking among the different laboratories, which would help to optimize the use of the different facilities and instruments.

- There is no safe disposal of hazardous waste from the laboratories.
- There are problems with regard to basic infrastructure and transportation. These include poor electricity and water supply and a lack of vehicles or boats for monitoring.
- Access to current scientific literature is very limited. There are no adequate library facilities and only very slow internet access, particularly at the university.

Conclusions and recommendations

Water resources

- *Ensuring adequate supplies:* In most parts of the tsunami-affected area, shallow groundwater, which is the main source of drinking water for the population, is often still brackish and contaminated with faecal bacteria. New sources of supply will need to be developed if the residents of the tsunami-affected coastal areas are to be provided with fresh and clean drinking water. Important potential alternative supplies include deep aquifer systems, karst springs, river water and possibly water collected from house roofs. Several suitable sources have been identified already, but supply systems need to be built as well as treatment systems, as appropriate. Further exploration and development of freshwater supplies is needed. Geophysical methods can enable more efficient exploration efforts, and BGR's surveys (Ploethner & Siemon, 2006; Simon et al., 2006; Eberle et al. 2006) should be taken into account. The USAID survey on water resources in the Aceh River watershed and the province's west coast should also be of great importance for identifying new water sources. It is further suggested to set up a hydrogeological database for Aceh. Such a database would allow water quality information to be related to hydrogeological conditions, which would provide a solid basis for further water resources development. BGR and NAD Mining Bureau have already started to collect hydrogeological information and to enter it in a database. NAD Mining Bureau could be regarded as an appropriate institution to coordinate this activity. In order to avoid future water quantity problems, watershed management practices should be established, including avoiding major deforestation in headwater areas.
- *Protection of deep aquifers:* The water from deep aquifer systems is mostly fresh and of good quality for drinking water purposes. However, there are some indications of saltwater intrusion and contamination with faecal bacteria, possibly as a consequence of inadequate drilling techniques. In some cases, the water from deeper aquifers contains high concentrations of heavy metals, particularly arsenic, which require further monitoring and some treatment. In general, however, the province's deep aquifer systems can be considered a major long-term drinking water source, and their protection should be considered a very high priority. Extraction must be limited to sustainable levels in order to avoid saltwater intrusion. Unnecessary losses from these aquifers, e.g., due to the absence of shut-off valves for artesian wells, should be avoided.
- *Rainwater collection:* As an additional source of fresh water, the potential of rainwater collection from roofs, particularly from newly built houses, should be assessed. Assuming an average roof area of 36 m2, a mean annual precipitation of 1,600 mm (as is the case in Banda Aceh) and a collection efficiency of 90 percent, an average of more than 140 litres of rainwater per day could be collected from a single roof. This could make a significant contribution to water supply, particularly for houses or settlements that are difficult to reach with piped water.
- *Protecting the public from contaminated water:* In order to reduce human exposure to water contaminated by faecal bacteria, the following measures are recommended:
    - Provide public water supplies to people using water from shallow wells in densely populated areas, particularly where water has been affected by salinisation. Use water from deep aquifers, karst springs, properly treated river water or rainwater collected from roofs.
    - Improve water treatment at Banda Aceh waterworks or look for alternative sources of water.

- Provide adequate sanitation for reconstructed houses. There is a significant risk of groundwater contamination from septic tanks if they are not properly made or maintained, particularly in areas with high water tables. Alternatives to individual septic tanks should be assessed, e.g., treatment facilities serving substantial clusters of houses. Where larger wastewater treatment facilities are not viable, a reasonable compromise can be seen in the approach used by GTZ-SLGSR: groups of houses use a common septic tank, the effluent of which goes into a well-maintained leach field (or constructed wetland, potentially). Microbial degradation in the septic tank, together with a soil passage on the leach field, should provide reasonable filtration and minimize groundwater pollution.
- Where only individual wastewater treatment is feasible, adequate quality septic tanks must be used. ADB housing projects provide good examples by typically requiring adequately sized and sealed double chamber septic tanks that have been built according to predefined quality standards and discharge to a leach field or at least soak away. ADB also requires minimum distances of 10 m, and preferably 30 m, from any water source.
- Sewage sludge from septic tanks must be properly treated and disposed. GTZ-SLGSR, UNICEF, BORDA and BALI FOKUS plan to build a sludge treatment plant for Banda Aceh that should provide a useful model for evaluation and possible replication elsewhere.
- An awareness programme on the importance and methods of proper sanitation is needed. Until proper sanitation and groundwater free of faecal bacteria becomes a higher public priority, sanitation systems will not be maintained, groundwater contamination will continue, and investments in improved sanitation will be ineffective.
- In general, the wastewater problem requires much more attention. An overall wastewater strategy should be developed, particularly for the reconstruction process, and a coordinating unit should be assigned to ensure its implementation.
- In order to monitor the adequate management of household wastewater for reconstructed houses, the following indicator could be used (at least in larger towns): percentage of houses from which wastewater is going to a communal wastewater treatment facility or, alternatively, to a septic tank with an intact sealing and which is emptied on a regular basis.

▪ *Water quality monitoring:* A monitoring system for water quantity and quality is needed, particularly for drinking water sources, and should include the following elements:

- All sources of water used or proposed for drinking should be monitored for salinity and compliance with Indonesian drinking water standards.
- Data from the monitoring system should meet internationally established quality standards. It should be consolidated with existing water quality data (e.g., from the Catholic Relief Services) and entered into a GIS-based database. The database would provide a major tool for water resources management decision-making. UNICEF's database could be used as a basis for the new database. The database information should be available to every community, institution or private company dealing with water resources management issues in Aceh.
- Laboratory capacities need to be upgraded and quality management systems introduced. The presence in water supplies of potentially hazardous substances, like volatile organic compounds or pesticides, should be monitored, although as a lower priority. Important steps towards development of a water monitoring system have been made by the implementation of the CIDA-funded Environmental Monitoring Capacity Development project and the rehabilitation of the laboratory of Bapedalda Provinsi NAD, supported by GTZ-SLGSR. It should be evaluated whether decentralized labs should be established

on the west coast (e.g., upgrading the CRS field lab in Meulaboh) and in Sigli.

  - For assessing the efficiency of a water monitoring system, the following indicators could be used: percentage of population receiving drinking water from sources that are monitored regularly for established water quality and salinity parameters.
  - Due to the long-term importance of deep groundwater aquifers for Aceh's water supply, very high priority should be given to monitoring for and preventing possible saltwater intrusions into these systems.
  - Investigations are needed into the possible contamination of groundwater in Banda Aceh, and other big towns, with volatile organic compounds from small industries using solvents as well as pesticides from agriculture. Both issues should be monitored, though with a lower priority.
  - Assuming the existence of a water quality monitoring program, the following indicators could be used to assess drinking water quality:
    - percentage of population receiving drinking water from sources that comply with Indonesian drinking water standards; and
    - percentage of population that uses drinking water classified as 'fresh water', according to pre-established parameters.
- *Surface water quality:* The province's surface waters are heavily polluted with faecal bacteria, mainly as the result of inadequate sanitation systems and the absence of wastewater treatment. Contamination is present in standing water bodies, rivers and the sea. Surface water quality in rivers and selected coastal areas in Aceh should be included in any monitoring system and basin-wide management practices should be combined with improved sanitation to protect water bodies.

Soil and mineral resources

- *Sedimentation:* It is very difficult to mix soil suffering from severe deposition and having very thick sediment layers (>30 cm) with underlying soil. Where this sediment layer is very sandy, soil fertility is normally reduced considerably. Removal of the sediment layer will probably be too expensive. Consideration should be given to providing affected families with adequate compensation and/or support for developing alternative sources of income. The possibility of using some of the deposited sand for construction (after screening) should be evaluated.
- *Improving drainage:* In fields where salt cannot be washed out due to bad drainage conditions, the possibility of improving drainage should be assessed using cost/benefit analysis to determine the economic feasibility of such an option.
- *Diversification of production:* In general, it may not always be reasonable to expect that agricultural lands can be restored to previous conditions. FAO has suggested the reconstruction process should be regarded as an opportunity for production diversification, e.g., by replacing parts of the rice production with livestock production. Saline soils can easily be used for fodder production, unlike paddy rice, which is quite sensitive to salinity.
- *Agricultural land use indicator:* area of agricultural land that still cannot be used for agricultural production due to the tsunami.
- *Heavy metal and pesticide contamination:* The extent of soil contamination with heavy metals and pesticides is still not clear, indicating a need for additional investigation. Although possible elevated levels are probably not due to the tsunami, it would be useful to understand background concentrations, particularly in agricultural soils.
- *Sand and gravel extraction:* The extraction of sand and gravel from rivers, particularly the Aceh River, should be regarded as a high priority concern An overall strategy should be developed to address this problem. The approval of new licenses must be reduced to an absolute minimum and given only after detailed evaluation of the possible environmental impacts of the activity, in accordance with decree 308/05. Licenses granted should always specify the volume that can be extracted and the reclamation measures to be implemented after completion

of the mine operation. Illegal extraction should be vigorously prosecuted, and the creation of related small-scale extraction projects to avoid environmental impact assessments should not be permitted. As an alternative, sand and gravel deposits away from the riverbeds should be explored and developed as needed. Geophysical exploration methods can assist with this task. For both, sand/gravel and hard rock quarrying, it is important to use appropriate washing and grading equipment to increase the proportion of material that can be used for construction and minimise leavings. Indicators of sustainable management of mining/quarrying activities might include: percentage of sand/gravel extraction from outside riverbeds; volume of sand/gravel extracted from quarries that have undergone legally required environmental impact assessment studies; and percentage of quarries that have implemented reclamation plans after finishing extraction activities.

- *Clay extraction:* The extraction of clay for brick production destroys invaluable agricultural topsoil resources. The extent of this practice and its environmental impact should be investigated in more detail.

Air quality

- *Building back better:* Although air pollution is not a high priority environmental issue in Aceh at present, steps can be taken during the reconstruction process to minimize pollution and avoid major problems in the future. For example:
  - newly installed refrigeration equipment should not contain ozone-depleting CFCs;
  - construction-related dust can be minimized by moistening the soil;
  - reconstructed houses should use fuel-efficient cooking stoves that do not create indoor air pollution; and
  - the use of burnt clay bricks for reconstruction should be reduced, and energy-efficient kiln firing techniques should be promoted.
- *Environmental assessments:* AMDAL studies should be carried out with respect to air pollution from point sources, and appropriate emission reduction measures should be required as needed.
- *Air quality monitoring:* In order to understand air quality conditions and prevent future degradation of air quality, the province should develop an air qualitymonitoring programme, including sampling equipment, laboratory facilities and intensive capacity building for technical staff. If possible, the system should include some mobile units for AMDAL studies and a few stationary units that can be sited next to major point sources and locations with heavy traffic.
- *Transport:* The existing emission control system for motor vehicles needs to be improved. The use of unleaded fuel and four-stroke cycle motorbikes should be aggressively promoted. The province should also begin to establish a system of public transport, which reduces air pollution and noise.
- Air quality indicators:
  - In order to assess the efficiency of air quality control measures, the following indicators could be used:
    - percentage of AMDALs including air quality measurements, particularly for projects that have major potential for air quality impacts;
    - number of air quality measurement units (mobile and stationary) operated and maintained by environmental authorities in the province;
    - number of sampling points providing air quality information;
    - number of air quality sampling hours per year; and
    - percentage of motor vehicles (including trucks) undergoing emission inspections every year.
  - As indicators of air quality and/or likely emissions (particularly after the air quality monitoring system is installed):
    - for monitoring stations near busy streets or relevant point sources:
    - number of days with exceedances of permissible air pollutant concentrations;

- number of motor vehicles (trucks, cars, motorcycles);
- percentage of cars that are using leaded fuel; and
- percentage of newly installed refrigeration systems that do not use ozone-depleting substances (especially CFC).

Solid waste management

- *Waste management:* The waste management systems implemented in the course of the reconstruction process are probably not yet sustainable. An overall waste management strategy should be developed and implemented. Similarly, the coordination of waste management issues between government offices and aid agencies needs improvement.
- *Waste disposal:* An important step has been taken with the identification of two suitable sites for a common sanitary landfill for Banda Aceh and Aceh Besar. The speedy construction of this landfill should be given a high priority, because the dumpsite at Gampong Jawa will reach its maximum capacity in only a few years. Landfills and dumpsites need to be built or upgraded throughout Aceh. The burning of waste in backyards should be prohibited.
- *Waste collection:* Waste collection is only reaching a minority of Aceh's population. Services must be considerably increased, requiring a major investment.
- *Building awareness:* An awareness programme is needed to inform the public about a number of aspects of waste, including:
  - the importance of minimising waste generation, and the benefits of composting for reducing waste volumes and improving soil quality;
  - the importance of effective waste collection;
  - the need to separate potentially hazardous waste (pharmaceuticals, batteries, oil, solvents, paints, etc.);
  - the harmful and risky effects of waste burning; and
  - the importance of a safe management of faecal waste.
- *Hazardous waste:* It is important to know more about the types and quantities of hazardous waste in Aceh, and to develop and implement a strategy for its safe handling and disposal. Particular emphasis should be put on the handling of hospital waste and waste from environmental laboratories, particularly solvents. When the cement factory is working again it might potentially be used for the temporary incineration of especially toxic waste.
- *Indicators:* The following indicators could be used to assess waste management performance: percentage of households receiving waste collection services; percentage of households from which waste is being dumped at a sanitary landfill or improved dumpsite.

Reconstruction of houses

- *Housing locations/spatial planning:* A significant number of houses are being built in areas that are not secure from an environmental perspective. These include areas at high risk of being affected by future natural disasters or where groundwater tables are very near the surface. Spatial planning is an indispensable prerequisite for sustainable housing. The reconstruction of houses should be based on a land use plan, taking into account such important existing tools as the Environmental Sensitivity Map produced by ADB & BRR (2006), the geo-hazard mapping performed by GTZ-SLGSR (Bapedalda NAD & GTZ-SLGSR, 2006) and the Kecamatan Action Plans established by ADB and BRR for up to 67 west coast kecamatans.
- *Housing locations/EIAs and checklists:* The potential environmental impacts of prospective housing sites should be assessed, particularly in high-risk and/or environmentally sensitive areas. If it is not feasible to implement a regular EIA, at minimum, a checklist should be used, especially when 10 or more houses are to be built. The checklist should take into account issues related to the proper location and design of the houses and the use of sustainably

produced, good quality construction materials, including the following:

- The availability of basic services, like electricity, water and sanitation. Single houses in the countryside should be avoided.
- The site should not be within an environmentally sensitive area or an area at substantial risk of being affected by natural hazards. Sites where the groundwater level normally comes within one metre of the surface should be avoided, as should land that has been used previously for agricultural or conservation purposes ('virgin' land). Priority should be given to sites that were used for housing or industrial activities, preparing the land as necessary (e.g., demolishing former construction).
- Avoid very extensive housing development projects in areas where the sealing of a large part of the land surface will seriously increase surface runoff and probably cause major soil erosion.
- Use alternatives to individual household septic tanks whenever possible. BRR could perhaps use a certain percentage of its construction budget to provide adequate sanitation systems as part of the development work for the construction sites and before aid agencies commence construction.
- To the extent possible, public water supplies should replace shallow wells, which are likely to be contaminated. If shallow wells are to supply drinking water, septic tanks, if used, must be setoff a safe distance from the wells.

- *Housing design:* In general, the locations and designs of the houses should take into account the needs of the inhabitants with respect to basic services. Problems regarding the provision of basic infrastructure, like water and sanitation, are apparent at present. In addition, houses designed at the standard size of 36m2 recommended by BRR may not be sufficient for large families, which would then need to consider enlarging their houses or possibly looking elsewhere for a more suitable alternative. If it is impracticable to work with different house sizes, large families could perhaps be given two joined 36 m2 houses.
- *Construction materials:* It is important to ensure that building materials meet established quality standards and that construction techniques account for the high risk of future earthquakes. Burnt clay bricks require excessive quantities of fuel wood in their manufacture and are a cause of deforestation. Alternative building materials, such as hollow concrete blocks,

should be promoted. Existing brick kilns should be retrofitted to reduce wood requirements. The technical measures required to improve the energy efficiency by 30-40 percent are relatively cheap (around US$380 per kiln). These should include fitting the traditional kilns with firing hole dampers/grates and rebuilding them as double-storey kilns (vertical shaft brick kilns, as, e.g., described by SDC in 2006). Alternative fuel sources, such as rice husks, sawdust or gas, should be evaluated. To further reduce timber consumption, the possibility of replacing timber used for windows or doors with alternative materials, such as aluminium or steel, should also be assessed.

Spatial planning and environmental impact assessment

- *Spatial planning/integration of environmental aspects:* Spatial plans are still lacking major environmental aspects, such as the locations of environmentally sensitive areas and areas likely to be affected by natural hazards. It is highly recommended that the spatial plans include the environmentally sensitive areas findings of ADB & BRR (2006) and GTZ-SLGSR's findings regarding areas at high risk of natural disasters (Bapedalda NAD & GTZ-SLGSR, 2006). A good example of spatial planning is ADB and BRR's elaboration of the Kecamatan Action Plans for up to 67 sub-districts on Aceh's west coast.

- *Spatial planning/awareness:* Spatial plans have often not been used effectively. An awareness and information programme on the proper use and usefulness of spatial plans is recommended. Particularly important is awareness raising regarding the risks of natural hazards, if houses are rebuilt in disaster-prone areas. Law enforcement related to spatial planning regulations is weak. Compliance with such regulations should be more strictly monitored and enforced.

- *EIA implementation:* A first priority task is to increase the frequency with which required 308/05-AMDALS are performed in a satisfactory manner. The lack of resources and availability of adequate tools on the part of the provincial Bapedalda is the major bottleneck with respect to EIA implementation for a large number of reconstruction projects. Support for Bapedalda, as was provided by GTZ-SLGSR, for example, is of prime importance to making reconstruction projects more sustainable. There is still a lot of work to be done in order for Bapedalda to cope with short-term peak demand. Consideration should be given to whether additional external help might improve the situation. Apart from the provincial Bapedalda, aid agencies should be trained in EIA procedures and techniques, particularly related to the application of 308/05-AMDAL. Along with the provincial Bappedalda, these agencies play a key role in taking into account environmental aspects of the reconstruction process. In cases where EIA regulations cannot be applied, and there are threats of negative environmental impacts of reconstruction activities, simple environmental checklists could be applied by donor agencies and BRR following appropriate training.

- *EIA screening process:* Under the 308/05-AMDAL screening criteria that determine whether or not a project requires further environmental assessment, many projects that could have a significant impact on the environment are not required to conduct full impact assessments. Included in this category, for example, are most of the housing projects. If limitations on the application of the AMDAL cannot be changed, a simple-to-use checklist should be introduced for assessing such projects, including applicable housing projects and projects related to the extraction of construction materials, such as clay extraction and gravel quarrying from riverbeds.

Environmental monitoring capacity

- *Monitoring strategy:* In Banda Aceh there is considerable laboratory capacity for environmental monitoring. An overall environmental monitoring strategy is needed, however, in order to provide a framework for monitoring activities, clarify the roles of different institutions and laboratories involved in the monitoring process, and specify capacity development needs. Cooperation and coordination among the different laboratories and between the laboratories and aid agencies will need to be strengthened.

- *Laboratory equipment needed:* The following accessories for existing equipment are needed to enable proper monitoring of organic contaminants: ECD and other detectors for GC; head-space analyzer for GC and GC/MS; pump and adsorbent tubes for sampling organic pollutants; thermal desorber for GC and GC/MS, and Soxhlet extractor. An air quality monitoring station, including a PM10 monitor, should be purchased, and sampling equipment is needed for soil and sediment monitoring. The mobile laboratory currently being rebuilt by Bapedalda NAD, should be equipped for emergencies in case of accidental releases of pollutants. This could include Draeger tubes and portable PM10, CO, Geiger counter and other monitors.
- *Capacity building:* A capacity development programme will be needed in order for staff participating in monitoring to update their knowledge and acquire additional skills. The monitoring of organic contaminants, for example, will require significant training of laboratory personnel. Similarly, staff in the laboratories monitoring soil should be trained in key methods of soil analysis, particularly those pertaining to heavy metals, pesticides and other organic pollutants.
- *Laboratory safety:* Safety features in virtually all of the laboratories need to be upgraded and improved to meet currently accepted standards. A solution must be found for the management of hazardous laboratory waste.
- The laboratories should also have an adequate system of quality control/quality assurance and should be accredited.

Reducing disaster risks

- The problems created by natural hazards, including environmental problems, can be avoided or at least mitigated to some extent with an appropriate disaster risk management system. The 2004 tsunami has provided an opportunity to reflect on the value of disaster risk management and to apply lessons learnt so that future natural disasters might have less severe impacts. It is highly recommended that stakeholders throughout Aceh join together to develop and implement an environmental disaster risk management strategy. (See Annex III, below.)

Chapter 3.

Institutional review - environmentally sound reconstruction

This chapter provides a general overview of the mandates, tasks and characteristics of the key institutional actors engaged in environmental reconstruction of Aceh Province.

Key institutions involved in environmental reconstruction

BRR (Agency for the Rehabilitation and Reconstruction of Aceh and Nias)

BRR was created in April 2005 to coordinate and facilitate post-tsunami reconstruction activities pursuant to the Master Plan, and to serve as a key interlocutor and partner of the Government of Indonesia (GoI) and MDF. The BRR has three parts:

- The **Advisory Board** provides direction in the formulation, planning and implementation of the rehabilitation and reconstruction process. Members of the Advisory Board are representatives of various stakeholders, such as the communities concerned, academicians/ universities, government at central and regional levels, and other stakeholders supporting the advisory function. Members of the Advisory Board are responsible for ensuring that the aspirations of the parties they represent are reflected in the rehabilitation and reconstruction process. The Advisory Board reports to the President of the Republic of Indonesia.

- The **Supervisory Board** is responsible for, among other things, supervising the implementation of the rehabilitation and reconstruction process; receiving and following up on community complaints; and auditing the performance of the Implementing Agency. Members of the Supervisory Board comprise individuals with sufficient supervisory skills, including national figures, independent Acehnese opinion leaders and representatives of donor countries and agencies.

- The **Implementing Agency** is responsible for, among other things, formulating BRR's operational strategy and policy; preparing an action plan; implementing rehabilitation and reconstruction activities, including projects based on agreements with other agencies/ institutions; and ensuring that rehabilitation and reconstruction funds are used with integrity and free of criminal acts of corruption.

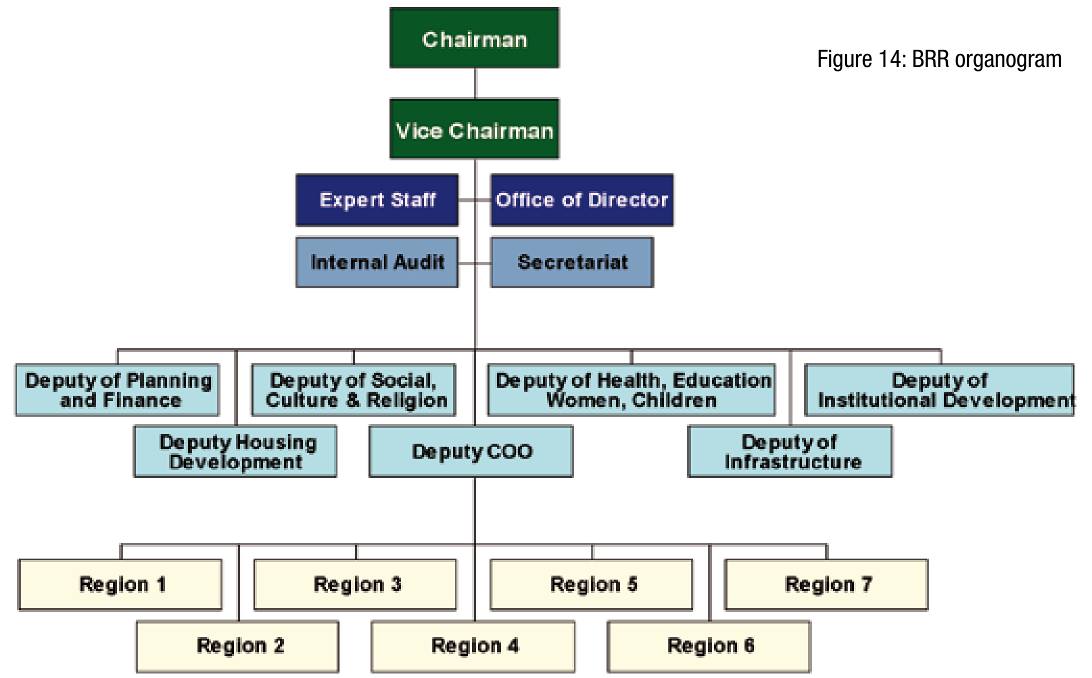


Figure 14: BRR organogram

According to the Master Plan, the BRR's work should be closely coordinated with, and have the full support of, the central and regional governments and related parties. To date, however, cooperation between BRR and, e.g., the environmental authority, Bapedalda, has been weak.

The structure of the Implementing Agency is illustrated in Figure 14 (June 2006).

Up to and throughout 2006, funds were disbursed through the BRR's sectoral divisions. As illustrated in Figure 15 below, the environment sector has been generally under-funded in the reconstruction process.

The roles of the sectoral divisions have been gradually changing during 2006. In response to the GoI's decentralization strategy, 2007 funds and those to follow will be allocated through the regional offices. BRR is opening branches in all 23 regions (municipalities and districts), with joint secretariats between BRR and the regions. As part of this ongoing restructuring process, the Chief Operating Officer (COO) is gradually gaining an increased mandate and internal power within the institution.

Environment Unit

It has not been possible to identify BRR's environmental policy or strategy. The agency's Environmental Unit has a staff of approximately seven people. Not all staff have specific competencies within the environmental field. The Unit has been moved between different sectors, and is now a sub-unit within the COO's office. The unit is principally occupied with the preparation of EIAs.

In response to the need for immediate action, BRR has begun initiating and implementing projects. The assumption of this role carries a risk of internally conflicting priorities and pressure to short cut or neglect environmental planning processes and procedures.

BRR has devoted resources to the development of EIA guidelines, but the process has not been coordinated with Bapedalda. In general, there is evidence of a lack of cooperation between BRR and Bapedalda during the reconstruction process, not least within the environmental field.

It has not been possible to identify other tools or systems that have been prepared and implemented to improve BRR's environmental performance. The linkages between the Environmental Unit and the sectoral and regional divisions are weak.

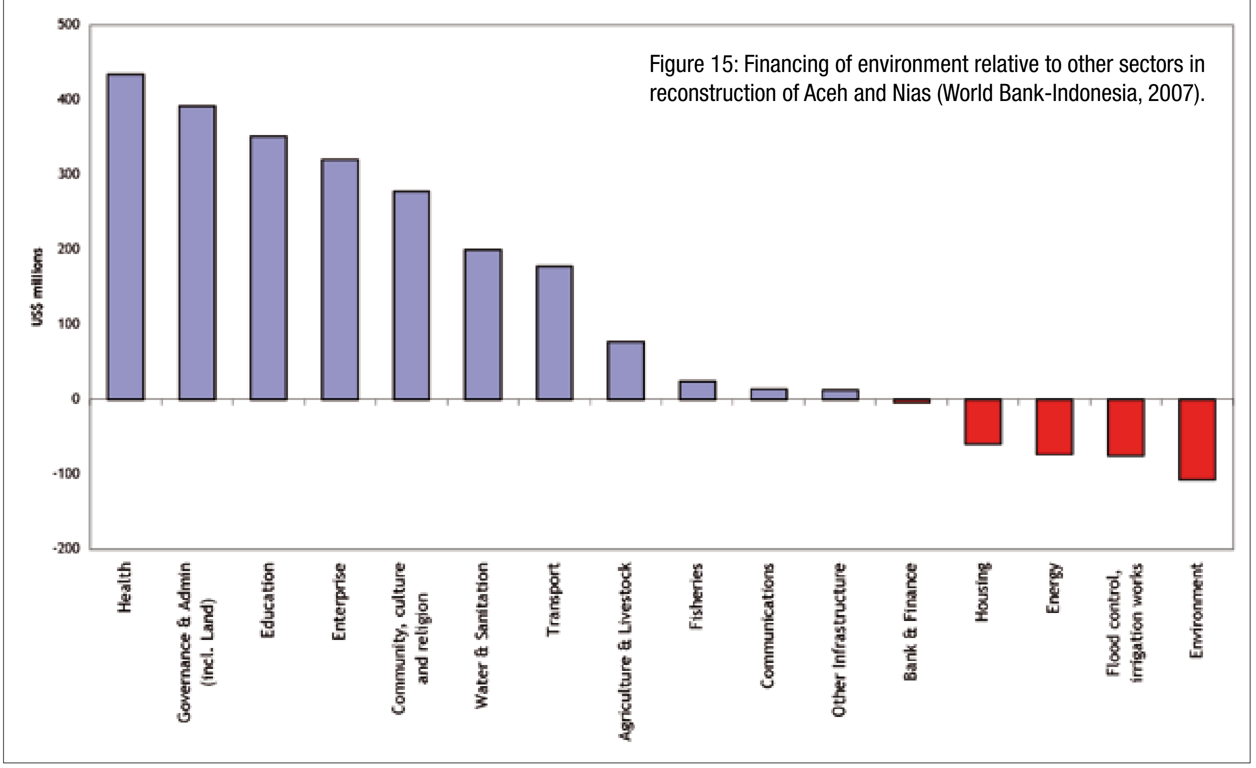


Figure 15: Financing of environment relative to other sectors in reconstruction of Aceh and Nias (World Bank-Indonesia, 2007).

Some divisions have staff with environmental competences, but the implementation efforts directed by the sectoral divisions reflect little evidence of concern with environmental matters.

Ministry of Environment

The Ministry of the Environment (KLH) is one of ten state GoI ministries. The KLH assists the President in the development, coordination, implementation, monitoring and evaluation of sustainable development and related policies. KLH's remit comprises three primary responsibilities:

- Formulation of policies to promote sustainable development and coordination of their implementation.
- Management of policy impacts, using the monitoring mechanisms provided by regulations.
- Promotion of change in societal attitudes and lifestyles in line with sustainable development concepts and the Earth Charter.

KLH's five-year plan reaffirms this strategic direction, identifying capacity development and the empowerment of the population as overarching requirements for achieving its goals. The EIA process will be integrated into land use planning at both strategic and project levels and will be a major vehicle for ensuring public consultation and participation in the management of development activities.

Decentralisation requires KLH to facilitate national environmental policy implementation in the provinces. This responsibility entails coordinating with local priorities and capabilities, and supporting the development of effective local capacities. In July 2005, KLH restructured itself to align its resources with decentralisation priorities and needs.

Provincial and District Environmental Authorities

Within Indonesia's newly devolved system of government, the higher levels of the government set framework legislation and policy, but they do not manage or direct institutions at the lower levels in the provincial government (Permintah Provinsi NAD). The Governor's Office for NAD is headed by a democratically elected Governor and under this office a Vice-Governor. The Governor's Office has four assistants to ensure the smooth operation of Provincial Governance. These Assistants have responsibility for a number of Bureaus corresponding to the particular area of governance. The Provincial Environment Agency (Bapedalda) reports to the Governor, while the District Bapedaldas report to the head (or Bupati) of the local District Governments. The higher-level agencies support implementation at lower levels on demand and to the extent possible consistent with their resources and priorities. Thus, district and provincial governments are crucial stakeholders in the local environmental management process.

Since the decentralisation reform, sub-national authorities have struggled to discharge their new responsibilities effectively. The lack of skilled human resources and an overall framework for environmental management are major constraints. The fulfillment of institutional responsibilities is especially challenging in the tsunami-affected region, where the disaster severely weakened agencies in terms of staff, buildings and equipment.

Governor's Assistant 1
Governance

- Bureau of Governance
- Bureau of Organisation
- Bureau of Law and Public Relations

Governor's Assistant 2
Economic Development

- Bureau of Economy
- Bureau of Development

Governor's Assistant 3
Special Issues for Aceh

- Bureau of Speciality of Aceh
- Bureau of Social Welfare
- Bureau of Women's Empowerment

Governor's Assistant 4
Administration and Public Relations

- Bureau of Civil Service
- Bureau of Finance
- Bureau of Public Affaires
- Bureau of Equipment

The provincial Bapedalda in Banda Aceh implements national policies. As such, it has not developed its own environmental strategy or policies. With a staff of approximately 110, the Bapedalda's specific environmental regulatory tasks are to:

- prepare ToRs for EIAs, and ensure that EIAs adhere to the ToRs;
- participate in the EIA Assessment Board and evaluate draft EIAs;
- monitor the ambient environment (and, until the tsunami washed away its laboratory and much of its staff, provide environmental laboratory services); and
- promote and enforce compliance, which has been very weak in Aceh Province historically.

The district-level Kabupatens do not, at present, have environmental competences. Some capacity will begin to exist with the arrival in the next months of international and national technical advisors in seven Kabupatens, an initiative supported by GTZ and Danida.

National Development Planning Agency

The National Development Planning Agency (BAPPENAS) is charged with the coordination of all planning activities at the national level and drawing up the national development plans for one, five and ten-year periods. BAPPENAS leads the Poverty Reduction Strategy planning process and has headed crosscutting environmental planning efforts such as the development of Indonesia's Biodiversity Action Plan. The Agency is a keystone in cross-sectoral coordination and harmonisation, including mainstreaming environmental policy and management among line ministries.

At the central government level, each line ministry prepares a strategic plan for the next planning period. BAPPENAS issues guidance to the ministries, setting forth the approaches they should take towards using natural resources in a sustainable manner. Plans are then reviewed by BAPPENAS for compliance with the guidance.

Regional authorities are requested to submit annual development plans for review in a similar fashion. In theory, these national and regional-level plans form the basis for budgeting at all levels. Requiring the plans to conform to sustainable development principles, therefore, provides a mechanism to ensure that the institutions of government integrate sustainability into development programmes at national and regional levels.

Within BAPPENAS, environmental issues are addressed primarily through the Directorate of Natural Resources and Environmental Management. While the Directorate acknowledges and actively pursues its role in mainstreaming environment across sectors, it also recognizes a number of constraints in doing so, including limitations in staff capacity, especially within the poverty-environment sphere. The limited availability of documentation and instruments to provide clear arguments and tools for assessing the economic benefits of sustainable environmental management is also a problem.

Provincial and District Planning Boards (Bappeda) play important roles in coordinating all planning and advising and monitoring development programmes. The Boards, therefore, indirectly share responsibility for conservation and environmental management. The Bappeda has not sought to directly influence environmental management in Aceh Province.

Line Ministries

The line Ministries (Departemen) are responsible for the execution of, and support to, policy in the respective sectors. Within environmental management, the key line Ministries with sectoral responsibilities include:

- Ministry of Mines and Energy
- Ministry of Forestry
- Ministry of Marine Affairs and Fisheries
- Ministry of Agriculture
- Ministry of Home Affairs
- Ministry of Public Works

The first four play central roles in defining the overall frameworks for natural resource extraction and management, and in supporting implementation of the frameworks in the regions. The Ministry of Public Works is a central government stakeholder in the development and regulation of infrastructure at national level.

Civil Society

Indonesia has a comparatively well-established network of local NGOs, although the number of NGOs addressing environmental issues is more limited. The majority of Indonesian NGOs tend to be location specific, but some have offices in several areas. WALHI, for example, implements local community-based projects through regional offices across the country.

A variety of local projects and activities are undertaken through the Indonesian NGOs, which frequently work in partnership with local, purpose-developed CBOs and/or larger international NGOs such as WWF, Conservation International, Wetlands International, Birdlife, Fauna and Flora International and others.

WWF Indonesia has been very active in Aceh Province and has achieved considerable recognition through participation in the development of timber certification procedures. WWF has prepared a *Green Reconstruction Guide for Aceh*, which contains suggestions for policies, interventions and indicators. The guide combines the national organization's hands-on experience in the reconstruction process with knowledge from its international parent organisation.

The University of Siyah-Kuala has different departments dealing with environmental topics. The Department of Biology cooperates with Conservation International and Flora and Fauna International on conservation projects and sustainable resource use initiatives. The Department of Environmental Science has specific knowledge on brown environmental issues and frequently consults authorities and international NGOs. Leuser International is presently establishing a new headquarters office on the university's premises.

Annex I. 'Green' strategic environmental projects

Concept 1: Biodiversity inventories and bio-prospecting

Title: *Promoting understanding and sustainable use of Aceh's biodiversity resources*

Duration: 36 months

Budget: US$ 1,000,000 (indicative)

Summary. The people of Aceh control the largest and most intact natural forest area and biodiversity resource in Sumatra, and one of the most important such reserves in the world (see Annex 2, Enterprise field 2). The rapid decline in global biodiversity and increase in ability to use biodiversity information productively ensures that Aceh's resource will appreciate in value over time. If the resource is preserved, documented and marketed effectively, it can be expected to attract increasing levels of investment, in commercially-oriented research (bio-prospecting), ecotourism, education, journalism, film-making, etc. This project would bring to Aceh the lessons learnt from efforts to use biodiversity productively in Costa Rica, Mexico, Guyana, the USA, Singapore, Malaysia and elsewhere. The project emphasises building capacity and the creation of a coherent strategy to inventory Aceh's biodiversity assets, develop educational programmes, establish a regulatory regime to promote equitable partnerships and deter bio-piracy, and negotiate favourable contracts with investment partners.

Concept 2: 'Building back better' in the fisheries sector

Title: *Promoting marine protected areas and compliance with regulations on destructive fishing methods for a sustainable fishery resource*

Duration: 36 months

Budget: US$ 1,000,000 (indicative)

Summary. This project would contribute to achieving a more productive and sustainable fishery in Aceh's waters. This will be done partly by promoting the establishment of district-level marine protected areas (MPAs), in which breeding fish could safely achieve large sizes and maximum reproductive output. The MPAs would also protect spawning areas for corals and other reef organisms, thereby supplying eggs and larvae for recolonisation over large areas of the sea. The creation of MPAs would be combined with dialogue with communities and traditional authorities focused on increasing compliance with regulations prohibiting destructive fishing methods and exploring ways to exclude fishing boats, especially trawlers, that are based outside of Aceh's waters. This combination of measures would offer the most effective available option for 'building back better' in Aceh's fisheries sector.

Concept 3: Mangrove aquaculture landscapes

Title: *Demonstration of community-based mangrove reforestation in aquaculture landscapes to promote ecological productivity, sustainability and environmental security*

Duration: 36 months

Budget: US$ 1,000,000 (indicative)

Summary. This project would respond to the repair and expansion of aquaculture (tambak) pond areas in coastal regions of Aceh. The pond development model currently being used replaces mangrove and other vegetation with bare mud and open water. This model is temporarily profitable but requires high maintenance, management and material inputs, is ecologically unsustainable and compromises environmental security. At present, there is little capacity to prevent the conversions on site. This project would emphasise the importance of wholesale planting of mangroves trees in and along all bunds, banks, canals, ponds and shorelines, with the aim of creating a forested aquaculture landscape that is healthier, more productive and safer than the prevailing model. Communities at demonstration sites in Aceh would be 'twinned' with community enterprises in Central Java, where mangrove reforestation in aquaculture landscapes has been accomplished over the past decade. Communities and small-scale enterprises in Aceh will be encouraged and enabled to copy the Javanese experience through on-site learning, self-organisation, the establishment of nurseries and the planting of mangrove seedlings. Edaphic conditions in and around ponds and canals will be baselined and monitored, as will the populations and spawning activities of offshore fish and prawns, in order to confirm the ecological benefits of the proposed measures over time.

Annex II. Sustainable commercial use of biodiversity in Aceh

In their quest to save biodiversity and ecosystem resources, conservationists have developed a wide range of techniques, some successful, others not. The key lesson learnt so far is that conservation programmes need to be adapted to their circumstances and generally require a long-term commitment of resources (Caldecott & Miles, 2005). Almost always needed is a shift in the way people perceive and relate to each other and their environment. Conservation programmes generally do not succeed unless they educate and empower, encourage and enable people to live better lives in their own terms, cause values to shift, and involve effective partnerships. New techniques, technologies and international markets make it possible for the conservation sector to achieve and sustain a primary economic role without necessarily conflicting with conservation aims. Investments can be directed to sustainable enterprises in full awareness that financing strategies based on sustainable uses of biodiversity will generally require innovation, experimentation and diversification of business activities and income streams. There follow summaries of two enterprise fields of potential relevance to Aceh (drawn from Caldecott, 2002).

Enterprise field 1: Educational services

Only a minute fraction of the total number of people interested in Aceh's wild species and places will ever go there. It may be possible, therefore, to market the province's biodiversity resource as a vicarious rather than a real-life experience. 'Virtual ecotourists' could contribute to the growth of a national and international support network, while promoting awareness, and generating revenues. This approach would provide conservation benefits without having any impact on the forests and would contribute minimally to carbon emissions. There would be no need for access, accommodation or waste management. Virtual eco-tourism would also be immune to fluctuations in the tourism market caused, e.g., by terrorism, crime, disease, political instability and changing fashions. Selling rain forest-based goods and services to stay-at-homes using proven marketing techniques could prove to be both reliable and profitable.

The most important goods and services that a tropical biodiversity resource can support are those based on knowledge. Aceh's ecosystems, for example, could be used to explain the complex world of natural history, ecology, and the behaviour and evolution of the hundreds of thousands of wild species that comprise the province's ecosystems. A typical market segment for such knowledge products would be the US school system, which has a total enrolment of over 53 million elementary and secondary students. A similar number of students is enrolled in European schools, of which at least the British and Irish systems are taught in English, bringing the total Anglophone school population in the US and Europe to over 60 million, in hundreds of thousands of schools (with more throughout the Commonwealth). Educational services developed in Aceh and offered in English could be directly useful to these school systems.

The educational market for knowledge-based services could be exploited by offering access to web-casts presented by subject matter experts, aiming to be broadly in line with national curricula. The content could include live feeds (once satellite communications are established) or archived highlights from web cams in the forest, and regularly scheduled live or archived web-casts with conservation area staff, resident naturalists or visiting scientists. Segments of 15-30 minutes would be appropriate for classroom lectures. By integrating interactive features, students could exchange ideas with the experts and other students at the same level around the world. Adding an educator resource area would allow teachers to exchange ideas with their peers.

Schools in the US and Europe now have considerable capacity in terms of computer hardware and network access. Teachers, however, often report that they have trouble finding the right resources to use. With limited design effort and investment in hardware, software and marketing (quite possibly eligible for grant support by the US Department of Education, European Commission or Commonwealth Secretariat), Aceh could help meet this global demand. Twenty thousand subscriptions to such a service at $50 per subscription, affordable for most US and European schools, would yield US$ 1 million per year to conservation in Aceh. Considering the size of the potential market, this estimate is very modest.

The same technology and marketing strategy could be used to offer distance-learning services to universities, perhaps leading to affiliation with particular universities and the awarding of degrees based at least in part on remote learning. An established vehicle for such distance learning services is the EC-supported Trans-Eurasia Information Network (TEIN). TEIN is a large-scale data communications network for the research and education communities in Asia-Pacific, enabling them to engage in joint projects. Offering direct connectivity to GÉANT 2, Europe's own network, TEIN allows regional researchers to collaborate with their counterparts in Europe and thus operate on a global scale. Now entering its third phase (TEIN 3), the enterprise is designed to extend and deepen connectivity within Asia and between Asia and Europe, particularly among research, education and e-learning communities.

Using these new technologies and opportunities, Aceh could offer its rain forests as a combination lecture theatre, demonstration laboratory and museum, and sell the resulting learning opportunities. To these approaches could be added a variety of other knowledge-based services, such as a subscriber-based satellite TV channel, and computerized learning, referencing and community work-space systems on tropical ecology, conservation, sustainable development and related subjects. These services could be sold to schools, universities, local governments and NGOs throughout the tropical world, and to donor agencies engaged with them.

Enterprise field 2: Bio-prospecting

Biodiversity prospecting, or bio-prospecting, is the process of finding commercially valuable information, products and processes within living systems. The potential role of bio-prospecting in sustainable conservation financing can be made clearer by considering the case of Costa Rica, which is the world leader among countries that have set out to develop bio-prospecting partnerships. In 1989, Costa Rica established its National Biodiversity Institute (INBio) as a non-profit, public-interest corporation. Since that time INBio has forged partnerships with a series of pharmaceutical and biotechnology companies (ten Kate and Laird, 1999), including:

- Merck & Co., in 1991;
- Bristol Myers-Squibb, in 1993;
- Givaudane Roure, in 1994;
- La Pacifica and the British Technology Group, in 1994;
- INDENA, in 1996;
- Analyticon, in 1996;
- Phytera, in 1998; and
- the Diversa Corporation, in 1995 and 1998.

These partnerships were authorized by a framework agreement between INBio and the Ministry of Environment and Energy (MINAE) under the Wildlife Law of 1992 and the Biodiversity Law of 1998. Under this agreement, 10 percent of all bio-prospecting budgets and 50 percent of all income from royalties are paid to MINAE for conservation purposes. Between 1991 and 1999, INBio's bio-prospecting agreements contributed more than US$390,000 to MINAE, US$710,000 to conservation areas, US$710,000 to public universities, and US$740,000 to other groups at INBio, for a total of US$2.55 million. These amounts seem small given the large sums involved in bio-prospecting investments. For example, an average of about US$500 million (and 12-13 years) is required to bring a new pharmaceutical product to market in the USA. The is probably due to the fact that bio-prospecting is relatively new and that INBio has chosen to take many up-front payments in kind, as technology transfer and training, rather than in cash.

INBio's 1995 agreement with Diversa committed Diversa to three years of soil and water sampling with INBio. The samples were processed at the Diversa laboratories in San Diego, California. The 1998 agreement, however, committed Diversa to set up a DNA processing laboratory at INBio's headquarters near San José, Costa Rica. The creation of the domestic laboratory was in line with INBio's goal of situating as much of the research and development process as possible within Costa Rica, believing this to be at least as great a source of long-term income as any royalty system is likely to produce. The INBio-Diversa agreement was the first of its kind in the field of gene prospecting and was the model for later contracts between Diversa and the State of Alaska and Yellowstone National Park in the USA, Bermuda, Indonesia, Russia, and the Council for Scientific and Industrial Research in South Africa.

These agreements have given Diversa the rights to discover genes and commercialize products from environmental samples. In exchange, Diversa supports the bio-prospecting activities of local organizations and their collaborators, and pays royalties on revenues from any products developed from the samples provided. Diversa's approach is to capture DNA directly from the environment and then to clone it, using ultra-high-throughput robotic screening systems to identify new enzymes and bioactive compounds expressed from single genes and gene pathways. Interesting compounds are then licensed to client companies in the pharmaceutical, seed, crop protection and biotechnology sectors.

Under the terms of the 1995 and 1998 agreements, INBio collects samples using its own techniques and proprietary technology provided by Diversa. INBio guarantees not to use Diversa's technology to collect or process samples for other companies, but is free to provide other companies with DNA from the same environments. All DNA sequences isolated by INBio for Diversa become Diversa property. All microorganisms isolated from the sites, however, remain the property of Costa Rica.

In return for this access, Diversa pays the salary and overhead of at least one INBio staff member, a contribution to INBio's core costs, and undisclosed royalties to INBio if Diversa licences to a client a product based on samples from INBio. Diversa also provides INBio with non-monetary benefits including technology, equipment for a molecular biology laboratory, training and access to Diversa's DNA sequencing facility.

The practice of establishing bio-prospecting agreements has, by now, been quite well explored. Partnerships are clearly feasible between institutions in biodiversity-rich tropical countries and international bio-prospecting corporations. These partnerships can bring considerable benefits to the countries that holds the biodiversity resources. In the case of Costa Rica, the first ten years' benefits have included at least US$ 2.55 million in cash, various forms of technology transfer, training and personnel support, and the development of capacity to absorb an increasing share of the research and development investment associated with each new pharmaceutical 'prospect'. A stake is also retained in the long-term success of bio-prospecting initiatives by contracting for royalties on later profits.

For Aceh to adopt a similar approach and take advantage of its biodiversity resources (and the failure of other territories in the region to conserve their own), a number of steps would be required, including the following:

- clarify ownership of the resources and the rights to allocate and benefit from their use;
- create a legal framework governing the allocation of use and exploration rights, and negotiate equitable and effective contracts between partners in this field;
- implement measures to minimize bio-piracy, bearing in mind that some of Aceh's biodiversity resources are shared with North Sumatra, requiring close cooperation between the two provinces; and
- establish institutional mechanisms, including, at least, a body responsible for bio-prospecting development on behalf of the people of Aceh.

In order to support global marketing of bio-prospecting opportunities in Aceh, some investment in inventory work would be needed, if only to establish the scale of the province's biodiversity resources. This would build on the work that has already been undertaken in the Leuser Ecosystem, but should expand into invertebrate and microbiological studies as a priority. A basic applied research facility would provide the beginnings of a bio-prospecting infrastructure. The facility would need to include a laboratory that at first would need only the capacity to sort and conserve samples, prepare extracts, and support training. The laboratory, however, should have the capacity to expand and diversify its role steadily over time. Following the example of INBio in Costa Rica, local people should be employed and trained as 'parataxonomists' to assist in biodiversity inventory and sampling work. Young local people could be hired, intensively training in biology and taxonomy, and then deployed to collect and process biodiversity samples. This would create a cadre of staff that could later rise through the system into more specialized and responsible positions as they gained experience and additional training. This approach has proven merit in terms of relieving constraints on graduate staff time and in its educational impact on the individuals involved and their communities. Absorbing and retraining some of the unemployed former combatants as parataxonomists would have particular resonance in the Aceh context.

Annex III. 'Brown' strategic environmental projects

In view of the large number and magnitude of environmental challenges Aceh is confronting, a few strategic environmental projects are suggested in the following table. The list below is not intended to be comprehensive, but instead refers to projects considered of major importance in order to avoid negative environmental impacts during the reconstruction process. Many of these strategic activities have already been implemented in one form or another, but sometimes only as pilot projects or otherwise in ways that are not adequate to meet the scope of the challenge presented.

The project proposals below are not well elaborated. They are intended to provide a basic orientation regarding priority issues and important steps and outputs towards solving them. The elaboration of the projects will require a much more detailed and participatory appraisal process that is beyond the scope of this study. Estimations of the costs and durations of the proposed projects, therefore, should be considered preliminary. Similarly, some of the suggested projects involve complex issues, e.g., solid waste management, that first require the development of overall strategies, to be followed by smaller individual projects consistent with the agreed strategic vision. In these instances, strategies will help improve coordination among agencies and will facilitate monitoring and evaluation of the BRR's activities.

The recommendations set forth in Chapter 2 aboveprovided important inputs for the definition of the projects described below.

Proposed strategic environmental projects

No.	Project title (short name)	Objective	Important outputs	Important stakeholders a)	Duration (months)	Estimated cost b) (US$)	Comments
1	Drinking water supply strategy	Develop an overall strategy for drinking water supply of affected population	Supply and demand in affected areas is known (in terms of quantity and quality). New drinking water sources identified and assessed. Water treatment needs defined and solutions proposed. Proposal for water distribution systems elaborated. Proposal for water management system elaborated. Concept for awareness raising and capacity building developed. Time, schedule and resource requirements for implementing the strategy defined.	BRR Bapedalda NAD Communities Waterworks UNICEF BGR USAID Catholic Relief Services GTZ	15	4,000,000	Very high priority.

(Continued on following pages)

No.	Project title (short name)	Objective	Important outputs	Important stakeholders a)	Duration (months)	Estimated cost b) (US$)	Comments
2	Monitoring system for water quantity and quality	Install efficient and user-oriented water monitoring system	Relevant drinking water sources recorded. Laboratories for water analysis acquire the instrumentation and know-how necessary to perform efficient and high quality work. Monitoring plan for drinking water established. Monitoring plan for water quantity and saltwater intrusion into deep aquifer systems developed. Extraction rates for water from deep aquifer systems defined, and control mechanisms established. GIS on water quantity and quality set up. Surface water monitoring system established. Concept for capacity development devised. Schedule and resource requirements for implementing the strategy defined.	Bapedalda NAD BRR Waterworks UNSYIAH UNICEF BGR USAID Catholic Relief Services GTZ	12	2,500,000	Can be regarded as part of the environmental monitoring concept (item 8). Due to its importance and urgency it has been proposed as a separate project.
3	Strategy for the provision of sand, gravel and stones	Develop overall strategy for environmentally acceptable extraction of sand, gravel and stones	Demand and current supply assessed. New sources identified and assessed. Proposal for exploitation and logistics elaborated. Concepts for EIA and restoration developed. Schedule and resource requirements for implementing the strategy defined.	BRR Bapedalda NAD Major aid agencies	12	1,500,000	BGR offered help with the exploration of new sources
4	Solid waste management strategy	Develop overall strategy and guidelines for solid waste management	Quantities and types of remaining tsunami waste and expected future household and hazardous waste analysed (incl. asbestos containing waste). Institutional framework for waste management analysed and elaborated. Waste collection concept elaborated (incl. hazardous waste). Waste recycling and treatment concept elaborated (incl. hazardous waste). Waste disposal concept elaborated (incl. hazardous waste). Proposal for awareness campaign and capacity development elaborated. Schedule and resource requirements for implementing the strategy defined.	UNDP BRR Bapedalda NAD Waste authorities GTZ	15	2,000,000	UNDP has extensive experience with waste management

No.	Project title (short name)	Objective	Important outputs	Important stakeholders a)	Duration (months)	Estimated cost b) (US$)	Comments
5	Checklist and guidelines for environmentally friendly construction	For the construction of houses, agencies use a checklist (and corresponding guidelines) to prove that major environmental aspects have been taken into account	Recommendations for adequate locations elaborated. Recommendations for adequate and environmentally friendly design and construction of houses developed (incl. sanitation and choice of materials). Guidelines for environmentally friendly construction (based on the above recommendations) published. Checklist for environmentally friendly construction elaborated. BRR regulation requiring all reconstruction projects to use the checklist issued. BRR, agencies and construction companies trained in the use of guidelines and checklist. Help Desk supports agencies using the checklist. Awareness campaign on environmentally friendly construction, particularly on the importance of an adequate sanitation system, implemented.	BRR Major agencies involved with construction Bapedalda NAD Communities UNEP	12	2,000,000	UNEP Sustainable Reconstruction Manual can be used as a basis for guidelines and checklist
6	Improved energy efficiency of brick kilns	Brick kilns implement measures to improve energy efficiency and reduce fuel wood use	Over 90 percent of active traditional brick kilns fitted with firing holes dampers/ grates and rebuilt as double-storey kilns. Potential of alternative energy sources for brick kilns (e.g., rice husk) assessed & pilot projects installed.	BRR Agencies involved in construction Brick kiln owners/ operators	12	2,000,000	
7	Development of EIA capacities	Good quality EIAs for reconstruction projects are carried out in a timely manner	Important instruments for EIAs developed (e.g., processing lists). Bapedalda NAD has equipment and other resources to carry out effective EIAs. Bapedalda NAD and aid agencies trained in how to carry out good-quality EIAs. Information system on EIAs established.	Bapedalda NAD BRR Major agencies involved in reconstruction	12	1,500,000	Important work done by GTZ (see Weber 2006)

No.	Project title (short name)	Objective	Important outputs	Important stakeholders a)	Duration (months)	Estimated cost b) (US$)	Comments
8	Environmental monitoring concept	Develop concept for environmental monitoring in NAD	Demand for environmental information in NAD assessed. Major available information collected and analysed. Concept of required monitoring parameters, locations and measurement frequencies developed. Analysis of existing monitoring capacities carried out. Proposal for GIS on environmental monitoring developed. Requirements for monitoring equipment and capacity development established. Work plan with schedule and resource requirements for implementing the strategy defined.	Bapedalda NAD BRR Major agencies involved in reconstruction	9	500,000	The CIDA (Canadian International Development Agency) funded project "Environmental Monitoring Capacity Development" can be regarded a good basis for this concept.
9	Environmental disaster risk management	The risks of future environmental disasters are reduced	Environmental problems related to the earthquake/ tsunami analysed with regard to measures to prevent/mitigate future damages (risk analysis). Strategic measures for environmental disaster risk reduction identified and implemented. Main stakeholders trained in disaster prevention and mitigation measures. Institutional setting for environmental disaster risk management improved.	BRR Major agencies involved in reconstruction Bapedalda	30	1,300,000	The experience of past damages should be used to avoid future disasters. The next disaster will happen.

a) List indicative and not intended to be complete or exclusive.
b) Very preliminary first estimate.

Annex IV.
Short description of environmental monitoring laboratories in Aceh (as of October 2006)

	Industrial Laboratory Centre Banda Aceh	Faculty of Chemical Engineering UNSYIAH	Chemistry Department, UNSYIAH	Public Health Laboratory UPTD	Institution for Drug and Food Monitoring
No. of technical staff	50	2	2	4	7
No. samples processed	100/month	Occasional	Occasional	150-300/month	60/month
Cleanliness	Medium	Medium	Medium	High	High
Safety Standard	Medium	Low	Low	Medium	Medium
Website			✓		
Accreditation	✓				
GF + FAAS			✓		✓
FAAS only	✓			✓	
Hg analyzer	✓		✓	✓	✓
Hydride vapour generator	✓		✓	✓	✓
GC		✓			✓
GC/MS				✓	
HPLC		✓			✓
UV/Visible	✓	✓	✓		✓
HACH spectrophotometer kit	✓	✓			
Mini API				✓	
pH meter	✓	✓	✓	✓	
Conductivity meter	✓	✓		✓	
DO meter		✓		✓	
Turbidimeter	✓	✓		✓	
Autoclave		✓		✓	✓
Centrifuge		✓	✓	✓	
Fume cupboard with laminar flow and UV lamp				✓	✓
Incubator	✓	✓		✓	✓
Microscope	✓	✓	✓	✓	✓
Oven	✓	✓	✓	✓	✓
Analytical balance	✓	✓	✓	✓	✓
High Volume Sampler	✓	✓ [a]			

a) Located in Environmental Studies Centre.

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Contributors

UNEP

John Bennett

Julian Caldecott

John Carstensen

Anne Cramwinckel

Glenn Dolcemascolo

Jon Godson

Josef Haider

Lily Laryea

Edmund McManus
(World Conservation Monitoring Centre)

Peace Nganga

Viktor Novikov

John Poulsen

Miroslav Radojevic

Pasi Rinne

Niclas Svenningsen

Bjørn Bauer, Plan Miljø

Tomas Poulsen, Plan Miljø

Bobbi Schiff
(Netherlands Commission
for Environmental Impact Assessment)

Syiah Kuala University

Bastian Arifin

Husni Husin

Ir. Mahidin

Wahyu Rinaldi

Wetlands International IP

Novana Sari (Team Coordinator)

Fadia Miralka

Ferry Hasudungan

Lili Muslihat

Ita Sualia

Eko Budi Prihanto

Dody Permadi

Sulfianto

Nyoman Suryadiputra

Other contributors

Salbiah Ahmad (UN Population Fund)

Ashley J. Bansgrove (ADB)

Richard Beresford (ADB)

Ben Collen
(Institute of Zoology, Zoological Society of London)

Nicola Demme (GTZ-SLGSR)

Mike Griffiths (Leuser International Foundation)

Rudolf Hermes (FAO)

Antun Hidayat (UNDP)

Ingrid Hofmann (CIM, Bapedalda NAD)

Helmut Krist (GTZ-SLGSR)

Timothy Nolan (FAO)

Thomas Rehmann (BGR)

Michael Schoene (GTZ-SLGSR)

Gie Siauw, (UNDP)

Scott Alexander Stanley
(Fauna & Flora International)

Nyoman Suryadiputra
(Wetlands International Indonesia Programme)

Petra van den Hengel (GTZ-SLGSR)

Holger Zahn (GTZ-SLGSR)

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Further information

Further technical information may be obtained from the Post-Conflict and Disaster Management Branch website at: http://postconflict.unep.ch/

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