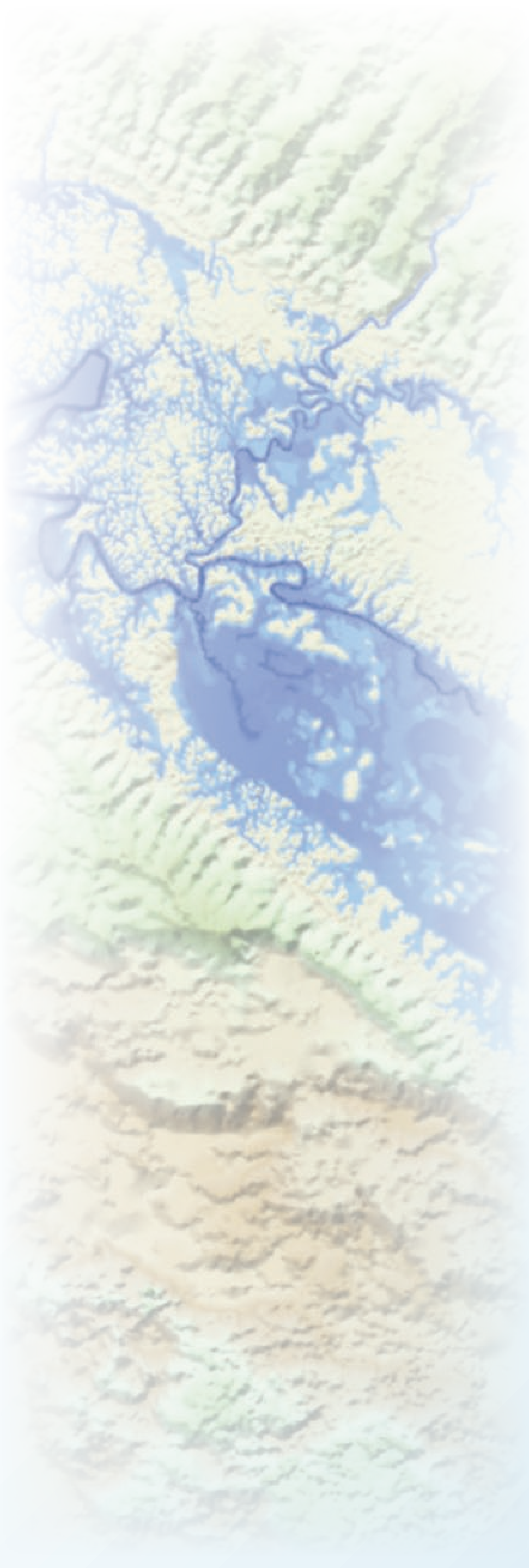


3. Assessment of Environmental Impacts

This chapter starts with a description of global issues such as the production of greenhouse gases and global biodiversity. This is followed by a presentation of regional issues, trans-basin diversion of water, intact river assessment, and regional biodiversity. The second section focuses on Project-specific issues.

Table 3.1: Comparison of generation per area flooded of several hydropower projects

Project	Reservoir Area (km^2)	Generation (GWh/year)	Generation per area Flooded (GWh/year/km^2)
Balbina, Brazil	3,147	970	0.3
Tucurui, Brazil	2,247	18,030	8.0
Churchill/Nelson Canada	1,400	16,000	11.4
Grand Rapids Canada	1,200	1,700	1.4
Nam Theun 2	450	5,636	12.5

The approach taken in this section is to first describe the baseline conditions and significant environmental issues, then to evaluate the potential environmental impacts, and finally to identify ways of avoiding these impacts. Mitigation measures, compensation measures and opportunities for environmental enhancement are discussed. The third section of the chapter focuses on the general and specific impacts associated with construction.

Global & Regional Issues

Two globally significant issues related to the Project are the potential for climate change due to production of greenhouse gases, and potential impacts to biological diversity. A number of regional issues have been identified as potentially influenced by the Project. These include: i) the trans-basin diversion of water; ii) CIA; iii) intact river assessment; and iv) regional biodiversity.

Greenhouse Gases

The Project could have some implications relative to contributing to global climate change through the production of greenhouse gases. There are two important factors relating to the contribution of GHG i) the amount of GHG generate by the Nakai Reservoir; and ii) comparison of the amount of GHG generated with production of GHG by fossil-fuelled power stations.

Following inundation of part of the Nakai Plateau, the store of organic carbon from the above ground vegetation (40 t (C) / ha) and from the soil (70 t (C) / ha) will decompose. Nutrients will be released to the water and additional organic production will take place. The decomposition of carbon will result in the production of carbon dioxide (CO_2) and methane (CH_4), the two greenhouse gases (GHG) most responsible for the anthropogenic increase in global GHG. Greenhouse gases will be produced throughout the life of the reservoir, with higher GHG emissions in the first few years after inundation. Ultimately, the original carbon stock will be dissipated as it: i) is diffused as gases to the atmosphere through the reservoir surface; ii) is transferred as gases to the atmosphere from reservoir waters in the downstream channel and rivers downstream from the PowerStation and spillway; iii) is converted into new life in the reservoir water or released water; and iv) remains stored in submerged and fallen trees.

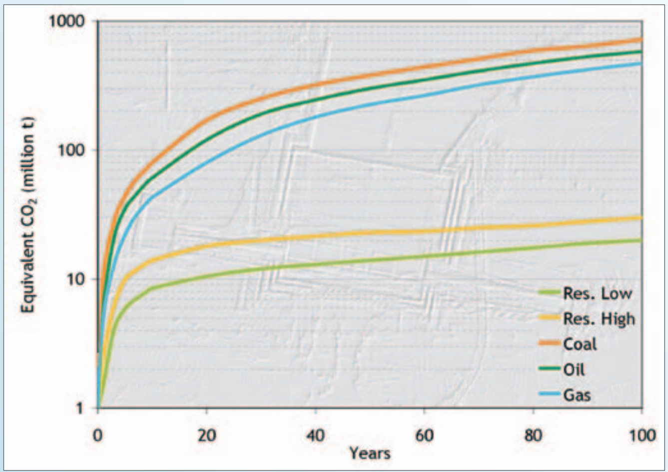


Figure 3.1: Comparison of cumulated greenhouse gas emissions

(Res. Low = 50% of Petit Saut Reservoir Emission; Res. High = 80% of Petit Saut Reservoir Emission)

The potential for GHG production can be gauged on the ratio of the annual GWh generated to the area flooded (McCully 1996). Table 3.1 illustrates that the NT2 Project is favourably placed in terms of generation per area flooded when compared to other hydropower projects. It is improved further by the fact that forests cover less than 50% of the inundation area.

It has been calculated that when power generation is less than 0.1 W/m^2 of reservoir area, thee risk that GHG emissions exceed that of thermal generation for the equivalent capacity is high. Where values exceed 0.5 W/m^2 of reservoir, scenarios have shown that this risk is reduced (WCD, 2000).

Several factors are considered when calculating the GHG emissions of the Project; including i) the amount of organic matter to be inundated; ii) methane emission from the reservoir; and (iii) seasonal drawdown. Based on calculations made for the Petit Saut Hydropower Project in French Guyana (Delmas, 2000), it is estimated the Project reservoir will produce only 50 to 80% of the estimated GHG emission of the Petit Saut reservoir. This is firstly because of a lower estimated amount of organic matter that will be subject to decomposition (5 million tonnes vs. 8.5 millions tonnes) and secondly due to a significantly larger drawdown area. This greater area means that a larger proportion of the organic matter will be oxidised to CO_2 rather than to CH_4, a gas more effective at inducing warming than CO_2.

Delmas and Garly-Lacaux (2000) compared the emission of GHG from the Project and a thermal power plant of similar generating capacity over a 100 year time-scale. As shown in Figure 3.1, emission of greenhouse gases from the reservoir represents less than ten percent of the emissions of a thermal power plant of comparable capacity. Furthermore the information presented in Figure 3.1 is based on a constant production of greenhouse gases over a 100-year period, when in fact methane emission is most significant during the first five years after impoundment, due to fast decomposition of the easily biodegradable fraction of the biomass in the form of leaves and grass.

Establishing that a reservoir emits GHG is not enough to assess the overall net impact. Natural habitats may also emit GHG, especially the areas of seasonal wetlands and wetland rice currently within the inundation area. However, due to the limited data available, the overall net fluxes from the reservoir were not taken into account in the calculations above. This certainly leads to an overestimation of emissions from the reservoir which would be considerably less than that of any thermal alternatives.

Mitigation

To date, no experience exists with minimizing, mitigating, or compensating the impact of GHG production. Pre-inundation removal of vegetation is one alternative that will be implemented by the Project, but the net effects of such an activity are not well understood (WCD, 2000). In addition, dissolved and particulate organic carbon fluxes from watersheds make a contribution to the production of GHG (Delmas 2000). Under the SEMFOP, the management of the NNT NBCA should help prevent any significant contributions to GHG being made by reservoir inflows.

Global Biodiversity

Lao PDR is one of the most biologically diverse areas in the world, with its central region recognised internationally as an area of outstanding biological diversity. Three NBCAs surround the immediate Project area. The most important of these is the NNT NBCA, which constitutes about 88% of the drainage for the reservoir. The other two NBCAs are the Phou Hin Poun NBCA, a region of karst limestone, and the Hin Nam Nor NBCA, located to the south of the NNT NBCA. Management of the NNT NBCA forms an important component of the Project's compensation and mitigation measures. Project commitments to the protection of the NNT NBCA are discussed below.

As a consequence of studies conducted by the IUCN and WCS, and with recommendations from the World Bank, a series of corridors between the NBCAs was established in 1993 by PM Decree 193. These corridors, shown in Figure 3.2, have effectively connected the three NBCAs to enable migration of wildlife between them.

Each of the areas is noted for the presence of several threatened and endangered species including the Asian elephant, the tiger, and the white-winged duck, as well as a number of other species identified by IUCN as globally endangered or threatened. During the IUCN/WCS studies, three new mammal species were identified as inhabiting the NBCAs. These included the saola, a new species of muntjac, and a new rabbit or hare species. The Heude's pig, long thought to be extinct, has recently been rediscovered in the area. Fish studies have also identified numerous new species.

A number of activities currently threaten the NNT NBCA and therefore threaten the survival of its globally important biodiversity. These activities include (i) logging; (ii) commercial extraction of wildlife and non-timber forest products; and (iii) unsustainable agricultural systems that utilise short-cycle swidden practices. It is therefore essential to allocate sufficient resources for the management of the NNT NBCA to prevent any further degradation of its regionally and globally recognized biodiversity.

Trans-Basin Diversion of Water

A major regional issue relative to the operation of the Project is the trans-basin transfer of water from the Nam Theun to the Xe Bang Fai.

Hydrologic Changes in the Nam Theun & Xe Bang Fai

The diversion of water from the Nam Theun to the Xe Bang Fai will dramatically alter the discharge regime in the Nam Theun downstream of the Nakai Dam and in the Xe Bang Fai downstream of the Nam Phit. When the Project is operating to meet peak power demands in Thailand and Lao PDR, the power station will divert up to a maximum of 330 m^3/s of water from the Nakai Reservoir filled by the Nam Theun to the Xe Bang Fai. On average, the diversion of water from the Nam Theun to the Xe Bang Fai will be approximately 220 m^3/s. Occasionally, the inter-basin transfer may drop as low as 30 m^3/s when the Project is not operating to meet baseload or intermediate peaking requirements. Additionally, if

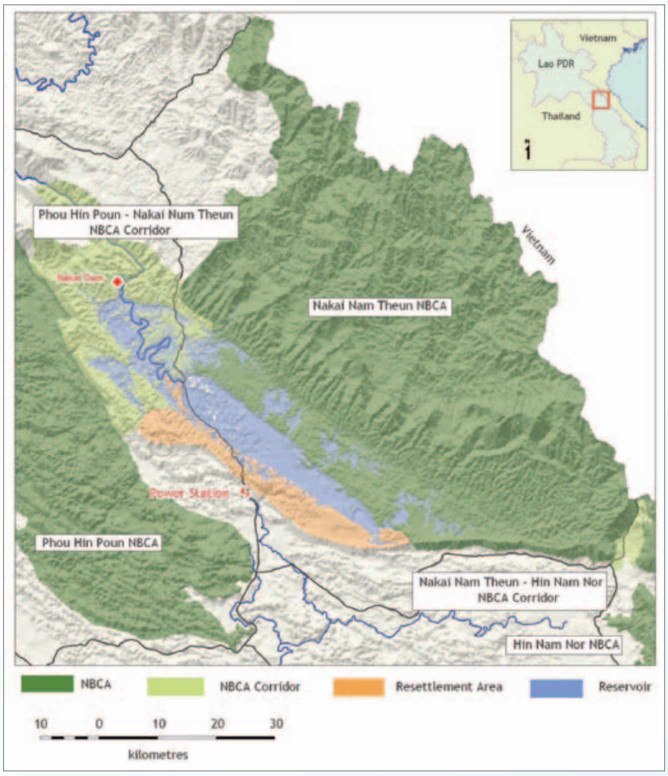


Figure 3.2: NBCAs and corridor areas

the Project is not operating for more than 16 hours in a given day, the diversion may drop below 30 m^3/s.

A consequence of the diversion of water from the Nam Theun to the Xe Bang Fai is that the discharge in the Nam Theun downstream of the Nakai Dam will be reduced to a minimum weekly average of approximately 2 m^3/s during the dry season. An analysis of the riparian release, and the implications of the reduced discharge on fish populations downstream of the Nakai Dam, is to be conducted during the dry season of 2004. This change in discharge will primarily affect approximately the first 12 km of the Nam Theun downstream of the Nakai Dam, after which a major tributary, the Nam Phao, joins the river. In addition to affecting the fish populations in the Nam Theun, the diversion of water will also influence the operation of the Theun Hinboun Hydroelectric Project, located downstream from the Nakai Dam.

Hydrologic Changes in the Mekong River

The annual flow in the Mekong River, over a distance of 189 river kilometres from the Nam Kading to the Xe Bang Fai, will be somewhat reduced due to diversion of water from the Nam Theun to the Xe Bang Fai. The activities of both the Project and the Theun Hinboun Hydroelectric Project will decrease the discharge of water to the Mekong from the Nam Kading. Over the year, the average reduction in discharge in the Mekong between the Nam Kading and the Nam Hinboun is estimated to be 302 m^3/s. Between the Nam Hinboun and the Xe Bang Fai, the Project will decrease the discharge of the Mekong River by an average of approximately 220 m^3/s. However, the reduction in discharge to the Mekong is relatively small in comparison with the total discharge in the river. Average discharge for the Mekong at Nakon Phanom is approximately 7384 m^3/s. Consequently, the diversion of water caused by the Project is only about three percent of the total discharge in the Mekong River, and therefore it is expected that the diversion will not impact navigation or fish populations significantly.

The Theun Hinboun Hydroelectric Project diverts approximately 82 m^3/s of water from the Nam Theun to the Nam Hinboun (RMR, 2000). Even when the Project is combined with this diversion, the variations in flow produced fall well within the natural range of annual variation in the Mekong. Unregulated, the Nam Kading contributed a mean annual volume of over 697 m^3/s to the Mekong River. The trans-basin diversion from both Projects is approximately 302 m^3/s, or 43% of the unregulated flow of the Nam Kading.

Part of the regional implications of diverting water from the Nam Theun to the Xe Bang Fai is the potential impact on the Mekong estuary. During the rainy season, the reservoir will store water in the reservoir and consequently reduce discharge to the Mekong downstream from the mouth of the Xe Bang Fai. This could result in some degree of salt water intrusion into the estuary. However, the average flow at Phnom Penh between June and September is 26,200 m^3/s. Therefore an average discharge reduction of approximately 500 m^3/s in August represents a reduction of less than two percent of the flow at Phnom Penh: the reduction in discharge of the Mekong during flood season will not be significant. During the dry season, the Project will supplement the discharge to the Mekong River and saltwater intrusion into the estuary may be lessened. On average, discharge to the Mekong during the dry season will increase by approximately 220 m^3/s, with periodical increases of 330 m^3/s. During periods of low discharge in the Mekong, the Project's supplement to the discharge will actually reduce saltwater intrusion into the estuary compared to current levels. When discharge is reduced to 30 m^3/s, saltwater intrusion will be approximately the same as it is under current conditions. The Cumulative Impact Assessment study currently being carried out will provide further information about Project impacts on the Mekong River.

Effects to Operation of the Theun Hinboun Project

The third major issue is how diverting water from the Nam Theun will affect the operation of the Theun Hinboun Project. Prior to construction of the Theun Hinboun Project, the Theun Hinboun Power Company (THPC) simulated operations both with and without the Nam Theun 2 Project. EGAT's request to operate the Nam Theun 2 Project on an intermediate peaking basis has introduced a change in the design of the power station since the evaluation of impacts to the Theun Hinboun operation was conducted. However, the design changes did not alter the anticipated operational impact on Theun Hinboun power generation capacity and downstream discharges. Analysis of Project impact on the Theun Hinboun project indicates that generation of energy by the Theun Hinboun power station will be reduced by just over 15% compared with pre-Nam Theun 2 Project generation. The spills from the Theun Hinboun diversion reservoir will decrease from an average 245 days to an average 190 days per year when the Project becomes operational (i.e. from 67% to 52% of the time). As a corollary, the periods when riparian discharge immediately downstream of the Theun Hinboun dam are limited to the minimum riparian release of 5 m^3/s will increase from an average of 120 days to an average of 175 days per year. Combined energy yield from the two hydropower stations will increase by approximately 350 percent to an estimated 7,100 GWh per annum (Lahmeyer Meritec, 2000), based on the assumption that the installed capacity at the Nam Theun 2 Project will be 1,070 MW. The Theun Hinboun power station will continue to receive benefits from operation through the Project construction period and during the period when the reservoir is filling. Analyses have shown that additional flow could be released from Project during the filling period and that partial regulation could be afforded by the cofferdam during construction (Lahmeyer-Meritec, 2000).

Effects of Diversion on the Xe Bang Fai

Diversion of water from the Nam Theun to the Xe Bang Fai will have a number of impacts on hydrology, river morphology, water quality, fisheries and the livelihoods of people living along the Xe Bang Fai. To ameliorate the increased flow, a regulating dam and pond will be constructed immediately downstream of the Power Station to regulate releases from the Power Station and ensure a relatively constant flow into a downstream channel during the period from Monday to Saturday.

When the Power Station is generating electricity, much of the water will be stored in the regulating pond. Controlled release from the regulating pond will enable a more constant flow to the Xe Bang Fai, thereby reducing discharge fluctuations in the river channel. Experience elsewhere indicates that fluctuating discharges increase the potential for erosion of riverbanks. Consequently, maintenance of a relatively constant flow in the Xe Bang Fai will reduce the potential for erosion. However, to reflect power demand on Sundays, the amount of water discharged from the regulating pond to the downstream channel may be reduced to a minimum of 30 m^3/s.

The normal dry season discharge in the Xe Bang Fai is approximately 20 to 30 m^3/s. Therefore the Power Station will increase the discharge in the river by about tenfold during the dry season and it is expected that the river channel will be eroded. Erosion will occur through a combination of weekly fluctuations in water level and because water diverted from the reservoir will have a small sediment load. As a consequence, the increased discharge will have a considerable capacity to carry sediment and erode the banks. The Xe Bang Fai's morphology will continue to enlarge until the river stabilises at a new cross section that can accommodate the low sediment-loaded Project discharge and water level fluctuations. The adjustment of the Xe Bang Fai channel will likely occur over a period of a number of years.

Within the downstream channel, an aeration weir will be constructed to aerate water discharged from the power station, with the objective of increasing dissolved oxygen and decreasing the amount of methane in the water.

During the rainy season, discharge from the Power Station will be restricted so that the Project does not contribute to natural flooding in the Xe Bang Fai region. When discharge in the Xe Bang Fai at Mahaxai approaches 1,970 m^3/s, discharge from the power station will be reduced and will have ceased before the flow in the Xe Bang Fai at Mahaxai reaches 2,270 m^3/s, in order to prevent the Project from causing any additional overbank flooding in the Xe Bang Fai.

Cumulative Impact Assessment

Introduction and Scope

Given the potential for Project impacts to have wider implications when considered in the context of other development trends, a Cumulative Impact Analysis (Norplan, 2004), was undertaken to analyse the combined impacts of a number of projects, either implemented together or in a sequence and of future developments and plans, in relation to the Project. The scope of the CIA includes effects other (future) developments have on the type and magnitude of Nam Theun 2 impacts (added impacts); and impacts of development in other sectors that are induced by the Nam Theun 2 Project (induced impacts).The geographical coverage of the CIA includes the Mekong Basin, Nam Theun/Nam Kading, Xe Bang Fai and Hinboun basins and the linear development zone of transmission lines and roads. In addition, border areas are covered in relation to social development, transport and biodiversity.

Table 3.2: Cumulative Impacts of Anticipated Regional Developments Including Nam Theun 2 Project

Impact Zone	5-year scenario	20-year scenario
Nakai Plateau	Impacts dominated by Project activities. Some additional impacts envisaged due to improved access following the construction phase and temporary population increase. Key impacts will be increased pressure on wildlife (e.g. from hunting and logging due to an influx of people and better access to the area), increased health risks (STDs including HIV/AIDS) and increasing frequency and severity of vehicular accidents.	Situation stabilized but significantly changed compared to current baseline. Transport communications will be significantly improved and new activities will have been attracted to the reservoir (e.g. commercial fisheries and tourism). Anticipated situation is: (i) Sanitation and water supply improved (ii) Oudomsouk population higher than during the Project construction period by some 140-150% (iii) Commercial fisheries will be established (iv) Health conditions improved with reduced incidence of malaria and food and water borne diseases, and shift from communicable towards non-communicable diseases (v) Health and education services improved (vi) Increased employment in service sector including tourism (vii) Increased cultural integration on the Plateau with blurring of ethnic identities
NNT NPA	(i) Reservoir will affect fish migration in the Nam Theun (ii) Better protection of biodiversity and forest resources through SEMFOP but also increased threats linked to road construction and population increase on the Vietnamese side of the border (iii) Improved delivery of social services including access to education, availability of medicines, possible reductions of malaria and nutritional problems (iv) Some integration of ethnic minorities but not to the same extent as on the Plateau (v) Some improvement in poverty alleviation (vi) Improved management and enforcement efforts in the NNT NPA may increase pressure on other NPAs	(i) Change in fish biodiversity and production dependent on type of fish population that establishes in the reservoir (ii) Increased threat to biodiversity due to population increase on the Vietnamese side of the border and increased exploitation of the NPA (iii) Further improvements in social services including immunisation coverage, hygiene and nutrition, health centres and functioning village schools (iv) Considerable out-migration and labour migration to urban areas due to natural population increase (v) Process of integration with lowland Lao culture will have proceeded further and led to assimilation of small Vietic groups (vi) Significant reduction of poverty in terms of food security, better market access and employment
Xe Bang Fai Basin and Surrounding Districts	Impacts of Project operation have started to be felt. New Road 12 will also have significant impacts. Cumulative impacts are likely to be: (i) Increased untreated wastewater due to higher population around Gnommalat and Mahaxai (ii) Commercialisation and intensification of agriculture in Mahaxai and Gnommalat, but only moderate expansion in irrigated rice area (iii) Increased logging in undisturbed forest and other areas (iv) Considerable expansion of Gnommalat and Mahaxai settlements (v) Increased prevalence of STDs (e.g. HIV/AIDS) and vehicular accidents more common (vi) Capacity of the various district services considerably strengthened due to Project support	No new large-scale hydrological changes are foreseen, but the transport corridors and accompanying urbanization will be a significant development in relation to cumulative impacts. Situation likely to be: (i) Reduced problem of oxygen depletion due to less organic matter in the reservoir and improved wastewater treatment (ii) Localised eutrophication and increased levels of pesticides in rivers and fish due to intensified agriculture (iii) Reduced biodiversity and fish production due to disturbed spawning cycles caused by changed hydrological regime. However increased flooding may increase flood plain and swamp production of fish (iv) Improved sanitation, health services and awareness on health issues. Water-borne illnesses and intestinal parasitic infestations substantially reduced and mortality from malaria and dengue fever strongly reduced (v) Substantial growth of Mahaxai and Gnommalat (perhaps by 200%) and of Thakhek (by 140-150%). Growth in service sector including tourism and expansion of cement industry in Mahaxai creating employment (vi) Some assimilation of ethnic minority groups in urban areas will have occurred, but cultural identity will be retained in rural areas
Nam Theun, Nam Kading and Nam Hinboun basins and surrounding districts	Nam Kading and Nam Hinboun will experience the combined impacts of Nam Theun 2 and Theun-Hinboun Extension Projects, in addition to the developments caused by improvement of Road 8 corridor, and increased cross-border trade and population movement. Predicted impacts are: (i) Reduced discharge in Nam Kading (below Theun Hinboun dam) in the flood season. With the Theun-Hinboun Extension, cumulative impact will be diversion of a larger part of the flood into the Nam Hinboun further reducing flows in the Nam Kading (ii) Reduced flood periods affecting fish migratory behaviour (iii) Increased threats to biodiversity due to population increase and increased trans-border traffic. (iv) Remaining and limited forested areas increasingly encroached upon but participatory village forestry will have been introduced (v) Increase in irrigated areas and irrigation schemes along Nam Hinboun (vi) Population of Lak Xao increased to 17,000 - 18,000, partially due to in-migration (vii) Gradual integration of ethnic groups into mainstream economy will be accelerated slightly due to Nam Theun 2 related activities, population influx, increased urbanisation, improved infrastructure and growth in service sector. Vulnerable Vietic groups will be under particular pressure of integration.	No further hydropower expansion planned in the basin. Development will be dominated by increase in transport related activities and impacts and developments on the Plateau. Situation likely to be: (i) Increased pressure experienced in Nam Kading NPA, Phou Hin Poun NPA and Nam Chat/Nam Pan Provincial Conservation Forest due to increased pressure of cultivation, logging and hunting and as a result of improved protection of NNT NPA (ii) Rural-urban migration trend reinforced and size of Lak Xao increased to 27,000 – 28,000 (iii) Full assimilation of smaller ethnic groups, in or near Lak Xao (including some Vietic groups), loosing their ethnic identity (iv) Hmong cultural traditions and language are likely to continue despite changes in the socio-economic conditions

Table 3.2 (cont.): Cumulative Impacts of Anticipated Regional Developments Including Nam Theun 2 Project

Impact Zone	5-year scenario	20-year scenario
Mekong River Basin (Scenarios include all hydropower developments in the basin including Yunnan)	Dominant factor will be some additional development of hydropower in Yunnan (China) and Lao PDR. The impacts are calculated to be: (i) Dry season discharge at Savannakhet may increase by 45%. During floods, discharge reduced by 7% (ii) Water levels at Phnom Penh will be lower during floods and increased during the dry season. Average annual maximum level of Tonle Sap lake will also be reduced (iii) Changes in flow pattern will have a small negative impact on floodplain and Tonle Sap lake fisheries as these are favoured by high wet season water levels (iv) Changes in flow pattern will however have a small positive impact by damping damaging flood incidents and by increased dry season water level that will support irrigation and reduce salt intrusion in the Mekong Delta	Dominant impact will be further development of hydropower in Yunnan (China) and Lao PDR. Impacts are calculated to be: (i) Dry season discharge at Savannakhet may increase by 135%. During floods, discharges may reduce by 22% (ii) Water levels at Phnom Penh will be lowered further during floods and increased further during the dry season. Average annual maximum level of Tonle Sap lake will be further reduced. (iii) Changes in flow pattern will have a significant negative impact on floodplain and Tonle Sap lake fisheries (iv) Changes in flow patterns will however have a significant positive impact by damping damaging flood incidents and by increasing dry season water levels that will support irrigation and reduce salt intrusion in the Mekong Delta

Two development scenarios have been assessed based on a 5-year and 20-year planning horizon. These scenarios cover a number of sectors by examining the present situation, existing plans and development trends. Sectors covered are: hydropower, transport, irrigation, water supply and sanitation, urban development, fisheries, forestry, industry, social development (including ethnic minorities, health, education and social disparity), and conservation (biodiversity issues). Of all these sectors, hydropower is the most planned and has the greatest potential to affect the whole Mekong Basin in terms of active (seasonal) storage of water. This results in increased dry season and decreased wet season flows.

Cumulative Impacts of Anticipated Regional Development

A summary of anticipated cumulative impacts of Nam Theun 2 when combined with the anticipated developments in other sectors described above over a 5 and 20 year planning horizon are presented in Table G.1.

The CIA also examined the specific contribution of the Project to the downstream changes in the Mekong described above. The Project alone is predicted to result in an increase (of c. 8%) in dry season discharge at Savannakhet while reducing flood discharges by 2%. The Nam Theun 2 reservoir is also expected to cause only minimum retention of sediments.

The CIA concluded that the Nam Theun 2 Project alone will have an insignificant (significance is based on whether or not the induced impacts of the Project are within the range of normal fluctuations) negative impact on the Mekong floodplain and on all aspects of the Tonle Sap lake including fish production. It recommends a number of best practice actions to mitigate and compensate impacts of developments and predicts the results of these actions on the 5-year and 20-year scenarios. These recommendations will be considered by GOL and jointly discussed and implemented with the donor community and international agencies such as the Mekong River Commission.

Sectoral Environmental Assessment of the Hydropower Sector

The Lao Hydropower Development Strategy was developed based on a series of studies on the power sector undertaken over the last 10 years. Many of these studies, have incorporated environmental and social criteria in choosing alternative hydropower development plans and discussed the environmental and social issues related to development in the sector. A Sectoral Environmental Assessment for the Lao Hydropower Sector (Norplan, 2004) has been undertaken to consolidate, update and expand this previous work in order to clarify the broader issues faced by hydropower development in Lao PDR and develop strategic priorities for improving the management of environmental and social issues within the sector. Broad recommendations relevant to all potential developments in the sector include water and land related mitigation measures, compensatory programmes including catchment protection, forestation plans, fisheries development plans, social and ethnic minority development plans and nature protection measures. Strengthening the capacity of GOL and its agencies to understand and take account of environmental and social issues is also recommended.

Intact River Assessment

The conservation of fresh water ecosystems throughout the world has become a significant issue, relative to the development of hydropower projects as well as water supply systems and irrigation systems. In many countries, policies for establishing intact river systems have become a national priority. Means for retaining river systems as intact rivers are developing in the United States, Switzerland, Norway, Sweden, and other countries around the world.

The Hydropower Development Strategy Study (Worley International, 2000) suggested that GOL establish a policy for retaining some of the rivers within Lao PDR as "intact rivers", thereby maintaining the diversity of habitats and species within those basins. This is being considered by GOL.

Regional Biodiversity

The designation of the NBCAs forms an integral part of maintaining biological diversity in the region. Significant areas of forest exist on the eastern side of the Mekong River basin. However, on the western side, much of the forests has been converted to agricultural production. The designation of more than 20% of Lao PDR's area as NBCAs is a prime regional and global issue.

Impacts of the Project on terrestrial and aquatic biodiversity are discussed later in this chapter. An initial contribution of US$ 6.6 million, together with an annual contribution, during operation, of US$ 1 million from NTPC to the management of the NNT NBCA, will assist maintenance of biological diversity of the area and will enable maintenance of a managed watershed for delivery of water to the reservoir. The provision of financial assistance to manage this protected area is important on both a global and regional level. The NNT NBCA is the largest protected area within Lao PDR and is considered to be one of Asia's most important protected areas (Robichaud 2002) and of outstanding importance in terms of global biodiversity (MacKinnon 1997). The NNT NBCA is also recognized as having the greatest extent and quality of forest cover (Berkmuller et al 1995), and is ranked highest in terms of threatened bird and mammal species (Ling 1999). Regionally, the NNT NBCA borders the Vu Quang Nature Reserve in Vietnam and is directly linked to the PHP NBCA and HNN NBCA in Lao PDR by corridor areas. Given its central location, the NNT NBCA is considered the cornerstone for the system of protected areas in the region. Maintenance of the watershed, particularly as an intact forest, will reduce the potential for sediments to flow into the reservoir and thereby reduce the storage capacity of the reservoir. This financial contribution will also be used to improve the livelihoods of residents of the NBCA as well as minimise the potential for future wildlife trade and abusive harvest from the forest.

Management of the NBCA is currently conducted by the District Department of Forestry with its headquarters on the Nakai Plateau. A framework of programmes will be implemented in the NBCA for management of the area and is discussed in the SEMFOP. These programmes include: i) forest and land use planning, allocation and management; ii) biodiversity monitoring, management and protection; iii) village livelihood development; and iv) community and social development. Some of the programmes are currently being implemented as a consequence of the initial programme conducted by IUCN/WCS and a continuing project known as the District Upland Development and Conservation Project. Among the programmes that have been implemented is a programme to reduce wildlife trade within the NBCA. Seven villages are participating in the programme at present and all of the villages within the NBCA should become involved in the future. Management of the wildlife trade is a major component in conserving the 16 endangered and threatened bird and mammals species known to inhabit the NNT NBCA. Some of the species that will benefit from these mitigation measures are globally threatened, including the Asian elephant, tiger and wild dog.

Topography, Geology & Soils

Baseline

Dam Site

The geologic formation at the dam site consists primarily of sandstone. The weathering of the rock has created from three to ten metres of colluvium overlaying the sound rock. The integrity of the rock at the dam site will influence construction of the dam and spillway sections. Some outcropping can be observed at the site and has influenced the actual design of the dam and spillway structures. Some mudstone and siltstone is evident in the sandstone layers. These will influence the design of the dam and will likely require a grout cut-off curtain to improve the safety of the dam. Some jointing of the rock is evident from the surface.

Nakai Plateau

Geology

The topography of the Nam Theun basin and soils are closely related to the geology. Shallow dipping sedimentary rocks form a broad synclinal basin, which trends northwest-southeast and varies from 15 to 35 km wide. Within the basin, the topography is generally gently sloping and coincidental with the bedding dip.

Within the Project area, the reservoir area can be divided into the Nakai basin, centred on the Nam Theun (80 km long and 30 km wide), and the tributary Nam Malou sub-basin, on the south-western flank of the Nakai basin. These basins are structural and correspond to syncline structures. From the centre of the Nakai basin, at El 520 m to El 550 m, the ground surface rises to a line of peaks at between El 1,100 m and El 1,300 m along the northeast margin of the basin. The southwest margin of the basin (and Nam Malou sub-basin) is marked by a lip at El 600 m to El 700 m with saddles or passes at elevations slightly less than maximum water level. This is where the saddle dams will be constructed to prevent loss of water over the escarpment. This lip marks the top of a prominent escarpment, which drops down to the Nam Kathang and Nam Hinboun basins. Downstream, these two valleys and the main streams they join cross a highly karstic limestone formation marked by rugged topography, with pinnacles rising 400 m. This area has been designated the Phou Hin Poun NBCA and is not directly impacted by the Project. Regional geology is depicted in Figure 3.3.

Potential Local Faults

Satellite imagery indicated that folded structures forming the Nakai syncline are repeated in the older underlying sedimentary rocks, including permo-carboniferous limestones. One fault was noted in the analysis, the Nam Gnouang fault, which is close to the Nakai Dam site (Roberts, 1996). This fault is part of a series paralleling the Red River Fault, which runs through central and southern Lao PDR. The main faults in this series are outside the proposed Nakai Reservoir area and there is no evidence of recent activity along these faults (EDF, 1996a). Several potential faults were observed, two of which were interpreted as faults near the Nam Kathang and the edge of the reservoir basin. These potential faults were investigated but did not indicate measurable displacements. Another potential fault was investigated in 1995. It represents the transition of bedding orientation from the tabular structure of the Nakai Plateau to the steep structure of the Nam Kathang rim, and the transition does not represent faulting. Based on available information, no major faults or interpreted faults that would affect any of the Project features have been identified (EDF, 1999). Additional geotechnical work will need to be done for the dam alignment, the tunnel alignment, the Power Station and the Downstream Channel before the final design is prepared.

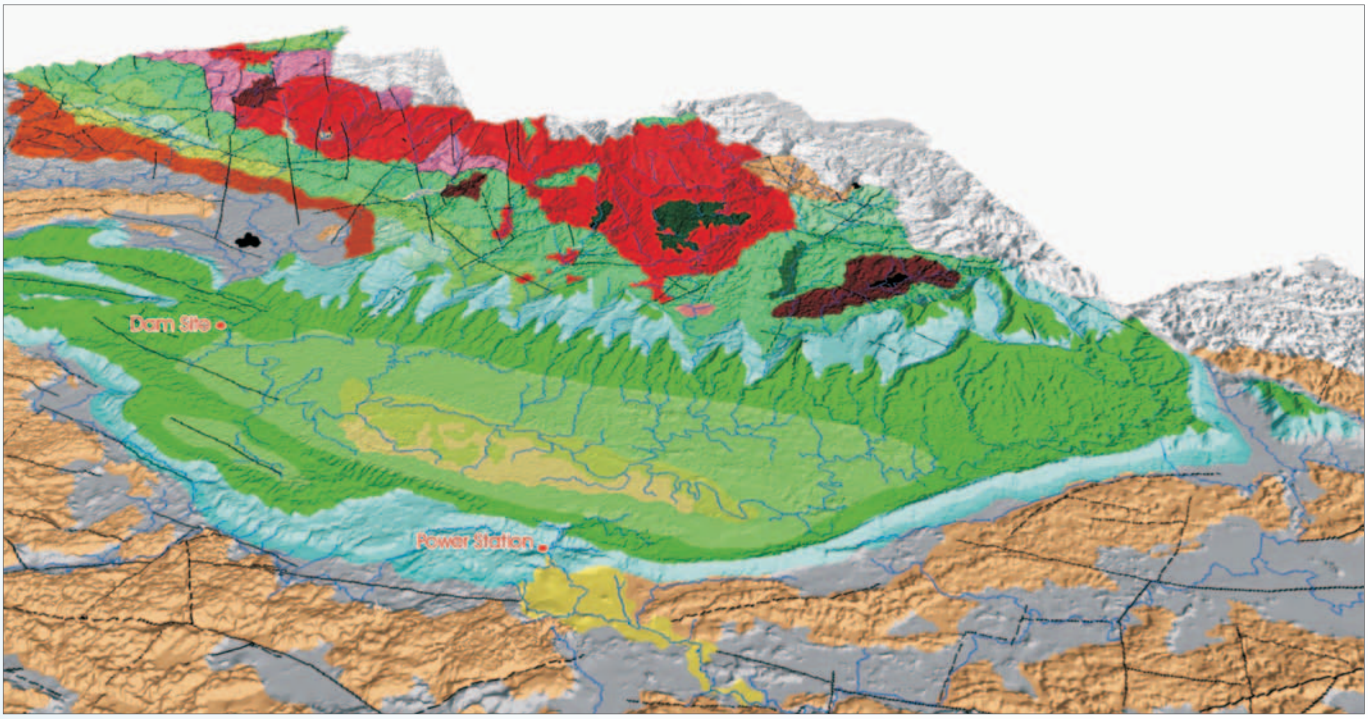
Soils

The escarpment consists of well-bedded siltstone, mudstone, and fine to medium sandstone. The upper part of the formation within which the dam is located also comprises coarse-grained sandstone and a pebbly soil horizon. In the very centre of the area lies the youngest basement geologic formation, composed of evaporite rocks, mainly halite with gypsum caprock when cropping out. Topsoils in other areas of the escarpment are stiff to hard lateritic material (meaning highly permeable weathered material from parent rock) of one horizon. A large portion of the basin, above the core area below the peaks to the northeast and edge of the escarpment, has forest cover growing in tropical soil horizons composed of Acrisols, and Ferralsols. Much of this area contains a higher proportion of rock than soils.

Alluvium deposition conditions exist in two areas in the Nakai basin. In the central part of the basin, late Tertiary deposits lie in a 38 km by 6 km band. The river meanders through this area and has created a number of wetlands. This wide band of deposition consists of soils that are soft to very stiff, silty clays and loams. Through this band, soils right along the river are more recent alluvium material that consists of fine to coarse sands. A second area of deposition exists in the sandstone area, upstream of the proposed dam site, and before the Nam Theun starts cutting down out of the Plateau. Soil horizons in this deposition area contain more sand and are sandy loams.

The better-developed soils are in the degraded gypsum area, but they tend to be salty and do not drain well. Soils in the Tertiary deposits band do drain and have supported a limited agricultural community. These alluvium soils are a mixture of loamy and sandy loam soils over loamy silts, with moderate permeability, but they tend to be slightly acidic, with low to moderate fertility.

The identified resettlement areas of about 3,460 ha have soils that are residual materials from weathered sandstone and mudstone.



Age	Formation	Map Key	Description	Approx. Thickness
Quaternary	Unnamed		Alluvium & colluvium: fine to coarse gravel & sand, silt & clay; unconsolidated to poorly consolidated gravel, sands & clays	–
			As above, with higher relief remnants of Maha Sarakhan formation (described below)	
Unconformity				
Mid Cretaceous to Tertiary	Maha Sarakhan		Crystalline halite & gypsum; red-brown & gray clay	< 150m
Lower Cretaceous	Khok Kruat		Fine to medium grained micaceous & quartzose red-brown & gray sandstone: brown-red to brown mudstone & siltstone	600 m
Middle to Upper Jurassic	Phra Wihan		(a) Fine to coarse-grained quartzose sandstone with pebbly to conglomeritic beds; light brown-white to gray to red-brown	1,100 m
			(b) Fine to medium grained quartzose to quartzlabile sandstone; green-gray to red-brown	
			(c) Brown-red/gray-green mudstone & siltstone (commonly sideritich)	
Lower Jurassic	Phu Kradung		Brown-red/gray-green mudstone & siltstone; thinly bedded grey mudstone/siltstone; fine to medium grained dark gray to green-gray quartzose sandstone; gray shale, purple & green marl & minor dark gray micritic limestone lenses near base	400 m
Unconformity				
	Sub-volcanic & Intrusive Complex		Sub-volcanic: Phase 1: porphyritic andesitodacite, porphyritic dacite; Phase 2: porphyritic rhyolite, porphyritic trachyrhyolite;	
			Intrusive: Phase 1: pink, porphyroid biotite granite, granodiorite (?), medium-grained biotite granite; Phase 2: aplite	
Upper Carboniferous to Permian	Unnamed		Karstic, dark gray, micritic limestone	100's m
Lower Carboniferous			Sandstone, gray silty sandstone, some thin interbeds of coal, beds: Calcareous, occasionally Nodular & fossiliferous, carboniferous	
	Intrusive Complex		Phase 1: porphyritic, coarse grained melanocratci biotite granite; Phase 2: Medium grained biotite granite, bearing cordierite; Phase 3: Pegmatite, aplite	
Unconformity				
Devonian	Unnamed		Gray siltstone & darg gray to black carbonaceous/calcareous shale; dark gray argillaceous limestone	–
Unconformity				
Proterozoic to Lower Paleozoic (Ordovician)	Unnamed Upper Ordovician		Partially to strongly metamorphised sediments: thin-bedded quartz serricite schist; thick-bedded quartz sandstone, quartz serricite schist;	–
	Lower Ordovician		Partiallt to strongly metamorphosed sediments & volcanoclastics: quartz-sericite schist, tuffaceous sandstone, with lenses of andesite & quartzitic sandstone, a little calcareous shale	
Proterozoic			Basement complex: low to high grade metamorphic schists & gneiss	

Figure 3.3: Regional geology

Most of the weathered soil is usually transported away, leaving a shallow soil layer with many rock outcrops. The soils are sandstone derived, free draining, and heavily leached. A further 1,000 ha has soils derived from sandstone, where the soils are fine sandy loam over a clay loam subsurface. The soils are acidic in both layers and are considered well suited for pasture, but moderately to poorly suited for field crops. Limitations are caused by the acidic nature and water deficiency, due to the moderately permeable nature of the soil that allows water to drain away. Results of soil surveys and analyses in the area of the pilot village are detailed in the report from the GOL Soil Survey and Classification Center (2001) and summarised in the SDP with indications of the agricultural implications.

Headrace Channel & Surge Shaft

Looking southwards along the layout of the headrace channel from the centre of the Nakai Reservoir, the topography is low relief, gently undulating and very gently rising with dip slopes to a major gully approximately 1,350 m from the intake. Between this gully and the edge of the escarpment at approximately El 550 m, about 600 m further south, the topography reflects the underlying steeply dipping strata with narrow ridges and deeply incised gullies. The surge shaft is located on the lip, formed with hills culminating at about El 550 m, which dominates the Nam Kathang and tributary valleys with steep slopes. The area surrounding the surge shaft is cut by deep thalwegs, at the bottom of which can be observed steep dips that are almost vertical.

Tailrace, Regulating Pond & Downstream Channel

The tailrace channel, regulating pond and a short segment of the downstream channel are situated in the Nam Kathang Noy valley. The foundation for the regulating dam and the right abutment are impervious mudstone and siltstone. The left abutment is an alluvium terrace with bedrock up to eight metres below the eventual pond level. Treatment to prevent seepage losses and subsequent possible erosion is planned for this area. Along the tailrace channel, the overburden is between 10 and 15 m deep. Overburden consists of silt, clayey silt with occasional sand, and gravelly intervals. The soil in this area is relatively fertile. From near Ban That, the downstream channel will be in a limestone formation and will require treatment to maintain the water in the channel. The limestone formations have numerous caves with potential for interconnection among them. Southwest of Ban Gnommalat, a subterranean course was identified for the Nam Phit (Process Design Geological Report, Open Air Works, EDF, 1994). The karst and the fracture network of the limestone massif form an aquifer with very high permeability, which is effectively in equilibrium with the alluvium water table. This will result in exchanges between the two and the downstream channel in either direction, depending on the season and the channel discharge regime.

Soils in the first 10 km of the downstream channel support rain-fed and irrigated paddy systems. The rest of the downstream channel route is primarily old alluvium common to riverbeds. Agricultural soils are similar to the better soils in the valley and have more sandy loams and loams with moderate permeability. Soils that support rain-fed lowland paddy tend to be highly weathered, moderately acid with a base saturation of 50% or more within 125 cm of the surface (Driessen and Dudal, 1991). Soils of the Gnommalat Plain typically have low clay content, low organic matter content, and extractable acidity (soluble Al and Fe). Their low water retention capacity makes them very drought prone (Lao-IRRI, 1995). Alluvium in the area consists of over-wash sandy to silty clay soils that are somewhat poorly drained.

Reaches of the Xe Bang Fai

Most of the lower terraces used for agricultural purposes along the Xe Bang Fai, below the Nam Phit junction and above the bridge on Road 13, are identified as Acrisols or Cambisols soils. Below the bridge, more Alisols than Acrisols are found. Due to the nature of sediment deposition along the river banks, the soils contain Arenosols that are coarser than sandy loam but still have less than 35% coarse rock in all horizons. Arenosols only have an orchic A or albic E-horizon (Driessen and Dudal, 1991).

Potential Impacts

Reservoir Induced Seismicity

In a synthesis of worldwide available data on this topic SMEC (1991) indicated that this risk is generally associated with the combined effect of a reservoir of over one billion m^3 capacity and a dam over 100 m in height. Reservoir impoundment alters the stress regime within the crust by increasing the shear stress due to the weight of the water and reducing the shear strength by increasing pore-water pressure. It is agreed that these changes are not sufficient to create failure in unfractured rock. It is possible however, that faulted rock with a high stress level may slip as a consequence of reservoir impoundment. The active storage volume of the Project reservoir is 3,930 million m^3 with an operating range of about 12.5 m. The Nakai Dam does not exceed 48 m in height and the maximum reservoir depth is restricted to a small area with an average depth of 7.1 m. Although the maximum reservoir volume of the Project exceeds the above volume criteria, the dam is small and the reservoir is relatively shallow. A theoretical approach to the analysis of potential reservoir-induced seismicity also indicated that the most susceptible sites are those under extensive tectonic activity, where vertical stress exceeds the horizontal stress. In the Nakai Plateau area, it is likely that the maximum stress component is approximately horizontal and the area has a notable lack of faults. The probability of reservoir-induced earthquake can be considered as low, and no significant impacts are expected from the reservoir loads.

Reservoir Water Tightness

The geological factors that could potentially lead to leakage of water from the reservoir at El 538 m are: i) the hydraulic relationship between the surface and the underlying limestone; and ii) the rim of the escarpment separating the Nakai basin and the Nam Malou basin from the Nam Hinboun and Nam Kathang Valleys.

Relationship Between the Reservoir & the Underlying Limestone

The geological layers forming the base of the reservoir are folded sandstones, siltstones and mudstones. The layers are about 2,000 m thick; at least 1,100 m at the dam site, and include the Nam Malou sub-basin. Some of the layers are typically considered watertight formations. A 566 m adit was opened in the vicinity of the power station and the power tunnel into the Plateau. The adit revealed that the rock was 85% sandstone within 200 m of the power station and tunnel alignment. Investigations with respect to groundwater in the adit indicated that the estimated maximum inflow was approximately 0.1 l/s. The purpose of determining the rate of inflow is to determine what measures need to be incorporated into the design of the tunnels and power station to prevent problems within the tunnels and power station structures. The level of water seepage from the adit indicates that there is very little water in the rock and that the sandstone will provide a watertight basin for the reservoir.

Table 3.3: Potential erosion rates

Scenario	Description	Topsoil Loss (mm/a)	Erosion Rate (kg/ha/a)	Sediment Load (tonnes/a)
I	Current rate, strict management of the NNT NBCA	0.04	580	231,530
II	Controlled land use and forestry management	0.20	2,920	1,160,000
III	Uncontrolled development	2.5	36,000	14,500,000

Relationship between the Reservoir & Adjoining Catchments

Investigations indicate that groundwater levels during the dry season are close to the reservoir future normal supply level or a little higher (El 534.5 m and 541 m). Test pits and borings at several locations requiring saddle dams indicate that foundations and abutments consist of clayey soils and are underlain by mudstones and siltstones. The foundation conditions for all of the saddle dams appear satisfactory. However, additional work will be done at the sites prior to the design of the saddle dams. Based on the results of these tests, it is anticipated that there will be no significant leakage of water through the saddle dams.

Impacts

Erosion & Sedimentation

Reservoir Area

Erosion Rates

The average annual sediment load in the Nam Theun was estimated at 231,530 tonnes by SMEC (2003) based on suspended sediment sampling at Ban Thalang (447 samples from 1988 to 2002) and at the Nakai Dam site (299 samples from 1994 to 2002). The Nam Theun catchment is eroding at an annual rate of 58 tonnes/km^2, or 580 kg/ha. This is equivalent to a top soil loss rate of 0.04 mm per annum. By global standards, and particularly for tropical areas, this is a very low rate of soil loss, but is consistent with the largely undisturbed, natural forested environment which characterises most of the catchment.

Loss of Storage Volume

Considering the capacity-inflow ratio of 0.52 (inflow of 7,527 million m^3, capacity of 3,910 million m^3) and the precision of the estimates of river sediment loads, SMEC assumes that all the sediment load of the Nam Theun will be trapped by the reservoir. The loss of storage volume in the reservoir will be determined by the incoming sediment load and the density of deposits. The sediment loads will depend on the future development of the catchment and the accelerated rate of erosion from the catchment. SMEC (2003) analysed the erosion rates of three land-use scenarios: i) Scenario I assumed that strict management of the NNT NBCA would maintain erosion rates at their current low levels; ii) Scenario II adopted a higher erosion rate expected from controlled land use and forestry management in the NNT NBCA; and iii) Scenario III adopted an erosion rate over sixty times the current rate that may result from uncontrolled development. The predicted sediment loads from these three scenarios are shown in Table 3.3.

The density of the deposits is influenced by the particle size distribution and is time dependent. Table 3.4 gives the percentage of the total storage volume occupied by sediment under the different scenarios.

At the current rate of catchment erosion, the loss of storage volume would be quite minor. The long-term reduction of reservoir storage can be exacerbated if development in the catchment is not properly managed (scenario III). Under scenario II, loss of storage volume after 100 years would be around 110 million m^3 or 2.8% of the total volume. The “dead” storage below the MOL of El 525.5 m is 380 million m^3. However, not all of the volume loss will occur in dead storage and the ratio will depend on the distribution of reservoir sedimentation, as discussed below.

Sediment distribution in the Nakai Reservoir was estimated by SMEC (2003) and is presented in Table 3.5.

Around 40% of the sediment deposits will settle in the live storage, according to computations for scenario III. This implies that if sediment yield were greatly accelerated under uncontrolled development within the catchment, loss of reservoir storage could be quite significant. Under scenario II, which can be considered as a possible scenario for the Project (SMEC, 2003), the reduction in power-generating capacity caused by the loss of storage volume would be acceptably small, even in the long-term.

Coarse sediments from tributary inflow (e.g. sand, gravel and cobble) will be deposited in the active storage of the reservoir, near the mouths of the tributaries, and will lead to the build up of a small delta. This will aggrade a short section of tributary channel upstream from the full supply level due to local changes in river gradient. Over time, the tributary deltas will gradually grow and the beds will aggrade for some distance upstream. Water levels in the aggraded reach will be higher than in the natural state. Some of the coarse sediment will be in active storage, with some in the aggradation zone and some reaching the dead storage. Some fine sediment (silt and clay) will be deposited in the backwater areas above and in active storage indicated by the spidery configuration of the reservoir where the tributaries enter.

Provided the amount of sediment deposited in the Project catchment is near to that predicted above, the impacts described above are not of serious consequence to either the function of the reservoir for energy production, or to environmental impact.

Table 3.4: Loss of storage volume (million m^3)

Years of Operation	Scenario I		Scenario II		Scenario III	
	Volume	%	Volume	%	Volume	%
10	2.3	0.05	12	0.3	118	3.0
20	4.6	0.12	23	0.6	231	5.9
30	6.8	0.17	34	0.9	343	8.8
50	11.1	0.28	56	1.4	562	14.4
80	17.5	0.45	89	2.3	886	22.7
100	21.7	0.55	110	2.8	1100	28.1

Table 3.5: Sedimentation distribution in the Nakai Reservoir

Storage	Sedimentation Distribution (%)		
	Type I Reservoir Scenario II	Type II Reservoir Scenario II	Type I Reservoir Scenario III
Live storage	41	25	40
Dead storage	59	75	60

Note: Type I refers to a “lake” classification and Type II refers to a “floodplain-foothill” classification (for more information refer to SMEC, 2003)

Proposed Mitigation & Monitoring

The appropriate management of the NNT NBCA should guarantee that measures are implemented to control erosion and sedimentation in the reservoir and to ensure that sediment yield will remain at the current estimated low level. From an economic and environmental perspective it is important that timber harvest in the NNT NBCA is eliminated and that slash-and-burn activities be limited to current levels or less. The objectives of the NTT NBCA management include activities to protect and rehabilitate the forest cover to ensure adequate water flows with low sediment to the reservoir. The management of NNT NBCA resources is discussed in more detail in the SEMFOP.

To assess whether the land use and forestry plans in the SEMFOP are being successfully implemented, the water quality monitoring programme will analyse levels of suspended solids and sediment size distribution in the Nam Theun tributaries entering the reservoir. Monitoring during the operational phase will be expanded to include sediment traps throughout the reservoir, to help develop an understanding of the sedimentation processes within the reservoir.

Although the resettlement area represents only a fraction of the catchment area, uncontrolled erosion will contribute to sedimentation in the reservoir. The implementation of the SDP will ensure that agricultural practices and forestry activities within the resettlement area prevent such erosion.

In-Stream Degradation

Downstream Nam Theun

As most of the products of catchment erosion and other sources of inorganic sediment will be deposited in the reservoir, the Nam Theun downstream from the dam will not receive its former supply of these materials. However, the low flows, which will be characteristic of this downstream reach after the dam is constructed, will be too small to cause erosive damage. Erosion of riverbanks in downstream sectors of the Nam Theun will not be a major problem as there are considerable lengths of rock zones present, and vegetation will tend to encroach in other zones. The infrequent spill events that will occur over the Nakai Dam when the amount of water coming into the reservoir is greater than the storage capacity of the reservoir will have the potential to cause erosion and remove the vegetation that will be established in the Nam Theun downstream from the Nakai Dam. Results from the riparian release and spill study will be discussed together with adaptive management of the flow and spills once the study is completed in December 2004.

Downstream Channel

The first 8.5 km of the downstream channel will be lined to avoid erosion. Downstream of the aeration weir, the downstream channel will be natural soil with rock protection at critical points. The confluence of the Xe Bang Fai and the Nam Phit will be lined to avoid erosion in this area. The situation will be monitored by NTPC and if it is determined that erosion is putting the structural stability of the downstream channel or the confluence area at risk, rectification works will be carried out as needed.

Nam Kathang

Project releases into the Nam Kathang will be equivalent to natural discharges. Therefore it is expected that the quantity released will not impact the current rate of erosion. The water discharged will tend to have a slightly higher capacity to carry sediment, but given the flow and lack of fluctuation, no significant increase in the erosion rate is expected.

Xe Bang Fai

The Xe Bang Fai is currently eroding, with slumping visible along its river banks. A trend of widening of the Xe Bang Fai channel has been observed over the period 1995 to 2002 based on a comparison of bench marked cross-sections (SMEC 2002). The river is characterised by banks 135m to 168m apart in the reach upstream of the Nam Oula confluence and generally 135m to 159m apart in the reach below the Nam Oula, although the channel width exceeds 200m in a few locations. The river bed is generally underlain by bedrock with a thick cover of alluvial deposits. The river bank is composed of fine grained alluvial material in the range of fine sand to silt. Isolated locations have clayey material in the banks. There are rock outcrops in the banks covering about 3-4% of the river length. The banks of the river display many areas of instability where slips have occurred, generally as a result of either toe scour and undermining, or excess pore pressures as the water recedes in the dry season. This is a natural process that is ongoing irrespective of the future Project. Changes in the hydrology, through both a difference in sediment load and fluctuations in discharge, will result in an increase in the rate of erosion whilst the Xe Bang Fai readjusts its morphology.

The total inorganic sediment load currently supplied to the Xe Bang Fai from upstream of the confluence with the downstream channel will not change significantly. However, as a result of sustained power station releases of water that is poorer in sediment, sand and finer sediment will be removed from the bed and bars in the river channel below the confluence with the downstream channel. Much of the bed profile of the Xe Bang Fai is controlled by rock outcrops and the river winds between hills of rock formations. The state of its bed and banks suggest that vertical stability of the channel is higher than its lateral stability. Its bed profile and general plan are therefore unlikely to change much. There may be stretches of weaker bank where the soil is sandy and easily erodible, while outside bends in the meandering river channel may erode because of larger and occasional low flows.

In the review of the river geomorphology, SMEC (2002c) predicted that erosion of the riverbanks will occur, with general widening of the river channel. Higher flows of low sediment-loaded water will increase the hydraulic energy for sediment transport, and increased frequency of high stage saturating riverbanks and weekly drawdown during the dry season will weaken the stability of bank material. Fluctuating water levels, particularly in the dry season, will tend to increase erosion through increased pore pressure while local increases in piping and tunnel erosion will occur due to the drawndown. In addition, inundation of existing bank vegetation for longer periods could impact riverine vegetation and reduce the binding effect of their roots, which would further increase the rate of erosion. However, it is expected that some species might become established up the banks, assisting in their long term stability. All increased rate of bank slumping and channel widening may be expected over several years after diversions commence. SMEC (2002c) estimated that widening of the channel could typically reach up to a maximum of 20 m during the initial active period of change, although widening will occur at the same rate everywhere. In general, the size of this loss will decrease as distance from the confluence with the downstream channel increases. Loss is predicted as being negligible by the time the river reaches the bridge on Road 13 (SMEC, 2002c). In 2004, SMEC conducted a further study (SMEC, 2004a) to refine this prediction on bank retreat and estimate the time it will take to reach the new equilibrium. The analysis of river bank regression utilized several approaches that take into account the new river regime and tractive force of the banks. The analysis was carried out on cross sections along the Xe Bang Fai, the locations of these are shown in Figure 3.4. The results of this additional study are presented in

Figure 3.4: Location of cross-sectional survey sites on the Xe Bang Fai (water level recorded December 2002)

Table 3.6 The revised estimate for bank regression using the river regime approach suggests that the average widening is 10.7m with an upper limit of 15.9m for the entire river. The revised estimate for bank regression is somewhat less for the tractive force approach, with an upper limit of 14.6m. The additional study reconfirmed the earlier SMEC (2002c) estimation that maximum widening of the channel would be no more than 20m. Over time, a new cross-sectional equilibrium that is able to accommodate the Project waters will establish, and the rate of erosion will decrease back towards existing levels. SMEC (2004a), using a Generalised Stream Tube model for Alluvial River Simulation (GSARS), estimated that the timeframe for a new state of equilibrium will not become established before two years after the new flow regime of the Xe Bang Fai starts. The process of adjustment to the river morphology is likely to be slow and obvious, giving communities sufficient time to adjust without unpredicted losses to property or injury.

Proposed Mitigation, Compensation & Monitoring

Several Project components are designed and will be operated to help minimise any increases in the rate of erosion in the Xe Bang Fai. These include: i) the retention of 8 million m^3 of water in the regulating pond and its controlled release to lessen water level fluctuations that could lead to increased pore pressure in the river banks and instability; ii) the operation of the regulating dam to limit the maximum rate of decrease in discharge through the downstream channel to 30 m^3/s/hour, in order to prevent rapid drawdown and the resultant pore pressure and iii) the downstream channel/Xe Bang Fai confluence will be strengthened to prevent erosion and will be monitored.

To establish natural erosion rates, NTPC is currently carrying out detailed cross-sectional surveys of 29 sites on the Xe Bang Fai. This monitoring will continue during Project operations to detect whether an increase in erosion rate has occurred. Figure 3.4 shows the locations of the cross-sectional survey sites on the Xe Bang Fai. Both remedial mitigation measures, such as bank protection and stabilisation (in those cases where it is economic to do so for important permanent structures or structures with community or cultural value), and asset and livelihood compensation will be considered and the most appropriate measure or combination of measures applied on a case-by-case basis by NTPC. Where building relocation is feasible, the Project will assist in the relocation of buildings that are under threat from the increased erosion. A survey of assets along the river bank will be undertaken prior to operations and mitigation and/or compensation will be planned for and implemented as required. Following the start of operations regular trips will be conducted by the Project to visually detect abnormal erosion, as well as impacts on previously identified village infrastructure and livelihoods. Villagers will also be able to alert the District Compensation Committees of any abnormal erosion rates or affected infrastructure and livelihoods.

Climate

Baseline

General

The climate of the Nam Theun and Xe Bang Fai catchments is influenced primarily by the seasonal southwest and northeast monsoons, the Intertropical Convergence Zone (ITCZ) and tropical cyclone disturbances such as tropical storms and tropical depressions.

The southwest monsoon (wet season) normally affects the catchments from mid-May to early October and is predominant when atmospheric pressure is low over Asia. This is a period of frequent and heavy rainfalls over the Project area. However, rainfall during the wet season usually exhibits a bimodal distribution, with a short dry period of one to two weeks, usually between June and July. After this period rainfall becomes more frequent, including heavy storms which result from tropical cyclones entering the region from the South China Sea, mostly during September and November. Flooding frequently occurs when two or more of these storms occur in succession or when the ITCZ, which is the forward edge of the southwest monsoon, has passed into one of its more active stages, with tropical cyclones following shortly thereafter.

A transition period, from mid-October to early November, is followed by the dry northeast monsoon (cold season) which normally blows from China between October and February. This season is characterised by sparse, relatively light rainfall, lower temperatures and humidity.

The northeast monsoon is followed by another transition period to the hot season from March to early May, and is characterised by increasing temperatures, rainfall and humidity. The transition is slower than the transition from wet to cold seasons.

Rainfall

Rainfall in the Project region is the highest that occurs in Lao PDR. The southwest monsoon produces a warm moist airflow into the area from May to September, and spatial variation of rainfalls is principally affected by orographic effects. High rainfall occurs

Table 3.6 : Predicted Width Increase in the Xe Bang Fai with Regime and Tractive Force Approaches

River Station	Width Original (m)	Regime Approach		Tractive Force Approach	
		Width Revised (m)	Width Increase (m)	Width Revised (m)	Width Increase (m)
1	136	146.1	10.1	145.2	9.2
2	167	179.3	12.3	178.3	11.3
3	136.8	146.9	10.1	146.1	9.3
4	215	230.9	15.9	229.6	14.6
5	143	153.6	10.6	152.7	9.7
6	163	175	12	174.1	11.1
7	168	180.4	12.4	179.4	11.4
8	147	157.9	10.9	157	10
9	155	166.5	11.5	165.5	10.5
10	154.3	165.7	11.4	164.8	10.5
11	135.1	143.5	8.4	142.8	7.7
12	143.1	152	8.9	151.3	8.2
13	152.9	162.4	9.5	161.6	8.7
14	140	148.7	8.7	148	8
15	135	143.4	8.4	142.7	7.7
16	230.8	245.1	14.3	244	13.2
17	202.5	215.1	12.6	214	11.5
18	165	175.2	10.2	174.4	9.4
19	207	219.9	12.9	218.8	11.8
20	144.4	153.4	9	152.6	8.2
21	159.2	169.1	9.9	168.3	9.1
22	147.9	157.1	9.2	156.3	8.4
23	169.6	180.1	10.5	179.3	9.7
24	134.9	143.3	8.4	142.6	7.7

Table 3.7: Mean monthly rainfall at representative stations with years of operation in parentheses (units: mm)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Ban Thalang (1987-2002)	5.3	24.6	55.3	85.4	306.6	442.8	561.2	526.4	296.7	97.3	12.3	2.8	2417
Nakai Damsite (1994-2002)	4.0	19.9	55.8	108.5	331.2	474.4	707.8	586.3	316.4	75.4	8.5	6.9	2695
B. Xoklek (1994-2002)	4.3	23.9	41.3	121.9	311.8	381.5	611.7	519.8	274.1	131.5	17.5	5.4	2339
B. Nameo (1994-2002)	11.6	14.5	28.7	14.3	202.6	240.6	470.8	594.1	287.4	313.3	41.3	16.2	1739
Mahaxai (1989-2002)	2.9	23.5	35.1	112.5	275.9	506.3	606.3	600.8	403.1	64.6	11.4	3.6	2646
Nakai Tai (1994-2002)	9.9	17.3	59.6	140.0	389.8	483.8	763.7	619.5	390.0	85.1	13.1	7.2	2979
Gnommalat (1994-2002)	0.0	21.2	34.1	110.6	245.6	400.0	578.5	497.7	293.7	35.9	4.8	1.6	2224
Nape (1922-44/1988-2002)	3.3	23.8	49.5	89.7	216.8	301.5	408.8	345.9	281.4	146.2	21.1	8.2	1896
Nakon Phanon (1953-2002)	5.1	25.8	48.8	101.7	249.2	452.6	454.0	572.6	292.8	66.9	6.5	3.1	2279

where physical barriers cause uplift. The limestone precipices and the main escarpment along the southwestern edge of the Nakai Plateau provide excellent conditions for orographic intensification of precipitation. The rugged terrain in the upper parts of the catchment acts as an additional barrier, but much of the moisture is precipitated at the first barrier. Apart from the spillover effect on the edge of the plateau, rainfall in the Nakai Plateau is likely to be rather less than in the upper parts of the catchment.

Monthly rainfall analysis indicates that the rainfall in the Nakai Plateau is highly seasonal, with 88% of the annual rainfall occurring between May and September (Figure 3.5). The average annual rainfall recorded at Ban Thalang between 1987 and 2002 was 2,417 mm (SMEC, 2003). The seasonal variation of precipitation is similar throughout Southeast Asia, with approximately 92% of the rainfall occurring between May and October. At Ban Thalang, 1994 and 1996 were the wettest years recorded between 1987 and 2001, exceeding the mean annual rainfall by approximately 30% at this site. The 1992 rainfall was the lowest recorded during the same period at Ban Thalang, at approximately 60% of the mean annual rainfall. Both 1992 and 1998 correspond with strong El Nino episodes. Table 3.7 shows the mean monthly rainfalls in the Project area and the station locations are shown in Figure 3.6. Precipitation records at other locations with a shorter length of record indicate relatively low variation in annual rainfall throughout the drainage area for the Nakai Reservoir. The mean annual rainfall for the Nam Theun catchment at the Nakai Dam site has been estimated at approximately 2,800 mm per year. Over an eight-year period (1994-2002), the average annual precipitation at the Nakai Dam site was 2,695 mm (SMEC, 2003). In the 14 years from 1989-2002, the mean annual rainfall at Mahaxai was 2,646 mm, and over the nine years from 1994-2002, mean annual rainfall at Gnommalat was 2,224 mm (SMEC, 2003). This indicates that significant spatial variation of rainfall occurs below the escarpment in the Xe Bang Fai catchment. Figure 3.6 incorporates the seasonal rainfall variability at relevant sites, while Table 3.8 shows the recorded maximum rainfall for 1-day, 2-day, and 3-day storm durations.

Relative Humidity

Mean relative humidity at Nakai Tai declines below 70% during the dry season, and exceeds 80% in the wet season, peaking at a mean 89% in July. Relative humidities near 100% can occur in the mornings at any time of the year. Humidity data for Nakai Tai, Nakon Phanom and Thakhek are presented in Table 3.9 and Figure 3.7. The Nakai Tai station is the most representative climatological station located within the Project catchment.

Table 3.8: Highest recorded rainfall in the Nam Theun region

Station	No. of Years of Record	Rainfall (mm)		
		1-Day	2-Day	3-Day
Ban Thalang	1987-2002	214	315	375
Nakon Phanom	1953-2002	459	517	545
Nape	1922-44/1988-02	356	449	500

Temperature

Reduced temperatures are experienced from November until February, with a peak in April before the onset of the south-west monsoon in May. Mean temperatures at Nakon Phanom, along the Mekong in Thailand, vary from 21.9° C in January to 28.8° C in April, with an annual mean of 25.9° C. Data collected in the Nakai Plateau shows temperatures are on average about 3° C cooler than at Nakon Phanom. Table 3.10 shows the monthly mean, average and extreme temperatures at Nakai Tai climatological station and Table 3.11 shows the monthly temperatures at Nakon Phanom climatological station. Figure 3.8 shows the seasonal temperature variability at Nakai Tai and Nakon Phanom climatological stations.

Wind Speed

Winds are generally light throughout the year with an average wind speed of 2.6 m/s at Nakai Tai, with some increase in average wind speeds during the dry season. During thunderstorm activity, convective currents may produce strong surface winds, usually of brief duration. The Project catchment is at the latitude where the maximum frequency of typhoon landfalls occurs along the Vietnam coast (15°-20° N). These occur most often from August to October. Although the Annamite chain presents a barrier to such storms, which usually dissipate rapidly overland, the catchment boundary is only 55 km from the coast and records indicate that during the past 40 years, three storms have retained typhoon strength (> 118 km/h) over the vicinity of the Nam Theun catchment area.

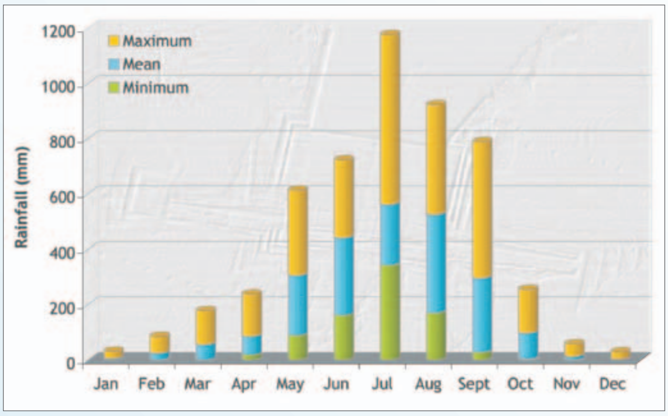


Figure 3.5: Recorded Ban Thalang rainfall data

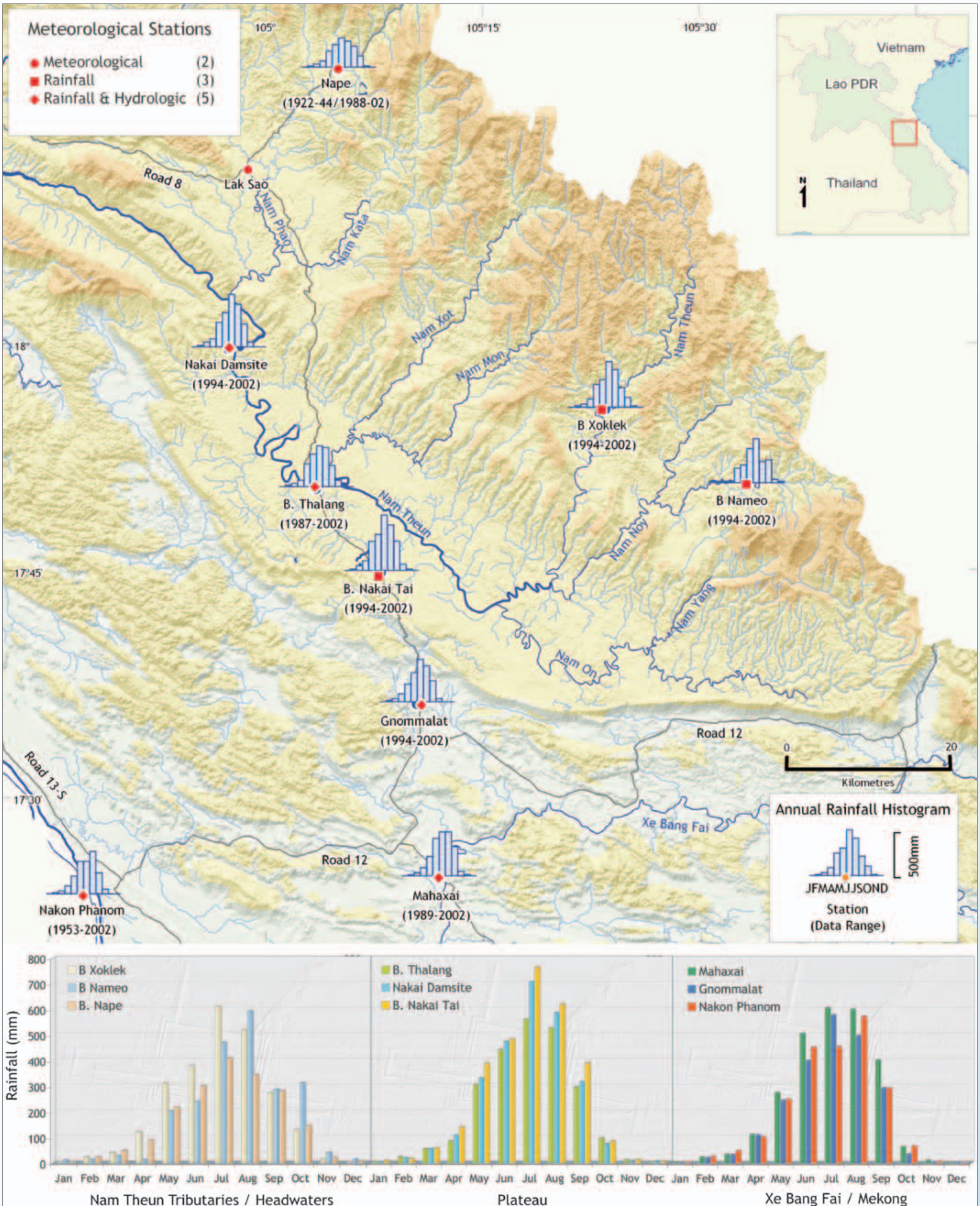


Figure 3.6: Location of meteorological stations in the Nam Theun & Xe Bang Fai regions and seasonal rainfall variability for selected locations

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Table 3.9: Mean relative humidity (%)

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Nakai Tai	63	64	65	60	78	86	89	87	83	79	79	68	75
Nakon Phanom	66	66	64	67	77	84	85	87	83	75	69	68	74
Thakhek	73	72	70	73	82	85	88	89	87	79	77	75	79

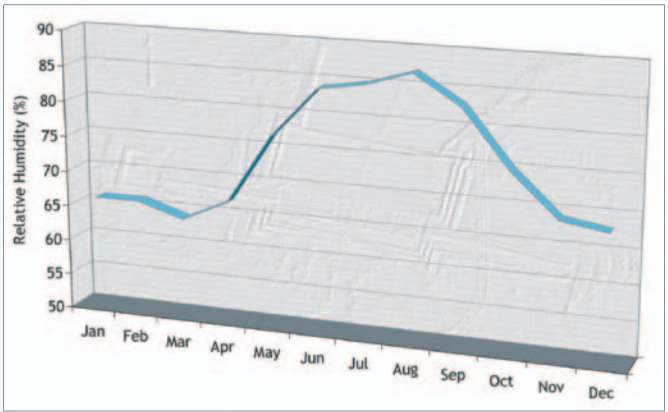

Figure 3.7: Average relative humidity

Table 3.10: Temperature at Nakai Tai (°C)

Month	Mean	Averages		Extremes	
		Max	Min	Max	Min
January	17.3	25.1	9.6	31.2	4.0
February	19.7	27.6	11.8	31.0	7.4
March	23.0	29.9	16.0	34.9	10.5
April	26.1	33.0	19.2	36.5	15.0
May	25.5	29.8	21.1	35.0	19.0
June	25.0	28.3	21.7	30.6	20.0
July	24.7	27.5	21.8	30.5	19.6
August	24.4	27.7	21.1	31.8	19.4
September	24.5	28.3	20.7	31.4	19.0
October	24.2	28.9	19.5	31.8	16.2
November	19.4	25.4	13.4	30.7	7.2
December	17.9	24.7	11.2	30.0	2.0
Annual	22.6	33.0	9.6	36.5	2.0

Table 3.11: Temperature at Nakon Phanom (°C)

Month	Mean	Averages		Extremes	
		Max	Min	Max	Min
January	21.9	28.7	14.7	36.1	3.1
February	24.0	30.4	17.7	38.9	8.0
March	27.1	33.3	21.0	40.2	8.5
April	28.8	34.5	23.4	42.0	13.8
May	28.3	33.2	24.2	39.2	18.8
June	27.5	31.5	24.3	37.9	20.3
July	27.3	31.1	24.0	36.3	20.6
August	26.8	30.5	23.8	35.0	19.0
September	26.9	31.0	23.4	35.6	19.6
October	26.3	31.1	21.5	35.2	13.9
November	24.4	30.1	18.5	34.8	7.8
December	22.0	28.6	15.2	34.6	4.1
Annual	25.9	34.5	14.7	42.0	3.1

Evaporation

Class A pan evaporation at Nakai Tai, Nakon Phanom and Vientiane is presented in Table 3.12 and Figure 3.9. SMEC (1991) carried out an estimate of the open water evaporation using the Penman formula, with monthly climatic data recorded at Nikhom 3 and with Class A pan data. The annual open water evaporation in Nakai Tai is estimated in the range of 1,215 mm to 1,388 mm per year. Table 3.13 shows the open water evaporation estimates for Nakai Tai, Nakon Phanom and Vientiane. Potential evapotranspiration is estimated to be 1,290 mm per annum. However, actual evapotranspiration losses would be less than this because of the development of soil moisture deficits during the dry season.

Potential Impacts

The replacement of 450 km^2 of forest, agricultural lands, grasslands and some seasonally flooded lands with the Nakai Reservoir will result in some changes to the air temperature and relative humidity over the water and around the shore.

Air & Water Temperature

During the southwest monsoon, the reservoir water is expected to be warmer than the air, and that trend will continue until the end of November. During the northeast monsoon, the air will become warmer than the water, but the difference will be small and the air will not able to heat the water until the end of February. Thereafter, the air temperature increases rapidly with the retreat of the cold northeast monsoon, so both air and water will experience marked increases in temperature. The southwest monsoon starts again in May, with the rainfall and runoff warmer than the mean air temperature. For eight of the twelve months, it is expected that the mean monthly temperatures of air and water will differ by less than one degree, and for six of these by less than half a degree. In the other four months, the difference will be 2°-3° C. Therefore, some change in the lakeshore temperature will occur during the southwest monsoon, but this will be difficult to notice because of the overbearing influence of the monsoon rain and its accompanying high humidity.

Unless the water body is very shallow, it is expected that the water temperature will not vary much over a period of 24 hours. However, the air temperature does and it is the differences in water and air temperature and their relative humidities that can produce manifestation of micro-climatic change. The climatic changes that could be conspicuous are relative humidity, wet haze, fog, cloud-base creation or suppression, katabatic winds, and to a lesser extent, precipitation enhancement. Most of these are phenomena that are features of some part of the hourly regime and not of a monthly mean.

The overpowering presence of the southwest monsoon, its rains and locally generated winds, will allow any micro-climatic changes that may occur to exist only for a short period of time. If there is any increase in precipitation, it will be immeasurable compared to the large amount that presently rains on the catchment during the southwest monsoon. The winds caused by the vertical convection will mix the lower air, preventing the establishment of differences in temperatures and humidity that could cause the formation of some noticeable micro-climatic phenomena. The concern then is

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during the northeast monsoon months when, during a daily cycle, the hourly reservoir and air temperature differences can be quite large. There is no published record of hourly temperature, relative humidity, or wind for the Nakai Plateau. But on a daily basis for example, in the yearly record simulated, the mean daily air temperature on the 18 February became 5.7° C warmer than the water. Conversely on the 29 May, the water temperature became 5.6° C warmer than the mean daily air temperature. The mean difference for all the days of the year is only 1.9° C, the water being warmer (Figure 3.10).

Air temperatures vary widely in the dry season. On the Nakai Plateau in 1990, daily air temperature for two months ranged as listed in Table 3.14. During these months however, the reservoir will be near its lowest level and its surface only about a third of its maximum. This reduction in area mitigates the other conditions contributing to micro-climatic change.

To assess the effects of the Nakai Reservoir on its surrounding climate, a general circulation model, shown in Figure 3.11, is employed. The model is valid for many situations including the development of such large features of global weather as the ITCZ. The model directs surface winds to blow from warm high pressure regions to cold low pressure areas. When the reservoir water is warmer than the air on the surrounding mountains, the colder mountain air flows to the reservoir. This is most likely to occur on clear nights during the northeast monsoon and in the spring transitional period. If the lake surface was larger during this period, the winds would be stronger. When the reservoir water is colder than the mountain air, possible during the hottest days, the winds will be from the water upslope to the hills.

The Nakai Plateau and its surroundings do not fit exactly into the general circulation model. The southern rim is only a hundred meters or so above the floor of the plateau, whereas to the north, the mountains rise to over 1,700 m above the floor. Also, in the south, the escarpment drops about 500 m to the Xe Bang Fai valley floor. Spill of air through the south rim will occur in its lower sections. Upslope winds from the valley below to the plateau will be difficult to achieve without help from regional winds.

Wet Haze & Fog

Still, cool air, when combined with the presence of hygroscopic particles in the air, forms wet haze or fog near the ground or water surface, even when the relative humidity is as low as 75%. With wet haze, the number and size of the condensed droplets are both small; with fog, there are more and larger particles. On the Nakai Plateau, the presence of condensation nuclei is probably very limited, as the plateau is isolated from the sea and its salt particles by mountains, and the air is relatively free of pollutants.

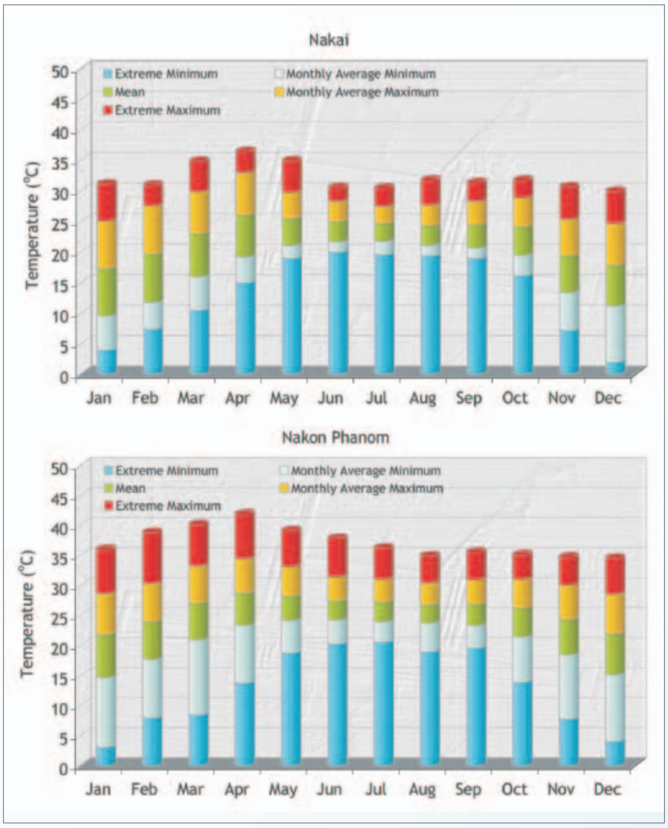

Figure 3.8: Seasonal temperature variability

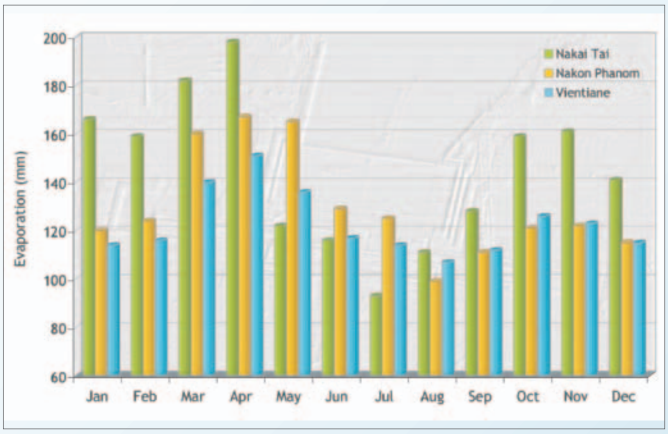

Figure 3.9: Average Class A pan evaporation

Table 3.12: Class A pan evaporation data (mm)

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Nakai Tai	166	159	182	198	122	116	93	111	128	159	161	141	1735
Nakon Phanom	120	124	160	167	1656	129	125	99	111	121	122	115	1558
Vientiane	114	116	140	151	136	117	114	107	112	126	123	115	1471

Table 3.13: Open water evaporation (mm)

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Nakai Tai	133	127	146	158	98	93	75	89	102	127	128	113	1388
Nakon Phanom	96	99	128	134	132	103	100	79	89	97	98	92	1246
Vientiane	91	93	112	121	109	94	91	86	90	101	98	92	1177

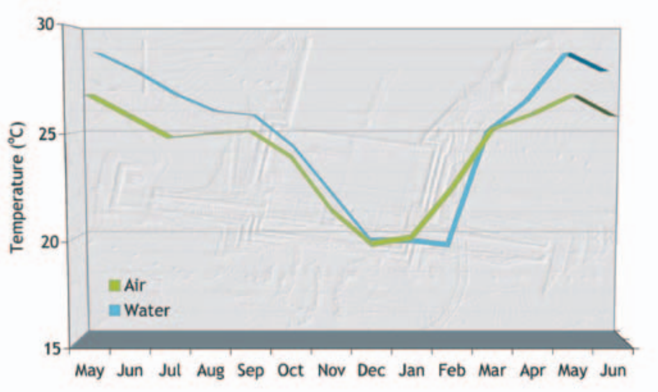

Figure 3.10: Relative difference between air and water temperature

Fog forms in different ways. When a surface is radiating its energy to the clear sky, the cooling surface then cools the air directly above it. This could happen only in areas of the reservoir where the water is very shallow. Otherwise, the warmer water below will replace the cooling water at the surface. If there is fog in the wetlands before the Project, more radiation fog can be expected on the fringes of the reservoir when it is drawn down. Alternately, warm moist air moves over cold water, the water cooling the air to the condensation temperature to form advection fog. In accordance with the general circulation model, this can happen only if the regional winds move warm air over a cool reservoir. During the northeast monsoon, the air is generally neither warm nor moist. In the spring transition, the air becomes hot at times but is not moist. A third type of fog, steam fog, is formed when cold air moves over warm water. The cold air causes the condensation of the evaporating water. The "steam" so formed drifts upwards and slowly disappears. The general circulation model indicates that this can occur at times when the mountain air is very cold and the reservoir water is very warm. This is most likely an early morning event when there is premature incursion of cold air from China and the reservoir is still in its warmer regime.

Precipitation Enhancement & Evaporation

Precipitation enhancement could only happen if dense fog forms often and drifts to the surrounding land. The fog droplets would collect on twigs, leaves, and grass. The engineering studies of reservoir evaporation and catchment evapotranspiration indicate that there will be about the same amount of water yield from the catchment both before and after reservoir construction. That is, the evaporation from the water surface and its drawdown area is approximately equal to the evapotranspiration of the forest, river, and wetlands that it replaces. Thus, the total transfer of moisture from the catchment and reservoir to the air will remain essentially the same as before the Project.

Downslope Winds

Downslope winds form when the mountain air is cold and the reservoir water is warm. The cold air collects in the tributary valleys and drains down to lower levels. The existence of warm water and cold air is not a general seasonal occurrence for the Project, as the air and reservoir water cool and warm together. If downslope winds occur now, there will be more and stronger winds with the reservoir.

Upslope winds could form if the mountains were to become significantly warmer than the reservoir. This is an unlikely occurrence, but if upslope winds do form, they would be limited to the lower valleys of the tributaries.

Table 3.14: Temperature variations

Temperature (°C)	March	April
Minimum	15.4	18.5
Maximum	28.6	31.7
Mean	22.0	25.1

Cloud Base Changes

Suppression of the cloud base can result when the circulation pattern is such that there is a subsidence of air over a cooler body of water; i.e. there is a hole in the clouds over the water. Conversely, when other circulation patterns exist and warm air rises from the water, clouds can form above the lake, even in a clear sky.

Hydrology & Water Resources

Baseline Hydrology

The operation of the Project will involve a trans-basin diversion of water from the Nam Theun to the Xe Bang Fai. Runoff from the catchment area at the Nakai Dam site is on average about 7,526 million m^3 (SMEC, 2003), as based on the extended record from 1950 to 2002. Of this amount, the reservoir will store on average approximately 7,000 million m^3 of water each year. Water stored in the reservoir will be diverted through the power tunnels to the Power Station and will eventually be discharged to the Xe Bang Fai. Consequently, the hydrology of three major rivers will be affected: the Nam Theun, Xe Bang Fai and Mekong. The pattern of seasonal discharge in the Mekong will change slightly as discussed in the Regional Issues section. More detail regarding the changed hydrologic relationships is presented in the following sections. The catchment areas for various sections of the Nam Theun/Nam Kading are presented in Table 3.15 with catchments for the major rivers of the area presented in Figure 3.12.

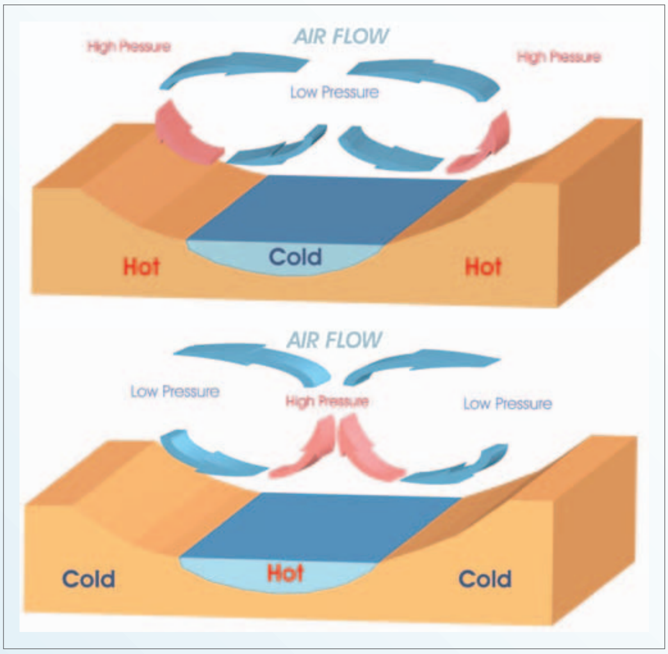

Figure 3.11: General ciculation model

Upper Nam Theun Basin

Discharge at Ban Thalang

River discharge is directly related to precipitation. Based on the available record, discharge in the Nam Theun has been monitored at Ban Thalang, located approximately 47 river km upstream of the Nakai Dam site, since 1986, and at the Nakai Dam site since 1994. Mean annual discharge at Ban Thalang for the 17-year period 1986-2002 is 205.6 m^3/s (SMEC, 2003). Figure 3.13 presents the average monthly discharge at Ban Thalang over the recorded period along with the ranges of discharge from the actual data. Refer to Annex E for more detailed information on discharges in the Nam Theun at Ban Thalang.

To enable evaluation of the economic feasibility of the Project, the record was extended using regression techniques to start at 1950, so providing a longer record for use in simulating the operation of the Project. The extension used information from the Nam Ngum Hydropower Project in Lao PDR and rainfall records at Nakhon Phanom, Thailand. Based on the extended record, 1950-2002, it is estimated that the mean annual discharge in the Nam Theun at Ban Thalang is approximately 208 m^3/s (SMEC, 2003). This is 1.2% higher than that estimated from the shorter historical record at the dam site and at Ban Thalang, the difference being that the hydrologic record for Ban Thalang is relatively short (1986-2002). Recorded monthly data from 1986 to 2002 can be compared with the estimated data. Where there is a lack of an extended hydrologic record, the extension of the record has been shown to be satisfactory. Independent variables for the regression analysis were obtained from sites with stream gauges and rainfall gauges. The monthly discharge variations in the river are illustrated in Figure 3.14. Statistical analysis of the two sequences has indicated that the mean annual runoff of the extended sequence is 1% greater than the mean annual runoff from the recorded sequence, which is well within the standard range of reliability (SMEC, 2003).

Discharge at the Nakai Dam Site

To estimate inflow at the Nakai Dam site, discharge records at Ban Thalang for the period 1950-1994 were adjusted based on the available records from the gauging station at the Nakai Dam site (SMEC, 2003). The relationship between discharge at the Nakai Dam site and Ban Thalang was calculated using regression to estimate the Nakai Dam site discharge, a factor of 1.15 needs to be applied to the Ban Thalang discharge. Based on the extended record of 1950-2002, the mean annual discharge at the dam site is 238 m^3/s (SMEC, 2003) within a drainage area of 4,039 km^2. The estimate corresponds to a mean precipitation of 1,875 mm per year. In the 53 years of the extended record, 1950-2002, the mean annual discharge has ranged from 121.6 m^3/s in 1998 to an estimated 382.5 m^3/s in 1981 (SMEC, 2003). Mean monthly discharge at the Nakai Dam site is illustrated in Figure 3.15, based on the extended record at the Nakai Dam site. As shown in the figure, approximately 85% of annual runoff typically occurs between June and October. Low discharge in the Nam Theun normally occurs in April, immediately before the wet season. Based on mean daily recorded levels, average discharge in April is 31.9 m^3/s (SMEC, 2003), with the lowest average monthly discharge for April being 25.4 m^3/s, compared to an average of 734.7 m^3/s in August (SMEC, 2003). At the beginning of the rainy season, much of the

Table 3.15: Catchment areas

Site	Area (km^2)
Nam Theun at Ban Thalang	3,501
Nam Theun at Nakai Dam site	4,039
Nam Theun downstream of Nam Phao	5,249
Nam Phao	1,128
Theun Hinboun at the Theun–Hinboun Dam site	8,937
Nam Theun/Nam Kading – entire Catchment to Mekong confluence	14,840

Figure 3.12: Map of catchment areas

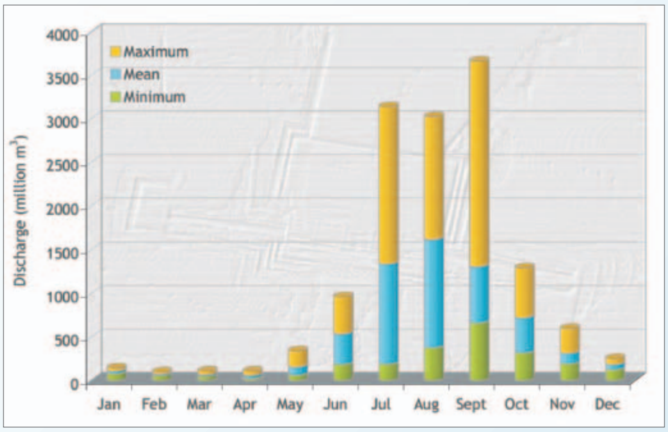

Figure 3.13: Average discharge at Ban Thalang

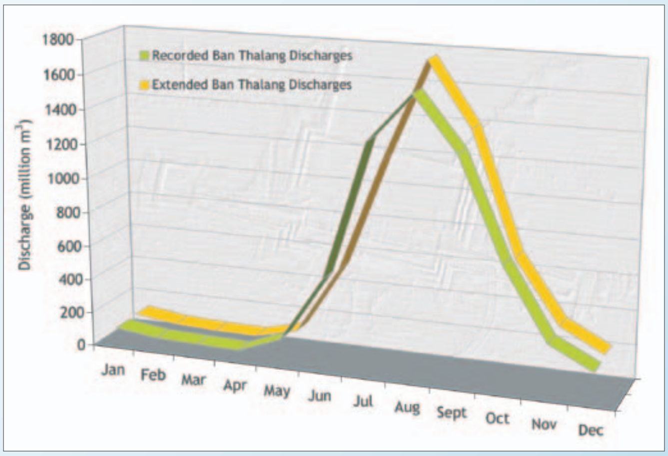

Figure 3.14: Recorded and extended monthly flows for Ban Thalang

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rainfall replenishes soil moisture depleted over the drier months of the year, which explains the lag between the monthly pattern of rainfall and the monthly pattern of discharge. After the rainy season there is a gradual decrease in discharge, declining through the dry season to April. Discharge in the river is sustained throughout the drier months from groundwater reserves until the period of intense rainfall returns in May. Figure 3.16 shows the annual volumes of flow estimates for the Nakai Dam site. Annex E provides more detailed information on discharges in the Nam Theun at the Nakai Dam site.

Extreme Discharges

From 1985 to 2002, the average annual instantaneous maximum discharge at Ban Thalang was 1,723 m^3/s, with the highest flood occurring in 1996 (3,054 m^3/s) (SMEC, 2003). At a discharge of 3,000 m^3/s at Ban Thalang, the mean velocity in the river is 1.93 m/s and the river stage (or depth) is 16.2 m (SMEC, 2003). Estimates of the flood frequency, using the observed data and fitting a log Pearson type 3 distribution, are presented in Table 3.16 (SMEC, 2003).

These estimates are consistent with feasibility estimates (SMEC, 1991) and were based on a regional flood frequency analysis for the Mekong River basin in Lao PDR (Seng, 1988). As part of the feasibility study, an estimate of the PMF was calculated (SMEC, 1991). The estimate was revised in 2001 (SMEC, 2001a) and was based on Probable Maximum Precipitation (PMP) determined for the area by the Australian Bureau of Meteorology. The recalculated estimate was based on an alternative method for estimating the PMF from the PMP. The revised method accounts for the non-linearity of the basin's response to rainfall. The revised calculations estimated the PMF to be 15,985 m^3/s (SMEC, 2003). A flood of this magnitude would result from a 24-hour storm that produced 800 mm of rainfall. The determination of the PMF is necessary to assure that the dam can withstand the maximum estimated flood that could be produced in the basin. Table 3.17 presents the results of analysis of extreme floods produced by PMP storms of varying durations.

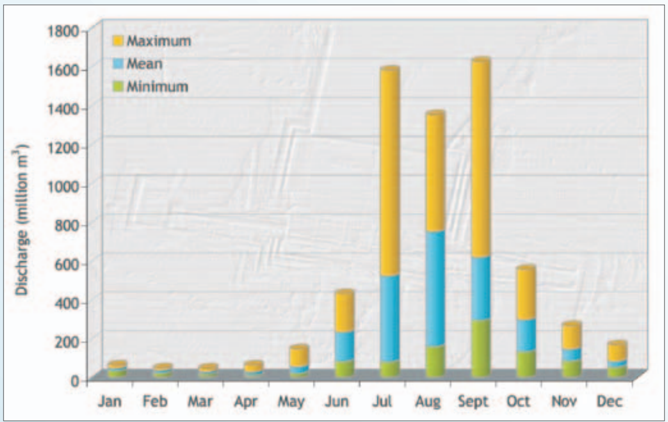

Figure 3.15: Mean monthly discharge at the Nakai Dam (extended series)

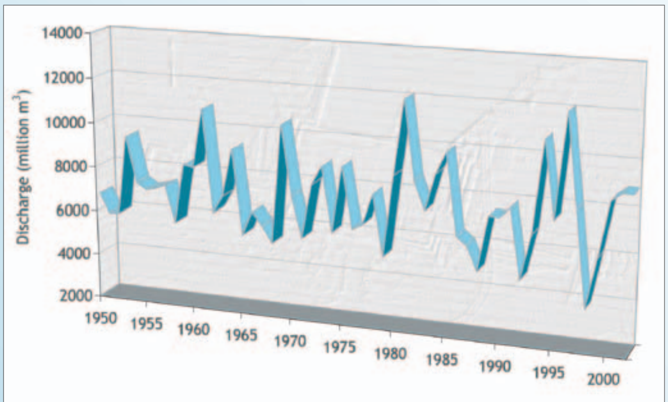

Figure 3.16: Annual flow volumes at the Nakai Dam site

Table 3.16: Flood frequencies estimates for the Nam Theun at the Nakai Dam site

Return period (years)	Probability of Exceedance (%)	Flood Peak Estimate (m^3/s)
2	50.0	1835
5	20.0	2410
10	10.0	2780
20	5.0	3120
50	2.0	3560
100	1.0	3895
500	0.2	4865
1000	0.1	5520
5000	0.02	7430
10000	0.01	8490

During months with little rain, river discharge is derived primarily from groundwater in the catchment soils. As noted above and based on mean daily recorded levels, the month of lowest discharge is normally April, when the average discharge is 31.9 m^3/s (SMEC, 2003) at the Nakai Dam site. The lowest discharge in the period of record at Ban Thalang was 4.4 m^3/s, based on mean daily recorded levels, in April 1986 (SMEC, 2003). The mean flow for the entire month of April 1986 was 10.3 m^3/s (SMEC, 2003).

Nam Kathang

Discharge

To monitor discharge in the Nam Kathang, a stream gauge has been in operation near the site of the regulating dam since 1994. Based on mean daily water levels (1994-2002) the mean annual discharge in the Nam Kathang is 10.2 m^3/s (SMEC, 2003) with a range of 5.7 m^3/s to 16.8 m^3/s (SMEC, 2003). Over the same period, mean monthly flow in the Nam Kathang was equal to or less than 0.3 m^3/s for the months of January through to April, with the highest average monthly flow of 38.5 m^3/s being recorded in September (SMEC, 2003). Figure 3.17 shows the monthly discharge in the Nam Kathang. Annex E contains more detailed information on discharges in the Nam Kathang.

Approximately 5 km downstream of the regulating dam site, the Nam Gnom, a major tributary, joins the Nam Kathang. A gauge has been operating on the Nam Gnom continuously since 1994 to measure discharge of this river into the Nam Kathang. From 1994-1998 discharge measurements were carried out and since 1998 gauge board readings have continued. Based on discharge measurements, the mean annual discharge from the Nam Gnom into the Nam Kathang is 8.9 m^3/s (SMEC, 2003), thereby almost doubling the flow in the Nam Kathang just below the Nam Gnom

Table 3.17: Nakai Dam site probable maximum flood estimates

Duration	Peak Inflow (m^3/s)	Volume (million m^3)
24 hours	15,985	3,270
48 hours	14,250	3,625
72 hours	11,460	3,595
15 days	13,855	8,720

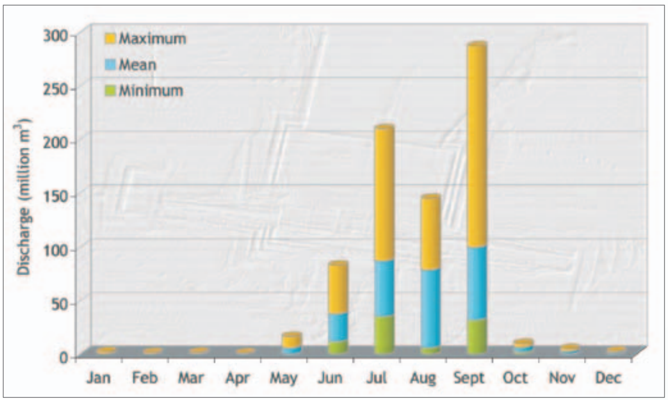

Figure 3.17: Monthly discharges in the Nam Kathang at the regulating dam

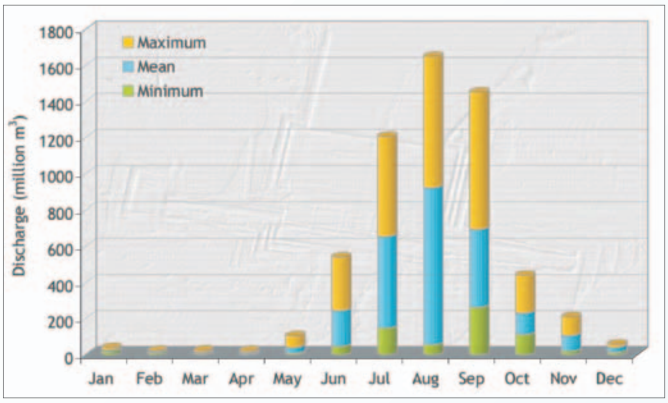

Figure 3.18: Mean, minimum and maximum discharges of the Xe Bang Fai at Mahaxai

confluence. Annex E provides more detailed information on discharges in the Nam Gnom.

Extreme Flows

The small catchment area of the Nam Kathang at the regulating dam location means the Nam Kathang exhibits little or no flow for four dry season months a year, with an extreme monthly minimum discharge of 0 m^3/s being recorded on 67% of occasions for the months of January to April. In these same months of 2002, a 0 m^3/s flow was observed on all occasions (SMEC, 2003). For the period 1994-2002, an extreme monthly maximum discharge of 612.9 m^3/s has been reported, based on mean daily level records in September 2000.

Xe Bang Fai at Mahaxai

Discharge

Based on records from a stream gauge station at Mahaxai on the Xe Bang Fai (1989 to 2002), the average annual discharge at Mahaxai is 265.4 m^3/s with a range of average annual discharges from 168.6 m^3/s to 335.5 m^3/s (SMEC, 2003). As with the Nam Theun, the lowest flows are recorded in April with the average monthly flow being 12.7 m^3/s (SMEC, 2003). The high discharges occur in August when the average monthly flow is 921.2 m^3/s (SMEC, 2003). Figure 3.18 presents the average monthly discharge at Mahaxai along with the minimum and maximum recorded discharges at the site. Field measurements of discharge have been made at Mahaxai over a range of conditions up to approximately 1,800 m^3/s (SMEC, 1996). The average maximum recorded discharge there (1988-2002) is 2,055 m^3/s (SMEC, 2003). More detailed information on discharges in the Xe Bang Fai is given in Annex E.

At Mahaxai, the bank full stage is approximately 15.5 m, corresponding to a discharge of approximately 2,270 m^3/s (SMEC, 2003, 1996). Subsequent measurements have indicated that the discharge rating curves vary from year to year (SMEC, 2002a) because of channel variations. SMEC recently updated the flood frequency analysis using 15 years of data available from 1988-2002 (SMEC, 2003). The results derived are presented in Table 3.18,

Discharge records are also available for Bridge 13 on the Thakhek-Savannakhet Highway. Backwater from the Mekong River influences this gauge and conversion from river levels to discharge at this site is difficult. However, the Mekong River Committee has devised a complex discharge rating which provided an estimate of the average discharge at this site at approximately 373.2 m^3/s (SMEC, 1991).

Extreme flows

Despite having a larger catchment area, flow records reveal that the minimum discharge in the Xe Bang Fai is consistently less than in the upper Nam Theun basin (SMEC, 2002a). Over 13 concurrent years (1989-2002), the average monthly discharge for the month of April in the Xe Bang Fai at Mahaxai was 12.7 m^3/s, with the extreme minimum mean monthly discharge being 6.7 m^3/s, as indicated by mean daily levels recorded in April 1993 (SMEC, 2003), compared to an average monthly minimum of 25.4 m^3/s in the Nam Theun at Nakai Dam site (SMEC, 2003). The maximum ever recorded discharge in the Xe Bang Fai at Mahaxai was 3,114 m^3/s in 1991 (SMEC, 2003).

Mekong River

Stream-gauging stations on the Mekong with long-term records are located at Nakhon Phanom, Thailand, and at Mukdahan, Thailand, opposite Savannakhet.

As seen in Figure 3.19, discharge in the Mekong at Nakhon Phanom is lowest in the months of March and April, with higher flows in the months of June, July and August.

The long-term average monthly discharges in the Mekong River at Nakhon Phanom over the period from 1924-1991 and Mukdahan over the period of 1922-1992 are presented in Figures 3.19 and 3.20, respectively. The mean annual stream flows in the Mekong at Nakhon Phanom and Mukdahan are 5,865 m^3/s and 6,960 m^3/s, respectively.

Flood frequency estimates for the two stations, based on records dating back to the mid 1920's, are presented in Table 3.19

The increase in catchment area between these two sites is 4.8%, though the increase in mean annual flood is shown as 11.2%. The mean annual flood is simply the mean of the annual maxima, so the difference between flood estimates at the two stations is excessive given the size of the intervening drainage area. A potential cause for this difference is that one or both of the rating curves

Table 3.18: Results of regional flood frequency analysis of the Xe Bang Fai at Mahaxai

Return Period (years)	Discharge (m^3/s) SMEC (2003)
2	2,170
Top of bank	2,270
5	2,490
10	2,700
100	3,190

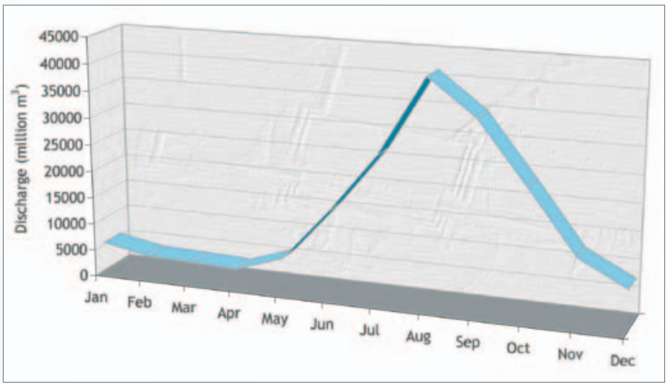

Figure 3.19: Discharge in the Mekong at Nakhon Phanom

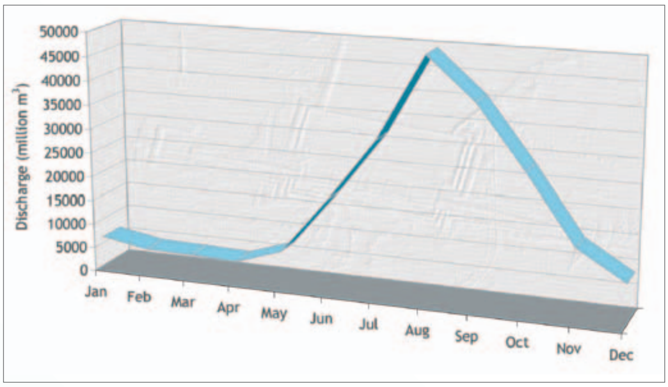

Figure 3.20: Discharge in the Mekong at Mukdahan

for the stations are slightly inaccurate. The accuracy of discharge ratings in natural streams is rarely better than about 10% for high discharge. Consequently, the estimates may be within the normal range of accuracy.

Long Term Trends

Trend analysis shows that the average annual discharge at Nakhon Phanom has decreased by over 10% in the past 75 years. This decrease could be a result of withdrawal of water in the upper reaches for irrigation or other uses; climatic change; or changes in vegetative cover and land use within the basin. The annual maximum monthly discharges in the Mekong River also exhibit a decreasing trend, indicating diminishing seasonal flood magnitudes. On the other hand, the series of annual minimum monthly discharges exhibits an increasing trend, with flow volumes in the months of lowest flow tending to increase by more than 10% over the past 75 years.

Baseline Groundwater Hydrology

Sedimentary rocks that outcrop on the Nakai Plateau form a three-layered aquifer system. The base layer of aquifer is a 1,100 m thick sedimentary formation. Outcrops of this layer are along the higher levels of the escarpment and form the resistant rim that surrounds the Nakai and Nam Malou basins. Below the escarpment, the 400 m thick layer of siltstone, mudstone and some limestone contains a viable aquifer. The formation extends into northeastern Thailand and into central Vietnam. The presence of wetlands on the Plateau indicates that water remains in the sedimentary formations and makes its way to the rivers. Sandstones in Plateau formations act as the best aquifer and have the best potential for domestic wells. Water in the caves below the escarpment also indicates effective aquifers. Of the three aquifer systems, the sedimentary areas form the most active aquifer layers.

On the Nakai Plateau, in the Phra Wihan geological formation, aquifers are charged directly from rainfall and abstraction rates generally range from 0.05 to 10 l/s. The change in water level in these aquifers from wet to dry season is in the order of 10 m. Aquifers associated with the Khok Kruat formation are also recharged directly from rainfall but abstraction yields are lower, at 0.05 to 3 l/s. For the Maha Sarakham formation, the aquifers are recharged from both direct rainfall and upward groundwater flow. Changes in water level, from wet to dry season, are less than 3 m with abstraction yields of less than 1 l/s.

Below the Nakai Plateau in the Gnommalat Plains, the aquifers reside in the Phu Kradung formation. These aquifers are recharged directly through rainfall, with water levels dropping by 5 to 7 m during the dry season. Abstraction yields in this region are generally less than 5 l/s.

Table 3.19: Flood frequency estimates for the Mekong River

Station	Catchment Area (km^2)	Flood	Peak Discharge (m^3/s)
Nakhon Phanom	373,000	Mean Annual	25,320
		10-year	30,200
		100-year	33,400
Mukdahan	391,000	Mean Annual	28,300
		10-year	34,100
		100-year	38,300

Potential Impacts

According to the current provisions and the operation of the Power Station on an intermediate peaking basis, an average of approximately 222 m^3/s will be diverted from the Nakai Reservoir through the Power Station to the Xe Bang Fai. This compares to the estimated mean annual flow of 238 m^3/s in the Nam Theun at the Nakai Dam site, and an average 265 m^3/s in the Xe Bang Fai at Mahaxai. The diversion will produce major hydrological changes in the lower reaches of both rivers. The diversion of water will impact the Nakai Plateau (Zone 1); the Nam Theun downstream of the dam (Zones 4, 5); the Gnommalat Plain (Zones 7, 8 and 9); the Xe Bang Fai (Zones 10, 11 and 12); and the Mekong River (Zone 15).

The magnitude of the hydrological regime changes is based on simulations of reservoir operations and energy production using the computer program EVALS. The following operating criteria were assumed:

- A minimum average riparian release of 2 m^3/s to the Nam Theun immediately below the Nakai dam;
- Hydropower generating station equipped with 4 x 250 MW Francis turbines plus 2 x 43 MW Pelton turbines;
- Turbines operated up to 16 hours per day, six days per week (Monday to Saturday) to produce primary energy;
- Secondary energy will be generated on demand, typically at half to quarter load (secondary energy may not be generated if retention of water is needed to provide primary energy);
- Minimum operating level is at El 525.5 m, power generation was optimised for reservoir operation to meet average annual energy targets of 5,936 GWh as stated in the PPA, including 4,641 GWh per year in primary energy and 1,295 GWh per year in secondary energy (EDF, 2000); and
- Power generation will be reduced when the discharge in the Xe Bang Fai approaches flood level and generation halted when the Xe Bang Fai is at or above 15.5 m at the Mahaxai gauge.

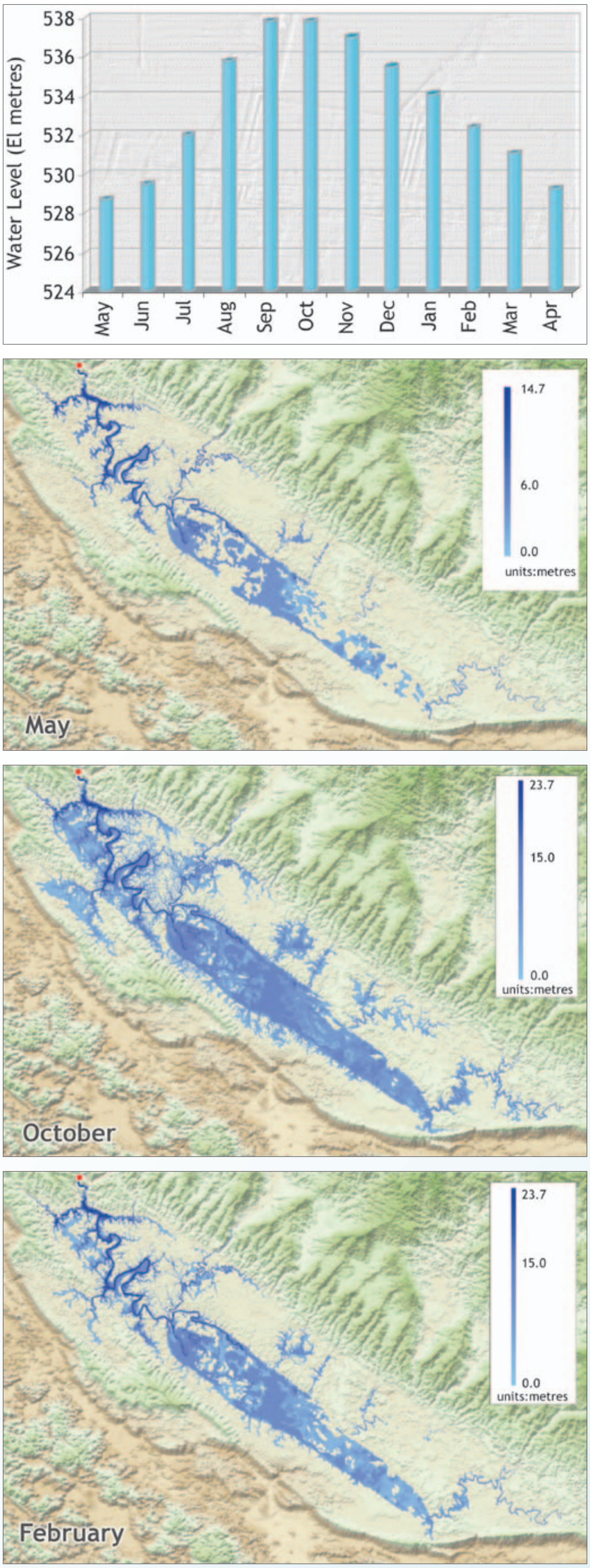

Figure 3.21: Nakai reservoir levels

Nakai Plateau

The Nakai Reservoir will impound approximately 195 km of the Nam Theun and its major tributaries (Nam On, Nam Noy and Nam Xot) upstream from the Nakai Dam site. This region will be converted from a river environment to a lake-like condition. Water discharged from the main stream and tributaries will be stored in the reservoir and will be diverted to the Power Station to generate energy. The Nakai Reservoir will be operated on an annual basis with the FSL at El 538 m. The MOL of the reservoir will be at El 525.5 m. Within this range of drawdown, the reservoir at FSL will have a surface area of 450 km^2, and at its minimum level the water surface will be approximately 82 km^2. When the reservoir is at FSL, the average depth of the reservoir is 7.1 m. When the reservoir is at its MOL, some of the Nam Theun will flow within its banks. Converting the river to a lake environment will have a major impact on fish populations in the river, as discussed later in this chapter.

In most years the Nakai Reservoir level fluctuates between a minimum level a little above MOL, to a maximum level that varies, but is usually below FSL. Figure 3.21 illustrates water levels and surface area throughout the year. On average the annual draw-down is predicted to be only 6 m, which would result in a drawdown area of 15,900 ha. The drawdown zone offers potential for the establishment and management of aquatic and other plant species for supplementary forage. This forage will be available during the mid to late dry season as the reservoir levels drop, and would provide a valuable contribution to the rations of livestock in the resettlement area. The management of supplementary forage is discussed further in the SDP.

Given that the chosen water source for the resettlement irrigation schemes is the Nakai Reservoir, the annual drawdown of the reservoir will have to be considered during the establishment of the irrigation scheme for each of the resettled villages. To accommodate water at MOL the sump bed level of the pumping station sump will be at El 524 m.

Nam Theun Downstream From the Dam & Nam Kading (Zones 4 & 5)

The minimum release from the Nakai Dam will be 2 m^3/s, as averaged over a week during non-spilling periods. At times, the discharge will increase when maintenance or operation of the gates is required.

During exceptionally wet years, spill will occur through the gates of the dam. Of 47 years used in the analysis of reservoir operation, spill through the gates will only occur in 18 years, when inflow into the reservoir is in excess of the storage capacity of the reservoir. The highest spills will occur in August as reflected from the annual hydrologic records presented above. For those years when spills do occur, the average spill during the peak of the wet season will last approximately 5 weeks, and will spill a total of 1,186 million m^3.

The potential impacts of the spill and riparian release will primarily affect fish populations but will also affect wildlife and plant communities associated with the river course, as discussed in more detail later in this chapter.

This portion of the Nam Theun includes the confluence of the Nam Phao downstream to the Theun Hinboun diversion reservoir. At the confluence of the Nam Phao, the Nam Theun will substantially increase in discharge. The average inflow from the Nam Phao is shown in Figure 3.22. The discharge records for the Nam Phao are from 1995-2002, with some years not complete.

The discharges are estimated from the Theun Hinboun inflow record and adjusted from the hydrologic record at Ban Thalang,

Impacts

using a ratio of drainage areas. During March and April, discharge in the Nam Theun downstream of the Nam Phao will be approximately 7 m^3/s, plus the riparian discharge of 2 m^3/s from the Nakai Dam.

The drainage area between the Nam Phao confluence and the Theun Hinboun dam is approximately 3,812 km^2. In the reach between the confluence of the Nam Phao and the Theun Hinboun headpond, discharge will average approximately 215 m^3/s. During September, the average discharge is as high as 802 m^3/s. The Theun Hinboun Project is, like the Nam Theun 2 Project, a trans-basin project. In the case of the Theun Hinboun, water is diverted from the Nam Theun to the Nam Hinboun, via the Nam Hai.

The impacts from the reduced flows in the Nam Theun between the dam site and the Theun Hinboun dam will affect vegetation and wildlife. No villages are present between the Nakai Dam and the confluence of the Nam Phao, although limited fishing has been observed in this reach. The riparian release study will provide information on community use of the Nam Theun downstream of the Nakai Dam.

Downstream from the Theun Hinboun Dam, the Nam Theun becomes the Nam Kading. The low flow in this reach will be that amount passed through the Theun Hinboun dam plus the amount picked up from local tributaries, which have a combined catchment area of 5,713 km^2. The Theun Hinboun Project has committed to a minimum release of 5 m^3/s into the Nam Kading. As a result of the Nam Theun 2 Project, the average number of days that the Theun-Hinboun will be limited to the minimum riparian release into the Nam Kading will increase annually from 120 days to 175 days. Other tributaries downstream from the Theun Hinboun dam will increase the discharge in the Nam Kading. Currently, minimum discharge in the Nam Kading at its confluence with the Mekong is estimated to average approximately 41 m^3/s in April each year.

The Nakai Reservoir will have a significant effect on floods immediately downstream of the Nakai Dam, retaining them completely in 29 of the 47 years simulated, and attenuating them in the remaining years. In general, flood peaks immediately downstream of the dam will be much lower. The impact of the Nakai Dam on downstream floods is to be included in a review of the riparian release, which will be conducted in the dry season of 2004. An outline of the approach to be taken for the analysis is presented later in the chapter. The findings of the review will be incorporated into the analysis.

Regulating Pond, Downstream Channel & Gnommalat Plain

Diverted water from the Nakai Reservoir will be channelled through the Power Station. From there, the water will be discharged to a regulating pond. Operation of the Power Station is described in Chapter 2. The increased discharge from the Power Station will fill the Regulating Pond and during off-peak hours the water level in the Regulating Pond will decrease. Although the actual operational details of the Power Station are not yet completely known, Figure 3.23 presents an indication of what would happen if the Power Station is operated to provide 50 percent secondary energy in addition to normal primary energy loads. The purpose of the Regulating Pond is to minimise the discharge fluctuations from the Power Station and release the water to the Downstream Channel at a more or less constant rate. Based on Figure 3.23, discharge to the Downstream Channel during the dry season will be approximately 275 m^3/s for this scenario. The major impact of the operating curve is that on Sundays, the discharge from the Regulating Pond will decrease down to approximately 80 m^3/s. This will impact the discharge in the Xe Bang Fai at the end of the Downstream Channel. In other scenarios, the discharge to the Downstream Channel could be as little as 30 m^3/s.

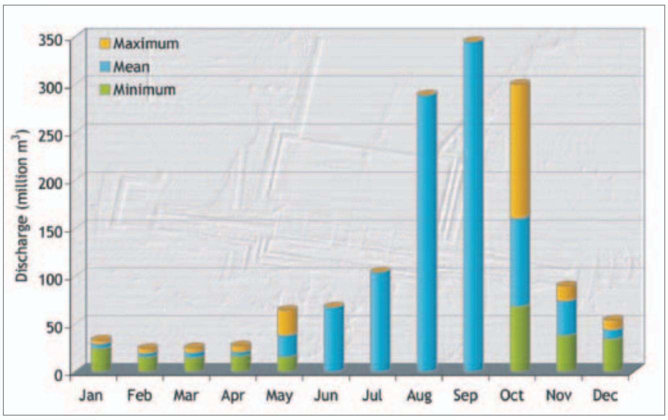

Figure 3.22: Monthly discharge in the Nam Phao (only mean values available from June – September)

As mentioned in Chapter 2, the Downstream Channel will be designed to convey a maximum discharge of 330 m^3/s plus additional inflow from the surrounding basin up to the two-year flood event. Floods in excess of the two -year flood event will cause flooding of land adjacent to the Downstream Channel, as is currently the case. In such conditions, when the Power Station will not be generating and therefore will not be discharging, the Downstream Channel may actually improve drainage of the adjacent land.

The Downstream Channel will include a tunnel of approximately one kilometre in length through a limestone pinnacle. Immedi-ately upstream from the tunnel, an emergency spillway will be installed to enable relief of the water in the channel to the Nam Phit, which would be the normal route for such floodwaters. The use of this spillway will be on an as needed basis when floods exceed the two-year level. The emergency spillway will enable water to be released from the Downstream Channel to prevent backwater effects in the channel upstream from the tunnel, and will prevent damage due to overtopping of the Downstream Channel.

A further consideration is the confluence of the Downstream Channel with the Xe Bang Fai. Discharge to the Xe Bang Fai may cause backwater effects at the downstream end, particularly during the wet season when discharge in the Xe Bang Fai is at or near flood conditions. The confluence area will be protected with rip-rap where the downstream channel joins the Xe Bang Fai. Monitoring of the channel will be conducted by NTPC and any observed erosion that threatens the structural stability of the confluence will be

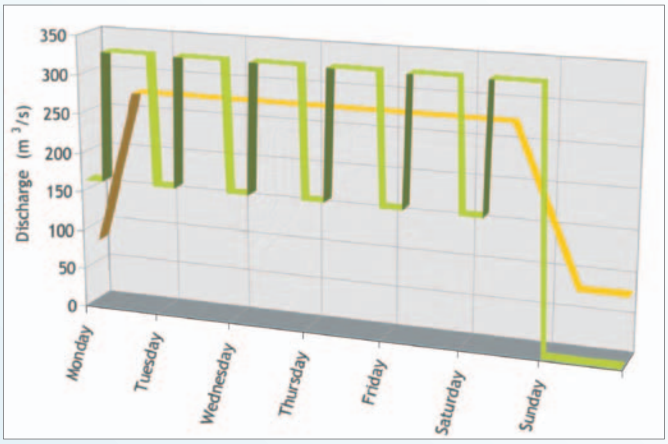

Figure 3.23: Regulating Pond inflow and discharge when generating 50% secondary energy

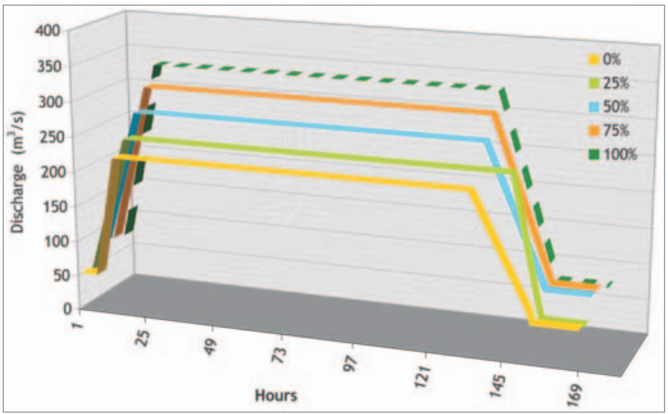

Figure 3.24: Discharge rate of Regulating Pond for different secondary energy levels.

corrected. The potential for erosion of the Xe Bang Fai channel is discussed in more detail earlier in the chapter.

Hydrologic Changes in the Nam Kathang

The Project intends to monitor inputs into the Regulating Pond, and to release into the Nam Kathang a discharge equivalent to its natural flow. Because the hydrology of the Nam Kathang remains unaltered, no hydrological impacts are expected to result from the Project. This also means the Nam Kathang will continue to experience its normal flood regime.

Hydrologic Changes in the Xe Bang Fai

The diversion of an estimated annual average of 220 m^3/s to the Xe Bang Fai will have impacts to the river and communities residing along it. The most noticeable changes will occur in the upper reaches of the river, directly downstream of the confluence with the Downstream Channel, while lesser impacts are expected further downstream.

Upper Xe Bang Fai

The Upper Xe Bang Fai will exhibit most of the impacts associated with diversion of discharge from the Nam Theun. The Project will almost double the annual flow in the Xe Bang Fai as measured at Mahaxai, from 8,370 million m^3 to 15,370 million m^3. Averaged over the entire year, this represents a Project discharge of approximately 220 m^3/s into the Xe Bang Fai. However, discharge is expected to vary over the seasons and over the week to reflect power demand. Table 3.20 shows indicative minimum and maximum discharges throughout the year, depending on the amount of secondary energy being generated. Figure 3.24 illustrates the weekly hydrograph for these generation scenarios. The maximum discharge into the Xe Bang Fai will be 330 m^3/s, while the guaranteed minimum discharge is 30 m^3/s. This minimum discharge will be maintained for up to 32 hours during Power Station shutdown.

The impacts will lessen further downstream from the Downstream Channel confluence as the catchment area for the Xe Bang Fai increases and the natural discharges become higher. The increased average discharge will be approximately ten times the current average discharge in the Xe Bang Fai during the months of December through April.

The additional water entering the Xe Bang Fai will result in an increase in water level. The impacts on water level are expected to be greatest at Mahaxai, the first major settlement downstream of the confluence with the Downstream Channel.

Throughout the year the impact on water level will be more prominent in the dry season. In the dry season, the addition of the maximum Project discharge (330 m^3/s) will increase the water level in the Xe Bang Fai at Mahaxai by up to 5.8 m. The increases in height resulting from the Project will be less in the wet season, with an average of only 1.5 m for the month of August. The estimated mean increases in water level of the Xe Bang Fai at Mahaxai are presented in Table 3.21 while Figure 3.25 illustrates the increase in water level for the indicative secondary energy generation scenarios presented in Table 3.20.

One important consideration in the analysis of hydrologic impacts to the Xe Bang Fai is the potential for causing additional flooding in the upper and middle regions. At the Xoy Gorge, the channel narrows considerably and creates a hydraulic control, separating the upper Xe Bang Fai region from the middle. Currently flooding occurs first in the upper and middle Xe Bang Fai at Mahaxai, when discharge in the river exceeds 2,270 m^3/s. Restrictions on outflow from the regulating dam will begin when flow in the Xe Bang Fai at Mahaxai approaches 1,970 m^3/s, and outflow from the regulating dam will cease before the natural flow reaches 2,270 m^3/s, thereby preventing any additional flooding. For more information on the mitigation strategies to be adopted by the Project, refer to the section on mitigation below.

Storage capacity in the regulating pond is insufficient to maintain regulating dam discharge at a constant level during the period of reduced generation, which starts on Saturdays and continues through Sundays. Consequently, the discharge in the downstream channel could be as little as 30 m^3/s when the Power Station is not operating, an amount of water which would then reduce the flow in the Xe Bang Fai. The lower discharge in the river will pass progressively downstream. The fluctuating water levels caused by this reduction in discharge, and the increased discharge as the Power Station begins to operate, will contribute to increased erosion of the Xe Bang Fai channel. A detailed discussion on the potential change in morphology of the Xe Bang Fai and the resulting implications, including impacts on both the fish population and human communities residing next to the Xe Bang Fai channel, is presented elsewhere in this chapter.

There are direct social implications for the new discharge regime in the Xe Bang Fai. Seasonal river bank gardens currently established by communities will be affected by both the increased water level and the erosion. Communities living along the Xe Bang Fai will no longer be able to use their current methods of crossing the river in the dry season, i.e. temporary bamboo bridges, and walking across rapids or shallow areas.

Table 3.20: Indicative minimum and maximum Regulating Dam discharges for a percentage of secondary energy generated.

Month	Season	Secondary Energy Level %	Minimum Discharge (m^3/s)	Maximum Discharge (m^3/s)
January	Dry	25	47	243
February	Dry	50	77	275
March	Dry	75	76	303
April	Dry	*		
May	Dry	50	77	275
June	Wet	75	76	303
July	Wet	100	70	330
August	Wet	100	70	330
September	Wet	100	70	330
October	Wet	75	76	303
November	Dry	75	76	303
December	Dry	50	77	275

Middle Xe Bang Fai

Approximately 34 km downstream of Mahaxai, the Xe Bang Fai passes through a range of limestone mountains, called the Sayphou Xoy Ridge. The narrow and steep grade through the rock essentially isolates the Upper Xe Bang Fai from the Middle Xe Bang Fai. In the absence of other developments, the low flow in the Xe Bang Fai at Road 13 Bridge will increase by the same amount as at Mahaxai i.e. 220 m^3/s averaged over the entire year. Impacts in this zone are similar to impacts already discussed for the Upper Xe Bang Fai, however, the impacts will be progressively mitigated as tributary inflows occur down the river. In the dry season, during periods of low flow in the Xe Bang Fai at Road 13 Bridge, the maximum Project discharge of 330 m^3/s will increase the water level by approximately 3.5 m. However, the precise change in water level is largely dependent on the level of water in the adjacent Mekong, and therefore any prediction in terms of water level increase can only be approximate.

It is likely that the increased discharge will result in some erosion of the river channel as the river comes to an equilibrium with the new discharge regime. As with the upper Xe Bang Fai, monitoring of the stream banks along the river is necessary to determine if people living along the river are adversely affected. Communities living in close proximity will experience simular impacts as those outlined for the upper Xe Bang Fai.

Lower Xe Bang Fai

Background: The region of the Xe Bang Fai between the Road 13 bridge and the Mekong River is referred to as the lower region of the Xe Bang Fai. Discharge in this region will be increased by approximately 220 m^3/s, as averaged over the entire year. Under normal conditions, this area is flooded every year due to backwater effects of the Mekong and flooding in the Xe Bang Fai. According to the 36-year hydrologic record obtained at Road 13 Bridge, the Xe Bang Fai flooded in 31 years – without any supplemental discharge from the Project. Because the Project will affect discharge of water from the Nam Theun/Nam Kading into the Mekong, it is estimated that there will be a fall of about 15 cm in the Mekong during flood events (SMEC, 1996). This should allow for quicker drainage of the lower Xe Bang Fai during times of flooding, and consequently partially offset the impact of the increased flows in this portion of the river.

SMEC hydrological modeling: In order to quantify the impacts of the Project discharge on the existing flood regime in the lower

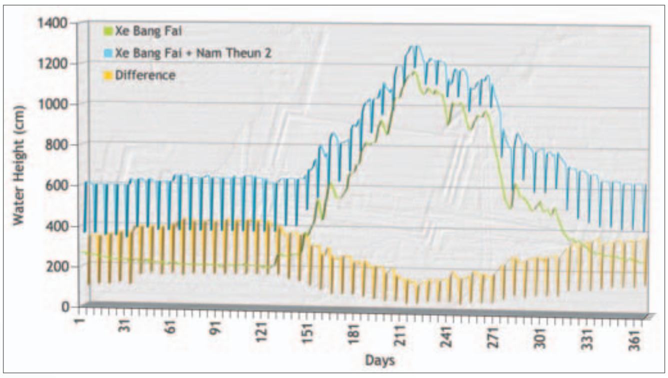

Figure 3.25: Water height in the Xe Bang Fai (Mahaxai) Pre & Post Nam Theun 2.

Xe Bang Fai area two mathematical models were constructed by SMEC, a hydrologic model of the whole Xe Bang Fai up to the Mekong, and a hydraulic model of the Mekong and of the Lower Xe Bang Fai (SMEC, 2004). A number of surveys were carried out to collect data on river cross-sections, floodplain topography, river bank profiles and flood control structures for input to the hydraulic model. The hydrologic and hydraulic models were calibrated and verified using the data recorded for floods that occurred in 1994, 1995 and 2000 for which records were readily available. Flood frequency analysis carried out on the historic flood records of flows and levels recorded on the Mekong and Xe Bang Fai during other investigations (SMEC, 1996 and SMEC, 2004a) were utilized to determine the appropriate design flood conditions in the Mekong to be applied in conjunction with flood events in the Xe Bang Fai, for the assessment of design flood cases.

The results of the SMEC report have to be considered as a worst case scenario as the release of water from the regulating pond will be stopped before the natural flow reaches 2,270 m^3/s at Mahaxai, thereby preventing any additional flooding caused by the Project.

Overall results of the SMEC modeling: The main results of the hydraulic model are as follows: A release of 315 m^3/s will increase by 3.75% the extent of the area flooded when added to the maximum flood flow allowed in the Xe Bang Fai immediately before discharges from the Regulating Dam are reduced. Figure x shows the increased extent of the flooded area, from 324 km^2 without the Project to 335 km^2 with a project discharge of 315 m^3/s. The flood levels in the river and floodplain are expected to increase by approximately 0.5, 0.4 and 0.2 m in the upper, middle and lower reaches of the lower Xe Bang Fai respectively when combined with floods exceeding the bankfull flow. Velocities in the river channel are expected to increase by 20% along the Xe Bang Fai for a 1 year ARI flood that is confined within the banks, and up to 7% for the over-bank floods. The hydraulic model showed that the duration of overtopping of the flood levees was increased on average by 3.6 days each year.

Quantification of the impacts: The results of the SMEC study were then further analysed in terms of impacts on agricultural lands only.

It was considered that the areas under more than 1 m of water during the 1.6 ARI flood events, without the additional release from the Project, will not be further impacted in terms of agricultural production, as, even without the additional release from the Regulating Pond, they are already under too much water to allow such production. The focus is therefore put on the areas that are currently subject to a flood of less than 1 m, and represented on Figure 3.26

Table 3.21: Water level increases in the Xe Bang Fai at Mahaxai

Month	Average pre-NT2 Monthly Discharge at Mahaxai (m^3/s)	Approx. Change in Elevation at Mahaxai with Maximum Project Discharge 330 m^3/s (m)	Approx. Change in Elevation at Mahaxai with Average Project Discharge 220 m^3/s (m)
January	25.0	5.2	4.2
February	17.6	5.6	4.6
March	13.3	5.7	4.8
April	12.7	5.8	4.9
May	40.3	4.3	3.4
June	244.3	2.7	1.9
July	655.8	2.0	1.4
August	921.2	1.5	1.1
September	693.9	2.0	1.4
October	230.4	2.7	1.9
November	106.6	3.4	2.4
December	41.6	4.2	3.3
Mean	265.4	2.6	1.9

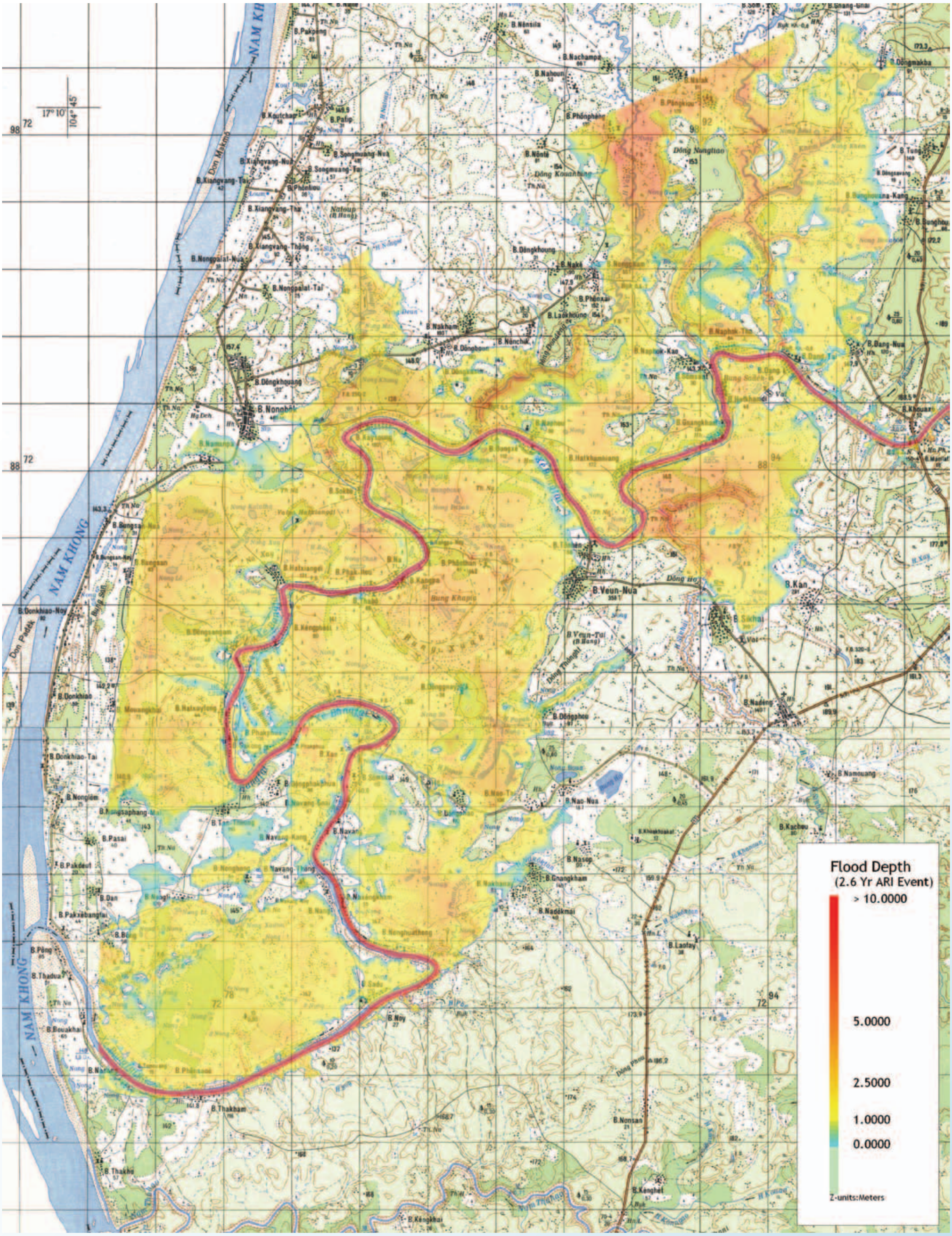

Figure 3.26: Maximum flood depths in the lower Xe Bang Fai for the 2.6 year ARI Even in Mahaxai (pre-Project)

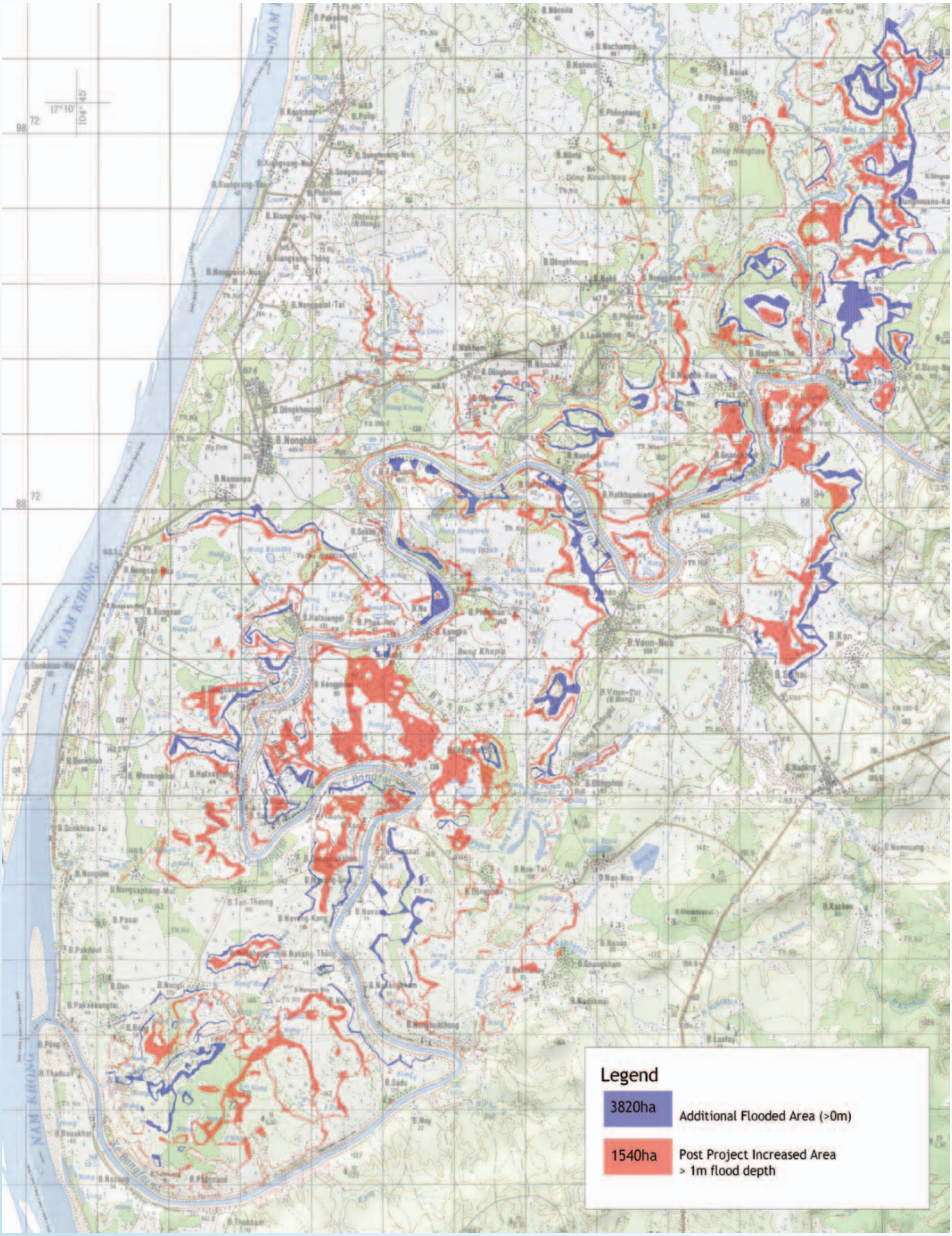

Figure 3.27: Impact of Powerhouse Discharge of 315 cumecs on Flood Extents in Lower Xe Bang Fai for 2.6yr ARI event in Mahaxai

The model indicates that 3,820 ha of land will be put under more than one meter of water because of the additional release of 315 m^3/s for an average duration of 3.6 days per year. The agricultural production on these areas might be impacted.

In addition the model indicates that 1,540 ha of land will be flooded during an average of 3.6 days per year when they are not without the release from the regulating dam. However these areas will be under less than 50 cm, therefore not threatening rice paddy production. The extent of the areas is shown on Figure 3.27

In addition, it is possible that the extended duration of the flood event on average by 3.6 days per year, could put at risk some of the 2,497 ha of land, which will be under a depth of water varying from 0.75 m to 1 m if the flood takes place before the paddy has been able to grow sufficiently in height.

The current use of the land will have to be confirmed as being productive agricultural land during the rainy season.

The increased flood plain created because of the additional release of water could impact positively fish production in the area.

Mitigations measures: Several measures could be considered to mitigate the impacts:

- Optimisation of the use of the existing irrigation schemes, including the timing of the opening/closure of the various gates.
- Use of rice varieties that are tolerant to flood episodes, in terms of duration of flood and depth of flood.
- Development of two dry season crops.
- Development of fisheries production.
- Raising the height of the existing dykes along the lower Xe Bang Fai.

The SDP presents with further details the villages that are located in this area, and the proposed mitigation measures that are parts of the Xe Bang Fai overall strategy

Mekong River

The reach of the Mekong between its confluence with the Nam Kading and the confluence with the Xe Bang Fai, including the adjacent floodplain, will be affected by the combined diversion of the Nam Theun 2 Project and the Theun Hinboun Project. Reduced flows will occur year-round, except during times when the Nakai Dam spills and when flows would be similar to existing levels. Over the year, the average reduction in flow between the Nam Kading and the Nam Hinboun confluence will be 302 m^3/s and the average reduction in flow between the Nam Hinboun and the Xe Bang Fai confluence will be 220 m^3/s. Below the Xe Bang Fai/Mekong confluence, the discharge in the Mekong River will be generally supplemented during the entire year as a consequence of the operation of the Project.

Water Balance Among the Affected Rivers

Diversion of water from the Nam Theun to the Xe Bang Fai will change the hydrologic regimes of three rivers: the Nam Theun–Nam Kading, the Xe Bang Fai and the Mekong. Storage of water in the Nakai Reservoir will affect discharge in the Nam Theun (known as the Nam Kading downstream of the Theun Hinboun Project) and the Mekong River. The most significant effect will be in the Xe Bang Fai, the receiving river for the diverted discharge from the Nam Theun. The discharge in the Nam Theun downstream of the dam will be dramatically reduced because of storage of water in the reservoir. The storage of water in the Nakai Reservoir will also reduce the discharge of the Nam Kading to the Mekong River. The major decrease in discharge to the Mekong River will be between the mouth of the Nam Kading and the mouth of the Nam Hinboun. The Project will reduce the discharge in the Nam Theun by an average 220 m^3/s, whereas the Theun Hinboun Project will on average further reduce the discharge by 82 m^3/s. Consequently, between the mouth of the Nam Kading and the mouth of the Nam Hinboun, discharge in the Mekong will be reduced by an average 302 m^3/s. Downstream from the mouth of the Nam Hinboun, discharge in the Mekong will be reduced by an average of 220 m^3/s. At the mouth of the Nam Hinboun discharge from the Theun Hinboun power station will return the 82 m^3/s back to the Mekong River. However, the replacement of the Nam Theun discharge to the Mekong will not occur until the discharge is returned to the Mekong at the mouth of the Xe Bang Fai. During the wet seasons, the reduction in discharge in the Mekong will probably not be noticeable. However, during the dry season, there could be some reduction in water level. Downstream from the mouth of the Xe Bang Fai, discharge in the Mekong will be augmented, particularly during the dry season (an average increase of 220 m^3/s). Figures 3.28 to 3.32 illustrate the change in the monthly discharge for the impacted rivers in the Project area. Detailed hydrological data for the water balance in the Project area is available in Annex E.

Groundwater

Groundwater exists in all Project zones, and will continue to serve its present function of providing domestic water to communities. Reduced amounts of water in the Nam Theun below the Nakai Dam are not expected to significantly affect the volume of groundwater in ground formations beside the river. Steep valley sides mean there can be little recharge to groundwater from the river.

Flows in the downstream channel will increase groundwater levels in the Gnommalat Plain and other contiguous areas, and will prove beneficial for local water supply.

Additional flows from the Project in the Xe Bang Fai will increase groundwater levels adjacent to the rivers. Increases would be most notable in the dry season, when the Nam Theun contributions would proportionally be largest in terms of the total discharge to the rivers. It is difficult at this time to quantify precisely how much groundwater levels may increase by, but they will tend to reflect the average rise in the river level itself. This increase will reduce energy requirements (electrical or human labour) for removing water from wells along the Xe Bang Fai.

The creation of the Nakai Reservoir will also increase groundwater levels on the Nakai Plateau. The amount of increase will vary according to the reservoir surface level but will tend, like the Xe Bang Fai, to reflect the average rise in the water body itself.

Proposed Mitigation Measures, Enhancements & Compensation

Flooding

The major mitigation measure is in the operational management of the Project, whereby diversion of water to the downstream channel and the Xe Bang Fai will be reduced during periods when overbank flooding is imminent, and shall be completely ceased prior to actual overbank flooding. These arrangements are designed so that discharge from the Project will not increase the natural overbank flooding, in terms of depth or frequency of flooding along the upper and middle sections of the Xe Bang Fai.

Based on studies to date, it is known that overbank flooding first occurs in the Xe Bang Fai upper and middle sections at Mahaxai, when discharge in the river exceeds 2,270 m^3/s. Consequently, outflow restrictions and cease generation obligations refer to discharge measurements at Mahaxai. Average frequency of overbank flooding at Mahaxai is approximately one in 2.3 years.

Outflow restrictions from the regulating dam will begin when flow in the Xe Bang Fai at Mahaxai approaches 1,970 m^3/s, and discharge

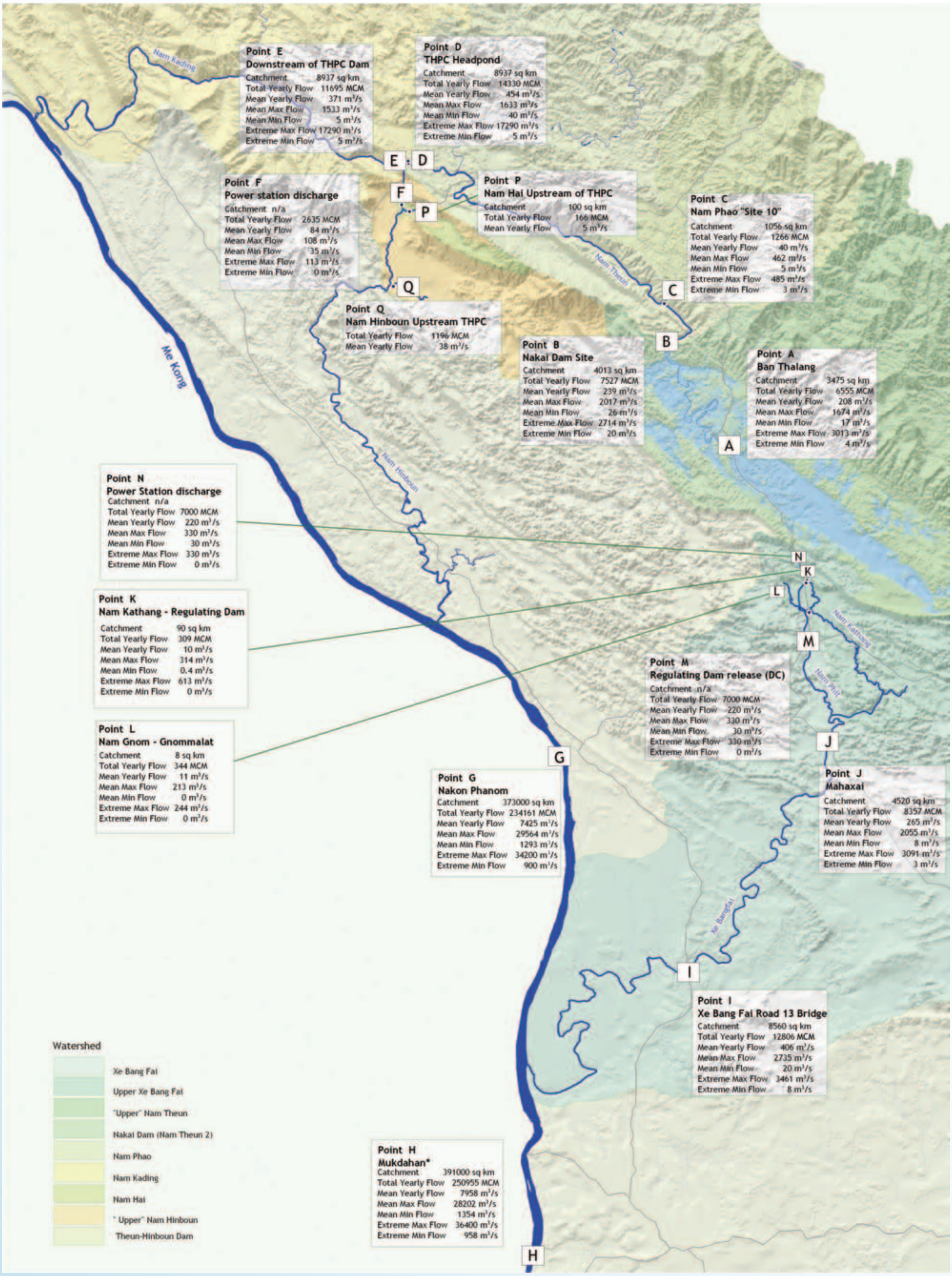

Figure 3.28: Water Balance monitoring points, showing pre-NT2 operation flow levels (A-L;P-Q) and predicted NT2 Power Station discharge (M-N)

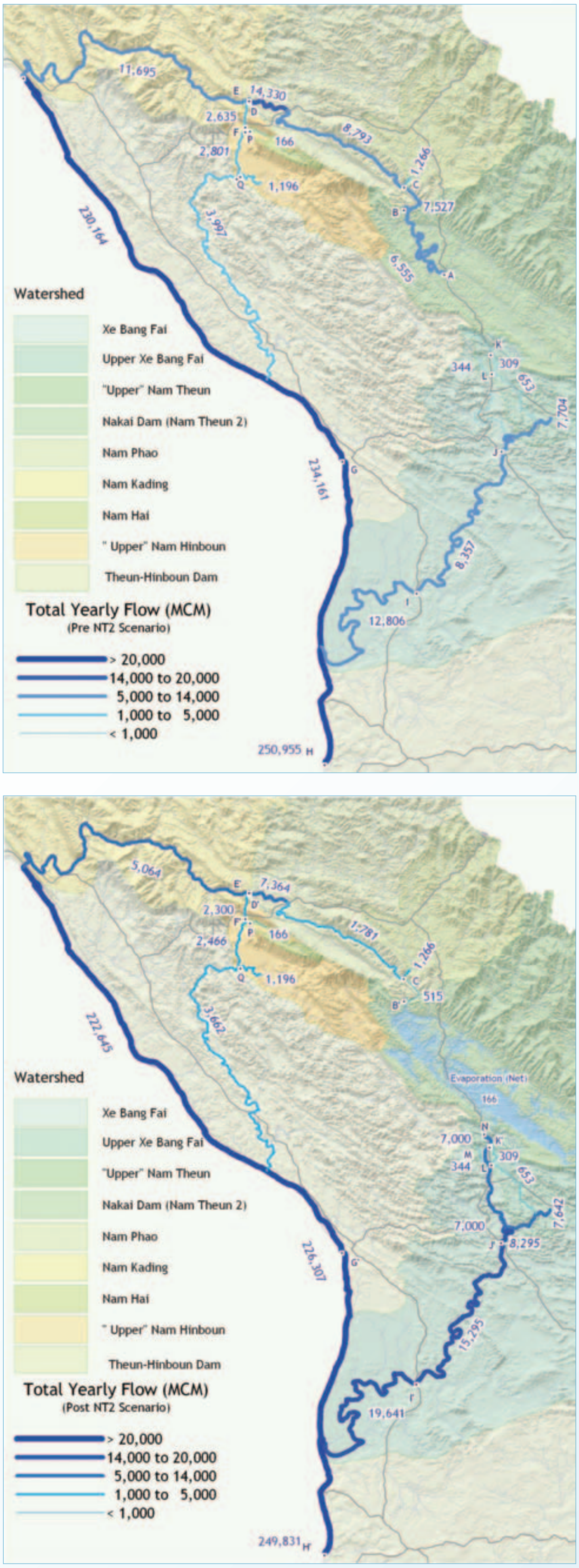

Figure 3.29: Water Balance modelling pre- (Top) & post- (Bottom) NT2 operation total yearly flow

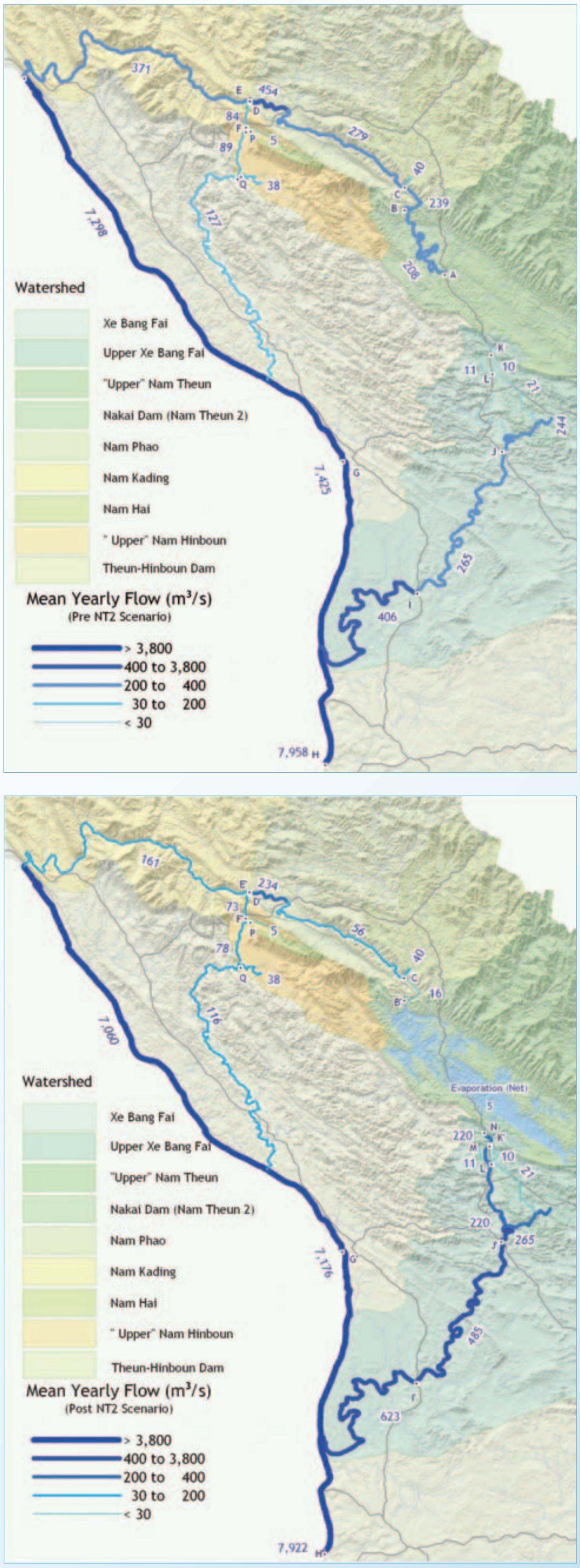

Figure 3.30: Water Balance modelling pre- (Top) & post- (Bottom) NT2 operation mean yearly flow

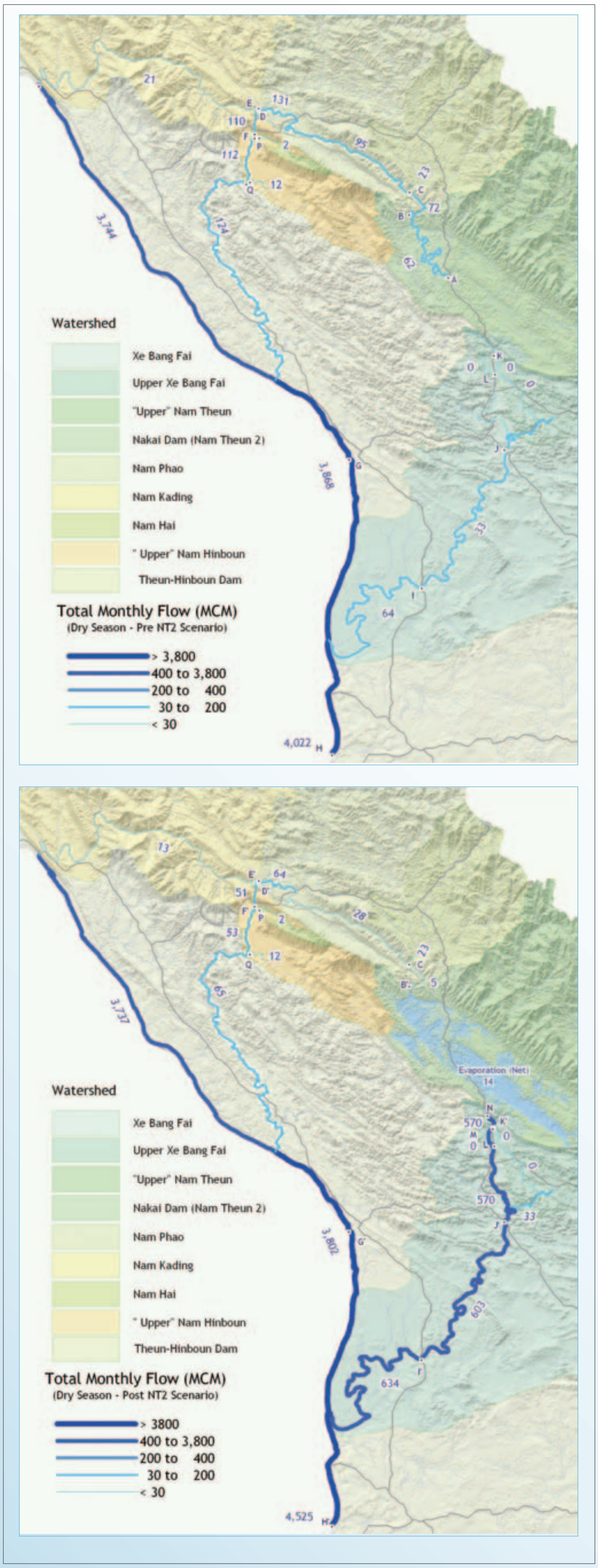

Figure 3.31: Water Balance modelling pre- (Top) & post- (Bottom) NT2 operation dry season (April) monthly flow

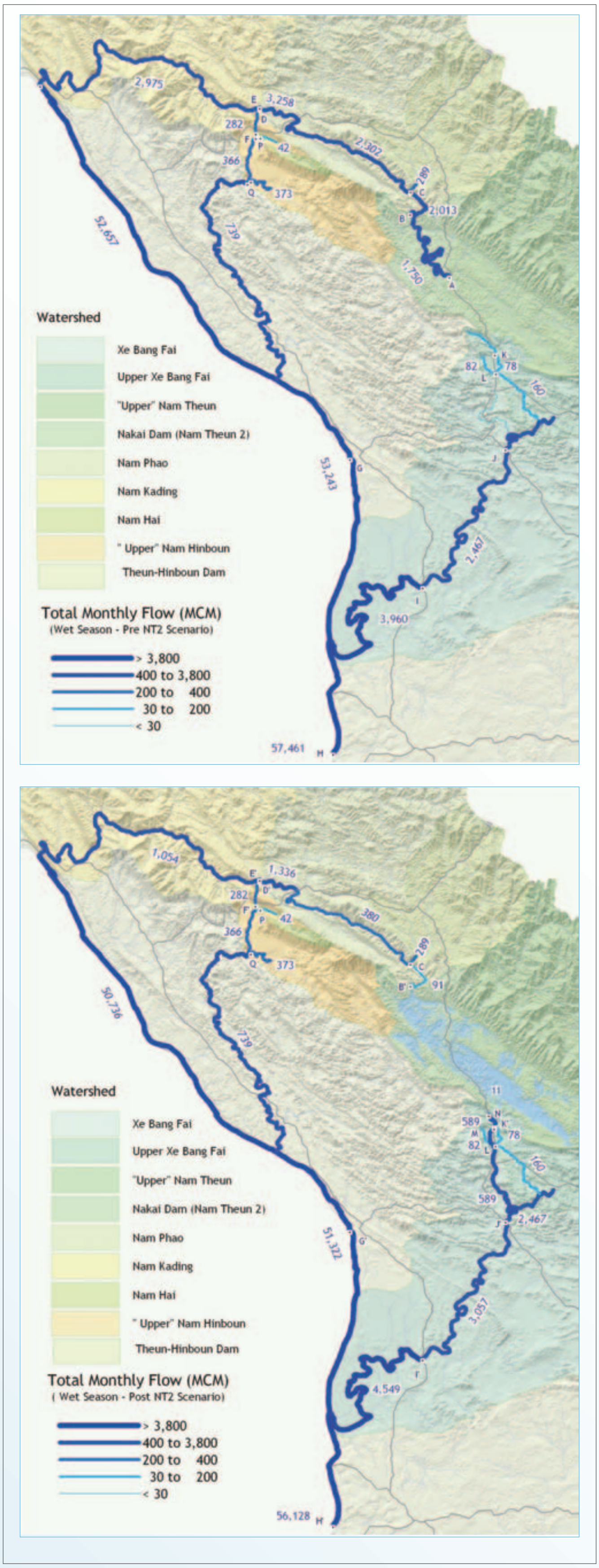

Figure 3.32: Water Balance modelling pre- (Top) & post- (Bottom) NT2 operation wet season (August) monthly flow

from the regulating dam will cease sufficiently before the flow in the Xe Bang Fai reaches 2,270 m^3/s at Mahaxai. This discharge must stop before the Xe Bang Fai overflows its banks at Mahaxai so that flows from the Project do not worsen natural overbank flooding of the upper and middle Xe Bang Fai. Travel time for diversion discharge from the regulating dam to the Xe Bang Fai is approximately seven hours. An additional travel time of approximately three hours is required from the downstream channel confluence with the Xe Bang Fai to Mahaxai. These travel times shall be an integral component of planning restriction and cessation of flows in order to prevent overbank flooding at Mahaxai. On the basis of records available at Mahaxai (SMEC, 1996), discharge restrictions are likely to be triggered about once per year on average, but this will depend on the outcome of further studies to determine appropriate trigger levels. The above measures will substantially mitigate the flooding impact of the diversion into the Xe Bang Fai.

In monetary terms, this mitigation measure implies an average reduction in generation of 44 GWh/year, which is equivalent to a loss of approximately US$ 1.8 million per year or US$ 10 million in Net Present Value over 25 years of operations (EDF, 2000b).

To facilitate the actual implementation of the above arrangement, the following reviews and actions are recommended. During the construction and operation phases, the provisions for restricting outflows from the regulating dam during flood events will need to be further reviewed, as additional hydrological data becomes available, and as portions of the Xe Bang Fai channel enlarge over time and discharge capacity increases. During the construction phases, such reviews and actions should include the following: i) additional comparative analyses of flow response in the downstream channel and flood rises in the Xe Bang Fai as it approaches bank full level; ii) further hydraulic analyses of the Xe Bang Fai downstream of the downstream channel to determine levels downriver for a range of river flows; to compare those levels with river bank heights, and then establish the incremental effects of additional flow from diversion operations. This analysis will provide confidence that there will be no aggravation of downstream flooding impacts, and will assist in refining flood control procedures; iii) prior to commencing operation of the power station, installation of a telemetered data acquisition system for real time monitoring of rainfall and river levels, at and upstream of Mahaxai, to enable flow to be monitored remotely at the Power Station and at the EGAT NCC. The data collected from this system will facilitate management of water releases from the regulating dam; and v) a review of hydrological information collected prior to and during the construction phase.

During the operating phase such reviews and actions should include the following: i) collection of hydrological data using the telemetered data acquisition system installed during the construction phase, in order to ensure that the operation management system of the regulating dam for flood control is based upon a maximum sample of available hydrographic data; ii) during potential flood periods, discharge will be physically monitored at Mahaxai, by personnel with direct communication links to the power station; and iii) review the effects of the proposed flood control operating procedures on the Xe Bang Fai to determine if any residual adverse impacts occur down the river.

Water Levels

To mitigate against any rapid increases in water level, the regulating dam will limit the rate of increase in discharge to a maximum of 20 m^3/s/hour. This represents an increase in water depth of approximately 0.5 cm/min in the downstream channel and 10-20 cm/hr in the Xe Bang Fai. This controlled rate of change will ensure people and animals have time to leave the area and are not in danger from rapidly raising water.

In terms of social impacts, it is likely that villagers will be able to adjust the position of their riverbank gardens to the new water level by relocating their plots further up the bank. Where it is not feasible or productive, NTPC will assist in re-establishing gardening activities. NTPC will determine the potential impact of the Project by means of: i) baseline socio-economic surveys; ii) a study of river gardens in each village, in terms of "gardening system", tenure and income or food productivity to be undertaken 2 years prior to COD; and iii) consultation with villages. Following COD, and if required by a particular village, a study will be undertaken to assess the actual effect on riverside gardens.

The weekly drawdown of the water level in the Xe Bang Fai will require adjustments to the current irrigation system that uses floating pumps attached to the supply pipes. The Project will assist with all pumping installation adjustments that are required due to increases in water level fluctuation.

Since the increased water level in the Xe Bang Fai will prevent some of the temporary modes of crossing the Xe Bang Fai in the dry season, the impact on such access needs to be determined. A study will investigate objectives, means and infrastructure used to cross the Xe Bang Fai and tributaries, and the seasonality of such access. Following the study, a prediction of the impact can be made. NTPC has committed to the purchase of additional boats for the concerned villages. The indicative costs, and the mechanisms for compensating communities for any losses or impacts on livelihoods resulting from additional discharges in the Xe Bang Fai, are presented in the SDP.

Enhancements

The main enhancement resulting from the Project is the improvement of the potential and economics for irrigated agriculture development through the provision of an increased and guaranteed water resource in the Xe Bang Fai during the dry season. Because the Xe Bang Fai floods almost every year, resulting in damage to wet season crops, communities are trying to move towards dry season irrigation and the food security it provides. As outlined above, the additional water from the Project will provide a greater irrigation potential in the dry season. Throughout the Xe Bang Fai there will be potential to irrigate larger areas because of the additional 7,000 MCM of water available. The benefits from the additional water are potentially greater for the upper and middle Xe Bang Fai communities, where their pumps currently run dry during the dry season.

Another beneficial consequence of the additional Project discharge is a reduction in pumping head, or the distance that that water must be lifted vertically from the Xe Bang Fai. This reduction in pumping head should significantly reduce pumping costs. Analysis estimates that the potential average saving that can be made in the dry season is greater than 28% from Mondays to Saturdays and a significant 16% on Sundays.

In the dry season, the increased height of water in the Xe Bang Fai will make river transportation easier, as rocks and rapids that are currently exposed by low water levels may be covered. Thus, navigation along the river and access to villages by boat will be improved.

Riparian Release

The Project will result in a reduction of flow in the Nam Theun and Nam Kading downstream of the Nakai Dam. In 2004, Kellogg, Brown and Root (KBR) were commissioned by NTPC to (i) qualify and whenever possible quantify environmental and social impact associated with the reduction of flow; and (ii) suggest operational procedures for the riparian release and complementary discharge

Table 3.22: Effect of Riparian Release on Flow Rates Downstream of the Confluence with the Nam Phao

Month	Nam Theun Natural Flow (Pre-dam at Ban Thalang) (MCM)	Nam Phao (MCM)	Nam Theun Natural Flow Downstream of Nam Phao (Pre-dam Nam Theun plus Nam Phao) (MCM)	Nam Theun Downstream of Nam Phao with Riparian Release (MCM)	% of Natural Flow Without Riparian Release	% of Natural Flow With Riparian Release
Jan	130	32.5	162.5	37.7	20	23.2
Feb	90	22.5	112.5	27.7	20	24.6
Mar	75	18.75	93.75	23.9	20	25.5
Apr	70	17.5	87.5	22.7	20	25.9
May	145	36.25	181.25	41.4	20	22.9
June	601	150.25	751.25	155.4	20	20.7
July	1362	340.5	1702.5	345.7	20	20.3
Aug	2111	527.75	2638.75	532.9	20	20.2
Sept	1539	384.75	1923.75	389.9	20	20.3
Oct	804	201	1005	206.2	20	20.5
Nov	382	95.5	477.5	100.7	20	21.1
Dec	230	57.5	287.5	62.7	20	21.8
Total	7539	1884.75	9423.75	1946.9	20	20.7

Sources: Nam Theun natural flow at Ban Thalang based on data from SMEC, 1996. Nam Phao flows based on catchment ratios.

to minimize impacts. The majority of the following sections are based on the findings of this KBR's assessment.

The Riparian Release

In order to help maintain the ecological value of the Nam Theun the Project will release a guaranteed minimum riparian release of 2 m^3/s from the Nakai Dam. An additional annual complementary release of 5 million m^3 will also be provided for adaptive management of flows.

The riparian release is intended to provide a minimum amount of water to maintain a basic level of natural processes and ecological value in the aquatic ecosystem. In particular, it is intended to maintain connectivity between pools to help ensure that a heterogeneity of aquatic habitats remain and habitats are not isolated. The ability to vary the flow from the Nakai Dam will be the basis for a strategically focused adaptive management programme. The programme will target the maintenance of aquatic productivity in the Nam Theun.

Geographical Description

Figure 3.33 presents the entire length of the Nam Theun and Nam Kading from downstream of the Nakai Dam to the confluence with the Mekong. As the impacts of the Project are expected to decrease downstream and because of the distinct hydrological features and the different types of impacts that might be realized, the Nam Theun/Nam Kading have been divided into three main reaches: (i) the Nam Theun directly downstream of the Nakai Dam to the first tributary, the Nam Phao; (ii) the Nam Theun downstream of the Nam Phao confluence until the Theun-Hinboun (TH) Dam Site; and the Nam Kading from the TH Dam site until the confluence with the Mekong. Where appropriate the discussion is presented by these three geographical river reaches.

Sources of Baseline Data

The baseline data comprises of a critical review of exiting reports as well as additional data gathered specifically for the assessment of the riparian release. For the assessment of the riparian release, biophysical and hydrological characteristics were collected from representative locations along the Nam Theun/Nam Kading and extrapolated to the entire river. Six in-stream flow requirement (IFR) sites were assigned to be representative of reaches along the Nam Theun/Nam Kading (KBR 2004), the locations of these IFR sites are shown in Figure 3.33. Plates 1 to 4 present typical aquatic and terrestrial habitats at selected IFR sites.

A survey of river profiles for each IFR site was undertaken (VGS 2004). Examples of typical rapid and pool cross sections at each IFR site are presented in Figure 3.33. Outputs from this topographic survey were inputted into a hydrological model in order to assess (i) the reduction in the wetted perimeter; and (ii) the ability of fish to negotiate the rapids during periods of low flow.

For the fisheries and social aspects, LARReC (2004) undertook a consultation-based fisheries survey to use local knowledge to develop an understanding of fishery dynamics and assess the level of socio-economic dependence upon the fisheries resource in the communities downstream of the Nakai Dam. Villages that participated in the survey are presented in Figure 3.34. The villages were selected through advice from the Khamkeut DAFO as being places with important fishing activities in the Nam Theun or its tributaries.

Baseline

Demographic Baseline and Impact Zones

The study area between the Nakai Dam and the TH Dam site falls entirely under the authority of Khamkeut District. In total 70 villages have been identified as being located within the district. The 70 villages within Khamkeut District were populated in 2004 by approximately 8,556 households and 53,754 people. For the purpose analysis of impacts, the villages in Khamkeut have been separated of into seven zones based on their use of different waterbodies and therefore the likely degree to which they will be impacted. The seven village zones consist of (i) Lower Nam Phao, (ii) Upper Nam Phao, (iii) Nam Phouang/Nam Phiat, (iv) Nam Kata, (v) Nam Ngoy, (vi) TH headpond and (vii) Nam Gnouang. The location of these villages, the designated zones and the demographic data for Khamkeut are presented in Figure 3.34. The population data is based on information provided by Khamkeut district staff in 2004. A more detailed breakdown of population data by village is available in the SDP.

It should be noted from Figure 3.34 that no permanent villages lie along the Nam Theun and no land is cultivated from below the Nakai Dam site until the TH headpond, some 40 km downstream.

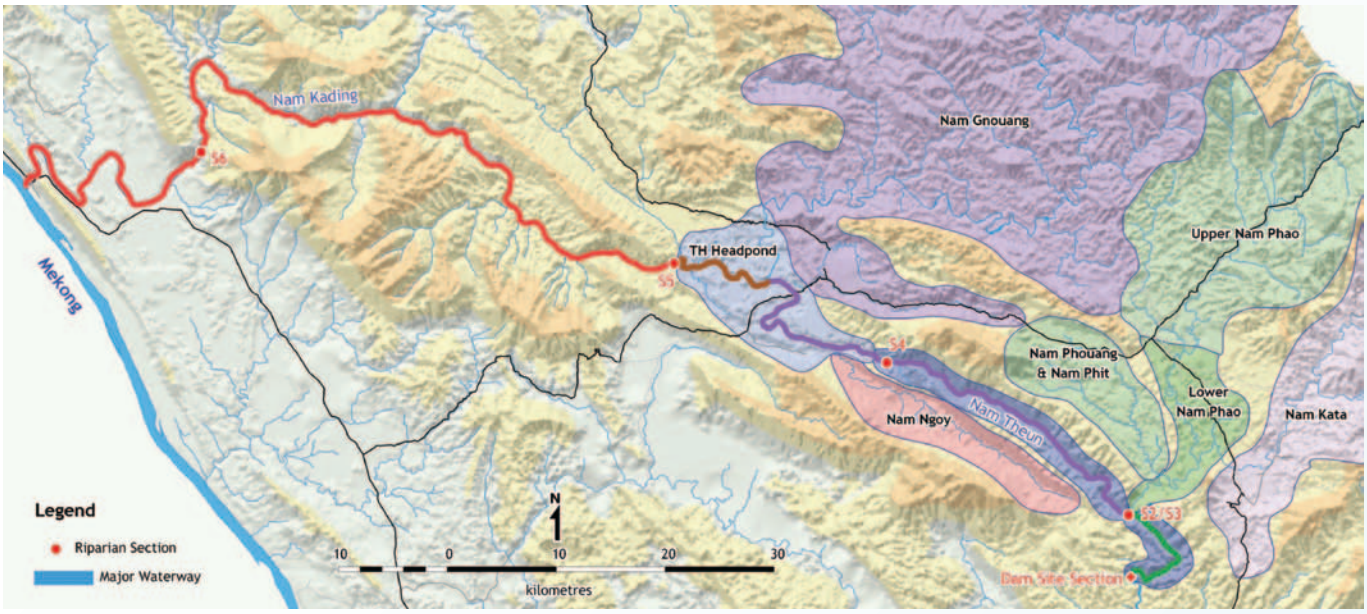

Figure 3.33: Zones of the Nam Theun / Nam Kading and sites of surveyed sections

Hydrology

The baseline hydrology and rainfall data used for the riparian release assessment is presented in Chapter 3. The effect of riparian release on flow rates downstream of the Nam Phao confluence is presented in Table 3.22 The baseline hydrology for the IFR sites in the dry season and wet season is presented in Table 3.23.

TH Spills and riparian release

The average diversion from the TH Dam is 80 m^3/s, which represents over 30% of the total incremental flow, or 15% of the total flow. Figure 3.31 shows that there is currently significant reduction in dry season discharge downstream of the TH dam resulting from TH Project operations.

Water Quality

Baseline water quality data for the Nam Theun are presented later in this chapter. In addition, KBR (2004) recorded the value of key parameters at each of the IFR sites. The input from the Nam Phao seems to influence water quality in the Nam Theun with conductivity downstream of the confluence being approximately twice the levels measured above the confluence. This increase in conductivity reflects the greater population densities that exist in the Nam Phao catchment.

Terrestrial

Analysis of aerial and helicopter photography shows similar vegetation in the geographic sections, from the Nakai Dam to the Nam Phao confluence and Nam Phao confluence to TH headpond. At all IFR sites, vegetation closest to the river tends to be dominated by grasses, woody shrubs and fast-growing tree species (KBR 2004). Tree species dominated 20 m above wet season water level. Local informants indicated that grasses, shrubs and tree species that were present along the Nam Theun were also common in ditches, drains or wetland sites outside of the Nam Theun river valley (KBR 2004).

Community Use

An overview of the baseline community usage of riparian resources of the Nam Theun indicates that this is limited to mainly aquatic

Plate 1: Section Site S1, showing both pool and Rapid habitats

Plate 2: Section Site S2/3, showing both pool and Rapid habitats

Table 3.23 Nam Theun/Nam Kading present flow (m^3/s)

IFR	Dry Season					Wet Season				
Sites	Absolute Min	Avg Min	Mean	Avg Max	Absolute Max	Absolute Min	Avg Min	Mean	Avg Max	Absolute Max
S1	5	25	46	79	887	21	134	420	698	3467
S2	5	26	47	81	911	22	138	431	717	3560
S3	6	33	59	101	1145	27	174	545	906	3640
S4	7	34	61	104	1184	28	180	563	936	3762
S5	5	5	25	78	1897	5	204	869	1550	8878
S6	8	15	42	107	2205	12	253	1019	1805	10260

resources and some terrestrial wildlife. However, these activities occur only in accessible areas (KBR 2004). The river corridor between Nakai Dam and TH headpond is inaccessible and therefore the riparian resources usage by communities in these areas is minimal (KBR 2004).

For those riparian resources that are used by communities, most terrestrial flora and fauna species collected by communities were present in both in the Nam Theun and sites outside the direct river valley (Table 3.24). These species were mainly collected in forest habitats not close to the river. These species are generally widely distributed and were recorded as being collected both within the river valley as well as other areas of the catchment. One exception was the Big-headed Turtle (*Platysternon megacephalum*) which specifically inhabits fast-flowing and rocky stream habitats. This habitat will be significantly reduced once riparian flows commence.

Fisheries

The LARReC (2004) survey included approximately 9% of households (HH) (169 HH and 1,109 Project Affected Persons (PAP)) in 20 villages representing a population of 12,600 people and 1,929 HH. The 20 villages surveyed formed a sub-sample of the total population of 70 villages in the entire study area, Khamkeut District, and were selected on the basis of their likely fishing activity and their direct use of the mainstream Nam Theun. The villages were also selected on the basis of their distribution within the catchment, and the survey aimed to establish (i) any differentiation between communities engaged in fisheries activities within the major tributaries, in relation to communities with a higher dependence on resource utilization of the Nam Theun mainstream; and (ii) the relationship between seasonal distribution and composition of fish stocks within the tributaries and the mainstream of the Nam Theun. In addition, persons interviewed were chosen specifically as the "fishers" of the village. Therefore, all estimates of the population mean fish catch from the Nam Theun should be considered as an overestimate of the true mean.

Table 3.25 illustrates the population data for the villages surveyed, and the estimated numbers of HH engaged in fisheries and aquatic resource collection. An underlying assumption is that 80% of HH are engaged in some form of aquatic resource extraction. Variation between villages is significant (between 20 and 100%) however it indicates that the fisheries are an important element of their livelihood strategies. This is reinforced by the importance attached to fish and aquatic animal capture. The fish and aquatic resource production is ranked second or third in terms of household food security after rice and vegetable cultivation, or other forms of natural resource exploitation (hunting and gathering of NTFP's).

Accordingly, results from the survey include two possible geographic delineations; the Nam Theun fisheries and, other tributaries and waterbodies (such as rice fields, ponds etc.). In terms of describing current use of fisheries resources and ultimately, ascribing potential impacts it is important to clearly distinguish areas that will experience impacts of different levels. Adopting the above assumption it is concluded that 6,844 HH are engaged in fisheries and aquatic resource collection with an average of approximately 15% or 227 HH in the Lower Nam Phao zone, 9% or 54 HH in the Nam Phouang/Nam Phiat zone and 6% or 91 HH in the Nam Kata zone engaged in exploiting fish resources directly on the mainstream Nam Theun.

A qualitative ranking of waterbodies in terms of fishery importance showed that tributaries of the Nam Theun tended to be of greater importance than the Nam Theun mainstream itself. Table 3.26 shows that approximately 40% of respondent ranked the Nam

Plate 3: Section Site S4, showing both pool and rapid habitats

Plate 4: Section Site S5, showing both pool and rapid habitats

Impacts

Table 3.24 Summary of community use of riparian resources

Species	Common Name	IFR S1	IFR S3	IFR S5
Flora				
Melientha suavis		•	•	•
Alpinia conchigera		•	•	•
	Bamboo Shoot	•	•	•
Crateva nurvala		•	•	
Eugenia zeylanica		•		
Calamus spp.		•	•	•
	Rattan Shoot	•		
Dracaena angustifolia		•	•	•
Colocasia petioles			•	•
Rhapis subtilis			•	•
Amomum ovoideum	Cardemom			•
Fauna				
Gallus gallus	Red Junglefowl	•	•	•
Bandicota indica	Great Bandicoot	•	•	
Tragulus javanicus	Lesser Mousedeer	•	•	
Callosciurus erythraeus	Pallas Squirrel	•		
Varanus bengalensis	Bengl Monitor		•	•
Ratufa bicolor	Black Giant Squirrel		•	•
Sus scrofa	Wild Pig			•
Paradoxurus sp.	Common Palm Civet			•
Hystrix brachyuca	E.A. Porcupine			•
Manis javanica	Sunda Pangolin			•
Platysternon megacephalum	Big-headed Turtle			•

Note: • Indicated by communities as only found in river vally

Phao and Nam Kata as the most important waterbodies. The mainstream Nam Theun ranked only seventh in terms of fishery importance with 5.6% of respondent ranking it as the most important.

In summary, the Nam Theun mainstream is not an exclusive source of fisheries production. Fishing activity on the Nam Theun above the confluence with the Nam Phao is limited to flooding periods only. A range of habitats are exploited, from rapids and waterfalls to ponds and rice fields. Again, no one habitat appeared to be utilised exclusively.

Effort

Figures 3.35 to 3.37 illustrate respectively, distribution of fishing effort, annual production trend, and mean household production per month.

The distribution of fishing effort and production correspond to the anticipated trend associated with exploitation of migrating stocks between April and July. The production trend peaks more sharply than the fishing effort due to the influx of migrating stocks and a correspondingly higher yield per unit of effort during this period. The trend between August and December is perhaps a little surprising in that downstream migration in October/November might have been expected to yield higher catch rates.

Socio-economic benefits

Fish Catch: A further analysis comparing catch rates within and between villages and locations utilizing all the villages that participated in the LARReC survey has been undertaken. A summary of the mean annual catch in each village zone is presented in Table 3.27. Based on the LARReC (2004) and Schouten *et al* (2004) reports some useful statistics on household catches and production trends emerge. There is a distinct spatial variation in the size of fish catches and the use of the Nam Theun mainstream. Villages in the Lower Nam Phao tend to have the greatest catches with an average of 142 kg/hh/yr or 12 kg/hh/month. Where as the mean annual household catches for villages in the Nam Phouang/Nam Phiat and Nam Kata catchments were slightly less, at just under 100 kg/hh/yr. The mean

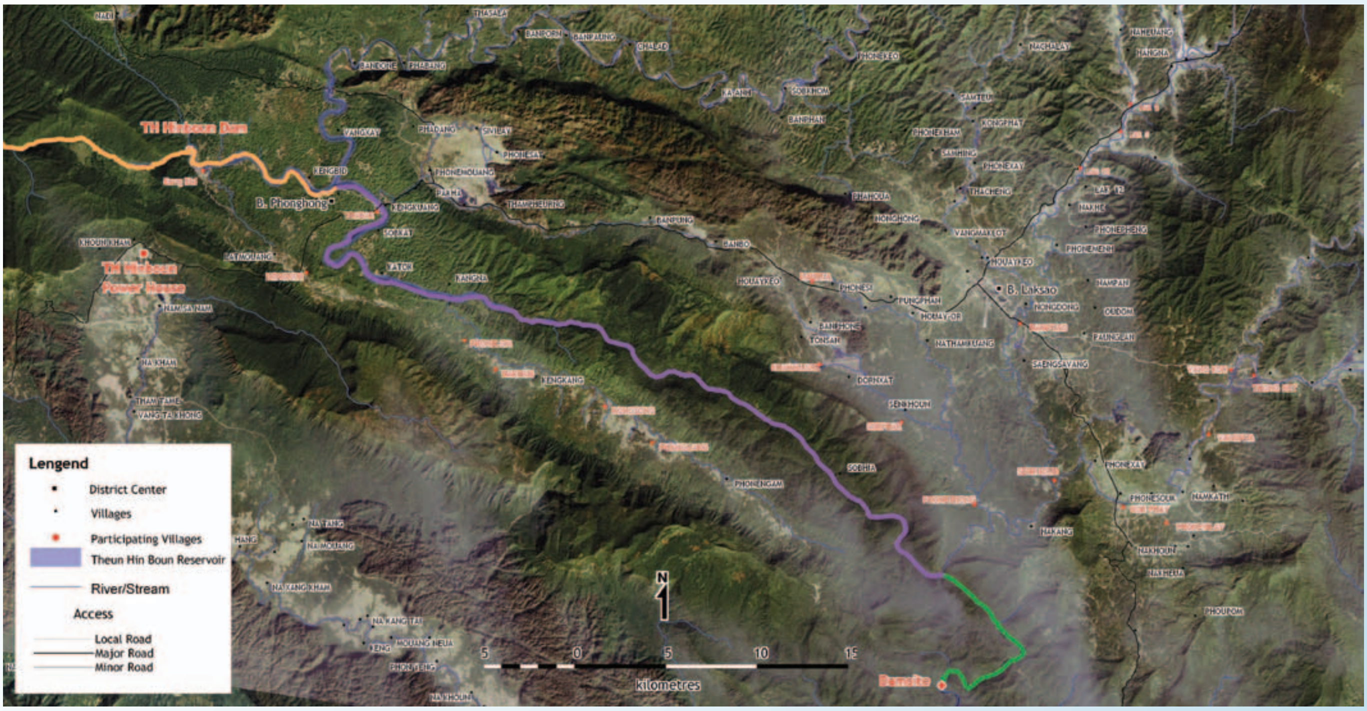

Figure 3.34: Villages surveyed for riparian study

Impacts

Table 3.25: Surveyed population and resource utilisation

Village	Popn	HH	HH fishing		% HH fishing		Interviews		x HH size
			NT	Other	NT	Other	HH	PAPS	
Nam Phao	556	99	0	79	0	100	7	42	6.00
Oudom	868	152	73	49	60	40	11	74	6.73
Phonelom	383	60	41	7	86	14	7	50	7.14
Phonethong	602	103	58	25	70	30	10	74	7.40
Thong	554	92	0	74	0	100	8	50	6.25
Keng Bid	632	102	61	20	75	25	8	50	6.25
Khammuane	650	105	0	84	0	100	8	42	5.25
Korphay	1250	161	0	129	0	100	7	47	6.71
Lak 10	804	106	0	85	0	100	8	65	8.13
Lak 5	698	101	8	73	10	90	11	73	6.64
Lak 7	761	114	0	91	0	100	10	81	8.10
Phayard (Nadeua)	?	?				100	9	55	6.11
Nong Kok	415	72	51	7	88	12	8	47	5.88
Pha Meuang	795	99	0	79	0	100	8	61	7.63
Phone Sy (Phonvilay)	433	67	0	54	0	100	8	52	6.50
Sopphouan	255	45	0	36	0	100	7	41	5.86
Tha Bac	1012	169	135	0	100	0	8	40	5.00
Thongkair	835	120	0	96	0	100	8	50	6.25
Vangkor	459	70	0	56	0	100	9	54	6.00
Vangpha	638	92	0	74	0	100	9	61	6.78
Total	12600	1929	427	1116			169	1109	6.56

annual household catch for villages in the Upper Nam Phao was very low at just 16 kg/hh/yr. This may reflect the fact that these villages at located on a main trade route, between Lao PDR and Vietnam, and have other opportunities to generate income.

Overall fish catches by communities in the downstream Nam Theun area are significantly lower than the mean monthly catch of 27 kg reported in the Xe Bang Fai area. This probably reflects that those villages in the Nam Theun area are generally poorer, which

Table 3.26: Ranked Importance of Waterbodies

Water Body	% Importance
Nam Theun - mainstream	5.6
Nam Theun - TH Headpond	13.0
Nam Ao	0.6
Nam Phouane	5.7
Pond/Rice field	8.1
Nam Kata	19.9
Nam Phao	21.0
Nam Thin	4.1
Nam Ngoy	10.7
Huay Ping El	1.7
Nam Gnoung	2.0
Nam Phiat	2.3
Reservoir	1.2
Bought	0.5
No response	3.1

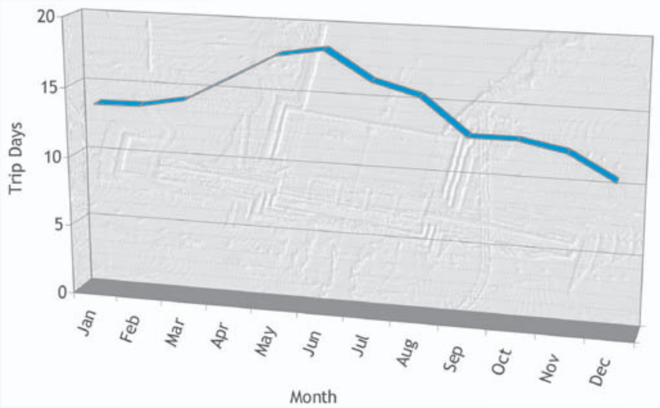

Figure 3.35: Distribution of fishing effort Ban Oudom

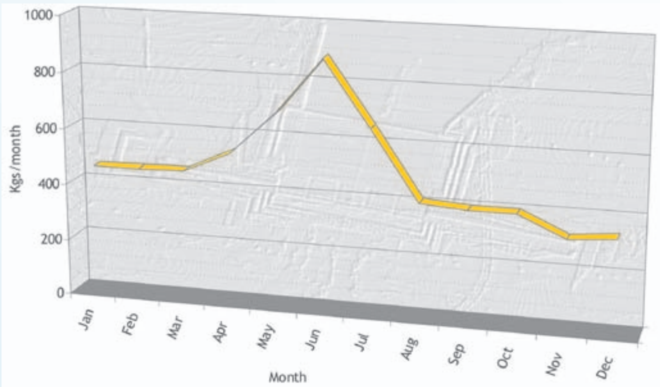

Figure 3.36: Annual fisheries production in Ban Oudom

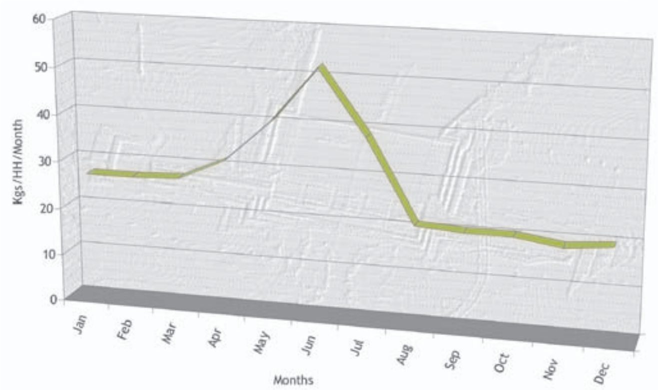

Figure 3.37: Mean annual fisheries production Ban Oudom

is also indicated in the fact that 85% of fish production is utilized for subsistence purposes.

In terms of dependency on the mainstream Nam Theun, predictably the villages in the Lower Nam Phao have the greatest use with an annual mean household catch of approximately 64 kg being sourced from the Nam Theun mainstream. This represents almost 45% of their total catch. Further up the Nam Phao catchment, in the Nam Phoang/Nam Phiat and Nam Kata zones the dependency on the mainstream Nam Theun is significantly less. Only 10% and 6% of their annual catch respectively is being sourced from the Nam Theun. Mean annual household fish catches from the Nam Theun in these villages only amount to 9.6 kg and 2.0 kg. The majority of their fish catch is sourced from either the Nam Phao or its tributaries. Further up the Nam Phao catchment, villages in the Upper Nam Phao zone do not use the mainstream Nam Theun which is probably a result of the distance required to travel and the difficult terrain.

Income: The range of income generated through fish and aquatic products varies considerably. The highest incomes are earned from fishing in these HH engaged in fishing in the Nam Theun and Nam Phao, where there are a higher proportion of professional fishermen. In these rivers the average reported household income from the 90% recorded as generating income is US$70 and US$71 respectively.

The lowest contribution of fising to income comes from the Nam Ngoy and Nam Kata villages with US$19 and US$22 respectively. It is also the case that there is a greater household effort in the collection of aquatic animals in these locations and these are utilized to supplement household consumption.

Based on 127 HH reporting some level of income from collection of fish and aquatic products, the average annual HH catch across all villages and river systems is US$41. Only 3% of those engaged in fish/aquatic animal collection utilise the catch for commercial purposes and for the 96% of household that utilise fish and aquatic animal production for household food security, 82% of the total catch is consumed within the household (Table 3.28). In the 20 villages surveyed in the present study, 57% of all HH generated income from a proportion of their catches, and 43% of HH utilised their catch entirely for domestic consumption. The distribution of income and consumption among HH is presented in Table 3.28 and the percentage contribution to household consumption is presented in Figure 3.38.

Generally, fishing activities were more important for income and household food supply. However, other aquatic products ranked highly as a food supply, with fewer respondents indicating these types of resources offered significant income in lieu of fishing. It is indicated that most of the aquatic products were collected from tributaries and other areas (such as rice fields, ponds) outside of the Nam Theun.

Aquatic Products: A variety of aquatic products are also caught either to supplement fish catches or for sale. Aquatic products catches almost exclusively consist of frogs, snails and shrimp. Aquatic products tend to be caught by the women and children of the household and can represent a substantial input into the household.

In terms of consumption and sale of aquatic products, an average of 81% of households participate in collecting and consuming aquatic products. Table 3.28 shows that of those households collecting aquatic products, 21% sell some of their catch but the proportion of aquatic product catch sold (11%) is low compared with the proportion consumed (89%). Similar to the situation that exists for fish, aquatic products are collected on a subsistence basis.

Only villages in the Lower Nam Phao, Nam Phouang/Phiat and Nam Kata zones utilize the mainstream Nam Theun for collection of aquatic products. Catches are extremely low, with the highest mean annual household catch of 0.5 kg being reported for villages in the Nam Kata zone (Table 3.29). Collection of aquatic products in the Nam Theun mainstream by villages from the Lower Nam Phao and Nam Phouang/Phiat is almost negligible. This is probably due the effort required to reach the Nam Theun therefore only the higher value fish are sought. Table 3.29 shows that the majority of aquatic products are sourced from either from the TH Headpond or tributaries of the Nam Theun.

Fish Consumption by Vulnerable Groups: LARReC (2004) requested survey participants to indicate whether vulnerable groups targeted or avoided consumption of certain species of fish. These vulnerable groups included the elderly (>60 years), pregnant women, breast feeding women and children. The survey found that these vulnerable groups had no preference for eating certain species of fish, although the majority indicated that breast feeding women activity avoided eating some species. The fish species that

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Table 3.27: Mean % of fishers and mean annual fish catch from each waterbody by village zone

Village zone	Mean % HH fishing	Nam Theun - mainstream		TH Headpond		Nam Kading		Nam Ngoy	
		Catch / HH (kg)	Yield (kg/yr)	Catch / HH (kg)	yield (kg/yr)	Catch / HH (kg)	yield (kg/yr)	Catch / HH (kg)	yield (kg/yr)
Lower Nam Phao	32	63.54	96009	-	-	-	-	-	-
Upper Nam Phao	36	-	-	-	-	0.52	1393	-	-
Nam Phouang/Nam Phiat	50	9.55	5768	-	-	-	-	0.01	6
Nam Kata	47	2.60	3058	-	-	-	-	-	-
Nam Ngoy	64	-	-	37.69	16772	-	-	52.37	23305
TH Headpond	48	-	-	72.31	39047	-	-	-	-
Nam Gnouang		-	-			-	-	-	-

Table 3.27: (Cont.)

Village zone	Mean % HH fishing	Nam Gnouang		Pond and rice field*		Nam Phao		Total	
		Catch / HH (kg)	yield (kg/yr)	Catch / HH (kg)	yield (kg/yr)	Catch / HH (kg)	yield (kg/yr)	Catch / HH (kg)	yield (kg/yr)
Lower Nam Phao	32			1.62	2448	79.12	116776	144.28	215227
Upper Nam Phao	36			6.09	16309	9.65	25843	16.26	43545
Nam Phouang/Nam Phiat	50	0.06	36	0.60	362	83.81	50627	94.04	56799
Nam Kata	47			0.08	122	32.14	49142	34.22	52322
Nam Ngoy	64	0.87	387	8.85	3938			99.77	44402
TH Headpond	48	0.55	297	0.01	6	0.26	140	73.14	39490
Nam Gnouang		118.02	147407		7606			118.02	155013

are avoided by breast feeding women are mainly (i) scaled fish of the Cyprinidae family (*Cyclocheilichthys enoplos*, *Mystacoleucus* aff. *Atridorsalis*, *Hemibarbus maculatus*, *Acheilognathus deignani*, *Hampala dispar*) ; (ii) catfish species of the Clariidae family (*Clarias batrachus*, *Clarias fuscus*); or (ii) eel species of the family Mastacembelidae (*Macrognathus circumcinctus*, *Macrognathus siamensis*, *Mastacembelus armatus*) and an eel-like species of the Synbranchidae family (*Monopterus albus*).

Spawning and Migration: The knowledge of the spawning and migratory behaviour of fish species in the Nam Theun is limited. An overview of the spawning and migratory behaviour of key Nam Theun fish species is presented in Annex K.

From the current knowledge, it appears that some fish species migrate upstream in the Nam Theun during different periods of the year. The hydrological regime of the Nam Theun is one of the major determinants of this upstream migration: (i) during May/June, at the beginning of the rainy season, when discharge is increasing, a large number of fish species migrate upstream to spawn in tributaries and ephemeral streams; and (ii) in September when discharge is high, many species (such as those belonging to the genera *Bangana* and *Tor*, and families Bagridae and Pangasiidae) migrate upstream to spawn when water levels recede and concentrations of suspended solids decline (Schouten, 2004). These two major upstream fish migrations and the success of spawning

Table 3.28: Percentage of fish catch and aquatic products consumed and sold, by village zone

Village	Fish				Aquatic Products			
	% of HH that catch and consume fish	% of HH that sell fish	% fish consumed[1]	% fish sold	% of HH that catch and consume AP	% of HH that sell AP	% Aq. Prod consumed[1]	% Aq. Prod sold
Lower Nam Phao								
Phone Sy	100.0	25.0	96.9	3.1	100.0	0.0	93.8	6.3
Upper Nam Phao								
Lak 5	100.0	63.6	64.5	35.5	72.7	18.2	87.5	12.5
Lak 7	90.0	44.4	77.8	22.2	90.0	30.0	75.5	24.5
Lak 10	87.5	71.4	71.9	28.1	100.0	62.5	67.5	32.5
Nam Phouang/Nam Phiat								
Khammouane	100.0	25.0	83.8	16.3	62.5	0.0	100.0	0.0
Sop Phouan	100.0	37.5	86.3	13.8	100.0	75.0	65.0	35.0
Nadeua	100.0	33.3	91.1	8.9	88.9	44.4	85.6	14.4
Nam Kata								
Kor Phay	85.7	33.3	88.3	11.7	71.4	0.0	100.0	0.0
Thong Ket	100.0	37.5	91.3	8.8	100.0	12.5	93.8	6.3
Vang Kor	100.0	44.4	81.1	18.9	88.9	0.0	100.0	0.0
Vang Pha	100.0	25.0	92.5	7.5	100.0	12.5	97.5	2.5
Nam Ngoy								
Phameuang	100.0	37.5	91.3	8.8	87.5	37.5	82.9	17.1
Nong Song	87.5	42.9	76.7	23.3	87.5	37.5	80.7	19.3
TH Headpond								
Keng Bid	100.0	75.0	73.8	26.3	50.0	0.0	100.0	0.0
Nong Kor	100.0	62.5	76.3	23.8	62.5	0.0	100.0	0.0
Ta Bac	87.5	85.7	62.9	37.1	37.5	12.5	93.3	6.7
Mean	96.1	46.5	81.6	18.4	81.2	21.4	88.9	11.1

[1]only respondents that indicated they catch either fish or aquatic products

Impacts

Table 3.29: Mean % of fishers and mean annual aquatic products catch from each waterbody by village zone

Village zone	Nam Theun - mainstream	TH Headpond	Nam Kading	Nam Gnouang	Tributaries (Phao, Ngoy, Phouane, Mouan, Thin, Kata) Pond and Rice	Total
	Annual Catch / HH (kg)	Annual Catch / HH (kg)	Annual Catch / HH (kg)	Annual Catch / HH (kg)	Annual Catch / HH (kg)	Annual Catch / HH (kg)
Lower Nam Phao	0.1				40	40.26
Upper Nam Phao					102.5	102.5
Nam Phouang/Nam Phiat	0.03		13.6		60.5	74.13
Nam Kata	0.53				56.3	56.83
Nam Ngoy		1.08			53.5	54.58
TH Headpond		75.7			77.5	153.2

are determined by discharge, water level fluctuations and water quality. Discharges determine the time, duration and frequency of existence of aquatic habitats that function as spawning grounds. Given the low primary productivity during the wet season, the fish are using the Nam Theun during this period mainly as a migration corridor and less so as a feeding, spawning or nursery ground (Schouten, 2004).

This migratory pattern was identified during consultations with communities, which suggests that the key period for spawning is February to May with peak spawning period for all water bodies occurring in March (Figure 3.39) (KBR, 2004). A secondary spawning in some species occurs in October which coincides with the downstream migration period. However, the *Pba Soi* migration observed in the Xe Bang Fai, when the juveniles of more than 20 species leave the drying floodplains and ephemeral streams to migrate in the Xe Bang Fai, does not occur in the Nam Theun (Schouten, 2004). This is an important part of the fishery for the Xe Bang Fai.

There is sufficient difference between individual species and individual tributaries to suggest that discrete spawning groups probably occur within tributaries and that spawning activity occurs over many months within individual species. It seems clear that peak migration occurs somewhat later than the peak spawning period.

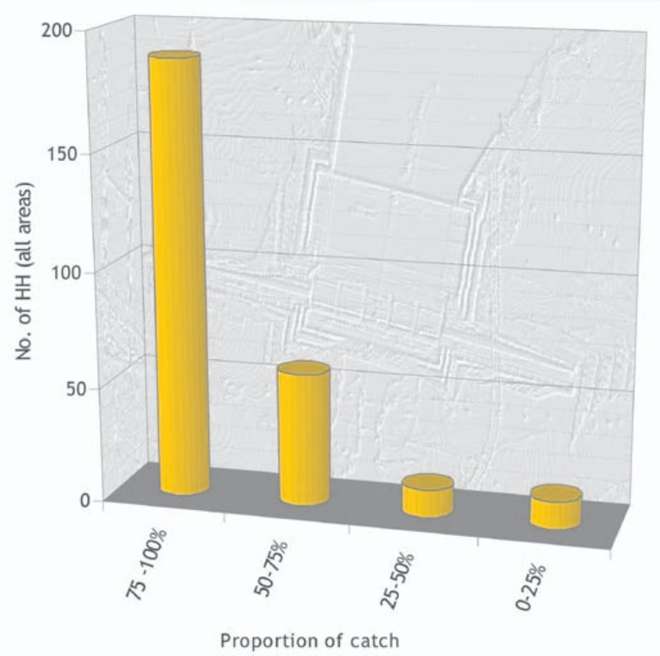

Figure 3.38: Proportion of catch utilised for HH subsistance

Figure 3.40 presents the distribution of species numbers in the catches over the year. The diversity of species during the downstream migration is significantly lower than for the upstream migration, and for this there is no clear explanation at this stage (KBR 2004).

During the LARReC (2004) survey, twelve species were identified as being vulnerable to high low flow conditions.

Non-migratory exotic species of fish, Common Carp (*Cyprinus carpio)* and Tilapia (*Oreochromis niloticus*), were recorded as common captures (KBR 2004). The presence of these fish is linked to escapees from fish culture programs in the upper catchment. These species are edible and may form an important local source of readily accessible protein.

Table 3.30: Contribution of fish and aquatic products to HH income

Village Name	Household Activity	Income Kip/year
Nam Phao	Fishing	2,200,000
Oudom	Fishing	12,480,000
Phonelom	Fishing	6,000,000
Ponethong	Fishing	4,750,000
Thong	Fishing and aquatic animals	1,700,000
Keng Bid **	Fishing and aquatic animals	2,300,000
Khammuane	Fishing and aquatic animals	700,000
Korphay	Fishing and aquatic animals	250,000
Lak 10	Fishing and aquatic animals	4,920,000
Lak 5	Fishing and aquatic animals	2,100,000
Lak 7	Fishing and aquatic animals	7,500,000
Nadeua	Fishing and aquatic animals	700,000
Nong Kok	Fishing and aquatic animals	1,070,000
Pha Meuang	Fishing and aquatic animals	280,000
Phonesi	Fishing and aquatic animals	120,000
Sopphuan	Fishing and aquatic animals	1,090,000
Tha Bac	Fishing and aquatic animals	4,350,000
Thongkair	Fishing and aquatic animals	1,450,000
Vangkor	Fishing and aquatic animals	2,200,000
Vangpha	Fishing and aquatic animals	500,000
TOTAL		56,660,000

** From Ban Keng Bid the enumerators have changed to represent the proportion of catches allocated to consumption or income

Impacts

Table 3.31: Other uses of the Nam Theun (dashed (-): do not use; cross (x): use)

Village	Other Use of the Nam Theun						
	Transport	Domestic	Irrigation	Livestock	Fishing	Washing	Waste Disposal
Lower Nam Phao							
Phone Sy	-	-	-	-	-	-	-
Upper Nam Phao							
Lak 5	-	-	-	-	-	-	-
Lak 7	-	-	-	-	-	-	-
Lak 10	-	-	-	-	-	-	-
Nam Phouane/Nam Phiat							
Khammouane	-	-	-	-	-	-	-
Sop Phouan	-	-	-	-	-	-	-
Nadeua	-	-	-	-	-	-	-
Nam Kata							
Kor Phay	-	-	-	-	-	-	-
Thong Ket	-	-	-	-	-	-	-
Vang Kor	-	-	-	-	-	-	-
Vang Pha	-	-	-	-	-	-	-
Nam Ngoy							
Phameuang	-	-	-	-	-	-	-
Nong Song	-	-	-	-	-	-	-
TH Headpond							
Keng Bid	x	-	-	x	x	x	x
Nong Kor	x	x		x	x	x	x
Tabac	x	x	x	x	x	x	-

Trends in Fisheries: Annex E shows that the current hydrological condition in the Nam Theun differs significantly on both a seasonal and annual basis. The seasonal and annual differences in the hydrological regime provide a dynamic environment for aquatic life. The distribution and annual productivity of fish populations fluctuate with these fluctuations of meteorological, hydrological and the subsequent water quality conditions.

Naturally occurring floods modify aquatic habitats which can result in significant impacts on aquatic life. An extremely high flood that occurred in both 1996 and 2002 had severe impacts on the Nam Phao and Nam Gnouang fisheries (Schouten, 2004).

If the number of fishers and fishing effort remained constant, the annual fish yield would fluctuate with these meteorological and hydrological cycles. However, the human population in the Nam Theun basin has been increasing and with the subsequent increase in the number of fishers and fishing effort, the annual household catch has been declining. To maintain their fish catches, fishers increase their fishing effort and use more destructive, non-sustainable fishing methods; such as explosives and blocking-off tributaries. Villagers in Ban Phonelom report hearing explosions at least twice a day and evidence suggests that fishers from Ban Tabac use explosives when fishing in the Nam Theun above the TH Headpond (Schouten, 2004). The combination of increased fish effort and non-sustainable fishing methods will further exacerbate the decline in annual fish catch which has been identified by communities within the Nam Theun basin.

In addition to increasing population, in the tributaries between the TH dam and the proposed Nakai Dam, evidence suggests that there has already been a decline in fisheries productivity and biodiversity as a consequence of the TH Project (KBR 2004). This is likely attributed to the change in flow conditions and water quality in the TH headpond and the inability of some downstream fish stocks to pass over the dam during upstream migrations. Villagers also suggest that there is a proliferation in the populations of non-indigenous fish species that probably originate from aquaculture or introductions into the TH Headpond.

During a field visit in 2004, impacts on the aquatic environment were observed in both the Nam Phao and Nam Kata (*pers. comm.* Roel Schouten). The sources of these impacts in the Nam Phao and Nam Kata were road construction and gold mining activities.

The cumulative effect of the impacts identified above have probably caused the decline in the fisheries of the Nam Theun basin that was identified by communities during consultation.

Aquaculture: Aquaculture appears not to be very well developed in the area. An average of only 8% of households own a fish pond, with almost half of the villages having no fish ponds at all (LARReC 2004). Reasons for such a lack of development of aquaculture are likely to be similar to those in the Xe Bang Fai areas, in that there is currently abundant fish in the rivers and TH headpond, the lack of infrastructure and well-developed market systems or transportation services, as well as the lack of knowledge about fish culturing techniques.

Other Water Uses

Other uses of the mainstream Nam Theun appears to be minimal. Apart from the fisheries and a small amount of aquatic product collection, no other direct beneficial uses of the Nam Theun mainstream were indicated by persons consulted during the LARReC survey (2004). Table 3.31 shows that only the villages of Ban Keng Bid, Ban Nong Kor and Ban Tabac use the Nam Theun for domes-

Table 3.32: Comparison of present and future average dry and wet season flows

IFR	Dry Season					Wet Season				
	Abs Min	Avg Min	Mean	Avg Max	Abs Max	Abs Min	Avg Min	Mean	Avg Max	Abs Max
S1	41%	8%	4%	3%	0.3%	10%	1%	12%	21%	51%
S2	43%	10%	7%	5%	3%	12%	5%	15%	22%	52%
S3	42%	28%	25%	23%	23%	30%	23%	31%	34%	71%
S4	45%	30%	27%	25%	25%	32%	25%	33%	36%	72%
S5	100%	100%	33%	27%	38%	100%	19%	36%	40%	58%
S6	100%	100%	61%	43%	46%	100%	34%	46%	48%	63%

tic water supply, transportation and watering livestock. These villages are located along the banks of the TH Headpond and therefore source their water from the headpond and not the Nam Theun mainstream.

Water abstraction from the mainstream Nam Theun for irrigation is negligible (KBR 2004). There is no evidence of any infrastructure associated with abstraction at any of the IFR sites and no evidence on the banks traveling to these sites. Ban Tabac is the only village indicating the Nam Theun as a source of water for irrigation but this village is located along the TH Headpond.

Assets

No permanent assets were identified during surveys along the banks of the Nam Theun at IFR sites S1 to S5 but some temporary fishing camps were present at sites S2, S4 and S5.

Impacts

Hydrology

An assessment of the impacts on hydrology is required in order to assess the subsequent impacts on the fisheries. Hydrologic regimes play a major role in determining the biotic composition, structure and function of aquatic ecosystems.

Table 3.32 compares the present and future flow conditions in terms of percentage of the mean annual runoff (MAR). MAR of the Nam Theun, between Nakai Dam and the Nam Phao confluence, will be reduced to 12.5%. This would increase on average to 30% below the Nam Phao confluence. On average only 50% of the Nam Kading flow will reach the Mekong River. The minimum wet season flows of the first 12 km reach of the Nam Theun will be reduced to about 3% of the existing flows, while the maximum dry season flow will be reduced to 4%. Similarly the absolute maximum flow during the dry season will be reduced to 0.3%.

Upon commencement of riparian releases, approximately half of the minimum dry season flow will be recorded between the Nakai dam site and the TH Headpond (IFR sites S1 to S4). There is no expected change in the minimum dry season flow downstream of the TH dam (IFR sites S5 and S6). Reductions in minimum wet season flows range from 10.5 to 3 times lower at the dam site (IFR sites S1) and above the TH Headpond (IFR site S4), respectively. Minimum wet season flows below the TH dam (IFR sites S5 and S6) are not expected to change.

Spills

Based on the daily time step reservoir simulation, water is spilled approximately once every 2.7 years. The average annual spill volume is 454 MCM with the largest annual flow of 3,428 MCM. A more detailed description of the spills from the Nakai Dam is presented in Annex F.

Table 3.33: Example of Wetted Perimeter Analysis at IFR S1

Q Total	Depth	Vel Chnl	Flow Area	Wetted Perimeter
(m^3/s)	(m)	(m/s)	(m^2)	(m)
		Rapid		
2	0.7	0.33	6.0	7.9
5	1.0	0.42	12.0	11.2
8	1.2	0.39	20.7	21.3
10	1.4	0.41	24.3	22.9
21	1.8	0.5	41.6	28.9
33	2.2	0.59	55.7	30.4
51	2.7	0.69	74.1	32.3
99	3.4	0.74	133.4	51.9
420	5.4	1.23	377.9	57.5
1757	9.5	1.87	1145.0	57.5
3467	12.6	2.29	1822.4	57.5
		Pool		
2	8.4	0.001	512.9	101.1
5	9.1	0.01	583.4	103.7
8	9.8	0.01	648.2	105.6
10	10.0	0.01	666.9	106.2
21	10.7	0.03	744.1	108.5
33	11.2	0.04	801.3	110.1
51	11.9	0.06	873.7	112.2
99	13.6	0.09	1057.5	117.5
420	17.6	0.28	1527.2	118.0
1757	23.4	0.79	2316.7	118.0
3467	27.7	1.25	2977.7	118.0

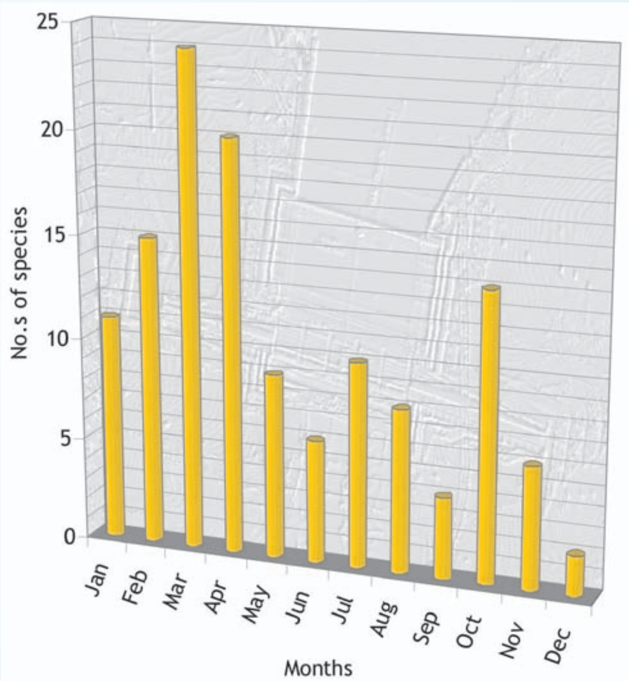

Figure 3.39: Distribution of spawning activity - Nam Theun and tributaries

Impacts

Table 3.34: Summary of wetted perimeter analysis for 2m³/s Riparian Release

IFR Site	Habitat type	Present mean dry season discharge	Present wetted perimeter	Riparian Release	Future mean dry season discharge	Future wetted perimeter	Impact on wetted perimeter
		m^3/s	m	m^3/s	m^3/s	m	%
S1	Rapid	25	29.4	2	2	7.88	73
	Pool	25	108.8	2	2	101.10	7
S2	Rapid	26	43.7	2	3	20.08	54
	Pool	26	Data not available				
S3	Rapid	33	23.3	2	15	10.29	56
	Pool	33	28.4	2	15	21.98	23
S4	Rapid	34	27.5	2	17	25.6	6.9
	Pool	34	34.9	2	17	12.16	65

Hydraulic Parameters and Wetted Perimeter

The wetted perimeter method has been adopted to assess the impact of the reduced flow on fisheries in the Nam Theun and surrounding tributaries. This method is a commonly used hydraulic rating methodology that is applied worldwide. It uses the relationship derived from changes in river wetted perimeter at representative cross-sections with changes in discharge. Productivity in mainstream Lao rivers occurs mainly during the dry season when conditions are more favorable. Dry season sunny days, low water depth and transparency all contribute to the annual primary production. The contribution of wet season production to overall annual production in the Nam Theun mainstream is negligible (Schouten, 2004). The wetted perimeter method uses the assumption that fish production is related to food production, which in turn is related to the amount of wetted river bed in the dry season. Because of this assumption uncertainties are associated with using the wetted perimeter method. The method is based on general principles and is not proven to be relevant for specific fish in a particular river.

VGS (2004) measured ten cross sections at 100m intervals at each IFR site. These cross sections were inputted in a one-dimensional steady state model, HEC-RAS (KBR 2004). This model has been developed by the US Army Corps of Engineering and simulates backwater profiles through a river reach for a given inflow. The downstream and upstream boundary conditions for the model were the surveyed river water levels and the estimated flows from nearby streamflow gauging stations, respectively. The stream channel roughness or Manning's n values were estimated during the model calibration process. The model was calibrated using the recorded river flows at Nakai Dam downstream gauging station.

Initial results are available only for a typical cross section of a rapid and a pool at each of the IFR sites. The wetted perimeter analysis for the remaining cross sections at each IFR site will be conducted to provide a more refined estimate of the reduction in the wetted perimeter and the subsequent impact on the fisheries.

Summary of the reduction in wetted perimeter resulting from the 2m³/s riparian release presented in Table 3.33.

At IFR Site S1, for a rapid is habitat, the current mean minimum discharge of 25.4 m³/s at the Nakai Dam site during the dry season would create a wetted perimeter of 29.4 m. The riparian release of 2m³/s flowing through the same rapid would give a wetted perimeter of only 7.9 m, which corresponds to a 21.5 m or 73% decrease in the length of river bed that is covered in water. For a pool habitat, the mean minimum dry season discharge would result in a wetted perimeter of approximately 108.8m. The riparian release of 2m³/s would create a wetted perimeter of 101.1m in the same pool, which is an impact of only 6.8%.

The severity of impact on the wetted perimeter generally diminishes with distance downstream of the Nakai Dam. For example, the impact on the wetted perimeter in rapid habitat of IFR sites S2, S3 and S4 is 54%, 56% and 6.9% respectively. The impact of the riparian release on the wetted perimeter of the pools is significantly less than the impact in the rapids.

Table 3.35: Future flood event occurrence in the Nam Theun and Nam Kading

IFR site	Average recurrence interval				
	1 year	2 year	5 year	10 year	20 year
S1	Present	Absent	Absent	Absent	Absent
S2	Present	Absent	Absent	Absent	Absent
S3	Present	Absent	Absent	Absent	Absent
S4	Present	Absent	Absent	Absent	Absent
S5	Present	Present	Absent	Absent	Absent
S6	Present	Present	Present	Absent	Absent

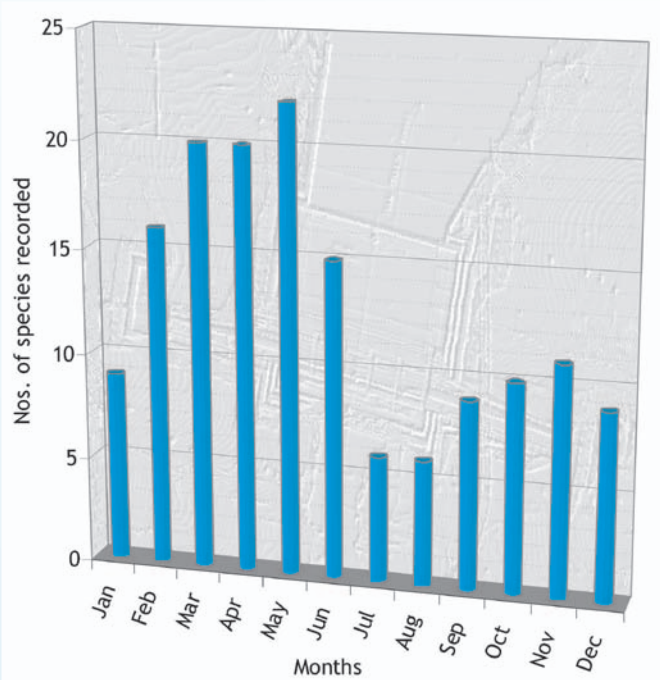

Figure 3.40: Distribution of fish species in monthly catches

Table 3.36: River channel hydraulic parameters for the future average minimum flows

IFR	Discharge	Water falls / Rapids				Pools			
		Water Depth	Channel Velocity	Flow Area	Top Width	Water Depth	Channel Velocity	Flow Area	Top Width
S1	10%	39%	66%	15%	27%	79%	3%	69%	95%
S2	11%	51%	43%	25%	46%	91%	3%	87%	95%
S3	30%	54%	89%	34%	44%	76%	46%	65%	79%
S4	28%	59%	55%	51%	87%	94%	29%	92%	98%
S5	100%	100%	100%	100%	100%	100%	100%	100%	100%
S6	100%	100%	100%	100%	100%	100%	100%	100%	100%

Impacts of the riparian release on other hydraulic parameters in the Nam Theun/Nam Kading are presented in Table 3.36. In the reach of the Nam Theun, between the Nakai Dam and the Nam Phao confluence, flow will be significantly reduced, by 90%, and as a consequence of the water depth in the rapids will be reduced by 60% and the flow area by 85% while in the pools the water depth is only reduced by 21%. The flow velocity will be reduced by 97%. Flow velocities in the pools are important since they are the key elements for the survival of aquatic species. Downstream of the TH Dam the impact of NT2 Project on the dry season flows are insignificant, as the average minimum dry season flows will be maintained by the TH releases.

River Morphology

For the riparian release scenario the flow velocities in rapids are greater than 0.3 m/s in all reaches of Nam Theun and Nam Kading, this means that biofilm development may not take place because the mobilization of sediments will provide sufficient scouring. However, in some pools the flow velocities are below the threshold velocities of 0.3 m/s required to mobilize fine sediment and there will be a potential for biofilm development during the dry season. Wet season spills with flows greater than 450m^3/s should mobilise the biofilms from the pool section.

Reservoir operation modeling indicates that flood flows below Nakai Dam will be severely reduced. Table 3.37 shows the comparison of the maximum floods for present and the future condition. The flood peak between Nakai Dam and the Nam Phao confluence would be reduced by 50%. In terms of occurrence 1-year Average Recurrence Interval (ARI) flood will be virtually lost from the system between Nakai Dam and the TH headpond (Table 3.35). The loss of this important flood event will cause channel morphological changes in terms of reduction in flow area and wetted perimeter, which are important features for the aquatic habitat integrity.

Colloidal Sediment Deposition

This is the only component of the total sediment load that will pass through the Nakai Dam and hence the colloidal load will increase proportionally in the reach between the Nakai Dam and the Nam Phao. If clay deposits become consolidated, then high velocities are required to remobilise these. The deposits may influence nutrient dynamics and turbidity in pools

Sand Deposition

Critical velocities for the motion of coarse and fine sand are 0.8 m/s and 0.3 m/s, respectively. Directly downstream of the Nakai Dam, sand deposits will become reduced with time. Sand deposits are breeding habitats for some aquatic species.

Gravel/cobbles/boulders Deposition

The coarser bed materials are transported at much higher velocities than sands. Decreased velocities will lead to increased infilling of interstitial spaces and when the larger elements are not displaced occasionally, then the bed could become solidified. The interstitial spaces in between coarse bed materials are an important habitat zone. However, during a spill event sufficient volume will be discharged into the Nam Theun to generate flow velocities greater than 2 m/s and then mobilise the accumulated material, avoiding the solidification of the river bed. During periods when Nakai Dam does not spill it may be necessary to release flows to mobilise these sorts of materials. Below Nam Phao confluence the impact to the movement of gravel/cobbles and boulders will be minimal.

Water Quality

Based on the hydrological impacts the relationship between these key water quality parameters and specific features are described below. The focus of the descriptions is for dry season flows, when water quality in rapids and pools will be directly influenced by a number of biological, physical and chemical factors. These relationships will determine the suitability and sustainability of some waterbodies for fish survival.

Rapids

The quality of water in rapids during the dry season will relate to flow rate and turbulence. Turbulent conditions tend to replenish the concentration of oxygen. The available turbulent flow of rapids will be reduced markedly under riparian release conditions. The profile of typical rapids directly below the proposed dam will be a depth of less than 0.8 m and an available flow area of just over 6 m^2. At a velocity of approximately 0.33 m/s, water will continue to flow over the rapids. The general impacts on key water quality in areas of rapids are as follows: with a larger surface to volume ratio the water temperature will be influence more by the ambient temperature. Below the Nam Phao confluence, water temperature

Table 3.37: Comparison of present and future flood peaks

IFR Site	Flood peaks (m^3/s)		
	Present	Future	Change
S1	3400	1757	52%
S2	3622	1804	50%
S3	4519	2251	50%
S4	4768	2375	50%
S5	8876	5116	58%
S6	10870	6571	60%

Table 3.38: Comparison of present and future MARs (1986-2003)

IFR	Present MAR (m^{3}x10^6)		Future MAR (m^{3}x10^6)		Future MAR as % of Present MAR	
	Mean	Median	Mean	Median	Mean	Median
S1	7395	5411	842	63	11%	1%
S2	7594	5556	1039	209	14%	4%
S3	9527	7497	2867	1705	30%	23%
S4	9846	7749	3185	1957	32%	25%
S5	14088	10078	5083	3077	36%	31%
S6	16737	12096	7732	5095	46%	42%

will be more influenced by tributaries and may increase due to the reduced depth of rapids; (ii) Conductivity measures below the Nam Phao may be expected to rise, as the Nam Theun will no longer provide a level of dilution; (iii) pH will remain similar above the confluence, but may be influenced by inputs from the Nam Phao in lower reaches; (iv) dissolved oxygen will remain high in areas of turbulent water movement.

Pools

In the area immediately downstream of the Nakai Dam, the flow area of pools will not reduce significantly, but flow velocity will reduce to 3%. Based on this reduced flow the general water quality parameters in pools will be as follows: (i) water temperature will be more influenced by ambient temperatures; (ii) periodic flooding events will reduce pool temperatures; (iii) conductivity in pools below the Nam Phao confluence will be directly influenced by inputs from tributaries and higher than current values; (iv) pH in pools will fluctuate according to biological conditions; and (v) dissolved oxygen pools below the Nam Phao confluence could be expected to remain higher than for pools above the confluence.

Plant and animal material deposited in pools will likely remain for longer periods under reduced flow conditions, so bacterial decomposition of any organic material will tend to deplete dissolved oxygen. With decreased availability of dissolved oxygen, the composition of biological resources in the pools will vary considerably and may not be conducive to supporting larger macroinvertebrate or vertebrate species.

Production of biofilms in pools located above the Nam Phao confluence will increase as the velocity decreases. In slow-flowing conditions, phytoplankton densities may increase, causing fluctuation in water quality that reflects the diurnal patterns in photosynthesis.

Supersaturation

Spill waters exiting Nakai Dam may produce supersaturated conditions during periods of high flow. However, the scale of impacts from these conditions should not be detrimental to downstream fish populations and will be rapidly assimilated into downstream waters. Spills will be received into a relatively shallow spill-pool, reducing the likelihood of creating concentrations of supersaturated waters lethal to fish species.

Terrestrial

Vegetation

The exposure of river banks under the reduced flow conditions will cause encroachment of terrestrial vegetation onto suitable substrates. The exposed river banks will be suitable for colonization by fast growing species such as gasses. However, the suitability of bank substrates for vegetation colonisation is variable. Analysis of photographs between the Nakai Dam and the Nam Phao confluence indicates only limited areas where significant transgression of vegetation towards the limits of dry season flow could be expected (KBR 2004). This section of the Nam Theun includes large areas of boulders and it is unlikely that these substrates would contain sufficient deposits of topsoil to support significant vegetation growth.

Downstream of the Nam Phao confluence to the TH headpond, the frequency of boulder and rock adjacent to the river is less. Reduction in river height in these areas may result in significant transgression of fast-growing species such as grasses and woody shrubs.

Stripping of vegetation between the dam site and TH headpond is likely to occur only intermittently with the periodic spill events.

Below the TH dam site, contributions from the Nam Phao, Nam Gnouang and Nam Mouan will influence the distribution of vegetation and few changes in the species composition and distribution of plant communities is likely to result from riparian releases.

Wildlife

Riparian flows should maintain existing terrestrial wildlife corridors and habitats in the Nam Theun valley. Current sources of drinking water, shelter, breeding sites, foraging and connectivity above the current high water level are not likely to be compromised with the reduced flow rate.

Riparian flows should not impact on the quality of habitat available for most of the terrestrial species recorded in the area. Expansion of vegetation onto exposed river banks may provide additional habitat resources for some wildlife groups. Species that currently exploit resources within forest will not be significantly impacted. Species that utilise arboreal, cryptic or ground-dwelling habitats are unlikely to be negatively impacted as their existing habitat is above current high water level.

The distribution of amphibians and other semi-aquatic species that rely upon fast-flowing water may be impacted between the Nakai dam before the Nam Phao confluence. The reduced flow area and velocity will likely influence the availability of breeding habitats and feeding resources for species reliant on fast flowing waters.

The presence of the endangered Big-headed Turtle species (Platysternon megacephalum) recorded downstream of the TH dam is important. This species is known to inhabit fast-flowing areas and is listed under IUCN and CITES conventions. The presence and extent of this species in the Nam Theun will be further investigated as part of the monitoring programs outlined below.

Community use of vegetation and wildlife

With the exception of the big headed turtle, all species identified by communities as being hunted for consumption can be found both within and outside the Nam Theun river valley. Given the known habits of species considered important by the local communities, the ecological requirements of most of these species should continue to be met by under the riparian release conditions. As a result, no significant social implications on riparian resource use should result from the riparian release.

Fisheries

The broad implications is that reduced flows arising from the riparian release will modify the hydraulic and physico-chemical conditions in the mainstream Nam Theun, especially in reaches between the Nakai Dam and the Nam Phao confluence. The subsequent reduction in the flow will reduce the carrying capacity of the river, both in terms of fish diversity and abundance. An important question will be if the aquatic habitats in the mainstream Nam Theun will still provide a dry season refuge for those species that migrate upstream in May/June and in September into the tributaries of the Nam Phao, Nam Kata, etc. The outputs from the wetted perimeter analysis will be used later in this section to determine the impact on the fisheries. This will have corresponding impacts on current fishing practices and levels of fish production, and subsequently on socio-economic conditions in the Nam Theun and tributaries. The limited available information on the biological requirements and migratory behavior of fish species, together with the numerous seasonal fluctuations in variables that control fish productivity, make it difficult to quantify the precise impact on the fisheries.

Biodiversity and Abundance

The section of Nam Theun from the TH dam to the NT2 Dam will be totally isolated from the Nam Theun upstream of the Nakai dam and potentially isolated from the Nam Kading downstream of the TH dam. There will be no possibility of migration of fish species to the Nakai Plateau. Therefore a loss in the number of species may be expected due to this fragmentation. Ongoing impacts identified earlier in the section that are independent of the Project, such as the ongoing destruction of the fisheries and flood events in the Nam Phao, will aggravate any impacts by the Project.

The upstream migration of fish species in the Nam Theun will be impacted by the reduction in discharge by the Project. Reduced flow during migration periods will place pressure on those species (Table 3.39) that demonstrate existing vulnerability to low flow conditions. However, discharges downstream of the Nam Phao confluence will still be approximately 20% of the current discharge.

It may be that the Nam Theun mainstream will still function as a dry season refuge for those species that migrate upstream into the tributaries during the wet season. Fisheries in the tributaries may therefore experience little impact other than through reduced productivity in the Nam Theun mainstream and isolation between the TH dam and Nakai dam. These fragmented populations will be more vulnerable to natural extremities such as flooding.

Modified water quality may be expected to modify spawning success in those species that spawn in the mainstream. Similarly the reduced depth and morphological changes will reduce access to spawning habitat among those species utilizing riparian vegetation. The area of spawning habitat will also be reduced. Although for those fish using vegetation as a spawning substrate, macrophyte stands that are initially stranded after dam closure should develop further down the bank to retain some heterogeneity of habitat. It is assumed spawning and recruitment in the tributaries will remain largely unchanged, albeit with a reduced spawning stock.

The reduced pool depth and water quality conditions may influence the availability of dry season refuge habitats, and correspondingly the carrying capacity of these areas will be impacted. The reduced water level will expose many of these refuges, limiting the complexity of habitat features above the Nam Phao.

It is likely that the abundance of exotic species (Common carp and Tilapia) will increase following the closure of the Nakai dam due to their capacity to adapt to a much wider range of conditions. This may put further pressure on the specialized indigenous fish species.

It is clear that following the construction of the TH dam the impounded stock have continued to migrate, spawn and sustain population in a significantly reduced environment. It is therefore expected that tributaries will continue to function although the overall stock will be reduced. The extent to which this impoundment will affect the gene pool is unknown. However, it is likely that susceptibility to disease will increase. Long distance migrant fish species that refuge in the Nam Theun during the dry season will be impacted by the Project. Those resident fish species of the tributaries that only undertake short distance migration will remain unaffected and may benefit from the reduced competition for resources by a decline in long distant migrants. A detailed discussion on the potential impacts on important migratory fish species in the Nam Theun is presented in Annex K.

Impacts on fish abundance will be most severe in the Nam Theun reach between the Nakai Dam and the confluence with the Nam Phao. Downstream of the Nam Phao confluence catchment inputs, including the Nam Phao itself, that are unaffected by the Nakai dam will help buffer the severity of any impacts.

Overall fish productivity will be reduced due to the significant reduction in the carrying capacity of the reduced discharge. However, the change in hydrology is not expected to result in the partial collapse of the food chain. Reductions in populations of species that are able to tolerate the modified hydrology may be buffered by any increases in productivity per unit area of periphyton, macrophytes and invertebrates that is promoted by an increase in water transparency and a reduction water depth. Fish that adapt to the low flow conditions may proliferate.

Table 3.39: Fish species potentially vulnerable to low flows (KBR, 2004)

Waterbody	Species Name
Nam Theun	• *Hemibagrus wyckioides* • Bagarius yarrelli • Poropuntius sp. • Hemibagrus Wyckii • Puntioplites wandersi • Acheilognathus barbatulus • Crossocheilus reticulatus • Garra imberbis • Hypsibarbus wetmorel • Cyprinus carpio
Nam Phao	• *Puntionlites falcifar* • Cychocheilichthys armatus
Nam Ngoy	• None indicated
Nam Kata	• None indicated
Other Tribs.	• None indicated

Downstream of the TH Dam site, it is assumed that stream biota have adapted to a certain flow regime and can survive the current periods of low flow. Therefore in terms of biota, the status quo is likely to be retained if the minimum flow does not fall below the current average low flow. Because the mean minimum low flow is maintained below the TH dam no impacts significant on biota is anticipated.

Socio - Economic Analysis

The environmental impacts of the Project proposed riparian release of $2m^3/s$ on the Nam Theun will have several negative impacts on the communities located downstream of the Nakai Dam. These impacts can be summarized as loss of production of (i) fisheries; and (ii) aquatic products.

In order to evaluate the socio-economic impacts of the Project the villages have been divided into zones based on the level of use on the Nam Theun mainstream and therefore severity of impact on the communities.

Fisheries

The Nam Theun mainstream is generally not an exclusive source of fisheries production, indeed the Nam Theun ranked only seventh in terms of importance. Therefore the severity of the impact on the Nam Theun mainstream will be buffered by the community's preferential use of tributaries and other water bodies.

Impact on Fisheries by River

The following section outlines 'ballpark" estimates for the maximum potential impact of the Project on annual fish yields and the value of any losses. The current fish catch data is sourced from the consultation based fisheries surveys of LARReC (2004) and Schouten *et al*. (2004). A market value of USD 0.8 per kg was adopted to calculate the value of the catch in monetary terms. Table 3.40 provide, a summary of the estimated impact by the Project by village zone and the subsequent value of the losses. These estimations are based on mean catch data recorded by LARReC (2004) and the estimated severity of impact identified below. The prediction of the impacts and the subsequent estimation of losses in fish yield can only be indicative at this stage. Only after dam closure when the impacts occur can the monitoring obtain a more accurate value.

Nam Theun Mainstream: The productivity of the fish species taking dry season refuge in the mainstream Nam Theun will be impacted by the reduction in dry season flow. Assuming that productivity is related to the amount of river bed that is inundated, productivity of the Nam Theun fishery may decrease by the same order of magnitude that the wetted perimeter is reduced. Based on the wetted perimeter analysis, the reduction in amount of wetted river bed in the mainstream Nam Theun, and therefore the reduction in the area for primary and secondary production, at sites IFR S1 to S3 is 73%, 54% and 56% respectively. This gives a mean impact of approximately 60% of the mainstream Nam Theun between the Nakai Dam and the TH Headpond. A 60% impact in the Nam Theun mainstream fisheries equates to a decline in fish catch of 62,901 kg/yr or USD 50,321. The decline in fish catch will be experienced most by villages in the Lower Nam Phao zone.

TH Headpond: After inundation by the TH Project the number of fish species in the TH headpond declined but the annual fish yields increased, indicating an increase in fish productivity. The proliferation of one species (*Cyprinus carpio*) more than compensated for the loss of productivity in the other fish species. The NT2 Project will have relatively little effect on the hydrology of this already lacustrine environment and therefore no impact on the productivity of those fish already adapted to the new conditions is perceived.

Project reductions in the inflow into the TH Headpond will influence the water quality in the TH-Headpond. During the dry season, low dissolved oxygen conditions currently develop at depths of more than 10 meters. Reduced inflows into the TH Headpond will most likely extend the period over which these low dissolved oxygen conditions. This may lead to a further reduction in the number of species inhabiting the TH Headpond. Whilst the majority of fish species are affected by dissolved oxygen less than 4 mg/l, *Cyprinus carpio* that has proliferated in the TH Headpond can tolerate dissolved oxygen as low as 2 mg/l so will remain largely unaffected by the change in water quality and, in fact, may proliferate because of the reduction in competition (Schouten, 2004).

Nam Phao and Tributaries: Non migratory and short distance migrant fish species that are residents of Nam Phao and its tributaries will not be affected by the Project. Only those species that refuge in the mainstream Nam Theun during the dry season then move into the Nam Phao in wet season will be impacted. Based on the assumption that approximately 60% of the fish species in the Nam Phao and its tributaries catch are long distance migratory fish, and the impact on those migratory species in the Nam Theun mainstream is 60%, the overall impact on fish catches could be up to 35%. The scale of impact on the Nam Phao is less than that on the mainstream Nam Theun but because of the greater use of the Nam Phao the value of the loss in higher. A 35% impact in the Nam Phao fisheries equates to a decline in fish catch of 83,908 kg/yr at a value of USD 67,126. The decline in fish catch will be experienced most by villages in the Lower Nam Phao zone, as well as the Nam Kata, Nam Phouang/Phiat and Upper Nam Phao zones.

The impacts on fish catch in the Nam Phao could be potentially buffered by migratory individuals in the Nam Theun being attracted into the Nam Phao during wet season by the relatively larger discharge in the Nam Phao compared to that in the Nam Theun above the Nam Phao confluence.

Nam Gnouang: Fish catches in the Nam Gnouang are already impacted by the presence of the TH dam which impedes the upstream migration of fish from the Nam Kading and Mekong. Although there is anecdotal evidence to suggest that some fish species can still navigate across the TH dam during the peak of the wet season, the TH Project has still resulted in a 40% decline in household fish catch in villages along the Nam Gnouang (Schouten et al. 2004). This decline is probably attributed to the inability of the majority of long distance migratory fish species to pass the TH dam or the timing of their migration not being compatible with TH spills. Therefore majority of the fish catches in the Nam Gnouang probably consist of non-migratory or short distance migratory fish species. The NT2 Project will have no impact on this proportion of the fish catch.

However, because the NT2 Project will cause an average reduction in the numbers of days that the TH dam will spill, from 245 days to 190 days per year, and reduce the mean monthly discharge in September from 1,323 m^3/s to 806 m^3/s, the NT2 Project will have an additional impact on any long distance migratory fish species that currently manage to pass upstream of the TH dam. This reduction in spills will particularly affect the fish population of the family Pangasiidae which may not be able to complete its full life cycle if isolated above the TH dam. Other fish species, such as those belonging to the genera *Bangana* and *Tor* and family *Bagridae*, are highly likely to be able to complete their full life cycle when confined to locations upstream of the TH dam (Schouten, 2004). The

Table 3.40: Estimated value of fisheries loss for the riparian release of 2 m^3/s

Village Zone	Source of Fish Catch													
	Nam Theun - mainstream		TH Headpond		Nam Ngoy		Nam Gnouang		Pond/rice field		Nam Phao and tributaries		Total	
	Decline in Yield kg/yr	Value of Loss USD	Decline in Yield kg/yr	Value of Loss USD	Decline in Yield kg/yr	Value of Loss USD	Decline in Yield kg/yr	Value of Loss USD	Decline in Yield kg/yr	Value of Loss USD	Decline in Yield kg/yr	Value of Loss USD	Decline in Yield kg/yr	Value of Loss USD
Lower Nam Phao	57,605	46,084	0	0	0	0	0	0	857	685	40,869	32,695	99,332	79,465
Upper Nam Phao	0	0	0	0	0	0	0	0	5,708	4,567	9,045	7,236	14,753	11,802
Nam Phouang / Nam Phiat	3,461	2,769	0	0	1	0	4	3	127	101	17,719	14,176	21,311	17,050
Nam Kata	1,835	1,468	0	0	0	0	0	0	43	34	17,200	13,760	19,077	15,262
Nam Ngoy	0	0	0	0	2,330	1,864	39	31	788	630	0	0	3,157	2,525
TH Headpond	0	0	0	0	0	0	30	24	0	0	49	39	79	63
Nam Gnouang	0	0	0	0	0	0	14,741	11,793	1,521	1,217	0	0	16,262	13,010
Total													173,971	139,177
NPV														1,172,113

population of these species will become fragmented which may eventually lead, over generations, to local extinction.

If it is assumed that 30% of the catch in the Nam Gnouang consists of long distant migrant species and the reduction in the number of spilling days is a conservative 30%, an estimated maximum potential impact of 10%, a 30% impact on 30% of the catch, has been attributed to the overall catch in the Nam Gnouang. A 10% impact in the Nam Gnouang fisheries equates to a decline in fish catch of 14,813 kg/yr at a value of USD 11,850. The decline in fish catch will be experienced mainly by villages in the Nam Gnouang zone.

Nam Ngoy: Similarly to the Nam Gnouang, fish catches in the Nam Ngoy are already impacted by the physical presence of the TH dam, as well as, the TH Headpond. Whether the fish species that manage to negotiate the TH dam are attracted solely to the Nam Gnouang or continue to migrate upstream through the lacustrine TH Headpond and into the Nam Ngoy remains to be studied. Either way, the majority of fish catches in the Nam Ngoy are probably made up of short distance migrants from the TH headpond or non-migratory resident fish species. The NT2 Project will have no impact on this portion of the catch. Therefore an estimated maximum potential impact of 10% has been attributed to the overall catch. A 10% impact in the Nam Ngoy fisheries equates to a decline in fish catch of 2,331 kg/yr at a value of USD 1,865. The decline in fish catch will only be experienced by villages in the Nam Ngoy zone.

Pond and Rice Paddies: No villages source their domestic water from the mainstream Nam Theun. The Project will therefore have no impact on the limited aquaculture already established in the area.

Given the steep terrain directly adjacent to the Nam Theun mainstream, between the Nakai Dam and Nam Phao confluence, the Project will have no hydraulic related impacts on naturally stock ponds or rice field fish populations in this reach. There no evidence of ponds or rice paddies along this stretch of river.

The Project will have an impact on seasonal, naturally stocked ponds and rice fields adjacent to the Nam Theun tributaries that rely on long distance migrating fish species to enter these areas for feeding, spawning and nursery habitats. Given that the species in the mainstream and tributaries will move into these flooded areas, the assemblages in the naturally stocked ponds and rice fields may be similar. The severity of impact should reflect the impact on the tributaries adjacent to the ponds. The estimated impact on the ponds and rice field fisheries equates to a decline in fish catch of 9,043 kg/yr at a value of USD 7,235.

Unfortunately the LARReC (2004) survey did not distinguish between aquaculture ponds and seasonal, naturally stocked fish ponds/rice fields therefore allocating a precise value to the loss is difficult.

Summary of Loss of Fisheries: Over the entire study area above the TH dam the estimated impact will result in a decline in fish catch of 173,971 kg/yr which equates to USD 139,177. In terms of net present value the loss is approximately USD 1.17 million over the 25 years of operation of the Project.

Aquatic Products

The Project will not have any impact on the aquatic products population in the TH headpond or in the tributaries of the Nam Theun. There will, however, be an impact on those populations inhabiting the Nam Theun mainstream between the Nakai Dam and the TH Headpond. The riparian release will cause a reduction in the wetted perimeter and therefore a decline in the area for primary and secondary production. Based on the wetted perimeter analysis an impact on productivity of 60% has been allocated.

The impact on productivity may be buffered by any increases in primary production in those areas still submerged. Primary production per unit area may increase due to a decrease in water velocity, a decrease in water depth and an increase in water transparency. These factors will favor photosynthesis and result in a proliferation of periphyton and macrophytes. This may buffer the negative impact on overall productivity of aquatic products.

Aquatic product collection in the Nam Theun mainstream is negligible. Only a few villages indicate use of the mainstream as a source of aquatic products. Villagers tend to collect aquatic products from local tributaries or ponds. Given that community use is so low the reduced populations of aquatic products may still be sufficient to provide a sustainable resource. Table 3.41 provides a summary of the estimated impact by the Project on aquatic product catch in the mainstream Nam Theun. The aquatic product catch data is based on the consultation based fisheries surveys of LARReC (2004) and a market value of USD 0.3 per kg was assumed for calculating the value of the catch. A 60% impact in the Nam Theun equates to a decline in aquatic product collection of only 588 kg/yr at a value of USD 407. In net present value terms this equates to only USD 4,000.

Note that no aquatic products catch data was available for the villages located long the Nam Gnouang. It is assumed that their aquatic products are obtained either from the Nam Gnouang or TH Headpond and therefore unaffected by the Project

Others Uses

Because communities indicated no “other uses” of the mainstream Nam Theun above the TH Headpond it is not expected to be any impacts to (i) riverside assets including riverbank gardens; (ii) domestic water use; (iii) irrigation systems; and (iv) navigation. Therefore the socio-economic analysis is limited assessing the value of the loss to the fishery and aquatic products, no value of loss has been attributed to “other uses” of the Nam Theun mainstream.

Value of the Riverine Ecosystem

At commencement of the riparian releases, the project will result in an impact on the aquatic ecosystems in the reach of the Nam Theun between the Nakai Dam and the TH Hinboun headpond. This ecosystem includes the habitats of at least one endangered species, the big-headed turtle. Given this lack of quantified data in this area, the most plausible approach for assessing the magnitude of the impact on these aquatic habitats is to estimate values for the entire ecosystems, rather than the specific species, by imputing a value in relation to terrestrial habitats.

Accordingly, it is assumed that one kilometer of river is equal, in conservation terms, to 50 hectares of terrestrial habitat (Louis Berger, 1997). The length of the river affected, between Nakai Dam and TH headpond, is 40 km. Using the same values as estimated on the Economic Impact Study of Nam Theun 2 Project (Louis Berger, 1997) of USD 75-125 per terrestrial hectare per year the Project would result in an estimated USD 150,000 – 250,000 per year of the loss for biodiversity, pharmaceutical and eco-tourism potential of these aquatic ecosystems. This is equivalent to a net present value in 2004 of USD 1.26 to 2.11 million.

Vulnerable Groups

If certain species of fish were exclusively consumed by a particular vulnerable group, such as pregnant mothers or children, then any impacts on those species would result in a disproportionately larger impact on those vulnerable groups. This would be important if the fish species were consumed for special dietary requirements, such as nutrients during child development. The LARReC (2004) survey found that vulnerable groups had no preferences for certain types of fish therefore no disproportionate impact is expected on those vulnerable groups.

Other non-Project Impacts

In addition to those impacts caused by the Project several other factors will influence the productivity of the fisheries, these factors have been identified by villagers as resulting in an ongoing decline in fish catch that is independent of any Project activities. These non-Project impacts include (i) proliferation of non-indigenous fish species that are probably escapees from aquaculture; (ii) population increase resulting in increased fishing pressure; and (iii) increased use of more efficient fishing methods.

Impacts of Other Planned Hydroelectric Projects

The Theun-Hinboun Extension Project is a planned storage reservoir on the Nam Gnouang that will increase the dry season flow into the TH Headpond and provide more water for electricity generation by the TH Project. When Theun-Hinboun Extension is constructed its operations will significantly impact both the discharge in the Nam Gnouang and inflows into the TH Headpond. It is expected that the TH Extension will commence operations around the same time as, or possibly before, the NT2 Project. No planned downstream discharges for the TH Extension are available thus the cumulative impacts on the Nam Theun/Nam Kading basin can not be estimated. Fish species of the Nam Gnouang, in particular *Scaphognathops theunensis*, will be significantly impacted by the TH Extension.

Trade-off

The potential socio-economic cost of the riparian release of 2 m^3/s has been estimated as USD 1.17 million for the fisheries/aquatic products and USD 1.26 to 2.11 million for the aquatic ecosystem in net present value terms. The overall cost of the 2 m^3/s riparian release is in the range of USD 2.43-3.28 million. Of these costs, the potential impacts to the aquatic ecosystem could be greater than the impacts to local communities in comparison to overall costs.

To determine the most appropriate riparian release a tradeoff analysis to estimate the potential financial costs and the ecological/social benefits of different riparian flow regimes was conducted. Based on the wetted perimeter analysis, the point of inflection of the wetted perimeter-discharge curve could be either 5 or 8 m^3/s.

The point of inflection on the wetted perimeter curve represents the maximum habitat for the minimum flow. A riparian release of 8 m^3/s would be sufficient to meet the minimum wetted perimeter for sites above the Nam Phao confluence. These additional riparian release discharges are still less then the current mean dry season flow so will themselves have an impact. Table 3.42 presents the wetted perimeter analysis and estimated magnitude of impact for the riparian release regimes of 5 m^3/s and 8 m^3/s.

The impact on the wetted perimeter, and the perceived impact on fish productivity, decreases with increasing discharge. For example, a riparian release of 5m^3/s and 8 m^3/s will have impacts of 62% and 27% respectively at IFR Site S1 which compares an impact of 73% resulting from the riparian release of 2m^3/s. Limiting the overall reduction in the wetted perimeter will mean larger areas for productivity of the fisheries will remain. A summary of the estimated potential impact on fish productivity is shown in Table 3.43. Similar assumptions as those for the 2m^3/s were used to generate these estimates.

The improvements in fisheries productivity by increasing the riparian release are limited to only the fisheries in the mainstream Nam Theun and Nam Phao. Productivity for long distance migratory fish species that refuge in the Nam Theun will improve as wetted perimeter is increased. No significant improvements in the impact on the Nam Gnouang and Nam Ngoy fisheries are expected by increasing the riparian release. These fisheries are impacted mainly by a reduction in the volume and number of days the TH dam is spilling. Small volumetric increases in the riparian release will cause little improvement relative to the total volume of the spill.

Table 3.44 presents the value of the losses in the fishery and aquatic products for the riparian release of 5 and 8 m^3/s. The estimated value of the losses in the fisheries for the riparian releases of 5 and 8 m^3/s, net presents value terms of USD 1.0 and USD 0.69 million respectively, are less than the value of the loss with the 2m^3/s riparian release. The estimated value of the losses in the aquatic products for the same riparian release scenarios is approximately NPV USD 3,300 and 2,000.

At this stage it is too difficult to allocate the improvement to the aquatic ecosystem that is gained by increasing the riparian release. Therefore for the trade-off the value of the loss remains constant for all scenarios.

Table 3.41: Estimated value of aquatic products loss for the riparian release of 2 m^3/s

Village Zone	Source of Aquatic Products													
	Nam Theun - mainstream		TH Headpond		Nam Ngoy		Nam Gnouang		Pond/rice field		Nam Phao and tributaries		Total	
	Decline in Yield kg/yr	Value of Loss USD	Decline in Yield kg/yr	Value of Loss USD	Decline in Yield kg/yr	Value of Loss USD	Decline in Yield kg/yr	Value of Loss USD	Decline in Yield kg/yr	Value of Loss USD	Decline in Yield kg/yr	Value of Loss USD	Decline in Yield kg/yr	Value of Loss USD
Lower Nam Phao	91	73	0	0	0	0	0	0	0	0	0	0	91	73
Upper Nam Phao	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nam Phouang / Nam Phiat	11	9	0	0	0	0	0	0	0	0	0	0	11	9
Nam Kata	486	389	0	0	0	0	0	0	0	0	0	0	486	389
Nam Ngoy	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TH Headpond	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nam Gnouang	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total													588	470
NPV														3,960

Impacts

Increasing the riparian release to benefit the fisheries downstream of the Nakai Dam will have a cost in terms of loss of revenue from power production. The loss of revenue for the 5 m^3/s and 8 m^3s riparian releases is USD 45 and 72 million respectively. Indeed for any significant reduction in the impact in the fisheries a 8 m^3/s riparian release would be required. The financial cost of a 8 m^3s riparian release is USD 72 million but the improvement in the fisheries only equates to approximately USD 0.5 million. The loss of revenue, a proportion of which will go directly into development programmes in the country, by far exceeds the ecological and social gains by providing the additional riparian release.

Mitigation

Mitigation Against Poor Water Quality

Like the Xe Bang Fai, the overall objectives of mitigation for water quality are to (i) maintain the current beneficial uses of water in the Nam Theun; and (ii) avoid or minimize any water quality impacts on the fisheries. It should be noted that, apart from fisheries, beneficial uses (irrigation, domestic water supply, etc.) has been indicated as minimal along the Nam Theun mainstream (LARReC 2004) with no permanent settlements existing between the Nakai Dam Site and the TH Headpond.

Biomass Reduction

In order to reduce the amount of biomass decomposition and therefore the extent of anoxic conditions that may develop in the reservoir in the initial years after inundation of the reservoir, the Project will encourage the removal of biomass through salvage logging and promotion of firewood collection and/or charcoal production by villagers.

Engineering Works

Multilevel Intake: The intake at the Nakai Dam site will help reduce the downstream impacts of any anoxic conditions that may develop in the Nakai Reservoir. The design of the intake will be such that water can be sourced from a specific depth in the Nakai Reservoir. The multilevel intake will source water for the downstream Nam Theun from only the good quality surface (epilimnion) water and not the potentially oxygen poor bottom (hypolimnion) water.

Cone Valve: At the Nakai Dam, the riparian release will be discharged through an aerating structure, a cone valve, into the stilling basin. It is anticipated that the cone valve can increase dissolved oxygen levels in the discharged water by up to 5 mg/l.

Detailed drawings of the structures associated with riparian release are presented in Annex D.

Mitigation against Sedimentation

To mitigate against any impacts associated with construction site erosion, the HC will prepare and implement an erosion and sedimentation plan for the various engineering works associated with the Nakai Dam. Mitigation measures will include drainage works, sediment traps and other structures designed to treat water to an acceptable quality before discharging into the Nam Theun. The HC will minimize working during the wet season to further minimize any erosion. Details of the requirement of this plan is presented in Annex L.

Mitigation Against Injury From Flash Floods

The Nakai Dam will be fitted with a siren that will be operated before any opening of the dam gates to warn people in the Nam Theun below of the impending increase in water depth and velocity.

Morphology

A number of physical interventions to channel morphology may be suitable for improving the wetted area of rapids and the flow in deep pools. These interventions include (i) setting channel dimensions to simulate natural conditions, albeit on a smaller scale; (ii) increasing the complexity of pool shorelines to provide habitat protection zones for fry and small fish; (iii) reinstating meanders to trap transported sediments and avoid scouring of biofilm; (iv)

Table 3.42: Summary of wetted perimeter analysis for the trade-off

IFR Site	Habitat Type	Present mean dry season discharge m^3/s	Present wetted perimeter m	Riparian Release m^3/s	Future mean dry season discharge m^3/s	Future wetted perimeter m	Impact on wetted perimeter %
S1	Rapid	25	29.4	2	2	7.88	73
				5	5	11.19	62
				8	8	21.34	27
	Pool	25	108.8	2	2	101.10	7
				5	5	103.66	5
				8	8	105.62	3
S2	Rapid	26	43.7	2	3	20.08	54
				5	6	31.11	29
				8	9	34.19	22
	Pool	26	Data not available				
S3	Rapid	33	23.3	2	15	10.29	56
				5	18	11.69	50
				8	23	31.10	46
	Pool	33	28.4	2	15	21.98	23
				5	18	22.74	20
				8	23	23.50	17
S4	Rapid	34	27.5	2	17	25.6	6.9
				5	20	26.2	4.7
				8	25	27.1	1.5
	Pool	34	34.9	2	17	12.16	65
				5	20	18.56	47
				8	25	29.22	16

Impacts

Table 3.43: Impacts on Fisheries Production for different riparian releases

Waterbody	% Reduction in Fish Productivity for Different Riparian Release		
	2 m^3/s	5m^3/s	8m^3/s
NT mainstream	60	50	30
TH Headpond	0	0	0
Nam Phao	35	30	20
Nam Ngoy	10	10	10
Nam Gnouang	10	10	10
Ponds/rice fields	Dependant on tributary	Dependant on tributary	Dependant on tributary

re-establishing pool-riffle morphology, modify the downstream edge of low velocity pools to increase outflows; (v) in long, deep pools current deflector may be appropriate to increase hydraulic diversity to improve the habitat complexity and to develop erosion areas; and (vi) increase the habitat complexity for fish; including selectively placing large boulders in pools, fish shelters to protect fry and smaller fish and large logs or other woody debris could be placed strategically.

The implementation of specific channel morphological techniques will require (i) a more accurate topographical study of the river profile; and (ii) a detailed assessment of important fish migration and spawning zones in the Nam Theun. However, the impacts of periodic flooding events are expected to significantly alter any channel morphological techniques that are implemented.

Adaptive Management

Because there is some degree of uncertainty in the assessment of the impacts, adaptive management of the 2 m^3/s riparian release and complementary 5 MCM will be adopted. The adaptive management of the riparian release will have the flexibility to respond to monitoring and evaluation of the environmental performance of the release regime. This will be an iterative process, repeated as long as it takes until the system stabilizes.

The adaptive management will cover two main periods of time, construction (including dam construction and impoundment) and operation. It will typically involve the following steps: (i) proactive experimentation, (ii) monitoring, (iii) reevaluation and experimental design, (iv) decision making involving multiple stakeholders.

The proactive experimentation will test the impact of different flow regimes on the downstream areas, within the operational limits of the riparian release and the modification of the morphology of the river. The monitoring will focus on water quality, flow and fisheries and this will be used to help optimize and test flow regimes. The monitoring data and modeling of the habitat, water quality, hydrology and potentially ecosystems of this area will be used to test and refine flow and habitat management approaches. An "environmental flow committee" including the EMO, the WMPA and local village resettlement committees representatives will make decisions on management objectives and approaches to flow management based on analysis and modeling provided by NTPC.

Compensation

The current under development of aquaculture in the communities highlights a significant opportunity to develop and expand aquaculture activities as part of a compensation strategy. Compensation may also take the form of providing capacity building in fisheries management in the Nam Theun basin. Encouraging abandonment of destructive fishing techniques and replacing these with sustainable fishing practices will compensate to some extent the reduction in fish abundance caused by the Project.

The compensation entitlements of the project affected persons and the process of compensation are presented in detail in the SDP.

Community Consultation

A disclosure and consultation program will be implemented in all the potentially affected villages with the objectives to (i) obtain more quantitative socio-economic data; (ii) conduct an awareness program in advance of dam closure to prepare communities for the potential impacts; (iii) elicit potential affected persons concerns; and identify further mitigation measures.

Similar methodologies to those used for the consultation process in communities along the Xe Bang Fai will be adopted, details of which are presented in the SDP.

Monitoring

Adaptive management will determine how the total volume release should be managed to maintain the predetermined, valued use objectives for the ecosystem. Predetermined use objectives, reflective of the intended ecosystem condition, will be used to measure and assess the effectiveness of the riparian release regime. With the outputs of this monitoring, the management strategy of the release can revised, while maintaining the same total volume of water. A monitoring and evaluation approach will be the driving force for optimizing the riparian release regime within the same total of water. The following monitoring programmes have been identified in the CA.

The WQMAP will include sampling stations on the Nam Theun to monitor the evolution of water quality released from the Nakai Dam site. Sufficient monitoring will be conducted prior to the closure of the dam to obtain adequate baseline. The water quality monitoring shall continue during the first five years of operations to determine whether the potential effects of increased retention time in the pools are disturbing or adversely affecting aquatic life and wildlife population. An indication of parameters, sampling frequency and locations of the WQMAP is presented in Chapter 3.

A monitoring program will be developed to enable NTPC to determine the ecosystem values and components of the Nam Theun downstream of the Nakai Dam. To enhance biodiversity and productivity, further studies shall be undertaken as part of the adap-

Table 3.44: Trade-off analysis of different riparian release regimes

Riparian Release	Value of Fisheries Loss	Value of Aquatic Product Loss	Value of Aquatic Ecosystem	Total	Value of reduction of loss	Cost of Addition Discharge
m^3/s	NPV MUSD	NPV MUSD	NPV MUSD	NPV MUSD	NPV MUSD	NPV MUSD
2	1.172	0.004	1.26 to 2.11	2.436 to 3.286		
5	1.005	0.003	1.26 to 2.11	2.268 to 3.118	0.168	45
8	0.689	0.002	1.26 to 2.11	1.951 to 2.801	0.485	72

tive management process; such as a seasonal study of hydrology and aquatic tropic dynamic.

As part of the adaptive management process, the monitoring programme shall be such to enable NTPC to determine productivity in fish populations downstream of the Nakai Dam during the first five years of operations.

The GOL and NTPC shall review the results of the studies. If necessary, based upon the results from the water quality and productivity/diversity monitoring recommendations on the management of the riparian and complementary releases will be made.

Intra-basin Coordination

The establishment of a Nam Theun/Nam Kading River Basin Committee is planned to help facilitate close cooperation between NTPC, THPC, TH Extension, and potential other projects, and GOL. Coordination of environmental impacts assessments, monitoring, mitigation and compensation activities between the different agencies will benefit both the environmental and social component of the Nam Theun/Nam Kading basin.

Water Quality

Water from the Nam Theun will be stored in the Nakai Reservoir before being released into the Nam Kathang and the Xe Bang Fai. There will be changes in the water quality during this storage period that will consequently affect water quality parameters in the Nam Theun, the Xe Bang Fai, the Nam Kathang, and potentially in the Mekong River downstream from the mouth of the Xe Bang Fai. The following analysis presents the existing water quality data, and the potential changes in water quality, of the Nakai Reservoir and of the rivers impacted, based on computer simulations for the reservoir and on a model of evolution of dissolved oxygen for the water released into both the Nam Kathang and the Xe Bang Fai. The analyis provides the best estimate of what will happen to water quality in the reservoir and the affected rivers. Annex G presents the water quality modelling assumptions and results in more detail.

After the analysis of impacts, the section presents an evaluation of management and mitigation measures, including steps to reduce biomass in the inundation area and the incorporation of aeration structures into the Project design. Finally, the section outlines a plan to implement a monitoring programme to gather baseline data and assess any change in water quality during Project construction and operation.

Baseline Surface Water Quality

Water quality sampling data is available for the Project area for the months of February and April 1990 (SMEC, 1991), February and March 1995 (TEAM, 1995), December 1996 (SKM), April and May 2001 (HYDRECO, 2001a), September and November 2001 (EDF, 2001 and HYDRECO, 2001b) and March 2002 (EDF, 2002). In addition, data was collected on the Nam Theun and Nam Kading below the Nakai Dam site within the Theun Hinboun Project area in December 1994, March, April and July 1995 (Norplan, 1995). Monthly water quality data has been collected since 1985 at the bridge crossing the Xe Bang Fai on Road 13, as part of the MRC water quality monitoring network. A summary of water quality data from the Nam Theun, Nam Kathang and Xe Bang Fai collected during the dry season and wet season of 2001 is presented in Table 3.45. A monitoring programme starting early in 2004 will extend this existing baseline data and further the knowledge of water quality dynamics before the start of construction and operation. More details on the monitoring programme are provided later in the section.

Nam Theun & Nam Kading

Dry Season

Temperature in the Nam Theun on the Nakai Plateau was measured at 17-22° C for December to February, and at 20-28° C in March. Continued warming of the river occurs in April, with temperatures reaching 31° C.

The Nam Theun basin is primarily situated on a sedimentary/sandstone bed within the reservoir area, and therefore measures of alkalinity (0.3-25.0 mg/l as $CaCO_3$), total hardness (7-9 mg/l $CaCO_3$), and total dissolved solids (4-76 mg/l) are in the low to normal range. Magnesium concentrations are less than 2 mg/l in the basin. Calcium concentrations are less than 5 mg/l in the Nam Theun, and less than 8 mg/l in the Nam Kading. Measures of chloride, sodium, and potassium are also low (< 4 mg/l). These relatively low values are most likely due to the lack of mineralisation in the basin.

Conductivity is low (2-90 µS/cm) from December to July in the basin. SMEC recorded conductivity values ranging 280-430 µS/cm in the Nam Kading in February and April of 1990, while measurements in the Nam Theun were within the range of 2-90 µS/cm during the same period (SMEC, 1991). The elevated conductivity values recorded in the Nam Kading, compared to the Nam Theun, were probably a result of inputs from the populated Nam Phao and the low values for the Nam Theun, a result of the lack of mineralisation in the basin.

Values for pH range widely from 5.8 to 8.9 (SKM, SMEC, Norplan, TEAM). Generally, pH of the water during the dry season is slightly basic (7.2).

Turbidity is very low in the Nam Theun basin (1-12 Nephrometric Turbidity Units (NTU)), indicating the absence of a large sediment or algal load carried by the river during the dry season months. This is confirmed by low total suspended solids (1-12 mg/l).

Dissolved oxygen in the Nam Theun/Nam Kading normally ranges between 5-12 mg/l. This falls within normal ranges, and corresponds with relatively low chemical oxygen demand values of under 6 mg/l.

Nutrient concentrations are low in the Nam Theun. Total nitrogen in the water is generally 10 µg/l in the area upstream of the proposed Nakai Dam site. Total nitrogen in the Nam Theun/Nam Kading stretch was more than ten times higher (98-190 µg/l). Normally, nutrient contents of rivers are higher as the river descends from it origin. Consequently, an increased nutrient content in the Nam Kading would be expected. Total phosphorus at all sites was less than 20 µg/l. Low phytoplankton density (less than 5.8 x 10^6 cells/m^3), low chlorophyll *a* (less than 2 µg/l) and the absence of frequent blue-green (*Cyanophyta*) algal blooms is associated with low nutrient content in the water.

Fecal coliform bacteria were found to occur at a concentration of 0-3 per 100 ml of Nam Theun water, and 6-24 per 100 ml in the Nam Kading. Elevated fecal coliformsin the Nam Kading may, as with conductivity, be related to human and animal activity in the lower river basin.

Dioxin and Polychlorinated Biphenyls (PCB) concentrations in Nam Theun fish samples taken for the Nam Theun Hinboun Impact study were found to be low (16.6 pg TE/g fat) (NORPLAN, 1994). The measurements of dioxin and PCBs in fish tissues are quite low and it is expected that the concentrations of these compounds in the Nam Theun reservoir area would be approximately the same.

Although the risk of war-time heavy metal pollutants in the Nam Theun has been suggested (NORPLAN, 1995), results of metal analyses indicate low concentrations (less than 0.50 µg/l for lead,

Table 3.45: Summary of water quality in the Nam Theun, Nam Kathang and Xe Bang Fai during 2001 (Hydreco 2001a and b)

Parameter	Nam Theun/Nam Kading		Nam Kathang		Xe Bang Fai	
	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season
Temperature (°C)	23.6 – 24.7	25.6	26.5 – 28.0	27.3 – 35.7	26.8 – 27.0	28.4 – 33.1
pH	6.45 – 6.52	7.23	7.24 – 7.50	7.55 – 8.50	7.48 – 7.73	8.10 – 8.40
Conductivity at 25°C (µS/cm)	28.7	57.4	205	320	329	322
Dissolved oxygen (mg/L)	6.7 – 7.1	6.5	7.7 – 7.8	4.6 – 14.1	6.4 – 7.2	6.2 – 9.4
Suspended matter (mg/L)	9.4	–	9.4	–	39.3	–
Ammonium (mgN/L)	0.02	0.04	0	0.04	0.02	0.04
Nitrites (mgN/L)	0.004	0.001	0.005	0.005	0.019	0.010
Total phosphorus (mgP/L)	0.15	0.09	0.20	0.11	0.19	0.10
Silicon (mgSi/L)	4.4	4.5	4.8	9.7	3.6	11.1
Calcium (mgCa/L)	0.31	0.85	0	–	0	–
Magnesium (mgMg/L)	2.88	1.50	0.81	–	0	–

zinc, copper, cadmium and arsenic). Manganese and iron levels were found to be 2 and 94 µg/l, respectively. The higher concentrations of iron may be due to the periodic acidic situations in the Nam Theun. Acid in the water will facilitate iron dissolution into the water column.

Wet Season

Wet season water quality results (EDF, 2001; HYDRECO, 2001a) from tributaries of the Nam Theun were characterised by a relatively low pH (6.5) but with low conductivity (28.7 µS/cm). The acid soils of the Plateau are derived primarily from the pine forest that used to be present on the Plateau. Wet season measurements during flood events would therefore likely decrease the pH values, whereas during the dry season values as high as 7.2 have been recorded. The seasonal trend in the Nam Theun water quality probably occurs because of the differences in discharge regime between the dry season and the wet season. HYDRECO (2001a) also found that the waters of the Nam Theun are relatively warm (24.1° C), and had good dissolved oxygen saturation (7 mg/l). The waters were not very clear; Secchi disk readings of less than one metre were recorded. The main tributaries (Nam On and Nam Xot) distinguish themselves from the main river by lower conductivities and higher concentrations of dissolved oxygen. Only the Nam Nian presents characteristics similar to the Nam Theun.

In summary, the water quality of the Nam Theun is relatively good, with high dissolved oxygen, and low conductivity and nutrients. This reflects the fact that the river is located in a relatively undisturbed catchment with a relatively small number of people engaged in shifting cultivation, and no industry of any type.

Xe Bang Fai, Nam Kathang & Nam Phit

Dry season

The water quality in the Xe Bang Fai basin is good. It shows higher measures of alkalinity, total hardness, conductivity and total dissolved solids than the Nam Theun basin, and reflects the fact that the Xe Bang Fai is primarily situated on a limestone bed. The Xe Bang Fai flows through numerous villages where most of the people are involved in agricultural and fisheries activities. During the dry season, riverbanks are used for growing vegetables. Livestock and the human population also use river water for bathing and drinking water.

During the dry season in the Xe Bang Fai, pH ranged from 6.3 to 8.4 (HYDRECO, 2001a). Measures of total dissolved solids (124-204 mg/l in February 1995 and 191-241 mg/l in March 1995), alkalinity (109-174 mg/l as $CaCO_3$), and total hardness (131-149 mg/l as $CaCO_3$) are approximately an order of magnitude higher than in the Nam Theun. Measured conductivity ranges from 11 to 36 µS/cm. Conductivities recorded in April, 2001 (HYDRECO, 2001a) were between 20 and 39 µS/cm.

Water temperatures in the Xe Bang Fai basin range from 21 to 33° C.

Measured dissolved oxygen levels ranged from 3.0 mg/l to 10.8 mg/l during sampling in 1995, and appear to be generally lower than those in the Nam Kading/Nam Theun basin. The lowest oxygen level (3.0 mg/l) was measured in the Nam Phit which had no water flow during the dry season at the time of sampling. In the dry season, water in the Nam Phit close to the confluence with the Xe Bang Fai consists only of stagnant backwaters from the Xe Bang Fai. Chemical oxygen demand measurements were considerably higher at the mouth of the Nam Phit (98 mg/l), where oxidizable compounds accumulate in lower discharge conditions, than at other sites in the Xe Bang Fai, where chemical oxygen demand ranged from 2-38 mg/l. Mean dissolved oxygen levels measured at the bridge of Highway 13 downstream in the Lower Xe Bang Fai were 7.7 mg/l in 1995, which compares with the mean dissolved oxygen concentrations of 7.5 mg/l, measured in the Mekong mainstream at Nakhon Phanom (Mekong Secretariat, 1997). Measurements of dissolved oxygen levels made in 1995 at 22 stations from Mahaxai to the Mekong confluence ranged from 5.7 to 7.1 mg/l, and generally indicate good water quality. This good water quality was confirmed by the water quality evaluations conducted by HYDRECO (2001a). They recorded dissolved oxygen concentrations between 4.6 to 14.5 mg/l in April 2001.

Turbidity in the Xe Bang Fai ranged from 14 to 23 NTU during the period January to March, 1995 at the various locations sampled. The concentration of total suspended solids ranged between 0.4 and 23.0 mg/l during the 1995 dry season.

Phytoplankton density is relatively low (less than 3.2×10^5 cells/m^3 at Mahaxai in February 1995) with a variety of algal groups represented. Additional chlorophyll *a* measurements were collected in April 2001 (HYDRECO, 2001a). These concentrations ranged from 0.9 to 13.6 µg/l and represent low to moderately enriched aquatic systems.

Wet Season

The Xe Bang Fai (at Mahaxai), the Nam Kathang and the Nam Phit were sampled during September 2001 (HYDRECO, 2001b). In the wet season, the water quality of the Xe Bang Fai appears to be fairly good. Conductivity measurements ranged between 13 to 38 µS/cm, pH was between 7.2 to 7.8, while dissolved oxygen concentration was between 6.4 and 7.2 mg/l. Nutrient concentrations were generally low, though orthophosphate concentrations would easily support phytoplankton growth.

HYDRECO (2001b) concluded that the Xe Bang Fai wet season waters present different characteristics to those of the Nam Theun, with adequate dissolved oxygen but low conductivity. The water tends to be warmer, slightly alkaline, and contains considerably more orthophosphates and total phosphorus.

Baseline Groundwater Quality

A description of the geological formations within the Project area is provided earlier in the chapter. In the Phra Wihan formation, groundwater quality is suitable for most purposes, with generally less than 1,000 mg/l total dissolved salts in the dry season. Contamination of the aquifer close to the weathered surface of the formation can happen through the lateritic profile. However, unweathered rock units in this formation protect the aquifer from contamination.

In the Khok Kruat formation, groundwater quality is suitable for all purposes. However, salinity ranges up to 2,000 mg/l in the dry season.

Analysis of ground water in the resettlement area, which overlays both the Phra Wihan and Khok Krut geological formations, found conductivity to be between 87 μS/cm to 388 μS/cm; pH was between 6 and 7.8; NO_3-N was between 0.006 to 0.096 mg/l; NH_4-N was between 0.070 to 0.097 mg/l and turbidity was between 6 and 27 NTU (STS, 2001). Quality is good because the overlying sandy layers filter the water as it passes to the surface aquifer.

In the Maha Sarakham formation located in the middle of the Nakai Plateau, most of the rocks are likely to have gypsum or even halite saturation. As a result, salinity increases from 7,000 mg/l to over 100,000 mg/l with depth at any time. The groundwater from this formation is essentially contaminated.

For the alluviums near the middle of the Nakai Plateau, groundwater is generally of good quality. Salinity ranges from zero to only 500 mg/l in the dry season.

In the Phu Kradung formation situated below the Plateau in the Gnommalat area, groundwater quality is suitable for most purposes. Many communities already use groundwater from this formation for domestic purposes. Salinity ranges from zero to over 1,000 mg/l. Groundwater quality is generally acceptable. The exceptions are in the limited areas subject to leaching of gypsum from deposits where the groundwater becomes too salty for use, up to 7,000 mg/l.

Predicted Water Quality in the Nakai Reservoir & Impacts

Models & Assumptions

A simulation of water quality in the Project reservoir was conducted in 1997 using the one-dimensional water quality model DYRESM-WQ for averaged long-term predictions of water quality and a three dimensional model ELCOM (Winters *et al.*, 1997). These models assessed the longitudinal variation in water quality along the reservoir over the critical first few years of operation. The one-dimensional DYRESM-WQ model was developed by the Center for Water Research, University of Western Australia and has been used to predict water quality conditions for hydropower projects and lakes throughout the world, including the Bakun Hydroelectric Project, Malaysia (Lewis, 1995), Lake Pamvotis, Greece (Romero *et al.*, 1999) and Lake Burragorang, Australia (Jha *et al.*, 1999).

A variety of dominant processes were identified as potential sources that would affect water quality in the Project reservoir, such as: i) the decay of residual above and below-ground biomass; ii) the thermal stratification; iii) the resistance to oxygen transport from surface to depth; iv) the oxygen and nutrient loading from the inflowing rivers; v) phytoplankton dynamics; and vi) the detailed circulation patterns leading to differential residence times within various sectors of the reservoir area.

Assumptions regarding the calibration of the model and the basic input parameters are described in detail in Annex G. It should be noted that the organic matter discharged from the power station is not indicated in the analysis and the model does not take into account the presence of any oxygen consuming gases in the turbined water. A re-evaluation of the water quality modelling was done in 2000 to take into consideration a number of design and operational changes made to the operation of the Project. The new model verified the validity of the past numerical study with six turbines in the power station (Romero *et al.*, 2000), and evaluated the dominant phytoplankton characteristics and conditions likely to result in algal blooms during the periods of dam construction (year 1), reservoir filling (year 2), and elevated levels of terrestrial biomass decay in the reservoir (years 1-3) and the subsequent seven years. The basic assumptions used in the 1997 water quality model were reintroduced into the new model.

A number of different operating scenarios were modelled for the Nakai Reservoir. Comparisons of the water quality at the entrance to the power tunnels, spills at the dam and riparian releases from the dam were simulated with the revised water quality model. The revised model considered the following conditions: i) ten-year periods of high flow; ii) ten-year periods of low flow; iii) three turbines operating; iv) six turbines operating; v) biomass as predicted in the study by Prosser (1997); and vi) potential for catchment degradation from logging or development.

The one-dimensional simulations conducted with the DYRESM-WQ model were coupled with the CAEDYM model to predict the vertical variations in stratification, nutrient cycling, phytoplankton production and the oxygen dynamics within the reservoir on seasonal and long-term time scales. The three-dimensional ELCOM model was used to predict the general circulation in the basin in response to representative wind and inflow regimes.

In particular, the likelihood of preferential advection of: i) low oxygen deep water during high wind events; or ii) turbid, nutrient rich flood discharges to the reservoir and to the power intake tunnels were investigated with ELCOM. The three-dimensional water quality simulations with high inflows and high winds using the ELCOM model were coupled to the CAEDYM model. The linked models were designed to determine whether specific current patterns were generated to the power intake tunnels. Input data for these models was obtained from site measurements, and augmented from existing scientific literature as reported by Winters *et al.* (1997).

Results of Water Quality Modelling

Water Temperature

The reservoir is expected to be thermally stratified each year from late dry season, just prior to the wet season when solar radiation is greatest. Vertical temperature gradients will likely be greatest between about 5-10 m depth from the surface of the reservoir, even when the reservoir is at its minimum operating level. The onset of thermal stratification generally occurs as water surface levels approach the seasonal minimum water level in late dry season. The thermal stratification will be maintained through the first months of the wet season when the water surface rises rapidly with the onset of wet season discharge to the reservoir (Figure 3.41).

At the end of the wet season, stratification weakens as solar radiation becomes less and the water temperature of the inflow water decreases. Then, when the surface level of the reservoir nears the seasonal maximum, water temperature in the reservoir will likely become nearly homogeneous with relatively cool water temperature (between 15 and 20° C). Maximum water temperatures at the surface of the reservoir, particularly when the reservoir is drawn down to its minimum seasonal level, could be approximately 30° C with bottom temperatures ranging between 20 and 25° C.

Dissolved Oxygen

Periodic episodes of low dissolved oxygen (< 2 mg/l) were predicted to occur in the deeper waters under thermally stratified conditions (Figure 3.41). Anoxic conditions generally lasted for one to three months, and because of the shallow nature of the reservoir these anoxic conditions affected less than 3% of the reservoir volume. The evolution of anoxic conditions in the bottom water generally occurs immediately prior to the onset of the wet season. The period of stratification seems to respond to the amount of suspended sediment that is discharged to the reservoir from the tributaries. The increased suspended sediment load facilitates the absorption of solar radiation and tends to inhibit the mixing of surface and bottom waters.

When stratification was evident in the reservoir, nutrient concentrations and chlorophyll *a* appeared to be moderate in concentrations and the productivity of the reservoir was at mesotrophic levels.

The dissolved oxygen concentrations in the dry season through the power tunnels, along with spillage of water from the dam and the riparian release, appeared to have dissolved oxygen concentrations above 5 mg/l and low nutrient concentrations. However, during the initial years of operation, when decomposition rates of inundated biomass were high, nutrient concentrations in the power tunnels, riparian release and spills through the dam, appeared to have relatively high concentrations. This is to be expected as decomposition of organic matter in the reservoir area proceeds.

Dissolved Oxygen in Other Regionally Relevant Reservoirs

Dissolved oxygen concentrations downstream from existing reservoirs (Nam Ngum, Theun Hinboun, Nam Leuk) were reviewed by HYDRECO in 2001a to anticipate some of the potential problems that may emerge at the Nakai Reservoir and downstream of the Power Station.

After thirty-five years of operation, water quality of the Nam Ngum Power Project is fairly good. However, some anoxic water is found at the bottom of the reservoir, but mostly below the intakes for the Power Station. Frequently, the water discharged from the power station has low dissolved oxygen concentrations (3.5 mg/l on average). However, downstream from the dam, the dissolved oxygen concentrations gradually increase. Methane concentrations are low. The biochemical and chemical oxygen demands in the water discharged from the power station are fairly low and do not impact oxygen concentrations significantly (HYDRECO, 2001a).

In 2001 water quality problems continued to exist at the Nam Leuk reservoir, impounded in 1999. The reservoir is anoxic from a depth of approximately 10 m to the bottom of the reservoir. Discharge from the power station indicates ferric oxidation and at times there is an odour of hydrogen sulphide. In the dry season, the water discharged from the power station is mostly anoxic with less than 0.5 mg/l of dissolved oxygen and a fairly high concentration of dissolved methane (5 mg/l). After passage over a simple aeration weir constructed from gabions, the dissolved oxygen increases to about 3 mg/l and the methane concentration is reduced by about 3 mg/l. The water discharged from the power station is highly reactive. Biochemical and chemical oxygen demand will eliminate all of the oxygen from the water in three days (HYDRECO, 2001a). The impounded area of this dam had residual biomass at the time of impoundment. Some of the biomass was burnt before inundation, making nutrient readily available in the initial years. Residence time of water in the reservoir is about the same as that expected for the Nakai Reservoir, but the Nam Leuk reservoir is deeper than the Nakai Reservoir.

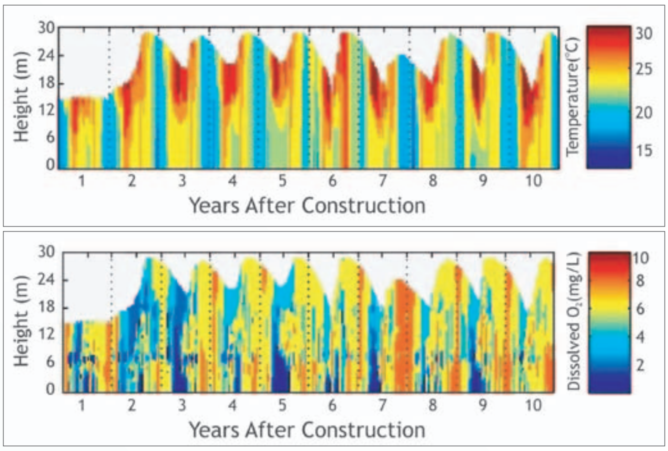

Figure 3.41: Predicted temporal and spatial variations in temperature (top) and dissolved oxygen (bottom) in the Nakai Reservoir

In April, the slightly older Theun Hinboun reservoir, impounded in 1997, had dissolved oxygen concentrations of 6.1 mg/l in the tailrace water discharged from the power station (HYDRECO, 2001a). The Theun Hinboun headpond was created within the existing river banks so there was no requirement to flood large amounts of vegetation. The reservoir area is smaller and consists only of a weir to divert water to the power tunnels and power station. Consequently, water quality downstream from the power station is fairly good.

Data from presently constructed projects in Lao PDR and also from modelling conducted by Winters *et al.* (2000) on the Nakai Reservoir indicates that dissolved oxygen concentrations will increase over time but will be affected by the presence of vegetation in the reservoir area for several years. In the early years of operation in these other projects, water discharged from the power stations may be low in dissolved oxygen and high in reducing elements (e.g. methane and hydrogen sulphide as well as other reducing chemicals). Over several years of operation, the concentrations of reducing compounds diminish and dissolved oxygen concentration increases.

Ammonia & Sulphide in the Nakai Reservoir & Other Regionally Relevant Reservoirs

Peak concentrations of 25 µg/l ammonia are predicted to occur during the wet season after destratification of the reservoir. These concentrations are close to the baseline values for receiving waters, and are not expected to have a significant impact on fish populations.

Samples of water discharged from the power station at Nam Leuk indicated that some ammonia is present in the water (> 0.3 mg $N\text{-}NH_4$/l). The water discharged from the Theun Hinboun power plant is oxygenated and ammonia concentrations are low. Water discharged from the Nam Ngum reservoir contains a small amount of ammonia (maximum 0.1 mg $N\text{-}NH_4$/l) (HYDRECO, 2001a).

Due to the continuous high oxygen levels in the epilimnion, no impacts of hydrogen sulphide are expected at the surface water layer. The water quality model (Winters *et al.*, 2000) predicts stratification of the reservoir. Anoxic conditions will likely arise in the hypolimnion but this water will not be diverted for riparian release into the Nam Theun downstream of the Nakai Dam. For the Power Station intake, water will be diverted from both the epilimnion and hypolimnion, reducing the concentrations of hydrogen sulphide and methane. Fish egg survival and fish fry development are particularly vulnerable to hydrogen sulphide (Boyd, 1979).

Other Water Quality Factors

The desirable pH range for good fish production is between 6.5 and 9 (Boyd, 1979). Predicted pH values for the Nakai Reservoir are within this range. Photosynthesis removes carbon dioxide from water during daylight, causing a rise in pH. When there are phytoplankton blooms in the Nakai Reservoir, the pH may increase significantly because the water in the reservoir does not have buffering capabilities. During the night, carbon dioxide concentrations will likely increase due to respiration by the phytoplankton and other aquatic organisms. When this occurs, the pH will decrease as carbon dioxide neutralises some of the ionised compounds in the reservoir.

Nutrient concentrations in the Nakai Reservoir will increase during the first few years of operation due to the decomposition of plant material that is present in the reservoir area. This is a common phenomenon in reservoirs throughout the world and results in an initial flush of productivity until the reservoir matures and the amount of decomposing plant material declines. An increase in nutrient concentrations frequently leads to phytoplankton growth in the reservoir. High nutrient levels are expected within reservoirs with insufficient removal of vegetation before impoundment. A consequence of the higher nutrient concentrations is that pH will fluctuate considerably in the reservoir until the nutrient concentrations come into balance with the water flowing into the reservoir area. The fluctuation in pH could affect fish production and could result in stress and diseases in the fish populations residing in the reservoir area.

Any increase of the sedimentation process may cause a significant negative impact on the reservoir fish. Given the relatively undisturbed nature of the catchment, suspended sediment concentrations in the Nakai Reservoir are expected to be quite low, with no impact to fish populations.

Agriculture activities in the resettlement areas may lead to an increase in the use of pesticides, which are extremely toxic to fish and can lead to bio-accumulation to levels harmful for human consumption

Conditions created in the Nakai Reservoir in the initial years could promote the methylation of inorganic mercury, bound to particles and organic substances, to methyl-mercury. Methylation rates are elevated under anoxic conditions and in the presence of organic matter, which stimulates growth of microbial populations. Methylmercury is readily accumulated by aquatic organisms, especially through the gills of fish, and can biomagnify in higher trophic levels, leading to potentially harmful concentrations for humans.

Supersaturation occurs when water and air mix under pressure and can impact fish at the lethal and sub-lethal level. Conditions created when spill water drops from the top of a dam causing air bubbles to mix with water at depth can result in supersaturation. The Nakai Dam will feature a drop of only 40 m, together with a shallow stilling basin and a shallow Nam Theun below. This combination should not result in a significant impact from supersaturation. An analysis of the potential for supersaturation below the Nakai Dam is to be included in the analysis of the riparian release and spills.

Experience from Other Hydro-Electricity Dams in Southeast Asia

A large number of hydroelectric dams have been constructed throughout Southeast Asia. Information relevant to the Project can be gained from briefly examining these already constructed dams. Water quality issues associated with these dams include: i) large rates of sedimentation because of basin characteristics and management; ii) changes in flow volume to downstream reaches; iii) poor water quality discharges downstream; and iv) aquatic plant proliferation. The first two issues have been discussed earlier in the chapter.

Downstream Discharges

Generally in Southeast Asia, only during the wet months are hypolimnetic releases of water from storage reservoirs acceptable for downstream aquatic life. Cooler air temperatures and wind and wave action during each wet season mix and destratify reservoirs, leading to higher dissolved oxygen concentrations and good water quality throughout the water column. During the dry season, thermal stratification of the water column occurs.

Following a review of 30 reservoirs with dams higher than 15 m in lower Mekong countries, Bernacsek (1997) indicated that most reservoirs suffer from hypolimnion de-oxygenation and hydrogen sulphide production. Thus any discharge structures or turbine intakes situated 15 m below the water line are likely to discharge cool and often toxic water downstream. Despite this knowledge, and the fact that the ability to destratify reservoirs with in-lake aeration has been well documented, it appears that many of these dams release hypolimnetic waters without adequate re-aeration devices downstream to improve water quality. To date, there appears to be no suitably designed destratification units working in Southeast Asian reservoirs, and little or no mitigation measures to improve downstream water quality from these reservoirs. One or two exceptions exist, including the simple gabion aeration weir built downstream of the discharge of the Nam Leuk reservoir.

In 2001, the seasonal evolution of water quality within the recently-constructed Nam Leuk reservoir was investigated by HYDRECO. This was conducted to provide local input data for the numerical methane water quality model for the project and to confirm some of the water quality predictions of the modelling undertaken for the Nakai Reservoir. Water column profiles taken in the dry season from the Nam Leuk reservoir showed that the lower half of the water body was lacking in oxygen a year and a half after being filled. The water discharged from the power station, deoxygenated (< 0.5 mg/l) and enriched in dissolved methane, flows over a weir, giving a gain of 3 mg/l of dissolved oxygen. The dissolved oxygen concentration averages 4.8 mg/l some 12 km downstream of the power station, just prior to mixing with the Nam Ngum Reservoir (HYDRECO 2001a). The simple aeration weir at Nam Leuk is constructed from gabions that, when the power station is operating, create a drop of approximately 1m during the dry season. In the wet season, the aeration weir efficiency decreases due to the increased turbine discharges and higher downstream levels.

Further measurements at the end of the rainy season showed an improvement in water quality, due to the increased speed of water renewal. The thickness of the oxygenated layer in the Nam Leuk reservoir increased by approximately 5 m and in particular, the water quality at the turbine outlet was considerably improved, with an oxygen level of 3-5 mg/l.

Aquatic Macrophytes

Excessive development and proliferation of aquatic macrophytes could affect water quality in the reservoir. Such proliferation could be caused by nutrient enrichment, or simply when introduced species have no natural predators or diseases, even in oligotrophic conditions. A number of species of aquatic macrophytes have been recorded in the Nam Theun and Nam Kading. Of particular significance is the presence of water hyacinth (*Eichhornia*) and water lettuces (*Salvinia* and *Pistia*) in the basin. Only *Eichhornia* has been recorded in the Nam Theun basin.

The Nam Ngum Reservoir was filled in 1972. A report completed on the Development and Management of Fisheries in Nam Ngum Reservoir found the occurrence of dense growths of *Azolla*, *Salvinia*, *Pistia* and *Eichhornia*. These dense growths occurred only in several embayments in the reservoir during the four-year study period. Other potential weeds are the submerged macrophytes *Hydrilla* and *Ceratophyllum*. *Hydrilla verticillata* was found in the Nam Ngum reservoir and grew abundantly in shallow areas 3-5 m from the shore and up to 4 m in depth. This plant could hamper fishing and navigation in the shallower regions of the reservoir (Interim Committee for Co-ordination of Fisheries in the Lower Mekong Basin, 1984).

It is likely some submerged aquatic plants will become established in the Nakai Reservoir. However the 12.5 m vertical fluctuation of water level on a seasonal basis should limit submerged and emergent macrophyte growth, and a balanced population could improve fish production by providing refuge and forage habitat (Bernacsek, 1997). This author reports that outbreaks of aquatic macrophytes frequently occur during the first year or two of operation of impoundments in the Mekong River Basin, often as a consequence of the concentrations of nutrients that are generated when the reservoir is first filled. Biological control methods for *Salvinia* have proved to be successful in Papua New Guinea and Australia. Water hyacinth control in smaller lakes is labour intensive and booms are used to collect this material.

Changes in vegetation community structure, species composition and biomass quantities are likely to occur in the downstream Nam Theun. Macrophyte communities are likely to be similar to those communities presently in the river. An assessment of the impacts on the macrophyte communities in the Nam Theun is to be included in the analysis of riparian release in the dry season of 2004. The submerged macrophytes, *Hydrilla* and *Ceratophyllum* and the emergent macrophytes *Sagittaria*, *Typha* and *Colocasia* may become established along the Downstream Channel, particularly in the unlined section of the channel.

In the Nam Theun below the Nakai Dam, under lower flow conditions, pools may support a large phyto-plankton and filamentous algal biomass. These pools may experience low dissolved oxygen concentrations in the early morning as a result of high nocturnal respiration rates, leading to a net reduction in dissolved oxygen concentration and an increase in fish stress. Residence times of water in these pools should be between one to two days, based upon the depth and width of the pools and the length of the river between the dam and the junction of the Nam Phao. This residence time in the stream channel could possibly reduce large fluctuations in algal productivity and dissolved oxygen concentrations. The impact of the Nakai Dam on flows and water quality in the Nam Theun is to be included in a further study of the riparian release. The findings of the study will be incorporated into this analysis.

Predicted Water Quality Downstream from the Power Station & Impacts

Modelling & Assumptions

Water discharged from the Power Station will be retained in the Regulating Pond, where the majority of the flow will be transferred to the Xe Bang Fai via the 27 km-long Downstream Channel. A portion of the water discharged from the Power Station, equal to its natural inflow into the Regulating Pond, will be diverted into the Nam Kathang. To evaluate the potential water quality conditions in the Nam Kathang, the downstream channel and the Xe Bang Fai, a model was developed by EDF (2001). The mathematical model consisted of the LIDO hydraulic code, using the Saint-Venant equations in one dimension, the Tracer transport software, and the EUTRO water quality modulus, which models river eutrophication processes. The model was designed to investigate the potential impacts caused by releases from the Project on dissolved oxygen concentrations in the Nam Kathang and the Xe Bang Fai. Three sets of results were used in the analysis: i) the updated CWR results of the water quality modelling for the Nakai Reservoir (Romero *et al.*, 2000); ii) assumption that the water quality will be similar to that observed in the first years of operation at the Petit Saut Hydropower Project in French Guyana; and iii) assumption that the water quality would be better than at Petit Saut but not as good as the water quality predicted by CWR. The Petit Saut scenario assumes water quality much inferior to that predicted for the Nakai Reservoir. A sensitivity analysis was performed to take into account uncertainties such as characteristics of the water discharged from the Power Station, the efficiency of the planned aeration systems and the self-purification capacities of the rivers. Other variables have been derived from water quality data collected from the Nam Leuk reservoir.

At Petit Saut, dissolved oxygen concentrations of zero were observed in water discharged from the dam for a much longer period than what is expected to occur from the Project. The Petit Saut analysis indicated the presence of oxygen-consuming gases (such as methane) in the water discharged from the turbines, in concentrations of up to 3 mg/l downstream of the aeration structures, whereas the CWR analysis did not indicate the presence of such gases in the turbined water. Other physico-chemical variables used for the Petit Saut analysis were from measurements made during its first few years of operation. The Petit Saut analysis assumed an oxidizable organic material load of 8 mg/l in the water discharged from the turbines. This is four times more than the oxidizable load predicted for the Nakai Reservoir (2 mg/l). Overall, the Petit Saut scenario took into account oxygen-consuming gases and had a greater organic load resulting in poorer water quality in the water discharged from the turbines. One of the driving forces for the high oxygen consumption at Petit Saut was the amount of organic matter that was inundated. At Petit Saut, the estimates for the amount of organic mater inundated were 160 tonnes C/ha for the vegetation and 120 tonnes C/ha for the soil. Current estimates on the amount of biomass to be inundated by the Nakai Reservoir are 40 tonnes C/ha and 70 tonnes C/ha for vegetation and soil respectively (Hydreco, 2001a).

Results of Water Quality Analysis for the Nam Kathang & the Xe Bang Fai

The basic calculations of the water quality model consisted of determining the longitudinal profiles of dissolved oxygen in the Nam Kathang and Xe Bang Fai. The months from December to May were selected for the simulation since they correspond to the dry season, when the Nakai Reservoir water quality will have more influence than in other months.

A series of field measurements was obtained in April 2001 to calibrate the model. Dissolved oxygen concentrations were measured in the Nam Kathang and the Xe Bang Fai, as well as from the Nam Leuk power station. The Nam Leuk data was specifically collected to obtain information regarding the intensity of the processes of oxygen consumption by methane and organic matter. Results of the dissolved oxygen and temperature measurements in the two rivers are presented in Figure 3.42.

The results of the modelling, using water quality predicted for the Nakai Reservoir, and discharge through the turbines in the Romero *et al.* scenario, and the water quality observed at Petit Saut, indicate that there will be no critical dissolved oxygen content in the Nam Kathang. The predicted evolution of dissolved oxygen in the Nam Kathang for both the CWR and Petit Saut scenarios is presented in Figure 3.43.

For the Xe Bang Fai, several scenarios were analysed: i) scenario A used the predicted water quality from the CWR model; ii) scenario B adopted the water quality discharge from Petit Saut and assumed a clean, efficiently functioning aeration weir and self-purification in the downstream channel; iii) scenario C assumed the same as scenario B except with a clogged and inefficiently functioning aeration weir; and iv) since the estimated biomass in the Nakai Reservoir is less than at Petit Saut, scenario D adopted better water quality, with approximately half the methane content of Petit Saut (scenario B and C). Analysis results from these four scenarios are presented in Figure 3.44.

For CWR scenario A, no critical values of dissolved oxygen were generated for the Xe Bang Fai. Equally, no critical values were generated for the Petit Saut scenario B with a clean and efficiently functioning aeration weir. However, for the Petit Saut scenario C, with a clogged and inefficient aeration weir, the model predicts that the dissolved oxygen in the Xe Bang Fai would be 2 mg/l for a substantial portion of its length. Such a low concentration of dissolved oxygen would be detrimental to fish populations. As indicated above, it is unlikely that the water from the Nakai Reservoir will be of similar quality to the reservoir of Petit Saut, because of its much lower biomass. Therefore a higher concentration of dissolved oxygen and a lower concentration of methane are expected. Scenario D would not result in any critical values in dissolved oxygen, with a minimum of approximately 4 mg/l.

Assuming the aeration weir is maintained and working efficiently, the dissolved oxygen concentrations in the Xe Bang Fai should lie somewhere between scenario B and the CWR scenario A, presented in Figure 3.45. A clean aeration weir seems critical for the dissolved oxygen in the Xe Bang Fai. Access for such cleaning would be possible during the periodic low discharge on Sundays.

Other Factors

Temperature

The colder water discharged from the Power Station will have a cooling effect on the Xe Bang Fai. This effect will be greatest in the dry season, when there is less water in the Xe Bang Fai to buffer the incoming Power Station discharge. In April, the power station discharge temperature is estimated to be 26° C, which compares to an average of 31° C in the Xe Bang Fai. The warming process on the Power Station discharge in the Regulating Pond, and during its transition along the 27 km-long Downstream Channel, (which includes the aeration weir where the surface to volume ratio significantly increases heat transfer), could increase the water temperature by 1° C. Because of this warming process and the mixing of waters from the Xe Bang Fai and the Downstream Channel, it is expected that in the dry season, the temperature difference will be less than 3.5° C in the middle Xe Bang Fai and a maximum of 3° C in the lower Xe Bang Fai. This will impact Xe Bang Fai fish populations.

In the wet season, the differential will be less, and will be buffered by the equal or greater quantities of water in the Xe Bang Fai, along with lower water temperatures.

Supersaturation

The entrance to the intake structure will be constantly drown and without vortices. Under normal operation there should be no air/water interface in the pressure tunnel or turbines, and therefore no mixing of air and water under pressure should result. Supersaturation is not expected to be an issue for the water discharge from the Power Station. Even under load rejection, the design of the engineering work specifies that air should not be drawn into the water in the pressure tunnel.

Pesticides

Increased agricultural activities in the Xe Bang Fai may lead to elevated uses of pesticides. Some synthetic chemicals can be toxic to fish and have the potential to bio-accumulate in fish tissue to levels that are harmful to the human consumer.

Social Impacts of Water Quality Changes

Many of the communities in the Project area live in close proximity to the existing water bodies and currently utilise surface water and groundwater for a variety of beneficial uses, including drinking water, recreation, washing, irrigation, fishing, and watering livestock. Therefore the quality of water is regarded as an important issue, not only for aquatic life but also for the multi-use of water by riverine and future reservoir residents. Any of the negative changes in water quality highlighted in the analysis above could impact these beneficial uses of water, and therefore the communities themselves. (This is discussed in the SDP).

Mitigation of Potential Water Quality Impacts

To prevent adverse water quality conditions in the riparian release downstream of the Nakai Dam, the water for the riparian release will be drawn from the epilimnion and the discharge will be made through an aeration structure, a cone valve, that will spray water to the downstream reach. This will effectively aerate the water and help fish populations to survive in pools downstream from the Nakai Dam, should the water be of poor quality. The Romero *et al.* (2000) model predictions are that the quality of water entering the aeration device for the riparian release and for dam spills should generally be good, having low organic loads and moderate to high dissolved oxygen concentrations. To alleviate impacts from the reduced flow, the analysis of riparian release and spills will make recommendations on how the flow regime in the Nam Theun should be managed

Aquatic weeds in the reservoir area, floating and submerged, can be controlled through the annual seasonal drawdown and refill cycle. The shallow basin should prevent floating aquatics from moving into the minimum operating areas and most of the plants

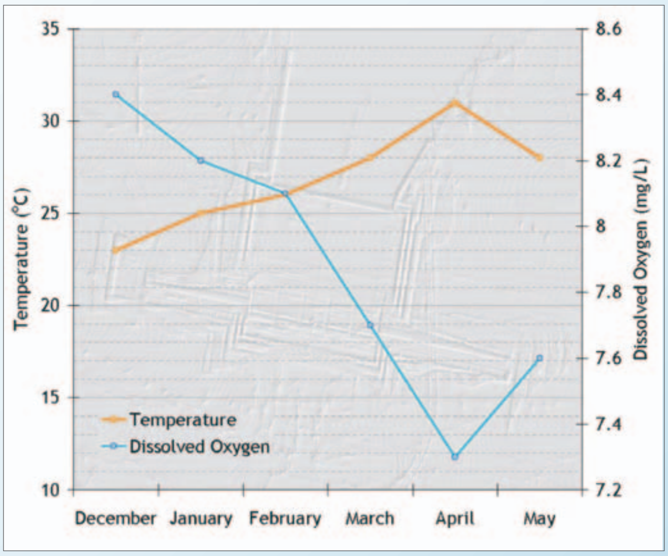

Figure 3.42: Results of water quality measurement in the Nam Kathang and Xe Bang Fai

Impacts

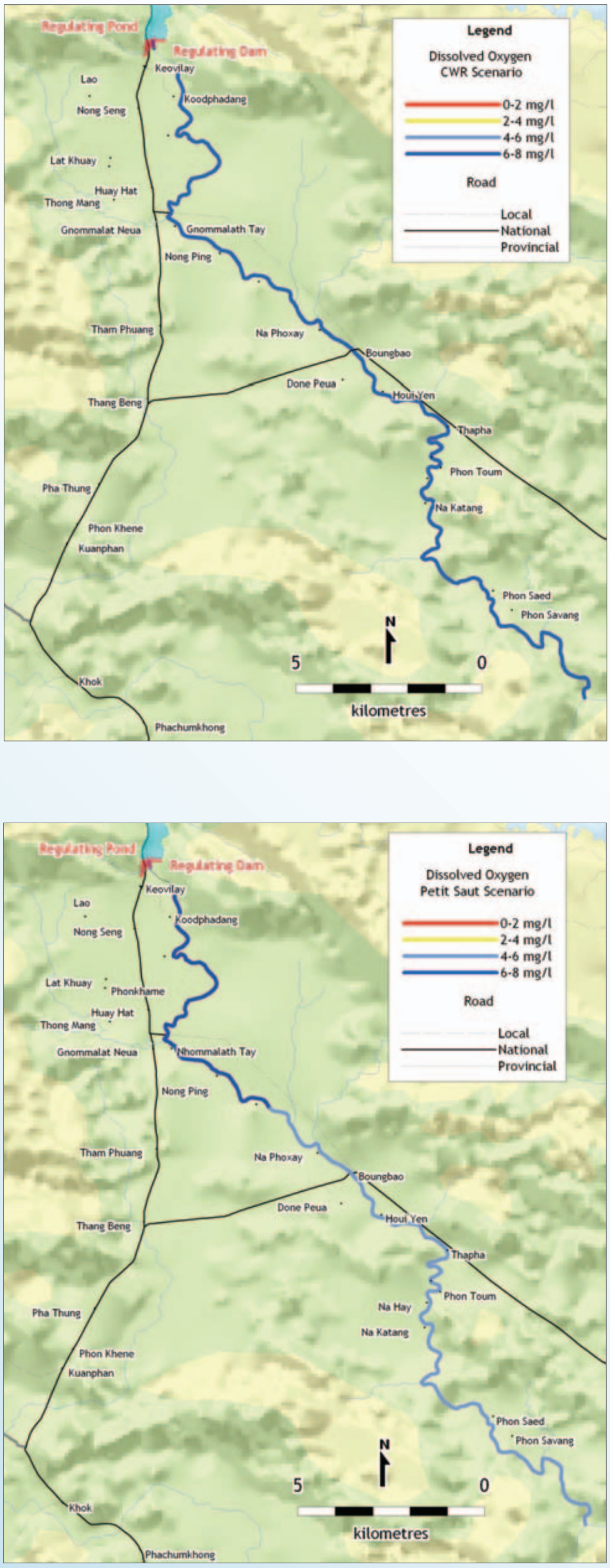

Figure 3.43: Predicted evolution of dissolved oxygen in the Nam Kathang for both the CWR (top) scenario A and the Petit Saut (bottom) scenario B for the month of April

will be left in the extensive mud flats as the reservoir is drawn down.

To help improve water quality in the Nakai Reservoir in the initial years after inundation, NTPC will encourage the removal of biomass from the inundation area prior to flooding through firewood collection and the salvage of timber. A survey of present biomass in the inundation area is currently being undertaken, based on the interpretation of a Landsat satellite image of the Nakai Plateau from March 2003. This exercise will update the biomass estimate in the area to be inundated. The results will be used to propose means for maximizing removal of biomass (timber and firewood) in high biomass areas of the Nakai Reservoir.

The Head Contractor's compliance with the existing construction schedule will help improve water quality conditions in the reservoir during the initial years. It is particularly important to avoid situations similar to that which occured at the Nam Leuk hydropower project reservoir. There, inundation occurred before the transmission lines were installed and the reservoir remained full without any possible exchange of water, for a longer period than planned. Even after cutting and burning biomass before inundation, the Nam Leuk reservoir turned anaerobic, resulting in fish kills in the reservoir and downstream after the start of power production.

Romero *et al.* (2001) carried out modelling of various destratification and direct oxygenation systems for the Nakai Reservoir. It was concluded that: i) the bubble plume system would result in oxygenated conditions and lower nutrient concentration in the bottom waters, but would not be feasible given the energy inputs for a reservoir the size of the Project's; and ii) direct oxygenation of bottom water would be prohibitively expensive. Experiences from other reservoirs indicate extensive costs. The installation cost of destratifiers in North Pine Reservoir in Australia was US$ 13.9/ha at FSL, and operation costs were US$ 2.3/ha/month. If these costs were extrapolated to the Nakai Reservoir, the installation costs would be more than US$ 5 million, and the operation cost would be US$ 1.2 million/year. Even a high fish yield of 45 kg/ha would not then offset the costs of aeration and destratification.

The intake structure for the Power Station is designed to draw water from the majority of the water column. The water discharge from the Power Station will therefore not consist only of potentially anoxic hypolimnion but also oxygenated epilimnion. A technical drawing indicative of the intake structure is presented in Annex D.

To improve the dissolved oxygen concentrations in released waters from the Power Station, re-aeration of these waters will be provided. This will be done by the discharge gates and structure at the regulating dam and the aeration weir located in the Downstream-Channel. The U-shaped structure will cause water to flow over the top of the broad-crested weir and fall into the channel downstream. The drop will be anywhere between 1.5 to 5.4 m depending on the discharge from the Power Station. This compares to the 1m drop of the Nam Leuk aeration weir. The Downstream Channel aeration weir will incorporate a specially designed nape with grids placed in a horizontal plane, designed to induce rainfall-type flow, and thus significantly increase the surface to volume ratio (Figure 2.13). This will enable entrainment of air into the water column and will be designed to increase the dissolved oxygen concentrations and reduce the methane and hydrogen sulphide concentrations.

To protect water quality in the Nam Kathang two aeration structures will be incorporated into the design of the Regulating Dam. The release structure of the Regulating Dam will include a hydraulic jump and a weir is to be constructed at the end of the stilling basin. Both these additional structures will increase turbulence, facilitating oxygenation and degasification of the water.

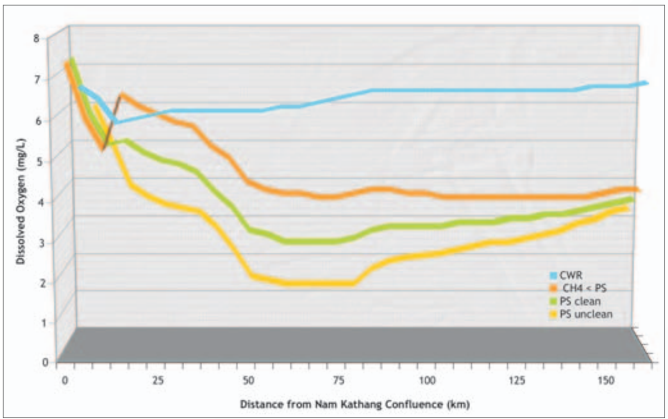

Figure 3.44: The evolution of dissolved oxygen in the Xe Bang Fai for various CWR and Petit Saut scenarios

Analysis of 1:30 scale models of both the Downstream Channel and Nam Kathang aeration structures concluded that the increase in the air/water interface and the aeration of water was effective over a range of flows (EDF 2002a and 2002b; LHM 2004). LHM (2004) concluded that for optimum aeration, the water/air exchange surfaces must be maximized and therefore bubbles should be as numerous and remain as long as possible under the water before rising to the surface. In order to improve the weir's efficiency, the bubble formation zone had to be transferred away from the overflowing nape in order to minimize disturbance. To achieve this, splitters were incorporated into the design to increase traversal velocities relative to horizontal velocities. In addition, during hydraulic testing, the weir's downstream portion was raised to achieve the target objective of uniformity of spilling over the entire nape. This recommendation has also been incorporated into the design of the aeration weir. LHM (2004) modeling also concluded that sediment deposits in the aeration wier have no influence on the overflowing nape. Technical drawings of these aeration structures are presented in Annex D.

The efficiency of the downstream channel aeration weir has been indicated to be around 70%. These efficiency forecasts are based on visualization of existing similar structures (weir and bottom outlet gates at Petit Saut) (Alain Gregoire, pers. comm.). Past experiences of the effectiveness of similar aeration weir designs include: i) Canyon Dam, with a 68% oxygenation efficiency; and ii) South Holston, with a 60% oxygenation efficiency.

The efficiency of the Downstream Channel aeration weir is based on a clean and functioning nape. Any bacterial or algal build up in the holes of the nape will lower its efficiency. Adequate access to clean the aeration weir's nape will be available during the periodic low discharge on Sundays.

Monitoring

To asses whether the Project is fulfilling its commitment, NTPC, under its contractual arrangements with GOL, will provide adequate monitoring of water quality in all water bodies concerned.

Terms of Reference for the Water Quality Monitoring & Assessment Programme

A Water Quality Monitoring and Assessment Programme (WQMAP) commenced early in 2005. The following section outlines its aims, methodologies and expected outputs.

Aims & Objectives of the Programme

The overall aims of the Programme are to: i) achieve effective collection, analysis, interpretation and presentation of water qual-

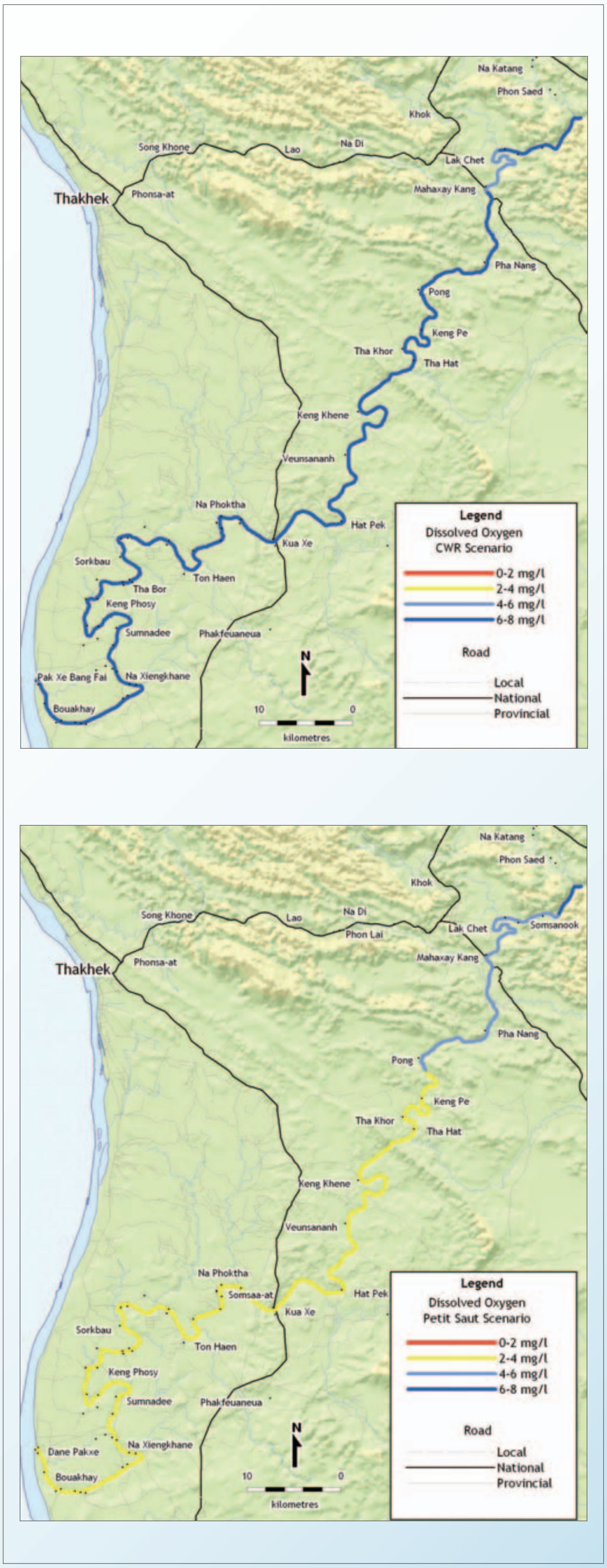

Figure 3.45: Predicted evolution of dissolved oxygen in the Xe Bang Fai for both the CWR (top) scanario A and the Petit Saut (bottom) scenario B for the month of April

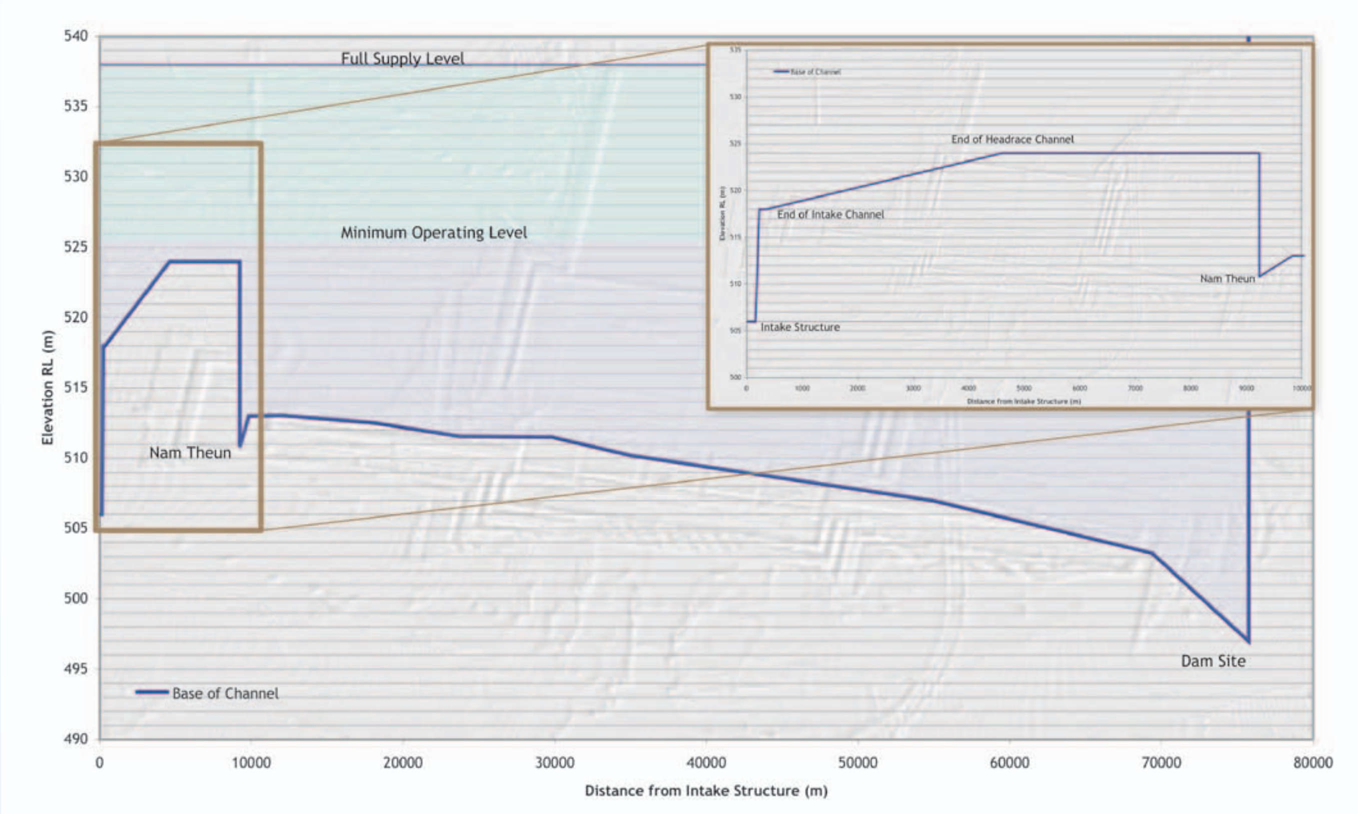

Figure 3.46: Section showing water level drawdown over long section from Intake to Dam Site

ity data for surface water and groundwater in the Project area; ii) monitor whether NTPC is fulfilling its obligations stated in the Concession Agreement; and iii) assist in the formulation of appropriate mitigation measures and adaptive management strategies to help reduce the impact of any deterioration in water quality that may result from Project activities.

The main objectives of the Programme are as follows:

1. Development of the WQMAP:

- Develop a WQMAP that provide adequate information on the pre-construction, preliminary construction, construction and operation phase groundwater and surface water quality;
- Evaluate potential impacts resulting from construction and operational activities, with tailoring of the WQMAP to monitor for these potential impacts;
- Develop a Standard Operating Procedures Manual for sampling, preserving and analysing surface water and groundwater; and
- Provide training and technical support to the Lao agency conducting the collection and analysis of samples.

2. Data Collection and Reporting:

- Initially focus investigations on baseline data acquisition in the pre-construction phase of the Project, then on the extent of water quality change in the preliminary construction, construction and operation phases;
- Assess water quality, identify variations, trends and abnormal levels, and investigate cases where trigger levels are exceeded;
- Develop a coherent reporting system;
- Develop a database for long-term storage and acquisition of water quality data; and
- Develop means to coordinate WQMAP with other ongoing and future monitoring programmes.

3. Mitigation Measures and Evaluation:

- Evaluate and recommend appropriate management and mitigation measures that could be implemented to prevent/nullify any adverse changes in water quality from pre-existing conditions; and
- Identify measures which may improve the WQMAP through ongoing evaluation during the implementation phase.

Approach & Methodology

United Analyst and Engineering Co. Ltd (UAE) are currently undertaking the WQMAP in close collaboration with the Lao counterpart, Department of Irrigation (DoI) Analytical Chemistry Laboritory. As such, a core component of the WQMAP is to provide sufficient training and technical support to strengthen the capacity of the DoI laboritory with a view to continuing involvement in this long -term monitoring programme.

Standard Operating Procedures Manual

A Standard Operating Procedures (SOP) Manual with detailed stepwise instruction on how to conduct the WQMAP has been produced and updated as required: This manual utilizes well defined and widely used methodologies. All relevant stages and procedures are detailed in the SOP Manual, such as: i) sample collection; ii) sample identification; iii) preservation techniques; iv) analytical techniques for each parameter; v) data management; and vi) QA/QC procedures.

Parameters & Frequency for Surface Water

The parameters given in Table 3.46 are initially included proposed for monitoring surface water. A periodic review of this suite of parameters will be made and recommendations provided on the requirement for additional parameters.

The majority of the parameters for surface water will be monitored with some indicating parameters (pH, conductivity, turbidity, etc.) being monitored on a weekly basis. A review of the sampling frequency will assess whether data has statistical rigour and is adequate to answer the tasks set out in the objectives.

Parameters & Frequency for Groundwater

Parameters presented in Table 3.47 are initially included for monitoring groundwater. Monitoring of these parameters is required under GOL Resolution No. 953/MOH on water quality targets for rural water supply systems.

The sampling frequency proposed for monitoring existing groundwater supply will be on a twice per year basis, at the end of the wet season (November) and at the end of the dry season (May).

Any domestic water supply systems established for communities as part of the Project's compensation package, or established for personnel associated with the Project, will require an initial assessment to ascertain whether the Project is supplying water of adequate quality. After this, the domestic water supply will be sampled on a biannual basis. A review of the sampling frequency for groundwater will be carried out and recommendations provided if any adjustment to the sampling frequency is required.

Table 3.46: Proposed suite of parameters for surface water monitoring

Parameter
Temperature
pH
Total Suspended Solids
Nitrate (NO_3^-)
Calcium (Ca_2^+)
Silica
Total Iron
Lead
Fecal Coliforms
Dissolved Oxygen
Conductivity
Alkalinity
Nitrite (NO_2^-)
Total Phosphorus (TP)
Potassium (K^+)
Magnesium (Mg_2^+)
Mercury
Biological Oxygen Demand (BOD)
Climatic conditions
Turbidity
Ammonia (NH_4^+)
Sodium (Na^+)
Manganese (Mn_2^+)
Arsenic
Chemical Oxygen Demand (COD)

Additional Parameter Requirements

Pesticides & Other Synthetic Chemicals

Pesticides, herbicides and other synthetic chemical use in the Project area is expected to be minimal and their use is to be controlled under the Pest Management Plan and the HCCEMMP. Hence monitoring for such complex compounds and their residuals will initially not be undertaken. If it emerges that such chemicals are being utilised for Project activities, then consideration will be given to monitoring for those specific compounds in use.

Petrochemicals

Petrochemical use and spillage during construction is to be controlled by environmental measures to be outlined in the HCCEMMP. If a major spill event occurs, then monitoring for such compounds will also be required.

Heavy Metals in Fish Tissue

As a result of the potential for mercury, arsenic and lead to bioaccumulate in fish tissue to levels that could be harmful to public health, the WQMAP will include the possiblelity to monitor for these metals in fish tissue. Procedures will be developed to take into account: i) site selection; ii) timing of sampling; iii) target species and size to be sampled; iv) type and number of samples per species; v) field handling procedures; vi) laboratory analytical procedures; and vii) trigger level procedures.

Biological Monitoring

Given the inherent temporal and spatial dynamic of monitoring aquatic ecosystems using only physico-chemical parameters, the WQMAP will be integrated with a biological monitoring programme. The monitoring of several trophic levels: i) phytoplankton; ii) benthic macro-invertebrates; and iii) fish, will provide a clearer understanding of any adverse water quality impacts that may develop, and provide an early warning system to monitor any proliferation of certain species of algae which can be toxic to both livestock and humans.

Surface Water Sampling Site Location

The sampling site locations are presented in Figure 3.47. The locations are chosen to enable assessment of water quality conditions in the Nam Theun both upstream and downstream of the proposed Nakai Dam and in the Nam Kathang/Nam Gnom, Nam Phit and Xe Bang Fai. additional sampling sites might be required during the main construction phase as the location of work camps and construction sites are finalised and construction starts. Sampling site locations for the Nakai Reservoir will be finalised after inundation

Table 3.47: Suite of parameters proposed for groundwater monitoring

Parameter
Conductivity
Nitrate
Iron
Number of thermo-tolerant Coliforms
pH
Manganese
Odour
Total Hardness
Turbidity
Fluoride
Arsenic

Groundwater Sampling Site Location

The initial goal of groundwater monitoring is to collect indicative baseline data for representative regions of the Project area. The number and location of the groundwater sampling sites is to be proposed once an assessment of domestic water supply system types, numbers and locations is carried out to facilitate the decision. In addition, any installation of domestic water supply systems associated with the Project will require monitoring.

Outputs

Monthly Reports

A monthly report shall be submitted during the course of the project which summarises all water quality data, including: i) parameters measured; ii) specific sample site locations, sampling dates and time of collection; iii) description of methodologies and any deviations from the agreed methodology; iv) values for parameter mean, range, standard deviation and variance; v) interpretation of the data in terms of trend analysis and/or diagnosis of problematic levels; vi) recommendations to alleviate problematic levels.

Inter-Programme Cooperation

Inter-programme cooperation with other relevant programmes might be required. WQMAP reports will serve primarily as an assessment of water quality, but also to facilitate the development and management decisions for other programmes, such as the Reservoir Fisheries Management Plan.

Figure 3.47: Water quality sampling sites proposed for surface water

Reporting of Hazardous Levels

NTPC will be immediately notified of any hazardous levels attained or when a trigger level for a parameter has been exceeded. When the trigger level is reached, the course of appropriate action will be assessed on a case-by-case basis. The results of analysis for surface water shall also be compared to agreed-upon and recognised standards. NTPC will also be immediately notified if groundwater parameter values exceed any one of the standards set by the GOL in resolution No. 953/MOH (14 July, 2003). The target values for rural water supply systems are presented in Table 3.48.

Values in excess of the Lao standard shall be regarded as a trigger for further investigation, including a major ion analysis. The results of analysis should be compared to agreed-upon and recognised standards for groundwater.

Water Quality Database

A data management system is being developed and maintained for effective storage and retrieval of data.

Evaluation & Monitoring

Periodic review of sampling techniques, site selection, analytical techniques and other elements will be carried out of to assess the effectiveness of the WQMAP and to check whether it is successfully addressing its specific objectives. Continual evaluation of methodologies and data outputs shall be made and recommendations given.

Aquatic Habitats & Fish Diversity

Despite the high diversity of fish in mainland Southeast Asia, with some 900 species known (Kottelat, 1989), and their importance for humans as a source of protein, knowledge of fish biology over most of Asia is very incomplete and often limited to lists of species (Kottelat & Whitten, 1996, Kottelat, 1990). Lao PDR is no exception. A synopsis for the whole of Lao PDR recorded 203 species in 1974 (Taki, 1974). The list had grown to 481 species by 2001 (Kottelat, 2001) after five exploratory surveys. Even with Kottelat's significant contribution to the increase in knowledge of fish distribution in Lao PDR since 1996, information on fish distribution, biology and ecology remains basic, making it sometimes difficult or impossible to prepare a proper and detailed assessment of impacts. In addition, data on fish distribution in Mekong River tributaries in Lao PDR and in the region is still insufficient to allow a comprehensive zoogeographic review. It will take years of surveys before a better knowledge is acquired (Kottelat, *pers. com.*). Ichthyological explorations of the Nam Theun, Xe Bang Fai and tributaries by Kottelat were the first ever to occur (Kottelat, 1996). Before these missions, no reliable data on fish distribution and biology was available for the Nam Theun and Xe Bang Fai basins. Surveys have targeted the main types of habitats found in these rivers: rapids, riffles, waterfalls, river confluences, pools (to some extent), slow water stretches of rivers, forest streams in their upper, middle and lower sections of the rivers and swamps on the Nakai Plateau. Stations surveyed are represented in Figure 3.48. This section is based on the work done by Dr. Kottelat from 1996 to 2003 (Kottelat, 1996, 1997, 1998, 2000, 2001, 2002, 2003).

Fish Habitats

The main types of habitats in the Nam Theun and the Xe Bang Fai are briefly described in this section. Species of fish presently recorded in the Nam Theun and Xe Bang Fai basins are presented in detail in Annex K. During the dry season, the types of habitats that are available to fish populations include waterfalls, rapids, riffles, forest streams, pools, underground water, swamps and stagnant pools. During the wet season, most of these habitats change

Table 3.48: Lao PDR water quality targets for rural drinking water

Parameter	Unit	Lao WQ Target for Rural Drinking Water[1]
Conductivity	μS/cm	1,000
pH	pH	6.5-8.5
Turbidity	NTU	< 10
Nitrate	mg/l	40
Manganese	mg/l	< 0.5
Fluoride	mg/l	< 1.5
Iron	mg/l	< 1
Taste & odour	n/a	Acceptable
Arsenic	mg/l	< 0.05
Thermo-tolerant coliforms	number/100 ml	0
Total hardness	mg Ca/l	< 500

Notes:
1: Taken from Resolution No. 953/MOH (14th July 2003)

completely and some are displaced to other areas. Fish populations frequently use habitats that are not available during the dry season for spawning, incubation of eggs, and rearing of fry. In the Nam Theun and Xe Bang Fai basins, habitats that are important to fish populations include riverbank terraces and floodplains, including the flood plains at the confluence of the Xe Bang Fai with the Mekong River. Flooded areas serve as nursery grounds and refuges for juvenile fish. Some habitats are underrepresented in the surveys. The fish from the deep pools (up to 44 m upriver of the dam site) of the Nam Theun main stream were obtained by fishermen using gill nets, and hook & line. It is possible that other species occur only in such habitats, which were not surveyed with ichthyocides after consideration of the volume of waters and the quantity of chemicals required, the potential important quantity of fish that would be killed by this operation, and the proximity of human communities.

Lower Nam Theun Basin

The river section (as defined here) extends from Ban Katok to the confluence with the Nam Gnouang (and is inclusive of the Theun-Hinboun headpond and dam).The river is wide, in a relatively open landscape. It flows over a muddy to sandy substrate with several sets of rapids. A few kilometres downstream, the Nam Kading enters gorges. The fish fauna consists of a mixture of a depauperate (in terms of species number) version of the fauna of the middle section of Mekong tributaries combined with species of the upper sector.

Middle Nam Theun Basin

This sector is a succession of rapids and runs in the gorges extending between the lower Nam Theun (around Ban Katok) and upstream of the Nakai Dam. The fauna is not very diverse but consists of species specialised for this habitat. The river-reach between the confluence of the Nam Phao with the Nam Theun and the location of the proposed Nakai Dam is nearly 12 km long. During the dry season it includes four large and three small rapids areas. The pools are at least 50 m wide and 1 km long and one pool is 4.2 km long and 150 m wide. Through this reach the river gradient is high, averaging 3.33 m per km. As a consequence, the water velocity is relatively high. The river reach has four sandbars. For the most part, substrates in the reach are primarily rock and rock outcrops with large boulders. The water surface consists of about four hectares of rapids and 124 ha of pools and runs.

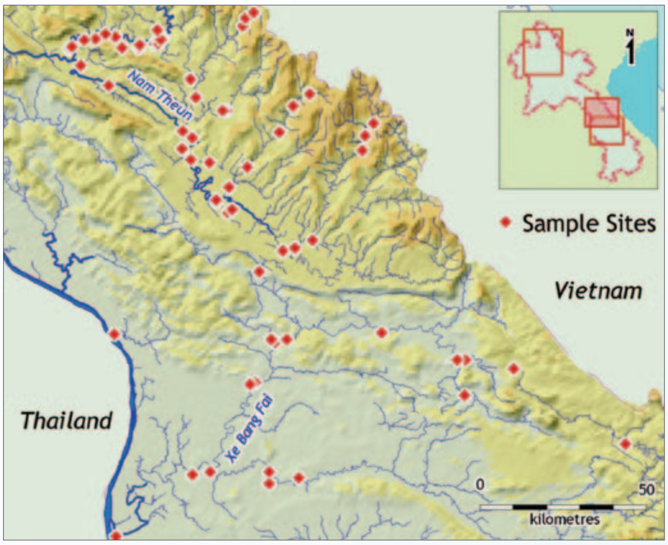

Figure 3.48: Fish distribution survey sampling site locations (Project Area & Surrounds)

The Nakai Plateau

The Nam Theun meanders over the plateau in a succession of relatively slow runs, rapids and deep pools. The substrate varies from sand (especially at the mouth of tributaries, e.g. Nam Xot, Nam On) to rocks. The water is relatively clear. The fish fauna can be classified as a somewhat depauperate version of the middle and upper Nam Theun, where the species specialised for the fastest waters are missing. Extensive areas are flooded in the wet season and some more or less perennial swamps exist. Those surveyed are inhabited by few species, all widely distributed in the Mekong basin.

Headwaters of the Nam Theun Basin

The surveyed headwaters (Nam Phao, Nam Xot and Upper Nam Theun) are all on relatively steep slopes, and consist of successions of waterfalls, rapids, riffles and fast runs over stony to rocky substrate, occasionally with sand banks. The water is very clear, except in the upper Nam Phao, where it is contaminated with agriculture and organic waste from Ban Lak Sao. The fish fauna mostly consists of species specialised for these very fast waters, many of them previously known only from the Mekong basin in Yunnan.

Plate 5: Rapids on the lower Nam Theun near Ban Katok (Kottelat)

Plate 6: Waterfall and rapids in the middle Nam Theun, upstream of the confluence with the Nam Phao (Kottelat)

Plate 8: Nam Theun upstream of Ban Thalang, on the Nakai Plateau (Kottelat)

Impacts

Lower Xe Bang Fai Basin

The lower Xe Bang Fai, which runs from its mouth upstream to the confluence with the Xe Noy, is characterised by a muddy to sandy bottom, with occasional rocky outcrops and rapids. The water is turbid, although compared to most other lowland streams in the Mekong basin it is still clear, with a visibility of about 50 cm. The depth is variable, from several metres to a few centimetres on some sandbars. The fish fauna is similar to other flood-plain rivers in the middle Mekong basin.

Middle Xe Bang Fai Basin

The middle Xe Bang Fai extends from the confluence of the Xe Noy upstream to the outlet of its underwater course, some 117 km upstream of Mahaxai. It flows in a succession of runs, riffles and occasional rapids and deep pools. The substrate is sand to rocks. The water of the mainstream is unusually clear for a river of this size in the lowlands. The fish fauna is shared with other similar habitats in tributaries of the Mekong, with a few additional species inhabiting the rapids and riffles. Small tributaries, such as the Nam Phit, are characterised by very sluggish or standing waters, usually very turbid, and are inhabited by species that prefer slow moving water.

Plate 7: Sandbar at the confluence with the Nam Phao (Kottelat)

Upper Xe Bang Fai Basin

Upstream of its underground course, the Xe Bang Fai flows mostly over a succession of rapids, riffles and runs in a karstic landscape: 6 km of its course are in a natural tunnel. The water is very clear (visibility was at least two metres at the entrance of the tunnel). The fish fauna is in part a subset of the middle Xe Bang Fai fauna specialised for faster waters, and with some species otherwise known only from the Nam Theun and from tributaries of the Mekong in Yunnan.

Fish Diversity & Endemicity

The fishes of the Nam Theun and Xe Bang Fai basins have been surveyed at 42 sites in 1996, at 25 sites in 2002 and 16 sites in 2003 (Kottelat, 1996, 1998, 2002, 2004). One hundred and thirty-one species have been observed in the Xe Bang Fai and 68 in the Nam Theun (Annex K). Eleven species (18%) of the Nam Theun fishes and five (4%) of the Xe Bang Fai fishes were known from nowhere else at the time of the first survey in 1996. As similar data was missing for other river basins, additional surveys were necessary to decide whether this apparent endemism was real or not. In 1997, several other basins of Lao PDR (Nam Xuang, Nam Ou, Nam Beng, Nam Tha, Nam Youan) were surveyed in order to identify which species were endemic to the Nam Theun and Xe Bang Fai basins and which were not (Kottelat, 1997). Figures 3.49 and 3.50 illustrate the sampling site locations of these additional surveys. The 1997 survey concluded that two species (*Schistura punctifasciata*, *Terateleostris aspro*) were considered as endemic to the Xe Bang Fai basin, with their distribution range including or restricted to areas upstream of the direct impacts of the Project. While they could exist in other basins they have not to date been collected. The failure to collect the species from other basins may be a function of the rareness of

Plate 9: Swamps on the Nakai Plateau, east of Ban Boua Kham (Kottelat)


Plate 10: Waterfall in the headwaters of the Nam Theun (Kottelat)


Plate 11: Rocky Stream in the headwaters of the Nam Theun (Kottelat)

the species, its narrow habitat requirements, or may be a result of a limited sampling effort in other basins. Within the Xe Bang Fai, *Terateleostris aspro* was collected from a single locality in an area that will not be affected by the diversion of water to the Xe Bang Fai. In 2002, *Schistura punctifasciata* was also collected from a location upstream from the confluence of the Nam Phit that will not be impacted by the increased discharge to the Xe Bang Fai. The 1997 survey also concluded that from the 12 species considered as endemic to the Nam Theun – Nam Gnouang basin, eight had a small to significant part of their known distribution range outside the area that will be directly impacted by the Project. One endemic species (*Bangana elegans*) was known to be migratory, but the extent of its migrations is still not known. The species lives in the upper Nam Theun and Nam Xot. Juveniles have also been found in the Nam Phao basin, indicating the species spawned there in 2002. In 2003, individuals of the whole known size range were observed in the upper Nam Xot and Nam Theun, above the FSL of the reservoir. Three species had their whole known distribution in areas which will be directly impacted by the Project and the Theun Hinboun project, and their survival was uncertain: *Scaphognathops theunensis*, *Schistura cataracta*, and *Pseudecheneis sympelvicus*. Since 1997 the latter two species have been observed elsewhere in Lao PDR (including the Nam Phao, the Nam Ngum and the Nam Ngiep), but an additional species, *Tor ater*, was reported as endemic to the Nakai Plateau. In March 2002, parts of the Nam Gnouang and Xe Bang Fai basins were surveyed in order to assess the possible presence of *Scaphognathops theunensis* and *Tor ater* outside of Project area. The survey was successful in showing that the distribution of *Scaphognathops theunensis* is not restricted to Project area but also includes the middle Nam Gnouang and the Nam Kading. Until 2003, Tor ater was definitively known only from three specimens said to have been collected on the Nakai Plateau. Another survey in May 2003 by Kottelat, found Tor ater in sections of the Nam Xot and the upper Nam Theun that will be unaffected by the Project. Observations and interviews with villagers suggest that Tor ater is present in the upper reaches of the Nam Theun and its tributaries. In that area, it inhabits deep pools in stretches with a higher gradient. Tor ater is absent from stretches with low gradients (e.g the Nakai Plateau) and does not undertake long distance migrations. The fish is expected to be able to complete its entire life cycle in these sections (Kottelat 2004). Therefore all the species currently known to be present in the Nam Theun and Xe Bang Fai exist either in other basins or outside the area of direct Project impact.

The diversity of fish in the Nam Theun is low compared with the Mekong mainstream (Taki, 1974, Kottelat, 1989, Roberts, 1995) and the adjacent Xe Bang Fai basin. The fish fauna in the Xe Bang Fai basin includes at least 131 species of fish – that is considerably more species than the Nam Kading/Nam Theun basin where 68 species have been identified (Kottelat, 2002). Sixty-seven (67) of the 131 fish species in the Xe Bang Fai were collected from the Lower Xe Bang Fai, while 96 species were found in the Middle Xe Bang Fai. Based on the results of these surveys, the fish communities in the Nam Kading and Nam Theun are not comparable to the fish diversity in the Xe Bang Fai. Major differences between the two rivers, such as topography, habitats, zoogeography explain the disparity: habitats

Impacts

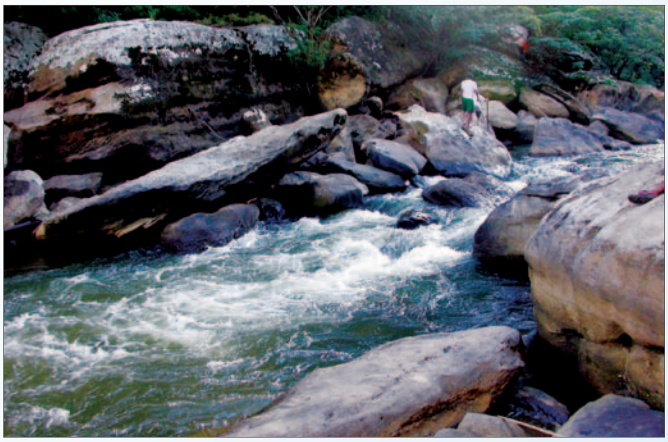
Plate 12: Rapids in the headwaters of the Nam Theun (Kottelat)


Plate 13: The lower Xe Bang Fai, near its mouth (Kottelat)

Plate 14: Middle Xe Bang Fai – exit of the underground course (Kottelat)

Plate 15: Upper Xe Bang Fai near Phou Taloun (Kottelat)

in the Xe Bang Fai are more diverse and the river has direct communication with the rich Mekong fauna. In comparison, the Nam Theun has a rheophilic fauna, closer to the one of Yunnan and its high level of endemism, than to the Mekong fauna.

Mitigation: The populations of critical species shall be monitored in order to detect possible declining populations and to help provide recommendations for appropriate support measures (e.g. restriction or ban of captures, establishment and use of captive stock for stocking and supporting wild population, increasing areas of protected pools). For rivers in the NNT NBCA, sustainable management programs will be established under the SEMFOP that will benefit biodiversity conservation.

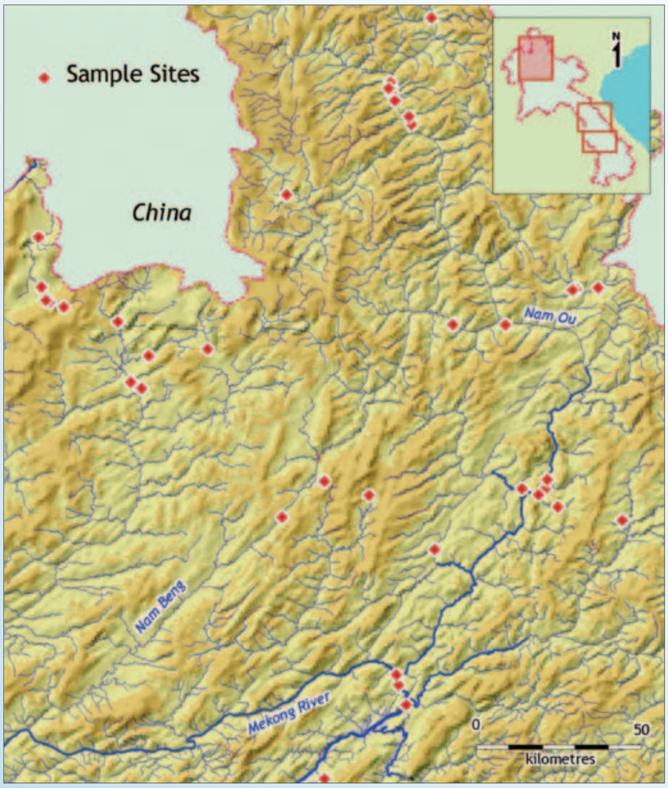

Figure 3.49: Catchment area of additional fish distribution surveys (Houapahn & Xieng Khouang Provinces, Lao PDR)

Faunistic Affinities

While the lower and middle Xe Bang Fai fauna can clearly be described as a middle Mekong fauna, the Nam Theun and the upper Xe Bang Fai fish fauna is very distinctive from what is known about the rest of the middle Mekong basin, and it shows obvious affinities with Yunnan fish fauna. Several species reported by Kottelat were previously known from the Mekong basin in Yunnan (*Folifer brevifilis*, *Garra theunensis*, *Hemiculterella macrolepis*, *Luciocyprinus striolatus*, *Onychostoma fusiforme*, *Poropuntius carinatus*, *Tor laterivittatus*, *Balitora lancangjiangensis*, *Homaloptera yunnanensis*, *Schistura dorsizona*, *Glyptothorax macromaculatus*, *G. zainaensis*, *Oryzias sinensis*). *Hemimyzon papilio* and *Pseudecheneis sympelvicus* are closely related to species known from the Mekong basin in Yunnan. *Oreoglanis hypsiurus* is closely related to species from northern Lao PDR and Yunnan. *Botia nigrolineata* and *Rasbora atridorsalis* from the Xe Bang Fai were previously known only from Xishuangbanna (Yunnan). Most of these species have since been found in other basins in northern Lao PDR (Kottelat, 1997), making a continuity of distribution from Yunnan to the Nam Theun basin. They do not occur in the Mekong basin in northern Thailand, possibly because of a lack of suitable habitats. *Misgurnus anguillicaudatus*, *Rhodeus laoensis* and *Hemibarbus* cf. *umbrifer* occur in or have affinities with species from Vietnam.

The Nam Theun fish fauna consists mainly of species specialised for hill streams and fast flowing waters; these waters are usually cooler and have higher oxygen content than lowland streams. Restricted distribution to headwaters may result from the absence

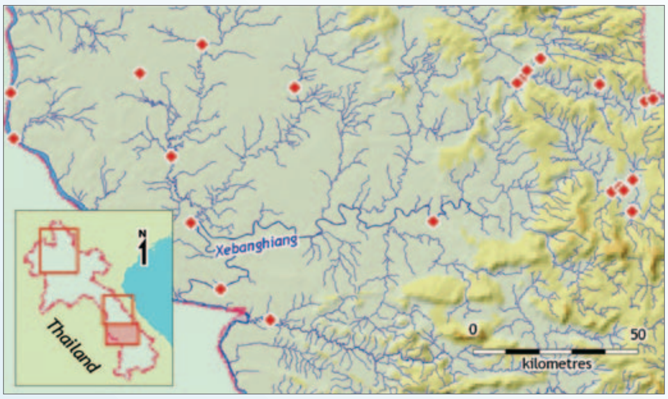

Figure 3.50: Catchment area of additional fish distribution surveys (Savannakhet Province, Lao PDR)

Plate 16: *Luciocyprinus striolatus* Cui & Cui, 1986. Found in the Lower Nam Theun.

Plate 18: Juvenile (top) and adult (bottom) *Tor ater* Roberts, 1999. Found in the Upper Nam Theun.

of morphologically suitable habitats downstream (some species may be unable to feed and reproduce in the lowland habitats), from the inability to survive at the temperature and oxygen concentrations in the lowlands, or a combination of both. Kottelat (1996) is of the opinion that there are no significant affinities with the Vietnamese fish fauna and one of the three species (*Misgurnus anguillicaudatus*) belonging to the Vietnamese fish fauna might have been introduced in the rice fields near Ban Lak Sao.

Fish Populations

Kottelat (1996) sampled different fish habitats in the Nam Theun and the Nam Kading to develop an estimate of the standing stock of fish in the basins during the dry season. As shown in Table 3.34, the highest standing stocks of fish are located at waterfalls and rapids, where high oxygen concentration, good light penetration and the rocky substrate allow an algae growth on which a variety of fish and invertebrates feed. The fish standing stock is lowest in habitats where the primary production is very low.

Kottelat sampled three locations with seines to obtain information regarding the standing stock of fish in the Xe Bang Fai. He estimated that the standing stock in the Lower Xe Bang Fai was between 6 and 23 kg per hectare (Kottelat, 1996). This number of fish is considerably less than what was expected considering higher nutrient concentrations. This could be the result of fishing activities by local fishermen and because samples were taken during the dry season when few fish from the Mekong were in the river to spawn.

Xe Bang Fai Baseline Fisheries Resource Survey

LARREC and Warren, commissioned by NTPC, are undertaking a pre-operations baseline study of the aquatic resources in the Xe Bang Fai. This investigation began in 2001 and will continue until sufficient baseline data has been obtained. The objective of the study is to quantitatively establish an index of the current fish resource in the section of the Xe Bang Fai to be impacted. The basis of the data is catch per unit effort (CPUE), which is commonly used throughout the world to monitor temporal trends in fish abundance, including Lao PDR (Warren, 1998, Noraseng and Warren, 1999). The CPUE provides a relative index of fish abundance.

Plate 17: *Scaphognathops theunensis* Kottelat, 1998. Found in the Lower and Middle Nam Theun, and on the Plateau.

In total, seven villages are involved in the study. These villages are located along the entire length of the Xe Bang Fai between the confluence of the downstream channel and the confluence of the Mekong (Figure 3.51). To collect the quantitative CPUE data three "skilled" fishers were selected from each village to record their daily catch data from gillnets once per week. Results from two years of sampling are presented in Table 3.49 (Warren, 2003, 2004). The results for fish species caught by fixed gillnets indicate that there are substantial differences in overall abundance between years and to some extent between locations on river stretches. Abundance was lowest at Dan Pakse at the confluence with the Mekong. Monthly variations in abundance along the river channel reflect seasonal migratory behaviour of fish. Most of the catch consists of medium size cyprinids (*Puntioplites spp*, *Hypsibarbus spp*, *Barbodes spp*, *Labeo chrysophekadion*, *Puntius orphoides*). Catfishes (*Pangasius siamensis*, *Clarias batrachus*, *Mystus wyckioides*, *Hemibagrus nemurus*) and snakehead (*Channa striata*) are less important. Following COD the study will continue and is designed to establish if the operation of the Project will increase or decrease the availability and "catchability" of fish for use by the communities along the Xe Bang Fai.

Migrations

Three geographically-defined fish migration systems are thought to exist in the Mekong Basin: lower, middle and upper Mekong migration systems (Poulsen et al, 2000, 2002, 2004). The Nam Theun and Xe Bang Fai basins fall within the middle Mekong migration system. Within this river section floodplain spawning and nursery habitats are associated with the tributaries. Adults and juveniles spend the dry season in deep refuge pools in the mainstream channel. At the onset of the wet season, they migrate upstream along the Mekong until they encounter a tributary, and then swim up the tributary until they encounter floodplain habitat or other possibly suitable spawning habitat. Many species spawn only once, soon after arriving on the floodplain, while others spawn several times during the flood season, and a few others spawn only once at end of the wet season or beginning of the dry season. The fry grow out on the floodplain which acts as a nursery and contains rich forage. As the flood water begins to recede from the floodplain, adults and juveniles migrate back in the tributaries and move downstream to the Mekong. There are over thirty medium and large size species of cyprinid and pangasiid catfish which exhibit this general migration pattern.

Migration in the Nam Theun

Various reports comment on upstream wet season migrations in the Nam Theun (Norconsult, 1994; NIVA/NIN-NIKU, 1995; Kottelat, 1996; NORPLAN, 1996), but the knowledge base is fragmentary and incomplete. It is not clear if upstream migration is carried out only by fish resident in the Nam Theun, or if it includes also migrating fish stocks entering from the Mekong. The difference in species diversity along the length of the Nam Theun suggests that one or more of the rapids (i.e. Keng Vang Fong) may constitute a natural barrier to migration/dispersal for some fish species. Certainly the Theun-Hinboun dam constitutes an additional impediment. It has been reported that fish up to 8 kg in size attempt to leap over the dam wall following the commencement of wet season. Species suspected of being longer distance migrants in the Nam Theun basin include *Bangana elegans* and some *Tor* spp.

Migration in the Xe Bang Fai

The first major fish migration of the year commences at the beginning of the wet season. At that time, according to villagers, a large number of fish species begin migrating up the Xe Bang Fai, and its larger tributaries, while other fish species are believed to move from deep-water pools to spawning areas in the Xe Bang Fai. According to Shoemaker (Shoemaker *et al*., 2001) together, these two migrating groups include the following taxa: Cyprinids *(Labeo chrysophekadion, Labiobarbus sp., Sikukia gudgeri, Hypsibarbus sp., Puntioplites sp.)*, Catfish *(Pangasius larnaudii, P. macronema, P. pleurotaenia, P. bocourti, Wallago attu, W. leeri, Bagarius sp, Hemibagrus wyckioides, H. nemurus, Helicophagus waadersi, Laides sp., Mystus spp.)*, Mud perch *(Pristiolepis fasciata)*, Glassfish *(Parambassis siamensis)*, River loach *(Schistura sp. or Nemacheilus sp.)*. During overbank flooding events fish migrate laterally to temporally inhabit adjacent flood plains for spawning and feeding. Migrations are a complex phenomenon involving dozens of species, each with its own migratory pattern and different times of movement. Little reliable data on fish migrations and reproduction in the Mekong basins is available (Tori, 1978, Kottelat, 1996, Shoemaker, 2001). Elements of information on migratory patterns are being collected with the long term LARREC and Warren study of the Xe Bang Fai.

Fishes are harvested at different intensities in the different rivers either as a source of protein or for sale in local markets. Fishing gear and equipment reported from the Nam Kading/Nam Theun and the Xe Bang Fai basins include explosives, poisonous plants, nylon monofilament gill nets, spears, hook and line, cast nets, scoop nets and many types of trap. Warren (2001) suggests that drift and fixed gillnets are the most important gear in terms of the size of fish landings made by fisherman from the Xe Bang Fai. The presence of only juvenile fish at some locations in the Nam Theun indicates locally intense fishing activity (Kottelat, 1996).

Various surveys (GOL, 2001, Shoemaker *et al.*, 2001) reveal the importance of fisheries to the local economy. This is further discussed in the SDP. The seasonal fish migrations between the Mekong River and Xe Bang Fai are important components of the economic livelihoods of villages on the Xe Bang Fai itself and many of its tributaries.

Fisheries

Fishing effort in the Nam Theun below the Nakai dam is minor. The main fishery in the Nam Theun is on the floodplain of the Nakai Plateau. On the Plateau there are some 864 fishing households (84% of all households). Almost all fishing is subsistence (60% of catch is consumed), with some excess catch (40%) being sold. The main fishing gears are gillnets (targeting carps and catfishes such as *Pangasius* and *bagrids*), hook and line (targeting *Clarias*, *Pangasius*, *Mystus* and *Tor*), traps (targeting snakeheads and eels), castnets (targeting small cyprinids and small floodplain resident species), liftnets, scoop nets, plunge baskets, harpoons and brushparks. Damming and fencing small creeks and hand col-

Table 3.49: Fish standing stock per habitat in the Nam Kading/Nam Theun basin

Fish Habitat	Fish Standing Stock		Number of Fish Species	
	Range (kg/ha)	Mean (kg/ha)	Range	Mean
Waterfall	927	927	11	11.0
Rapids	46 – 224	155	6 – 21	11.5
Riffles	78 – 129	100	12 – 15	13.6
Runs	46 – 117	81	8 – 9	8.5
Forest stream	40	40	14	14

Figure 3.51: Fisheries monitoring sites.

lection are also practiced. Some fishermen have boats and engines and range up to 10 km when fishing. Fishing takes place in the main river channels, and also in wetlands (targeting air breathing species such as *Clarias*, *gouramies* and snakeheads). Average household fish consumption is about 330 kg per year and total annual catch from the Nakai floodplain is estimated at about 285 t. Fish stocks on the Nakai plateau are considered significantly depleted due to increasing fishing effort during the last decade.

The population of the mainstream Xe Bang Fai is some 40,601 persons with an additional 3,356 fishers identified in the hinterlands (SDP 2004). Some 67% of all households along the mainstream fish only for subsistence consumption, while the remainder sell part of their catch (GOL, 2001). Fish constitutes the major source of animal protein.

Fishing gear and equipment reported from the Nam Kading/Nam Theun and the Xe Bang Fai basins include explosives, poisonous plants, nylon monofilament gill nets, spears, hook and line, cast nets, scoop nets and many types of trap. Warren (2001) suggests that drift and fixed gillnets are the most important gear in terms of the size of fish landings made by fisherman from the Xe Bang Fai.

Catch shows significant seasonal variation, and fishermen change their fishing gears to adapt to seasonal habitats and target species. The main Xe Bang Fai channel and some tributaries are the most important fishing ground during the dry season (when fish congregate in refuge habitats such as waterfalls, rapids and deep pools), while tributaries and habitats on floodplains (flooded forests, swamps, backyard ponds, paddy fields) are important during the wet season.

Catches consist mainly of cyprinids and catfishes, many of which in-migrate from the Mekong mainstream. Catches in the floodplains also include resident species such as snakehead, mud perch, spiny eels, climbing perch, walking catfish, and gouramies. Anecdotal information suggests that production has declined over the last 10-15 years. Average fish size and the number of species caught have also declined. The reason for the decline is thought to be overfishing and use of small mesh monofilament gillnets.

Other than a number of trap ponds on the Nakai Plateau, there is no aquaculture activity in the Nam Theun basin. The level of aquaculture activity in the Xe Bang Fai is marginally higher, with less than 3% of households involved. Backyard ponds, ricefield fish culture, and village swamp fish culture are the most important types of fish culture. Net cages are least important. No production estimates are available for aquaculture activity in the Project area

Potential Impacts on Aquatic Habitats

Analysis of potential impacts is somewhat constrained by limited information on fish distribution and biology, and no information on the precise ecological requirement or the reactions to environmental stress of the fishes native to the surveyed area. The analysis presented here is derived from Dr Kottelat's experience with other, related species in adjacent areas and expertise. Two main types of impacts are presented: i) impacts related to the construction and ii) impacts related to the permanent changes to the various aquatic habitats. Mitigation measures are proposed whenever possible.

Construction Related Impacts

The possible impacts of the Project on aquatic habitats and biodiversity during construction include: i) work in the riverbed; ii) construction of Project infrastructure; iii) water pollution; iv) use of explosives; v) vegetation clearing; and vi) limestone extraction in karstic formation.

Work in the Riverbed

Construction of the coffer dams, the Nakai Dam and the Downstream Channel are activities that could potentially increase sediment load. Fish living in clear water habitats are directly affected by increased suspended sediments that may damage their gills or accumulate in their gill chambers, leading to death. Indirect effects include: i) silt deposition over rocky habitats; ii) destruction of spawning sites (some fish species may migrate to very precise spawning grounds and may not breed if these areas become silted); iii) silt deposition over freshly laid eggs or newly hatched larvae; and iv) reduced primary production as a result of reduced light penetration (affecting herbivorous fishes, fish preying on invertebrates that feed on algae, and fish that use algae as either a refuge or spawning substrate).

Mitigation: The works at the Nakai Dam site will expose the riverbed. However a diversion tunnel associated with the two coffer dams will create a shortcut in the course of the river during the dry season, isolating the river from the main construction area. As a consequence the dam construction should not result in an increased sediment load in the river. The diversion tunnel will be completed before beginning any work in the riverbed. Standard mitigation methods and limiting the construction of the diversion tunnel to the dry season should help limit the amount of sedimentation in the Nam Theun. Construction material, including material for the diversion works, will not be dumped in the river but transported to secure disposal areas, above the level of the rainy season flows. Construc-tion sites will be cleared before they are flooded.

The HC will adhere to the erosion plans set down in HCCEMMPs to help limit sedimentation resulting from construction of the downstream channel. In the Xe Bang Fai, some species are adapted to high loads of suspended solids, to which they are currently subjected to in the wet season.

Infrastructure Construction

Construction of infrastructure can affect the freshwater ecology through increased sediment load (effects are as indicated above). Impacts occur when: i) construction material is washed into the water course; ii) unstabilised infrastructure is washed away in the rainy season; iii) small streams are dammed instead of bridged (this often results in the creation of a reservoir of biologically dead water upstream of the weir and a dry stream bed downstream); and iv) inappropriate bridges are constructed (e.g., partial damming of the stream, pipes, extensive modification of the stream bed and banks). When temporary infrastructure or roads are constructed there is a greater potential for ii) and iii) to occur.

Mitigation: All infrastructure, including temporary constructions, will be stabilised and bridges will be built to respect the existing stream/river bed and bank morphology. Construction material will be transported to disposal areas. Temporary roads will, as much as is possible, be built in the area to be flooded. Particular attention will be paid to the logging roads that will be necessary for clearing vegetation in the reservoir area, especially to those which may need to cross areas which will not be flooded. This action will respect existing stream morphology. No streams (even temporary ones) outside the flooded area will be dammed by road or infrastructure construction.

Water Pollution

Spills of fuel and chemicals may have direct and indirect impacts on the aquatic fauna, as well as on humans and animals feeding on aquatic products. Pollution most often occurs where pollutants are stored, but also when they are used incorrrectly.

Mitigation: Retention tanks will be constructed around every area where liquid and solid fuels or chemicals are stored. Empty packaging material will be eliminated in the appropriate way. Recyclable packaging will be preferred whenever possible. The construction force will be trained in the safe and proper use of fuel and chemicals and instructed in non-damaging disposal. Safety (human and environmental) measures (legal as well as commonsense) will be controlled and enforced.

Use of Explosives

Use of explosives in water is highly damaging for fishes and other aquatic organisms. If they are not killed instantly, their internal organs may be severely injured leading to death within a few minutes to a few days, even if they were at a considerable distance from the explosion site. In theory, little or no explosives will be used underwater during construction of the Project. However experience shows that at most construction sites, large quantities of explosives are stolen or diverted from their proper goal and used for fishing. Besides being illegal, fishing with explosives is a very inefficient method as most killed fishes cannot be recovered. Additionally, the explosives damage the fish habitats and occasionally kill fishermen. As these occasional "fishermen" are usually Project workers, this issue is also of concern for Project security.

Mitigation: Explosives will not be used in the riverbed. Fishing with explosives by Project workers will be banned and the ban will be enforced.

Vegetation Clearing

In order to reduce the extent of any anoxic conditions that may develop in the initial years after the inundation of the reservoir, some vegetation will be cleared from the inundation area. This will result in some short-term increased sediment load in the river during the wet season. Early removal of riverine forest will affect the riverine fish stocks by reducing food supply leading to reduced stock abundance, which in turn will negatively affect the founding stock once the reservoir is filled.

Mitigation: Several measures to reduce the transport of sediment to the main river will be taken, including proper road construction and sediment traps. Sediment traps will be checked frequently and maintained. Sediment will be transported to proper disposal areas. The riparian forest along the Nam Theun will be kept intact until dam closure, keeping a 50-100 m forest corridor along the river. This corridor will have two main functions: i) it will contribute to trapping sediments, ii) it will keep the riverine habitat intact as long as possible. If the riverine vegetation is eliminated right at the beginning, the siltation will increase and most fish will lose their food source, either allochtonous (insects, fruit etc. falling in the water) or autochtonous (algae, invertebrates, etc.) and the fish population will be seriously decreased before the reservoir is flooded. For fish to have a chance to adjust to reservoir conditions and develop healthy populations, it is important to keep the original (founder) stocks as healthy as possible.

Limestone Extraction in Karstic Formations

Karstic formations usually include underground water bodies and streams that may host a very specialised, highly endemic fauna. Exploitation of limestone for construction work may threaten this component of biodiversity if quarries are located in these areas, either directly by destruction of the habitat or indirectly by pollution.

Mitigation: The sites where limestone will be quarried and the location where the downstream channel passes through karst will be surveyed for possible presence of caves and springs. As this is part of a very extensive karstic area, it is very unlikely that limestone extraction will threaten any endemic species. If any caves are present, the opportunity to explore them scientifically should be taken. Particular attention will be given to avoid all types of pollution in karstic areas, as in such places contamination may spread faster and over greater distances than in any other soil types.

Operation Related Impacts

The creation of the reservoir, the water quality of the reservoir, the diversion of water from the Nam Theun to the Xe Bang Fai, the interruption of fish migrations and the destruction of spawning grounds will all have long-lasting impacts on aquatic habitats and biodiversity. They are presented in the section below. Other potential impacts to rivers are presented at the end of the section. Mitigation measures are discussed whenever possible.

Reservoir Creation

The creation of the reservoir will have the following effects on the aquatic environment: transformation of the habitat from a lotic environment (a flowing river with rapids) into a lentic environment (largely stationary water); creation of a relatively barren underwater landscape; increased water turbidity and temperature; seasonal fluctuations of water level; potential introduction of exotic plants and animals; and changes in water quality.

Impacts on native fish fauna: Species which need fast-running waters will be negatively impacted or eliminated from the area (e.g. *Bangana elegans*, *Barilius pulchellus*, *Garra theunensis*, *Onychostoma fusiforme*, *Scaphiodonichthys acanthopterus*, most species of the families *Balitoridae*, *Sisoridae* and *Gobiidae*).

Because of sediment deposition, most of the stones, rocky outcrops and other elements of the underwater landscape will progressively disappear. These are the main habitats of the species listed above. Algae living on the stones will disappear, as well as the invertebrate fauna associated with them. Fish feeding on these algae and fauna are unlikely to switch to other food sources and will disappear. Sediments may cover spawning grounds and affect most of the species of interest to the local subsistence fisheries: *Bangana sinkleri*, *Garra theunensis*, *Onychostoma fusiforme*, *Poropuntius carinatus*, *Scaphiodonichthys acanthopterus* and *Scaphognathops theunensis*.

It is not certain whether submerged aquatic macrophytes will be able to develop on the new substrate or cope with the fluctuations in water level. Algae will probably develop, but it is not clear whether the species presently growing on stones in fast flowing water will be able to develop on a soft substrate. Whether those algal species growing on the soft substrate can be used by the algae-eating fish now inhabiting the Nam Theun is be open to debate. Most of these fishes scrape algae with the trenchant edge of their lower jaw and it is not known whether they are able to switch to other ways of handling their food items.

The increased water turbidity will negatively affect all the species presently living in the Nam Theun mainstream. The real impact of increased water temperature cannot be predicted, but it will result in decreased oxygen concentration and the two factors might place some species under stress.

The seasonal fluctuations of the water level will affect a significant part of the reservoir area within which limited terrestrial and aquatic life will be possible. Most of the Nam Theun fishes will probably be unable to use this area. Those species presently occurring in the swamps of the Nakai Plateau should have no difficulty in colonising these habitats, but they are among the less interesting species from the biological diversity point of view because they are widely distributed and abundant throughout the Mekong basin. Impact on Nakai Plateau floodplain: The total surface area of the current floodplain on the Nakai Plateau is approximately 27 km^2. After closure of the Nakai Dam, the reservoir waters at FSL will cover the entirety of this floodplain. During drawdown however, the floodplain will become exposed, and the reservoir will become largely confined to the existing Nam Theun. The existing floodplain would therefore be converted into reservoir habitat for part of the year, and revert back to floodplain habitat during the remaining. The implication is that the total area inundated is in reality a reservoir/floodplain complex rather than a reservoir in the conventional sense. When inundated, the drawdown zone will likely be used by the reservoir fish stocks as a large breeding, nursery and forage habitat.

Impact of water level fluctuation: The seasonal fluctuations of the water level will affect living conditions for aquatic and terrestrial fauna. Under infrequent extreme conditions a maximum drawdown of 12.5 m from FSL would cause 81.8% of the reservoir area (i.e. 368 km^2) to become exposed. This may lessen the impact of habitat modification in peripheral areas of the Nakai Plateau that will be flooded for limited periods. Some wetland areas currently existing during the wet season are likely to persist and may benefit from greater water supply. These areas will continue to function more like floodplain/wetland habitats rather than reservoir habitats. Drawdown may result in stranding of fish in small water bodies in some areas. When the reservoir is at FSL, a number of islands will be formed, particularly in the western end of the reservoir area, and contribute to shoreline development which in turn is generally beneficial to the productivity of littoral fish species. However, a large drawdown over a limited time period will result in a rapid lateral displacement of the shoreline. This could negatively impact fish which breed in shallow water during this period by forcing them from breeding habitats, stranding larvae and fry, and/or leaving spawn undefended against predators. The drawdown phase will concentrate fish stocks into a smaller residual volume of reservoir water, and this 'concentration' effect will increase the catchability of fish.

Infestation by floating macrophytes: There is a potential for floating macrophytes such as Eichhornia or Salvinia to become established in the reservoir and form large floating mats. The infestation results in localized deoxygenation below the mat and an increase in acidity, which can cause a reduced fish production in affected areas. Infestation also affects fishing activity, navigation and can damage turbines in the power station. Water level fluctuations of the magnitude predicted for the Nakai Reservoir will contribute substantially to the control of floating macrophytes by stranding and desiccation. This has been the experience in other reservoirs with a high dam wall (Bernacsek, 1984, 1977).

Drawdown zone vegetation: The drawdown zone will likely become covered in terrestrial vegetation tolerant of temporary inundation. Wind fetch across the plateau will likely aerate littoral water and reduce the deoxygenation effect of annual inundation of the vegetation. Drawdown vegetation will produce large quantities of biomass and become the basis of the trophic web in the drawdown zone. The annual input of nutrients from drowned vegetation will allow substantial productivity of fish stocks, and cause the littoral zone to function as a large spawning ground, nursery and foraging area, and contribute to reservoir fish production. Rooted aquatic macrophytes may not become abundant in the reservoir because annual drawdown of greater than 3.5 m negatively affects rooted aquatic macrophytes (Bernacsek, 1984). However some species may survive in residual wetlands, thus directly contributing to the food supply of herbivorous fish species, and providing extensive surface areas for periphyton growth which are eaten by grazing fish species.

In many reservoirs exotic species of plants and animals have been introduced, voluntarily or not. Very few of these introductions have had the expected results and very few resulted in a real increase of fish productivity. Most introductions have had very negative impacts on the native aquatic communities including, but not restricted to, extinction of native species and sometimes extinction of the subsistence fisheries, introduction of pathogens (to both humans and animals), and habitat destruction (Kottelat, 1996b). The native aquatic fauna of the Nam Theun, already put at stress by the Project, would be put under more stress if exotic fish species are introduced to the reservoir. This would affect not only the reservoir but could affect fish populations in the NNT NBCA as well.

Taken alone, any of these factors may have significant impacts on the different fish species, but may not be enough to place them at risk. When the factors are combined there is a synergistic effect and a great likelihood that many species will simply disappear from the reservoir.

Table 3.50 indicates the known or guessed adaptability of the Nam Theun fish species to reservoir conditions and habitat modification. For most species, no concrete data exist and the adaptability has been guessed on the basis of their known ecological requirements. In some instances, we know that related species in other areas have or have not adapted to reservoir conditions.

The extensive swamps and man-made reservoirs already existing on the Nakai Plateau possibly give an image of what the aquatic community might be in most of the future reservoir. Their fauna consists of only a few ubiquitous species (*Hampala macrolepidota*, *Channa striata*, *Clarias batrachus* and *Anabas testudineus*) found throughout Southeast Asia and species known elsewhere to live exclusively in swamps and standing waters (*Lepidocephalichthys* aff. *hasselti*, *Trichopsis schalleri*, *Oryzias sinensis* and *Odontobutis aurarmus*). A few other species will be present, in smaller numbers: *Cyclocheilichthys repasson*, *Puntius aurotaeniatus*, *Rasbora paviei*, *Danio fangfamgae*, *Pangio fusca*, *Channa gachua*, and possibly *Hypsibarbus vernayi*, *Mystacoleucus marginatus* and *Mastacembelus armatus*. *Rhodeus laoensis* may be present if the mussels it needs as a symbiotic host for its eggs and larvae are able to survive. The adaptability of *Hemiculterella macrolepis*, *Poropuntius carinatus*, *Raiamas guttatus*, *Hemibagrus wyckoides* and *Pterocryptis inusitatus* can only be guessed. Several of the adaptable species are very widely distributed in the Mekong basin or in Southeast Asia and are of little conservation value.

Mitigation: There is no direct mitigation for many of the impacts in the reservoir area and it will be more efficient to concentrate on compensation actions, particularly in the protection of the NNT NBCA. Most of the species at risk in the reservoir area also occur upriver and an efficient and sound management of the NNT NBCA will ensure the safe survival of the species as long as they do not need extensive migrations for the completion of their life cycles. The fragmentation of their range will result in the genetic isolation of the populations in the different tributaries. Except for large size species with low population densities and possible migration (*Tor laterivittatus*, *T. tambroides*, *Scaphognathops theunensis*, *Luciocyprinus striolatus* and *Bangana elegans*), this should not have any significant impact. But, as fast swimmers and large predatory fish, the population density of *Luciocyprinus striolatus* is probably low and the fragmentation of its range could be a significant impact. Accumulations of boulders and stones could be created at different depths and in areas where they will not be covered by deposited silt to compensate for the rocky habitats that will be lost.

Landscaping of part of the floor of the reservoir could avoid the formation of small lakes where fish can be trapped and subsequently stranded when the water lever decreases. Priority areas should be determined for protected fish sanctuaries where the main tributaries enter the reservoir.

No introduction of new species is planned for the reservoir for at least the first 5-10 years. This is the minimum time required for the local aquatic communities to stabilise after creation of the res-

Impacts

Table 3.50: Fish species of the Nam Theun basin, their known or guessed adaptability to reservoir conditions and distribution

Family *(Species)*	Adaptability	Distribution
Cyprinidae		
Bangana elegans	Unlikely to adapt	Endemic
Cirrhinus molitorella	Adaptable	Wide
Cyclocheilichthys repasson	Adaptable	Wide
Danio fangfangae	May adapt	Wide?
Folifer brevifilis	Not adaptable	Wide
Garra cambodgiensis	Not adaptable	Wide
Garra cf cyrano	Not adaptable	Limited
Garra theunensis	Not adaptable	Wide
Hampala macrolepidota	Adaptable	Wide
Hemibarbus cf. umbrifer	May adapt	Wide
Hemiculterella macrolepis	Unlikely to adapt	Wide
Hypsibarbus vernayi	May adapt	Wide
Luciocyprinus striolatus[1]	May adapt	Locally restricted
Mekongina erythrospila	Unlikely to adapt	Wide
Mystacoleucus marginatus	Unlikely to adapt	Wide
Neolissochilus stracheyi	Not adaptable	Wide
Onychostoma fusiforme	Not adaptable	Limited
Opsarius pulchellus	Unlikely to adapt	Wide
Poropuntius carinatus	May adapt	Wide
Puntioplites falcifer	Adaptable	Wide
Puntius aurotaeniatus	Adaptable	Wide
Raiamas guttatus	Unlikely to adapt	Wide
Rasbora paviei	Unlikely to adapt	Wide
Rhodeus laoensis	May adapt	Endemic
Scaphiodonichthys acanthopterus	Not adaptable	Wide
Scaphognathops theunensis	May adapt	Endemic
Tor ater	Unlikely to adapt	Endemic
Tor cf. tambra	May adapt	Wide
Tor tambroides	May adapt	Wide
Tor laterivittatus	May adapt	Limited/wide?
Gyrinocheilidae		
Gyrinocheilus amonieri	Not adaptable	Wide
Balitoridae		
Balitora cf. annamitica	Not adaptable	Limited
Balitora lancangjiangensis	Not adaptable	Wide
Hemimyzon papilio	Not adaptable	Limited
Homaloptera smithi	May adapt	Wide
Nemacheilus arenicolus	Unlikely to adapt	Endemic
Schistura sombooni	Unlikely to adapt	Limited
Schistura kongphengi	May adapt	Limited
Schistura atra	Not adaptable	Endemic
Schistura nudidorsum	Not adaptable	Endemic
Schistura obeini	Not adaptable	Endemic
Schistura dorsizona	Not adaptable	Limited
Schistura sp big head	Not adaptable	Endemic?
Schistura tubulinaris	May adapt	Endemic
Cobitidae		
Lepidocephalichthys aff. hasselti	Adaptable	Wide
Misgurnus anguillicaudatus	Adaptable	Wide
Pangio fusca	May adapt	Wide
Bagridae		
Hemibagrus wyckoides	Adaptable	Wide
Pseudomystus siamensis	May adapt	Wide
Siluridae		
Pterocryptis inusitata	Unlikely to adapt	Endemic
Clariidae		
Clarias batrachus	Adaptable	Wide
Sisoridae		
Glyptothorax laosensis	Not adaptable	Limited
Glyptothorax macromaculatus	Not adaptable	Limited
Glyptothorax zainaensis	Not adaptable	Limited
Oreoglanis hypsiurus	Not adaptable	Endemic
Pseudecheneis sympelvicus	Not adaptable	Limited
Oryziidae		
Oryzias pectoralis	May adapt	Wide
Oryzias sinensis	Adaptable	Wide
Odontobutididae		
Neodontobutis aurarmus	Adaptable	Limited
Gobiidae		
Rhinogobius lineatus	Not adaptable	Limited
Papuligobius ocellatus	Not adaptable	Wide
Anabantidae		
Anabas testudineus	Adaptable	Wide
Osphronemidae		
Trichopsis schalleri	Adaptable	Wide
Channidae		
Channa gachua	May adapt	Wide
Channa striata	Adaptable	Wide
Mastacembelidae		
Mastacembelus armatus	May adapt	Wide
Ambassidae		
Parambassis sp.	May adapt	Limited

ervoir. If anoxic waters develop in the reservoir at some locations and for some time, this stabilisation period will be longer. Aquaculture development of the reservoir will focus on species already locally present (e.g. species of *Tor* and *Bagarius*, *Hemibagrus wyckoides*, *Bangana elegans*, *Hypsibarbus vernayi*, *Luciocyprinus striolatus* and *Scaphognathops theunensis*) and there is no requirement to introduce exotic species. The potential benefit of such introduction is by far outweighed by the potential threat of disease and decline in biodiversity.

Species occurring in the lower Nam Theun in quieter stretches might be stocked into the reservoir, but their potential impact on the native fauna should first be carefully examined using the Food and Agricultural Organisation (FAO) guidelines and code of practice (Coates, 1995). Other species from the lower Nam Theun that might develop in the reservoir are *Puntioplites falcifer* and *Cirrhinus moliorella*.

From a fisheries point of view it is important to plan the final closure of the dam between the months of July and October. During the month of June after the first rainfall of the wet season, many fish species migrate upstream for spawning. Some of these upstream migrating fish species migrate downstream in July while the majority of species migrate downstream in October/November. If closure takes place between July and October, a large number of fish species will be trapped in the reservoir, including fish larvae and juveniles. This will benefit production of fish during the first months after inundation and will accommodate a higher fish yield than if the dam was closed at another time of year. Experience from other regional reservoirs shows that the reduction in the number of species may be an artefact created by inappropriate closure schedule (Bernacsek 1997). However most of the species which really need to migrate upstream also need to return downstream. Most of these species prefer rapids and they will not be able to grow in the reservoir.

Reservoir Water Quality

Decomposition of submerged vegetation will affect reservoir water chemistry during the first few years in what is termed the 'trophic upsurge' phase. Impacts include: i) local deoxygenation of the water column, leading to stress and avoidance by fish, ii) production of toxic gases (ammonia, methane and hydrogen sulphide), and iii) release of nutrients into the water column (leading to phytoplankton blooms and enhanced fish productivity and bumper catches). At some concentrations, hydrogen sulphide and ammonia are toxic for aquatic organisms. The exact lethal concentrations may vary from species to species and there may be a synergistic effect with other factors (temperature, presence of other chemicals, presence of pathogens, etc.). Only very few fish species are able to survive in anoxic waters more than a few minutes and they all belong to species with the least conservation value.

Mitigation: Water quality mitigation measures are discussed in more detail earlier in the chapter. Vegetation will be removed before flooding the reservoir. This clearance is not limited to valuable timber but also includes non-commercially valuable timber collected for firewood. The priority shall be to clear the vegetation in areas which will be permanently flooded. The results of the ongoing biomass survey of the inundation area will be used to as a means for maximizing removal in areas of high biomass. The vegetation along the Nam Theun will be removed at the last moment in order to reduce the stress to the aquatic community. Trees that are left standing form important surfaces for periphyton growth, and will provide forage and shelter for some fish species. This is particularly important in the deep water pelagic zone which will otherwise be a largely featureless landscape. In the drawdown zone which is only temporarily flooded, tree species that normally withstand regular floods will not be removed, but can be harvested later if they do not survive. These tree species might create new habitats for fish populations in terms of refuge and spawning, and a substrate for algal growth and invertebrate refuge which the fish feed upon.

To monitor the evolution of water quality within the reservoir, a water quality monitoring programme will be developed, the outputs of which will assist in decision-making processes of the Reservoir Fisheries Management Plan (RFMP) and help in the formulation of appropriate mitigation measures and adaptive management strategies. Details of the programme objectives, methodology and its inter-programme coordination with the RFMP are discussed earlier in Chapter 3.

Water Diversion

Diversion of Nam Theun waters into the Xe Bang Fai will have the two obvious consequences of increased flow in the Xe Bang Fai and reduced flow in the Nam Theun, with several secondary consequences including changes to water quality.

Increased Xe Bang Fai Flow: The increased flow in the Xe Bang Fai will result in the increase of the minimum water level in the river. Several habitats will definitively disappear, some may be displaced and others will be altered. Several dry season rapids will be permanently flooded and some extensive rocky outcrops that form permanent rapids will be dis-placed. Some stretches functioning as rapids only during high discharge may become permanent rapids. It is likely that most rapids-inhabiting species could be able to adjust to these shifts.

More significant is the fact that some of the rapids may be spawning grounds. Some species may need shallow waters in the rapids for spawning and an increased water level may have significant negative impact on their reproductive success. The lack of reliable information on fish reproduction and migration does not allow further discussion of this impact.

Shallow water gravel beds (e.g. downstream of the Nam Phit confluence) will be permanently flooded, at least until the river deposits new gravel beds. With the loss of these gravel beds, several species may disappear from that reach of the Xe Bang Fai (e.g. *Schistura daubentoni*, *S. isostigma*, *S. punctifasciata*, *Nemacheilus longistriatus*, *Serpenticobitis zonata*, *Amblyceps serratum*). All of these species were observed in the Xe Bang Fai upstream of the Nam Phit confluence or in other river basins. As a consequence, their future is not at risk, assuming that they are not threatened in the other parts of their distribution.

Apparently, the remaining species and communities may not be affected by the change in water level. The habitat of some could be shifted laterally. Our knowledge of the life history and ecology of these fishes is still too limited to allow a prediction of the possible impact of these changes. The main impact will be the transformation of the Xe Bang Fai from a river with cycles of shallow-slow and deeper-swift river into a permanent deep and swift river, even during the dry season. It is likely that a significant number of species will not be able to survive locally under these permanent conditions and a lowering of fish diversity and productivity is to be expected. In the case of the Theun Hinboun project, a significant diminution of standing crop has been noted since the start of the operation.

The diversion will introduce cooler water into a warm lowland river. This difference in temperature will be reduced by passive warming of the water in the 27 km run from the power station to the Xe Bang Fai. Aeration of the water in the Downstream Channel will also assist this warming process. In the dry season, the temperature difference is expected to be less than 3.5° C in the upper Xe Bang Fai. In the wet season, the differential will be less, and will be buffered by greater quantities of water in the Xe Bang Fai. Alone, the change in temperature is possibly not significant (Kottelat, *pers. com.*), but in synergy with the other impacts it could significantly increase the stress on the aquatic community. Fish are sensitive to rapid changes in temperature, which can result in stress and leave them susceptible to diseases, especially fungal infections. In the wet season, the quantities of water in the Xe Bang Fai will buffer the Power Station discharge. In the dry season, the Xe Bang Fai will be mostly comprised of the Power Station discharge and will largely take its characteristics from this discharge. Because of this, sudden temperature changes in the Xe Bang Fai are not expected.

It is known from other areas that rapid increase of the discharge in tributaries, lower water temperature and changes in water chemistry are among the stimuli that initiate the start of migratory movements. The diversion of Nam Theun waters into the Xe Bang Fai and then the Mekong may enhance wet season conditions and thus affect some species by providing an increase in flooded areas, in the lower Xe Bang Fai. For spawning and nursery grounds, the long-term impact of these changes is not known. The LARREC and Warren study outlined earlier in this section will give an indication of how the fish populations respond to the increased discharge, the change in the channel configuration, and to the potential effects on water quality in the Xe Bang Fai.

Mitigation: Mitigation methods to help minimize impacts resulting from erosion and water quality are discussed earlier in the Chapter; including the Regulating Dam, the Aeration Weir and bank protection at the Downstream Channel confluence. In terms of the quantity of discharge, operations of the Regulating Dam will limit any increases in discharge to 20m^3/s/hr which should prevent flash flooding but also dampen any discharge stimuli for migration. To sustain fish populations that may develop in the Nam Phit, NTPC will release a guaranteed 30 m^3/s during the times when the Power Station is not generating. This guaranteed release can be sustained for a period of 32 hours. Any socio-economic impacts resulting from the modified discharge regime will be either miti-

Impacts

gated or compensated for as detailed in the Xe Bang Fai Strategy of the SDP. One compensatory option is a fisheries replacement programme to replace any losses of fish currently caught in the Xe Bang Fai. The programme could include (i) stocking fish in rice fields; (ii) introducing fish ponds into irrigated areas; (iii) introducing irrigation, rice-fish and fish ponds to existing rice fields; and (iv) cage culture. Improvement of natural fisheries management could increase fishery yields significantly and thus help counter any losses resulting from the Project.

Reduced Nam Theun Flow: The reduced flow in the Nam Theun will result in a decrease in water level compared to the present lowest level, but the existing morphology will only be slightly affected. The deep pools will remain and large species, which would be affected by the decrease in absolute water volume, would likely take refuge in these pools. Runs, riffles and rapids will become narrower and shallower, with slower water. The slower water may affect the survival of some species of *Balitoridae* and *Sisoridae* will likely reduce population size. It will very significantly reduce the habitats suitable for the endemic *Scaphognathops theunensis*. The virtual suppression of most of the seasonal, cyclic successions of low and high waters will probably have a much more significant impact on the aquatic diversity than the reduction of the minimum flow. It is likely to severely affect their growth, reproduction and migrations.

For many species, variations in the water discharge play an important role as a stimulus for the start of migration. Suppression of this stimulus may seriously affect migrations in the Nam Theun below the dam, but also between the Nam Theun and its tributaries, such as the Nam Phao, (ie tributary flow will be greater than mainstream flow, and attract migrating fish away from the mainstream). Several fish species which typically select lentic habitats may become established and compete with rheophilic species. The occasional flood spills from the reservoir may be the source of such species, as well as upstream migrants from Nam Theun-Hinboun reservoir and intermediate tributaries.

A permanent low water level will have a negative impact on fish as it will drastically reduce the available food sources, reduce the number of hiding places and increase predation (by other fish as well as terrestrial animals and humans) and will increase their sensitivity to diseases through increased stress.

Mitigation: Modifications of the Nam Theun river topography will narrow some rapids, in areas where the river is wide and shallow, and will maintain stretches of deep and fast rapids. As the fishes most interesting from the biodiversity point of view are specialised for rapids, this can be an important mitigation and compensation for the loss of habitats.

Interruption of Fish Migrations & Destruction of Spawning Grounds:

Fish Migration: The completion of the Nakai Dam will block possible migrations between the Nakai Plateau and downstream areas, from the Nam Theun above the Theun Hinboun project. Upstream migration across the Nakai Dam will be completely blocked to species occuring in the lower river section. Downstream migration will be theoretically possible via the occasional flood spillage. Information on fish migrations in the Nam Theun is at present incomplete and somewhat contradictory, and does not allow clear conclusions about which fish migrate, during which season and for what purpose.

The following species observed in the Nam Theun seem to undertake migrations: *Bangana elegans*, *Hypsibarbus vernayii*, *Scaphognathops theunensis*, *Tor tambroides*, *Tor laterivittatus*, *Bagarius yarrellii* and possibly *Hemibagrus wyckioides*. The exact timing of the migration, the distance they travel or the obligate character of the migration is not known.

The degree of adaptability of migratory species is also not exactly known. Thus, when the dam is closed, migratory species may: i) disappear for reasons not related to migration (habitat destruction, pollution, etc); ii) be unable to reproduce because they cannot complete their migration; or iii) be able to reproduce without migration or find new migratory routes and spawning sites. Some migratory fish species may travel relatively long distances between precisely delimited feeding and breeding grounds. Long distance migratory fish are already impacted by the Theun Hinboun project dam that obstructs the Nam Theun some 100 km downstream of the proposed Nakai Dam. Others may migrate for a few kilometres between different places within the main river, or between the main river and tributaries. It is objectively impossible to assign these species to any of these categories, but it seems that *Bagarius yarrellii* and *Hemibagrus wyckioides* may migrate over relatively long distances in the Nam Theun basin. In many localities of the lower and middle Nam Theun and on the Nakai Plateau, the presence of juveniles and large adults of the two *Tor* species indicates that they probably have several spawning grounds and possibly do not undertake extensive migrations.

Spawning Grounds: As well as the presence of barriers to long-range migrations, such as the Theun Hinboun dam further downstream on the Nam Theun, a problem remains for those species migrating only in the Nam Theun (between the lower Nam Theun and the Nakai Plateau or the headwaters). Such fishes may be more numerous than the species involved in long-distance migrations, but they may be more likely to have numerous spawning grounds in the basin and so be able to pursue their lifecycles in the tributaries of the reservoir or downstream from the reservoir, providing that the minimum discharge is sufficient. The presence of juvenile Tor laterivitatus of apparently the same size class (20-40 mm) in numerous stations across the whole Nam Theun basin supports this hypothesis. This also seems to apply to Bangana elegans, for which juveniles of apparently two size classes occur both in the headwaters and downstream of the dam site. The flooding of the Nakai Plateau will probably result in the destruction of part of the spawning grounds of some species, but as the data on reproduction biology and migration are incomplete, and as there is no precise information on the location of spawning grounds, it is difficult to comment on this aspect.

Mitigation: Fish ladders have been constructed at many dams to allow for fish to migrate. The concept has been developed in northern and temperate countries of Europe and America and has sometimes worked. They work mainly where the fish fauna consists of only one or two species for which the fish passage facilities are specifically designed. These are mostly trout and salmon, fishes that are known to be good jumpers, and the ladders (a succession of closely set weirs with resting pools) are not obstacles to migration

Fish ladders (or fishways) have rarely been constructed in tropical countries, and when they have, they were of a wrong design or of inappropriate size, as at the Pak Mun Hydropower Project in Thailand. There is no report of instances were they have been efficient, but there are accounts of their inefficiency (Roberts, 1994). These failures can be attributed to poor construction (ladders leading from a dry place of the river to a place in the reservoir that is dry at the time of migrations), poor or no maintenance (ladder filled by sediments in a few days) and poor design (lack of biological considerations). Important biological considerations are: i) tropical fish communities usually include numerous species (sometimes more than a hundred) and each species may have different requirements in terms of season, hydrodynamism, position in the water column, and swimming behaviour; ii) fish must find the entrance to the ladder; and iii) after ascending a ladder, the fish (or their offspring) will have to come back down through the barrier structure, i.e. the dam. For example, migratory catfishes usually follow the bottom of the river and are unlikely to find the entrance to a fishway located along the shoreline. As all fishways constructed in tropical locations to date have been of the "salmon" type, catfishes, which are not able to jump out of the water, cannot use the ladders. This example could apply to most other tropical fish species.

Water Pollution

Any increase in the use of pesticides, fertiliser and other synthetic chemicals associated with Project activities has the potential to elevate their concentrations in the surrounding water. Although low concentrations of these synthetic chemicals may not be acutely toxic to aquatic organisms, they may exhibit chronic effects and potentially bio-accumulate to levels that are harmful to humans.

Mitigation: A Pest Management Plan has been developed to ensure the safe storage, use and disposal of synthetic chemicals. A detailed discussion of this occurs later in this chapter and the Pest Management Plan is presented in Annex M.

Potential Impacts by River Sector

Potential impacts and mitigation measures are listed here by river sector and refer to the above descriptions of the different impact types. The potential impacts resulting from Project operations on the Nam Theun and Xe Bang Fai, together with the mitigation measures, are presented above. Additional aspects, unique to a given sector, are also discussed (Table 3.51).

Nam Theun Headwaters

If the NNT NBCA is properly and successfully managed, integrating social and biodiversity issues, the Project is not likely to have much impact on the headwaters of the Nam Theun. If the NNT NBCA management is not enforced, then the following impacts can be predicted: deforestation and the resulting rapid siltation of most riverbeds; overfishing, introduction of exotics and their pathogens, and pollution with pesticides.

Some species may migrate between the headwaters and the main Nam Theun on the plateau and unsuitable habitat in the reservoir may negatively impact their populations. However, this should not lead to extinction as it seems that they should still be able to find acceptable conditions at the river mouths to support smaller populations. Species needing to migrate between the headwaters and the middle or lower Nam Theun are likely to disappear locally.

Nam Phit

The Nam Phit is dry most of the year for most of its course. Only the lowermost reach has permanent water. The Project will transform the middle and lower Nam Phit from a temporary stream with a dry riverbed most of the year, into a wide channel with constant flow. As there is no permanent aquatic diversity (the stream is repopulated from downstream populations during each wet season), the impact on it will be very limited. Re-aeration of the water in the Downstream Channel should make dissolved oxygen suitable for the establishment of fish populations. But the species likely to colonise such a channel will probably be different from the original Nam Phit fauna and may take several years to become fully established and flourish. The present lower Nam Phit community will be unable to establish viable populations in the channel as the current will be too swift. The lower Nam Phit fish fauna is typical of sluggish streams and most species have not been observed in the mainstream Xe Bang Fai, where dry season flow is inferior to the channel discharge. The fish in the Nam Phit currently survive the high water discharge in the wet season by moving laterally into the flooded lowlands.

The Downstream Channel will pass through a small seasonal wetland downstream of the tunnel. It is part of the floodplain of the Nam Phit. Depending upon how the channel is constructed through this wetland area, parts of the wetland could be maintained or could be drained. However, the wetland may be recharged on occasion when discharge in the Downstream Channel is greater than the two-year flood event.

The annual in-migration of large fish species from the Mekong and Xe Bang Fai into the flooded forest will likely continue in some form (although it is likely that the forest itself will be altered by the change in hydrology). It is not clear what effects there will be on the migration of fish into the caves of upstream tributaries of the Nam Phit, or on the annual spawning aggregation and fishery for Schistura or Nemacheilus sp or spp at the confluence of the Nam Phit with the Xe Bang Fai. During the first few years, diversion flow will likely cause some change in water quality of the Nam Phit. Flooding of terrestrial vegetation will release nutrients but deoxygenation is not likely to become a major problem due to downstream flushing and mixing with well oxygenated water in the Xe Bang Fai. There may also be some erosion and consequent increase in turbidity which could affect some sensitive fish species. Eventually the Nam Phit channel should stabilize under the new discharge regime, which would only be temporarily and infrequently disrupted by Power Station shutdown episodes.

Mekong Mainstream

Table 3.51: Main potential Impacts by river sector

Main Potential Impacts	Additional Aspects Unique to the Sector/Remark
Reservoir area	
Reservoir creation and reservoir water quality.	Some of the fish species present in the reservoir may disappear if recruitment is dependent on migration between the plateau and downstream.
Nam Theun between Dam Site & confluence with the Nam Phao	
Construction period, reservoir water quality, reduced Nam Theun discharge and interruption of fish migration.	
Nam Theun downstream of confluence with Nam Phao	
Construction period, reservoir water quality, reduced Nam Theun discharge and Interruption of fish migration.	Adverse impacts may be more serious because of synergistic effects with impacts of the Theun Hinboun Project.
Middle and lower Xe Bangfai	
Reservoir water quality and increased Xe Bang Fai discharge.	Importance of fish to the human population along the Xe Bang Fai.
Underground water in Khammouane Limestone NBCA and other karstic formations	
Construction period and reservoir water quality.	Such environments are extremely sensitive, especially to pollution. As there is no known connection between the Nakai Plateau and the karstic formations, pollution is only a remote possibility.

Changes in the run-off and probable changes in the water temperature and chemistry of the Nam Kading, Nam Theun and Xe Bang Fai may interfere with the natural stimuli responsible for the start of migration, but the biological data is not available to speculate on this. Most Mekong fish do not spawn in the Mekong mainstream but enter flooded areas and the tributaries, usually during the wet season, to spawn (Taki, 1978). Some travel only a few hundred metres while others may undertake extensive travels (usually large-size species, including *Bangana behri*, *Cirrhinus microlepis*, *C. molitorella*, *Probarbus* spp). Tributaries are of the utmost importance for Mekong mainstream fish; without access to tributaries, most stocks would be negatively affected and some may even disappear. It is likely that the increased discharge in the Xe Bang Fai may instigate spawning migrations into the river. However, this can only be observed once the Project is operating.

The increase in average flood discharge during the wet season of the Xe Bang Fai will result in a larger area of floodplain inundation in the lower Xe Bang Fai and this should contribute to fish production.

Potential Impacts on Fisheries

Nam Theun Fisheries Downstream of the Nakai Dam

Fishing in the lower Nam Theun will be heavily impacted by the Nakai Dam due to a severe reduction in discharge (both during the wet season and the dry season) and due to blockage of fish migration. This will result in deterioration of the fish production habitat and the fishery stock itself. A more detailed description of the impacts of the Project on the fisheries of the Nam Theun and the possible mitigation measures are presented in the Riparian Release section.

Fisheries Resources and Fishing Methods of Nakai Plateau and Reservoir

The floodplain and riverine fishery of Nakai plateau will be transformed into a reservoir fishery, with some residual floodplain characteristics. The existing river fishery will largely cease to exist in its current form during the wet season due to inundation of the river channel and blockage of upstream fish migration by the Nakai dam. During the dry season drawdown a portion of the original river channel will re-emerge, but fishery conditions will not be equivalent to pre-impoundment in terms of the fish stocks which will be present (ie some rheophilic species will be replaced by lentic water species). Various residual aquatic refuge habitats will continue to exist in the drawdown zone. These will possibly benefit from an increased water supply which could prevent some wetlands from desiccating by the end of the dry season. The major expansion in area of lentic habitats on the plateau will cause a proliferation of lentic fishery resources to occur. Existing fishing gears are adequate to harvest most of the species in the reservoir and drawdown zone wetlands.

Mitigation: Strategies for developing infrastructure and fishing techniques with the goal of achieving the economical potential of the reservoir fisheries are discussed in the Reservoir Fisheries Management Plan in the SDP.

Fisheries Resources and Fishing Methods of Xe Bang Fai Basin

A detailed discussion on the impacts and mitigation measures for the fisheries of the Xe Bang Fai is presented in the Xe Bang Fai Strategy of the SDP.

Aquaculture Activity

The Project is unlikely to have major impacts on existing aquaculture (which are generally underdeveloped in the Project area as a whole). There is some risk that increased flooding in the lower Xe Bang Fai could threaten pisciculture in ponds and ricefields. This can be mitigated by raising bunds to prevent flooding, or alternately temporarily quartering fish in floating cages inside the ponds and ricefields until the flood recedes. Some trap ponds on the Nakai Plateau floodplains are likely to be seasonally or permanently flooded. The Project will create new opportunities for cage culture in the reservoir and possibly also in some peripheral wetlands, which would readily compensate losses.

Terrestrial Biodiversity

Baseline

This section examines forest diversity and wildlife resources that occur in the inundation zone (Zone 1), the dividing hills (Zone 2), the resettlement area (Zone 3), and the area downstream of the Nakai Dam (Zone 4). These Zones are the major ecosystems affected by the Project.

Units of Biodiversity & Zoogeography

The area of the Project straddles two regional biotic units. The reservoir and drainage basin (Zones 1 to 4) are located in the Annamite (Trung Son) mountain chain, while the Power Station, Downstream Channel, and Transmission Lines (Zones 7, 8, 13 and 14) are in the Central Indochina lowland plains. A number of new species of mammals, birds, fish and plants have been discovered in the Annamite Mountains, which is recognised as an area of global significance in terms of biodiversity (Baltzer et al., 2001; Wikramanayake et al., 2002; Kottelat, 1998). Wildlife species of global and national conservation significance recorded in the NNT NBCA are listed in Table 3.52 and the full list of mammals, birds, reptiles and amphibians recorded in the area is presented in Annex J.

The regional climate and the diversity of geological conditions in this area have fostered a wide variety of habitat conditions. The climate of the area is postulated to have led to a highly diverse deciduous forest at the expense of evergreen forests. At one time, the Nakai Plateau maintained an extensive coniferous forest that had its own set of flora and fauna. The combination of moist tropical forests of the higher Annamites and generally cooler lowlands in Indochina led to a greater expanse of “new” grasslands and alluvial marshlands with their representative fauna such as tiger, Eld’s deer, hog deer, rhinoceros, elephant, kouprey, banteng,water buffalo and other related extinct forms (Lekagul and McNeely, 1977). The contemporary mammalian faunas are more or less island remnants and many of them have only been discovered at the end of the twentieth century. Thus, a faunal collision of lowland Asian forms, highland forms in Pleistocene refugia, and in-migrants from cooler northern steppes has led to this extraordinarily high diversity, isolation, and endemism. A review of zoogeographic relationships for Lao PDR in Duckworth et al. (1999) assigns the NNT NBCA area to their “Annam” unit, which extends over the mountains into Vietnam and to the South China Sea. Since most of the catchment is remote, sparsely populated and difficult to access, a large portion, particularly within the NNT NBCA, remains in near pristine condition.

Primary Habitat Elements

Interacting biophysical (elevation, soil type, moisture, flooding, slope), climatic and anthropogenic factors (logging, burning, agriculture, fuelwood collection, hunting, non-timber forest product gathering) have resulted in the development of a mosaic of forest and vegetation types in Zones 1-4.

The habitats that will be impacted by the Project are classified based on the existing forests and land use types. They include: dry evergreen forest, mixed deciduous forest, dry dipterocarp forest, broadleaf and coniferous forest, coniferous forest, lowland riverine forest, riparian gallery forest, open woodland forest, savannah,

Table 3.52: Wildlife species of global and national conservation significance recorded recently in the NNT NBCA and on the Nakai Plateau

Scientific Names	Common Names	GTS	NRS
Reptiles			
Platysternon megacephalum	Big-headed Turtle	EN	ARL
Cuora galbinifrons	Indochinese Box Turtle	CR	ARL
[Cuora trifasciata]	[Chinese Three-striped Box Turtle]	CR	CARL
Cyclemys dentata	Asian Leaf Turtle	NT	PARL
Pyxidea mouhotii	Keeled Box Turtle	EN	ARL
Sacalia quadriocellata	Four-eyed Turtle	EN	PARL
Indotestudo elongata	Elongated Tortoise	EN	ARL
Manouria impressa	Impressed Tortoise	VU	ARL
Amyda cartilaginea	Asiatic Softshell Turtle	VU	PARL
Physignathus cocincinus	Water Dragon	0	PARL
Varanus bengalensis	Bengal Monitor	0	PARL
Varanus salvator	Water Monitor	0	PARL
Python molurus	Burmese Python	NT	PARL
Python reticulatus	Reticulated Python	0	PARL
Ptyas korros	Indochinese Ratsnake	0	PARL
Ptyas mucosus	Common Ratsnake	0	PARL
Ophiophagus hannah	King Cobra	0	PARL
Birds			
[Coturnix chinensis]	[Blue-breasted Quail]	0	LKL
Lophura diardi	Siamese Fireback	NT	PARL
Rheinardia ocellata	Crested Argus	VU	ARL
[Pavo muticus]	[Green Peafowl]	VU	ARL
Anser anser	Greylag Goose	0	ARL
Cairina scutulata	White-winged Duck	EN	ARL
Picus rabieri	Red-collared Woodpecker	NT	0
Buceros bicornis	Great Hornbill	NT	ARL
Anorrhinus tickelli	Brown Hornbill	NT	PARL
Aceros nipalensis	Rufous-necked Hornbill	VU	ARL
Aceros undulatus	Wreathed Hornbill	0	ARL
Alcedo hercules	Blyth's Kingfisher	NT	PARL
Ketupa flavipes	Tawny Fish Owl	0	LKL
Treron sieboldii	White-bellied Green Pigeon	0	LKL
Ducula aenea	Green Imperial Pigeon	0	ARL
Gallinago nemoricola	Wood Snipe	VU	LKL
Vanellus duvaucelii	River Lapwing	0	ARL
Vanellus cinereus	Grey-headed Lapwing	0	PARL
Glareola lactea	Small Pratincole	0	PARL
Milvus migrans	Black Kite	0	ARL
Ichthyophaga humilis	Lesser Fish-Eagle	NT	ARL
[Ichthyophaga ichthyaetus]	[Grey-headed Fish-Eagle]	NT	ARL
[Aquila clanga]	[Greater Spotted Eagle]	VU	LKL
[Aquila heliaca]	[Imperial Eagle]	VU	LKL
Microhierax melanoleucos	Pied Falconet	0	LKL
Ardea cinerea	Grey Heron	0	PARL
Ardea purpurea	Purple Heron	0	PARL
Ciconia nigra	Black Stork	0	ARL
Pitta soror	Blue-rumped Pitta	0	PARL
Urocissa whiteheadi	White-winged Magpie	0	PARL
Cissa hypoleuca	Indochinese Green Magpie	0	PARL
Terpsiphone atrocaudata	Japanese Paradise-flycatcher	NT	LKL
Cinclus pallasii	Brown Dipper	0	PARL
Turdus dissimilis	Black-breasted Thrush	0	LKL
Turdus feae	Grey-sided Thrush	VU	LKL
[Niltava davidi]	[Fujian Niltava]	0	PARL
Ampeliceps coronatus	Golden-crested Myna	0	PARL
Sitta formosa	Beautiful Nuthatch	VU	PARL
Jabouilleia danjoui	Short-tailed Scimitar Babbler	NT	PARL
Paradoxornis atrosuperciliaris	Lesser Rufous-headed Parrotbill	0	LKL
Emberiza aureola	Yellow-breasted Bunting	NT	0
Mammals			
Manis pentadactyla	Chinese Pangolin	NT	ARL
Manis javanica	Sunda Pangolin	NT	ARL
Cynocephalus variegatus	Sunda Colugo	0	LKL
[Rhinolophus luctus]	[Large Woolly Horseshoe Bat]	0	PARL
Rhinolophus paradoxolophus	Bourret's Horseshoe Bat	VU	PARL
Rhinolophus malayanus	Malayan Horseshoe Bat	0	PARL
Rhinolophus thomasi	Thomas's Horseshoe Bat	NT	PARL
Rhinolophus affinis	Intermediate Horseshoe Bat	0	PARL
Hipposideros cineraceus	Least Roundleaf Bat	0	PARL
Hipposideros rotalis		n/a	PARL
Hipposideros scutinares		n/a	PARL
Hipposideros armiger	Great Roundleaf Bat	0	PARL
Aselliscus stoliczkanus	Stoliczka's Trident Bat	0	PARL
Myotis annectans	Hairy-faced Myotis	NT	LKL
Myotis montivagus	Large Brown Myotis	NT	LKL
Myotis ricketti	Rickett's Large-footed Myotis	NT	PARL
Miniopterus schreibersii	Common Bent-winged Bat	0	PARL
Murina huttonii	Hutton's Tube-nosed Bat	NT	LKL
Nycticebus coucang	Slow Loris	DD	LKL
Nycticebus pygmaeus	Pygmy Loris	VU	LKL
Macaca nemestrina	Pig-tailed Macaque	VU	PARL
Macaca assamensis	Assamese Macaque	VU	PARL
Macaca mulatta	Rhesus Macaque	NT	PARL
Macaca arctoides	Bear Macaque	VU	PARL
Semnopithecus francoisi hatinhensis	François's Langur (Hatinh Langur)	EN	PARL
[Semnopithecus phayrei]	[Phayre's Langur]	0	ARL
Pygathrix nemaeus	Douc	EN	ARL
Hylobates leucogenys	White-cheeked Crested Gibbon	DD	PARL
Cuon alpinus	Dhole	EN	ARL
Ursus thibetanus	Asiatic Black Bear	VU	ARL
Ursus malayanus	Sun Bear	DD	ARL
Mustela sibirica	Siberian Weasel	0	LKL
Mustela strigidorsa	Back-striped Weasel	VU	LKL
Arctonyx collaris	Hog Badger	0	LKL
Melogale sp(p).	Ferret badger sp(p).	0	LKL
Lutra lutra &/or Lutrogale perspicillata	Eurasian and/or Smooth-coated Otter	DD/VU	(C)ARL
Aonyx cinerea	Oriental Small-clawed Otter	NT	ARL
Viverra megaspila	Large-spotted Civet	0	PARL
Prionodon pardicolor	Spotted Linsang	0	LKL
[Arctictis binturong]	[Binturong]	0	ARL
[Hemigalus owstoni]	[Owston's Civet]	VU	LKL
[Felis chaus]	[Jungle Cat]	0	ARL
[Prionailurus viverrinus]	[Fishing Cat]	VU	LKL
Catopuma temminckii	Asian Golden Cat	VU	LKL
Pardofelis marmorata	Marbled Cat	VU	LKL
Pardofelis nebulosa	Clouded Leopard	c	ARL
Panthera pardus	Leopard	0	ARL
Panthera tigris	Tiger	EN	ARL
Elephas maximus	Asian Elephant	EN	ARL
Rhinoceros sondaicus &/or Dicerorhinus sumatrensis	Lesser One-horned Rhinoceros &/or Asian Two-horned Rhinoceros	CR	CARL
Sus scrofa &/or Sus buc-culentus	Eurasian Wild Pig &/or Heude's Pig	0/DD	PARL
Cervus unicolor	Sambar	0	PARL
Muntiacus vuquangensis	Large-antlered Muntjac	DD	
Muntiacus rooseveltorum &/ or Muntiacus truongsonensis	Roosevelts' Muntjac &/or Annamite Muntjac	DD	LKL
Bos gaurus	Gaur	VU	ARL
Bos javanicus	Banteng	EN	ARL
Naemorhedus sumatraensis	Southern Serow	VU	PARL
Pseudoryx nghetinhensis	Saola	EN	ARL
Ratufa bicolor	Black Giant Squirrel	0	PARL
Callosciurus inornatus	Inornate Squirrel	VU	LKL
Trogopterus / Hylopetes sp(p).	Small flying squirrel sp(p).	0/EN/0	LKL
Rattus sikkimensis	Sladen's Rat	VU	0
Chiromyscus chiropus	Fea's Tree Rat	0	LKL
Hystrix brachyura	East Asian Porcupine	VU	0
Nesolagus timminsi	Annamite Striped Rabbi	DD	LKL

Notes:
1. Scientific and English-language names follow Duckworth et al. (1999) with amendments for bats and murids.
2. Global status follows the IUCN 2004 red list of threatened animals www.redlist.org. CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near-threatened; DD = Data Deficient; 0 = least concern; n/a = not assessed.
3. National risk status follows Duckworth et al. (1999). ARL = At Risk in Lao PDR; PARL = Potentially At Risk in Lao PDR; CARL = Conditionally At Risk in Lao PDR (i.e. taxon is certainly At Risk if extant in Lao PDR); LKL = Little Known in Lao PDR.
4. Species not certainly known from the NNT and Nakai Plateau area are in square brackets.
5. GTS = Global Threat Status; NRS = National Risk Status

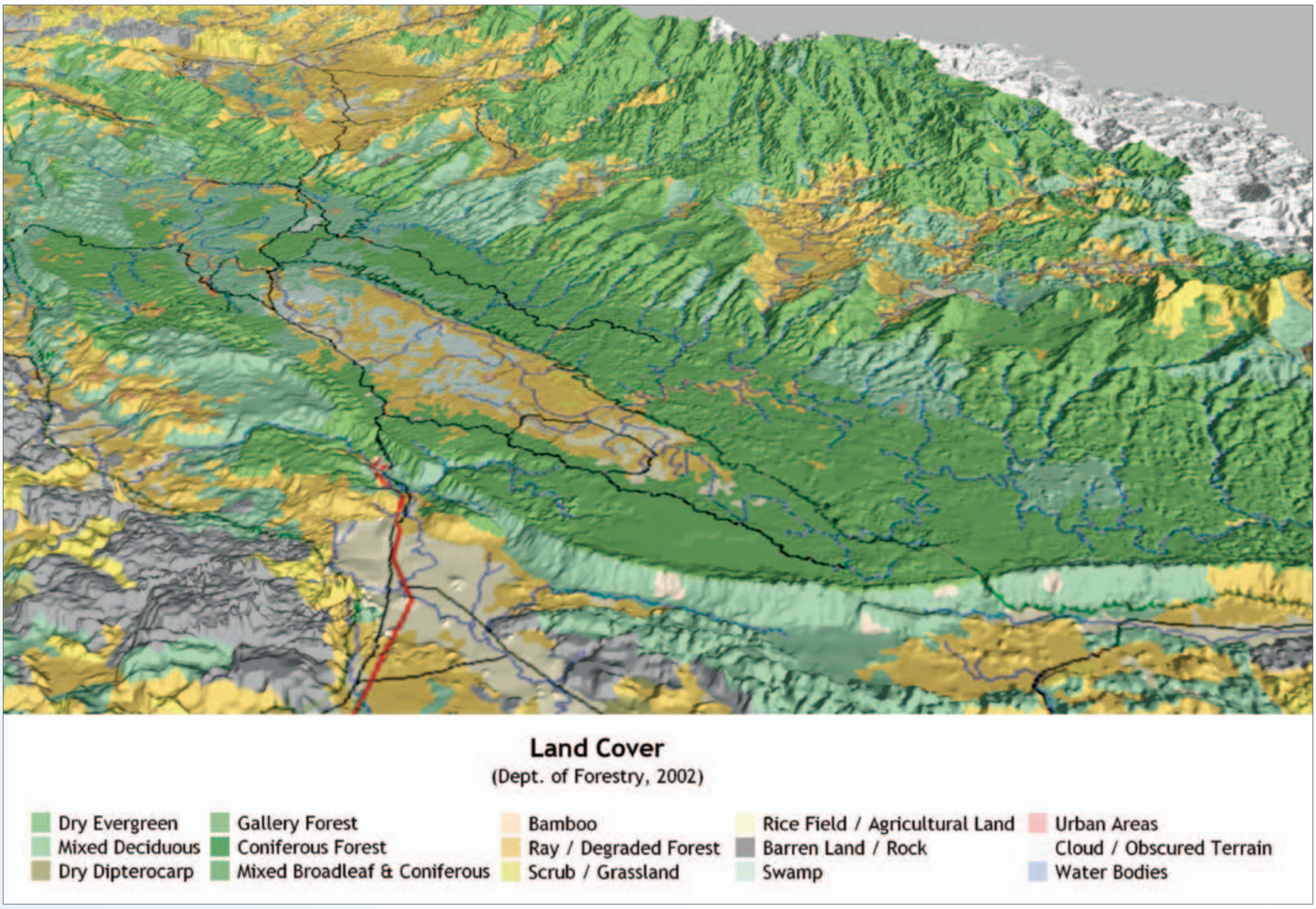

Figure 3.52: Forest types & land use within the Project area

Table 3.53: Occurence and account of loss of habitats in the Project area

Forest Type/Land Use	Area of Habitat in the 3 Provinces[1] (ha)	Percent Occurrence in the 3 Provinces[1]	Area Lost or Degraded due to the Project (ha)	Percentage Loss to the Project	Loss Rank
Upper Dry Evergreen	447,505	7.4	16,820	3.8	5
Lower Dry Evergreen	11,878	0.2	0	0.0	–
Upper Mixed Deciduous	1,480,886	24.6	19,119	1.3	11
Lower Mixed Deciduous	182,666	3.0	469	0.3	13
Dry Dipterocarp	716,417	11.9	5,511	0.8	12
Gallery Forest	4,091	0.1	286	7.0	3
Coniferous Forest	1,849	0.0	93	5.0	4
Mixed Broadleaved & Coniferous	100,838	1.7	27,208	27.0	1
Bamboo	20,111	0.3	0	0.0	–
Ray	92,486	1.5	1,603	1.7	8
Savannah	79,092	1.3	0	0.0	–
Scrub	126,746	2.1	216	1.6	14
Rice Paddy	544,133	9.0	8,716	1.6	9
Other Agriculture	6,103	0.1	174	2.9	6
Barren Land & Rock	211,072	3.5	165	0.1	15
Grassland	68,237	1.1	9,560	1.4	10
Swamp	45,955	0.8	4,702	10.2	2
Urban	10,788	0.2	302	2.8	7
Water	89,694	1.5	0	0.0	–
Total	**9,023,453**		**94,944**		

Note: 1. The three provinces are Khammouane, Bolikhamxai and Savannakhet

Plate 19: Nam Theun downstream of the dam showing mixed deciduous/ dry evergreen forest

Plate 20: Nam Theun near Ban Thalang showing riverine/ bamboo forest

grasslands, wetlands, agricultural areas (lowland and upland) and temporarily deforested areas. These land cover types are described in Annex H and shown in Figure 3.52 and Plates 19-24.

As indicated in the Table 3.53, the total footprint of the Project will affect approximately 95,000 ha of land. During construction, this will increase to approximately 130,000 ha of land. The largest area that will be impacted by the Project is the mixed broad-leaved and coniferous forest (27% of this vegetation type in the three provinces impacted by the Project). The second most affected area will be swamp (10%), and the third the gallery forest (7%).

A number of surveys to determine the forest composition and to record the structure of the tree canopy of the Nakai Plateau and adjoining NNT NBCA have been carried out (Burnside, 1996, IUCN, 1998, Margules Groome Poyry, 1996, WCS, 1995a, WCS, 1995b, WCS, 1996, Jarvie, 1997). However, there have been only a few systematic surveys to determine the floral composition of the main forest ecosystems, and therefore little is known about the regional and national conservation status of plant species of Lao forests. Studies of wildlife distribution and NTFP use at the subsistence level by human communities tended to categorise findings in terms of major forest communities and not in terms of habitat types.

Three species belonging to the *Gymnospermae* deserve special mention. *Fokienia hodginsii* is the only species of its genus and is restricted to south China, Lao PDR and Vietnam. This species prefers high elevation habitats and is not present on the Nakai Plateau, but found in the upper reaches of the NNT NBCA, which according to Jarvie (1997) may be one of the last significant refuges for the species. However, this species is planted in northern Vietnam. *Keetelaria evelyniana* is endemic to the region, and occurs in Lao PDR and Vietnam (Jarvie, 1997). It occurs occasionally on the Nakai Plateau, but is locally common in the NNT NBCA and is grown on plantations in Vietnam. *Pinus latteri* is more widely distributed in the region. Most of the old-growth stands of *Pinus latteri* in the Project area have been impacted by logging, though substantial areas remain above the inundation zone at several sites on the northeast bank of the Nam Theun and in the southernmost sections of the Plateau. The habitat it provides, both on the Nakai Plateau and the NNT NBCA, highlights the need for special measures directed towards its conservation.

Habitat Affinities of Wildlife

Wildlife habitat is that space where the animal lives over the seasons of a year. Habitat most often has come to mean a physical location that contains both the resources that are exploited for food or nutrients, as well as those which provide other essential requirements for life, such as cover. The use and importance of a habitat can be determined using three general approaches: i) by direct observation during the course of surveys or inventories; ii) through research involving more detailed observation and experimentation; and iii) by intersecting known habitat affinities with the presence and condition of suitable habitat. The habitat affinities for the Project area are derived from WCS (1995, 1996, and 1997) and Duckworth et al. (1999). Generally, areas that are difficult to access and are rarely visited by knowledgeable scientists are ascribed a habitat value by inference using pre-existing information from the literature. The work carried out in the NNT NBCA, Nam Theun – Phou Hin Poun Corridor and Nakai Plateau by WCS, IUCN, DUDCP, and during the preparation of the EAMP, employed relatively crude survey methodologies. Nevertheless, for most part, these are the only objective observations available for the area. Surveys were carried out primarily using direct sightings and indirect evidence (tracks, signs, etc.) and through interviews with local residents. These efforts have provided a basis for the current knowledge base of the wildlife and plant associations in the study areas. Nevertheless, they do not permit any measure of variability, statistical confidence, or assessment of completeness. Data continue to be intermittently collected and are expected to progressively reveal additional and significant information about the wildlife and their habitats.

Plate 21: Grassland typical of the Nakai Plateau


Plate 22: Wetlands on the Nakai Plateau


Plate 23: Agricultural land on the Nakai Plateau

Reservoir Area

The inundation area was evaluated by grouping habitats and determining the potential wildlife species that could be present there. Since extensive population estimates were not performed, it is not possible to determine the viability of the populations for the majority of species. In contrast to other fertile .at areas in Southeast Asia, surveys by WCS (1995) found that the wildlife assemblage on the Nakai Plateau is sparsely populated. WCS (1996a) further noted that the mammal species recorded were at population levels below that expected for intact forest tracts that have very low hunting pressure and wildlife trade. The secondary, dry deciduous, evergreen and conifer forest habitats of the Nakai Plateau support at least 210 bird species, and probably several dozen more The current significant loss of habitats on the Nakai Plateau is occurring in the pine forests, the riparian areas along the rivers and tributaries, and in the wetlands. Data from aerial photo analysis, Burnside (1996), and WCS (1995), points to a nearly complete loss of once significant (>40% of the total area) Nakai Plateau non-flowing wetlands. Although the riparian zone supports two key or indicator mammal species, the non-flowing wetland habitats, on the other hand, are remarkable for having lost their key or indicator mammals. The 13 key bird species and 4 key mammal species currently found in the wetland and riparian habitats do not include the Eld's deer and the hog deer, which are presumably extirpated. Some of these, as well as species which make significant use of wetlands, such as tiger, are candidates for an extensive conservation effort. The inventory presented in Annex J of wildlife species recorded in the NNT NBCA and on the Nakai Plateau is based on information gathered by different workers to date. An exception is the Asian elephant, which is now reasonably well known following the studies of Boonratana (2000) and Khounboline (2002). A summary of these observations is presented in Table 3.54 and 3.55.

Nam Theun Downstream from the Nakai Dam

The Nam Theun gorge downstream from the Nakai Dam is an area of open, dry evergreen forest bisected by the river. Here, the Nam Theun dramatically changes character from the slow, warm, 75 m-wide river of the Nakai Plateau to a 50 km-long 40m-wide series of alternating rapids and pools cutting through the sandstone and mudstone rock, with large boulders strewn within the river channel. These areas provide considerable habitats for invertebrates that provide food for fish in the river. An occasional remnant, a quarter-hectare pool that is separated from the river and frequently dries during the dry season, is another feature of this diverse riparian zone. The vegetation along the Nam Theun downstream from the dam site consists of good quality primary evergreen forest. Flat alluvial shelves lie along both sides of the Nam Theun, about 25 m above the water surface in January, and support a low 12 m-tall forest containing abundant bamboo (*Bambusa arundinacea*, *Oxytenanthera parvifolia*) with small trees and shrubs. There is no distinctive riparian forest along the river except the bamboo. Below this area the vegetation is patchy, comprising several grasses, a sedge and several broadleaf herb species. These species are probably confined to the clay-rich alluvium. Vegetation lines the riverbanks except where rock outcrops border the Nam Theun. Specific habitat types for the Nam Theun gorge were identified from the vegetation map, augmented by partial coverage by aerial photography. The habitat types along the Nam Theun downstream from the Nakai Dam are presented in Table 3.56. These habitats are typical of this area, although other habitats are also present in minor amounts. The primary habitat of interest in Zone 4 is the river habitat.

Dividing Hills

The vegetation types and habitat elements of the dividing hills are dominated by dry evergreen forest and to a lesser extent by mixed deciduous forest. Other vegetation types and habitat elements occurring in the dividing hills are outlined in Table 3.57

Resettlement Area

The proposed resettlement site of approximately 21,000 ha is situated on the southwest side of the inundation area, where 17 villages will be relocated. The predominant vegetation type is broadleaf


Plate 24: Degraded forest area on the Nakai Plateau

Table 3.54: Key bird species recorded from flowing and non-flowing wetlands on the Nakai Plateau.

Key Bird Species	Threat/ Risk status	Wetlands association	Status on Nakai Plateau
International Red List			
White-winged Duck	EN	Flowing and non-flowing wetlands near trees	Localised resident in 1994-1995; no subsequent information
Blyth's Kingfisher	NT	Shaded forest streams	Well distributed resident in suitable habitat
Wood Snipe	VU	Shaded forest streams	Winter visitor or passage migrant with few records; possibly much overlooked
Lesser Fish-Eagle	NT	Shaded forest streams and rivers	Resident, several pairs in 1994-1996; no subsequent information
[Grey-headed Fish-Eagle]	NT	Forest rivers and lakes on gentle terrain	A few possible records perhaps stem from confusion with preceding species
[Greater Spotted Eagle]	VU	Open areas especially around wetlands1	Non-breeding visitor; two records, not certainly identified to species
[Imperial Eagle]	VU	Open areas especially around wetlands1	One fly-over migrant, not certainly identified to species
Lao At Risk List			
Greylag Goose	ARL	Large wetlands amid open areas	One record only; certainly not common
Tawny Fish Owl	LKL	Presumed flowing and non-flowing wetlands near trees	Occurs, presumed resident, but distribution and abundance unclear
River Lapwing	ARL	Wide rivers with extensive seasonally-exposed sedimentary features	Well distributed breeder in suitable habitat in 1994-1996; no subsequent information
Grey-headed Lapwing	PARL	Short turf, bare mud and open marshy areas in and around wetlands1	Fairly numerous winter visitor
Small Pratincole	PARL	Very wide rivers with extensive seasonally-exposed sand- or gravel bars or rock outcrops	One record only; certainly not common
Black Kite	ARL	Open areas usually near wetlands1	Non-breeding visitor, now very scarce
Grey Heron	PARL	Wide variety of open wetlands	Scarce non-breeding visitor
Purple Heron	PARL	Wide variety of secluded wetlands	Scarce non-breeding visitor
Black Stork	ARL	Mostly forest-stream ecotone, sometimes in more open wetlands	Non-breeding visitor, now very scarce

Notes:
1. Although individuals may be found outside wetlands with some regularity, species probably depends upon wetlands
2. Species predominantly of narrow forest streams are excluded
See also Table 3.52

Table 3.55: Key mammal species recorded from flowing and non-flowing wetlands on the Nakai Plateau.

Key Mammal Species	Threat/ Risk status	Wetlands association	Status on Nakai Plateau
International Red List			
Rhesus Macaque	NT	Riverine forest and scrub1	Common
Eurasian and/or Smooth-coated Otter	NT/VU	Flowing and non-flowing wetlands	Frequent
Asian Small-clawed Otter	NT	Flowing and non-flowing wetlands	Frequent
[Fishing Cat]	VU	Habitat not well known1?	Not certainly recorded but seems likely to occur
Asian Elephant	EN	Flowing and non-flowing wetlands1	Viable population with predictable seasonal movements encompassing defined parts of the Plateau
Lao At Risk List			
[Jungle Cat]	ARL	Grassland, scrub, open deciduous dipterocarp forest and other non-closed-forest habitats with ready access to standing water1	Presumably occurred historically but may now be locally extinct

Notes:
1. although individuals may be found outside wetlands with some regularity, species probably depends upon wetlands
2. insectivores, bats, murids and species from other orders that are predominantly of narrow forest streams are excluded
See also Table 3.38

and coniferous forest, which covers 53% of the total area proposed for resettlement. Other vegetation types represented are dry evergreen (33%), secondary (7%), mixed deciduous (5%) and grassland (1%). Riverine fringe and riparian habitats are also present in the area. The area is generally fragmented by human occupation and use.

Wetlands

Non-flowing wetlands of the Nakai Plateau include permanent and seasonal freshwater lakes and ponds, marshes, and flooded grasslands. Many of the wetlands exist as depressions up to one metre deep. Other wetlands are associated with grassland, bam-

Table 3.56: Habitat types of the Nam Theun Gorge

Vegetation Types/Habitat Elements	Nam Theun Gorge Corridor (% of 32,560 Ha)
Mixed deciduous	15
Dry evergreen	51
Open/scrub	35
Old field succession	1.5
Karst/limestone/outcrop	1.0
Bamboo	3.0
Savannah grassland openings	1.0
Agriculture (upland paddy)	0.5
Sandbars	0.2

Table 3.57: Habitat types for the dividing hills

Vegetation Types/Habitat Elements	Dividing Hills (% of 41,705 Ha)
Mixed deciduous	28
Dry evergreen	66
Open/scrub	4
Old field succession	1.5
Karst/limestone/outcrop	1.0
Bamboo	3.0
Savannah grassland openings	1.0
Agriculture (upland paddy)	0.5
Sandbars	0.2

boo, savannah and woodland vegetation in poorly drained areas. Many lakes and ponds on the Nakai Plateau are located in open grasslands where livestock is maintained by the local villages. Claridge (1996) estimated that 50 km^2 of seasonal wetlands exist on the entire Nakai Plateau, of which approximately 27.4 km^2 will be inundated by the Nakai Reservoir. Wetland plant communities in the Nakai Plateau change in species composition along a moisture gradient. The most abundant types of vegetation associated with ephemeral wetlands include *Panicum maximum* and *Eragrostis sp.* in the wettest areas, *Eragrostis malayana* in the drier areas, and *Lasiandra sp.* occurring in the relatively dry, outer fringe of the wetland areas. These wetlands are flooded to varying degrees for approximately 8-10 months of the year. *Lasiandra sp.* is the dominant pioneer species in the waste ground that frequently borders ephemeral wetlands. In permanent wetlands, *Phragmites sp.* is found in water up to approximately one metre in depth. Species extending out from the wettest areas are *Zoysia sp.*, *Panicum maximum*, and *Eragrostis sp.* Vegetation in the driest, upper zone of the permanent wetlands includes *Eragrostis malayana, Zoysia matrella, Centella asiatica,* and *Veronica undulatum*. Submerged aquatic vegetation includes *Ceratophyllum demersum* and *Vallisneria spiralis* in shallow, sheltered, permanently inundated areas up to one metre deep. These species provide important refuge areas for cyprinid fish species and are a food source for other herbivorous fishes. Key bird species inhabiting the wetland areas are presented in Table 3.54. Key species of mammals that utilise the wetland habitat are listed in Table 3.55. A variety of crabs, shrimps, frogs, snails, tortoises will also be affected as the wetland habitats in which they are found become inundated.

Dynamics of Habitat on the Nakai Plateau

Logging on the Nakai Plateau has been ongoing for the last 20 years, primarily based on a concession by GOL to the state enterprise Bolisat Phatana Khet Phoudoy (BPKP). BPKP was allocated control over the Project's entire catchment. From the early 1980s BPKP developed and expanded timber harvest, transport and processing capacities. When the Project started to develop, BPKP was directed by GOL to focus logging activities within the inundation zone because the commercially valuable pine would not survive inundation. Volume of timber extracted expanded from earlier levels of 20,000-40,000 m^3/yr to nearly 441,000 m^3/yr in 1995 (BPKP Logging Report, 1998-99). This rate of clearing would have removed a total of 1.1 million m^3 of commercial pine and hardwood, representing virtually all of the commercial volume in the inundation area (Prosser, 1997).

To help further clarify the dynamics of the habitat loss, Aruna Technology (2004) conducted a detailed chronological assessment of biomass clearance, for both within and outside the reservoir area and to estimate the biomass currently present in the inundation area. The details for the chronology of biomass clearance are available and are provided below. The assessment of habitat type and vegetation cover is ongoing and will be included in the next version of the EAMP.

The chronology of biomass clearing on the Nakai Plateau between the years of 1973 and 2003 was assessed through the comparison of supervised classifications of MSS and TM satellite images for the years 1973, 1989, 1996 and 2003. From 1973 to 1989 clearing and logging was concentrated largely within the inundation area, with some clearing apparent in the adjacent proposed resettlement area (Figure 3.53). The proportion of clearing occurring outside the inundation zone in the period 1989 to 1996 was greater than that inside the inundation zone. This coincides with a period of intense logging activity from 1994 to 1998, of between 217,000 m^3/yr and 441,000 m^3/yr as indicated in the (BPKP) logging report of 1998-1999.

Based on the analysis, the following conclusions have been reached and are presented in Figures 3.54 and 3.55: i) from 1973-2003, forest cover within the area of the Nakai Plateau decreased from 71% to 60%; ii) for the same period, forest cover within the inundation zone decreased from 61% to 48%; iii) 57% of all clearing in the period 1989-1996 occurred outside the inundation zone; and iv) 43% of all clearing in the period 1996-2003 occurred outside the inundation zone.

It seems that the establishment of the NNT NBCA in 1993 (Berkmüller et al. 1995), which covers the area to the north of the inundation area, has been largely ignored by the logging operators in this period, with 57% of all clearing occurring outside the inundation demarcation. Between 1989 and 1996 very little of this change of forest cover can be attributed to shifting cultivation. The trend is reversed in the following period, 1996-2003, when the boundary of the NNT NBCA was observed more stringently by logging operators. The proportion of clearing occurring outside the inundation zone decreased in the period from 1996 to 2003, but was still significant (43%) (Aruna Technology, 2004). In the last years logging activity has slowed considerably, as shown by visual reference of 2000 SPOT multispectral data and the 2003 Landsat ETM data. The report of the World Bank logging survey team of 2002 noted that no logging has occurred in this area since 2000. However, clearing of limited scale within the NBCA area still occurred in this period, but could not be attributed to logging or shifting cultivation.

In addition to the current threats from logging, traditional collection of NTFPs focusing on tree species, with emphasis on fragrant woods and barks, may also be putting pressure on forest resources. The availability and use of NTFPs is important during years of poor agricultural harvest. Bamboo, wood, rattan and leaves are used for construction and making implements. Traditional medical practitioners also rely exclusively on non-timber forest products for medicines.

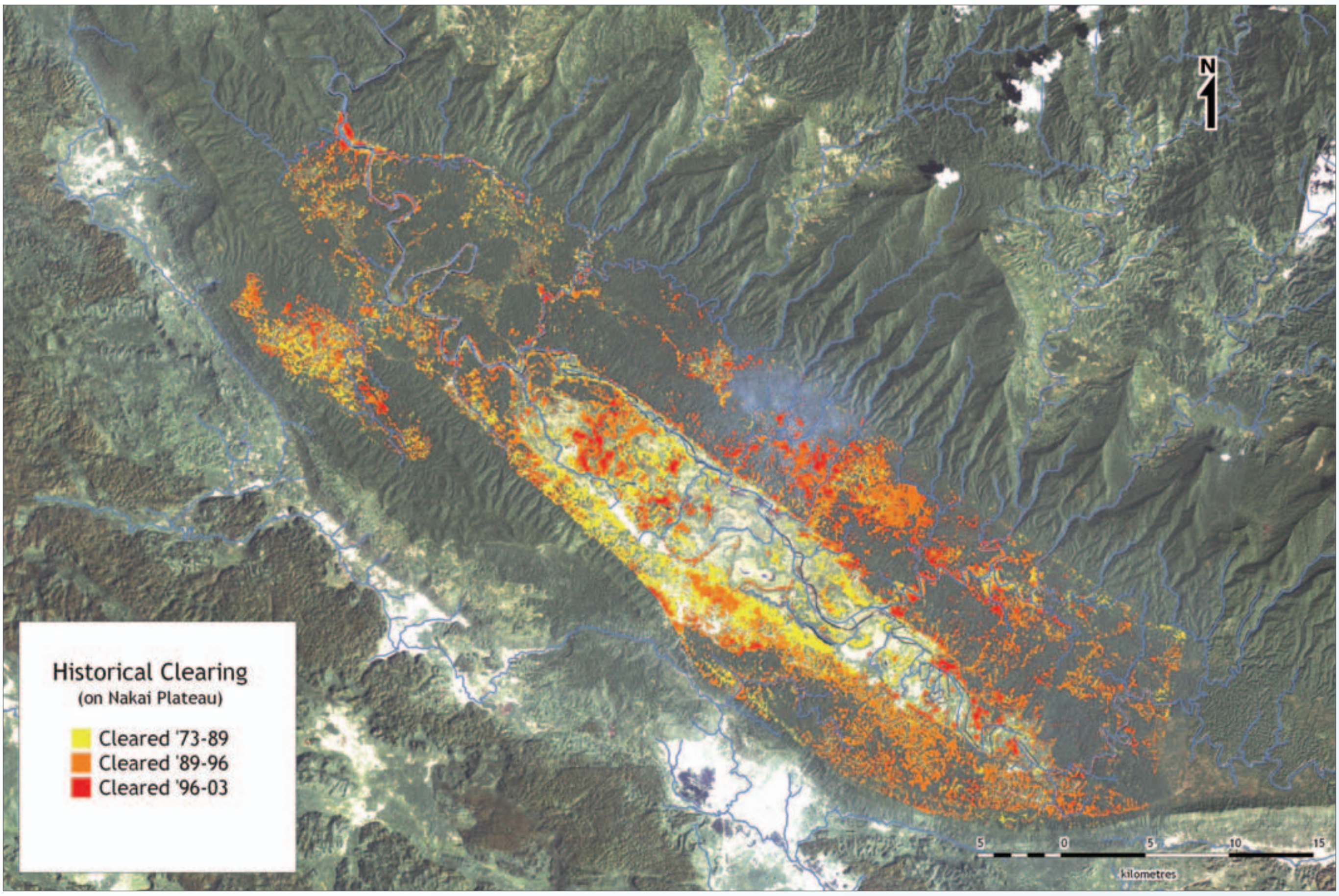

Figure 3.53: Historical clearing on the Nakai Plateau, 1973-2003.

Potential Impacts

Impacts to the terrestrial ecosystems on the Nakai Plateau will be fairly significant during the construction, operation of the reservoir and operation of the Power Station. They will be either direct impacts related to the physical clearance, degradation or disturbance of ecosystems and/or indirect impacts resulting from increased population and improved access. A full accounting of habitat loss as a result of the Project has been undertaken and has rationalised the adequacy of the conservation offset (Annex I).

The Annex indicates that the lower mixed deciduous, dry dipterocarp, and mixed broadleaf and coniferous habitats are not represented in the NNT NBCA, but this impact was not considered significant at provincial and national levels. The greater loss will be the environmental conditions of the river in this area, which constitutes a habitat for the white-winged duck. This species has restrictive habitat preferences, and any habitat loss would be of global significance, as discussed further in Annex I.

The various impacts will be discussed relative to the following components: i) the Nakai Dam and the downstream Nam Theun; ii)the Nakai Reservoir; iii) the regulating pond and the Downstream Channel; iv) the Xe Bang Fai; and v) the Transmission Lines.

Nakai Dam & the Downstream Nam Theun

Approximately 1,325 ha have been allocated for the construction of the Nakai Dam and its access road. The construction of the Nakai Dam itself will only require 10-15 ha of clearance. Apart from the actual siting of the Nakai Dam, the main impacts to the terrestrial system will occur downstream from the Nakai Dam in the 12 km reach between the dam and the Nam Phao. Additional impacts may occur downstream from the Nam Phao, but these are expected to be minor. The primary impacts associated with the Nakai Dam and the 12 km reach downstream from the dam to the Nam Phao include the following: i) reduction in discharge and encroachment of vegetation into the river channel; ii) periodic flooding of the area and possible scour of established vegetation; and iii) construction of the access road to the dam site and the dam itself.

Because the amount of water discharged from the dam will be reduced from an annual average of approximately 238 m^3/s to an annual average, taking into account the riparian release and spills, of just 16 m^3/s, the potential for encroachment of vegetation into the river channel is quite likely, in addition to a change of the riverbed vegetation. These encroachments could provide an additional source of food for mammals moving through the corridor between the NNT NBCA and the Phou Hin Poun NBCA, and may create new habitats for mammals, reptiles and amphibians that will be present in the pools associated with this reach of the river. However, during extremely wet years when the reservoir is filled and spill occurs to the Nam Theun, much of this vegetation will be scoured and the establishment of vegetation in the area will then resume. The nearby forest should not be affected. The reduced flows in the Nam Theun from the Nakai Dam to the confluence with the Nam Phao will have an impact on terrestrial wildlife relying on fish in this stretch of the river. A number of terrestrial vertebrates depend upon the aquatic diversity and productivity of the Nam Theun for food and shelter. The key and indicator species are diverse because the gorge has a diversity of habitats not seen in more uniform forested areas. Bird species of special concern

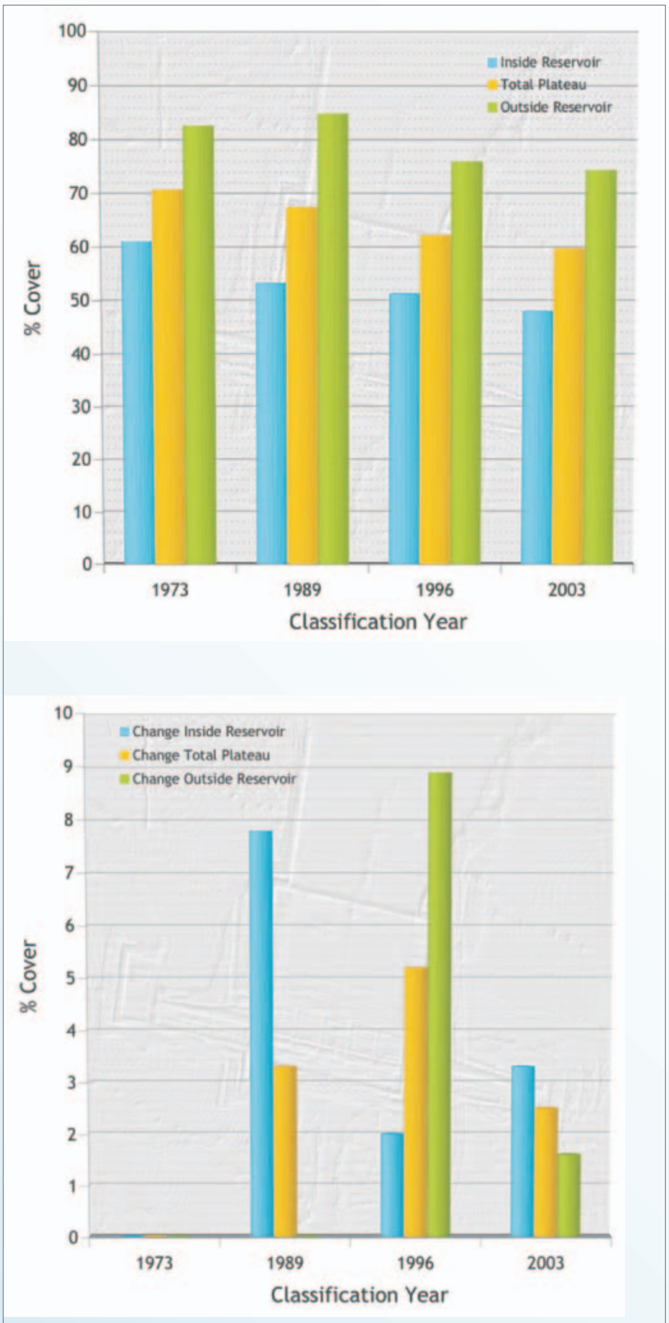

Figure 3.54: Percentage change in land cover over time

include the lesser fish-eagle and perhaps black stork. The mammal species include otters. The intact riparian habitat is important for the many species reaching highest densities in the forest--stream ecotone. It is currently not known whether the amount of prey in this section of the river will increase, remain static or decrease for birds such as the lesser fish-eagle and mammals such as otters.

Downstream from the Nam Phao, the discharge in the Nam Theun will be increased as other tributaries discharge into the Nam Theun. However, the reduction in discharge, as a consequence of storage of water in the Nakai Reservoir, will continue downstream. The reduction in discharge will increase the number of days that the Theun Hinboun reservoir will discharge its minimal riparian release of 5 m^3/s. As a result, the discharge to the Nam Kading will be significantly reduced and there is a potential for encroachment of vegetation into the channel downstream from the Theun Hinboun dam. Whilst severe impact on the vegetation is not considered likely, the dependence of key and threatened species of mammals on the aquatic ecosystem is an important element of the Nam Kading's biodiversity. An analysis of the riparian release will be conducted in the near future and its findings incorporated into the EAMP.

Nakai Reservoir

The Nakai Reservoir operation will affect forests, woodlands, and land cover in the inundation zone, of which 57% has already been disturbed (Figure 3.55). Forest and woodland plant communities and land use types on the Nakai Plateau consist of 13 ecotypes, and form a mosaic of habitats that once was inhabited by an outstanding density and diversity of wildlife species. These species have come under increasing pressure over the last 30 years from settlement expansion, logging and hunting.

The impacts associated with the initial filling of the Nakai Reservoir are discussed in the construction and development impacts section. The reservoir will be refilled and drawn down on an annual basis. At full supply level, the reservoir will be at El 538 m, this will flood approximately 450 km^2 of land area on the Nakai Plateau, approximately 40% of the total area of the Nakai Plateau. At FSL, all forests, savannah, grasslands and wetlands within this area will be inundated by the reservoir and their vegetation will be lost. During the drawdown period, the reservoir area could be reduced to a surface area of approximately 82 km^2. This will create numerous wetland areas where fishing could occur as well as a vast area of mudflats, devoid of permanent terrestrial vegetation. It is expected that grasses and shrubs could become established along the margins of the reservoir area, with similar species those in the existing wetlands on the Nakai Plateau.

The marginal areas of the reservoir could serve as a food source for livestock and potentially provide supplementary garden area for the Resettlers. It is unknown how this potentially diverse range of habitats will influence the prevalence of wildlife, particularly when so much of it will be either in or adjacent to a protected area. More commonly, some species such as shorebirds and shoreline breeders, ungulates, and others species could be negatively impacted

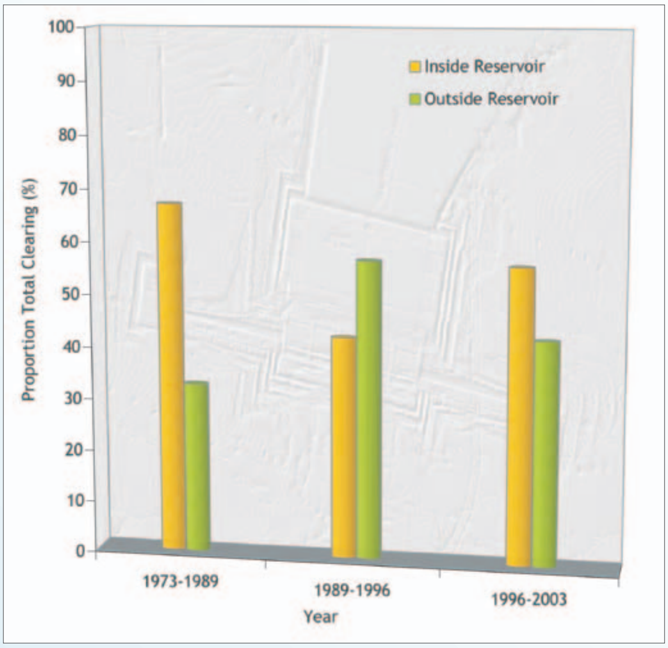

Figure 3.55: Percentage of area cleared (1973-2003)

where large areas are exposed with extensive mudflats, when the reservoir is drawn down.

The area of shoreline littoral zone will vary between approximately 25 km² at minimum operating level to approximately 200 km² at FSL. The moist soils will harbour a wide array of semiaquatic invertebrates such as molluscs and insects, as well as vertebrates such as snakes and turtles, thus providing a forage area for predatory animals. The standing vegetation exposed at drawdown (mostly dead trees) may provide cover for some wildlife species as well. However, the degree to which this area will provide the resources lost by inundation of the original wetlands is difficult to determine. It is recommended that both habitat requirements and alternative areas that can be utilised by vulnerable species be studied prior to inundation. Such mitigation measures are discussed in Chapter 6. The many vulnerable key species include the black stork (*Ciconia nigra*), Blyth's kingfisher (*Alcedo hercules*), lesser fish-eagle (*Ichthyophaga humilis*), river lapwing (*Vanellus duvaucelii*), snipes (*Gallingo spp.*), tawny fish-owl (*Ketupa flavipes*) and potentially congeners, and white-winged duck (*Cairina scutulata*).

Information gained from the study of habitat requirements and alternative areas can then be used to preserve or enhance areas containing habitat or food resources that would otherwise be available to the species of concern. The information can also be used to evaluate the likelihood that migrating birds might be able to find and utilise neighbouring wetland areas on the Nam Hinboun, Nam Thon and Xe Bang Fai, all less than 60 km away. However all these areas are presumably heavily hunted and thus are unlikely to be suitable under current conditions.

In addition, 2,700 ha will be impacted by construction activities related to Road 8B as detailed in Annex I and will divide the corridor area, possibly hindering movement and migrations of mammals and other wildlife from the NNT NBCA to the Phou Hin Poun NBCA.

The presence of the reservoir may make some areas easier to access, in particular for hunting, and therefore increase the vulnerability of the wildlife. For example, all of the dividing hills will become accessible if hunters camp for a night.

Regulating Pond & Downstream Channel

At FSL the regulating pond will inundate approximately 1.5 km². The placement of the regulating pond in this area will require removal of vegetation and will impact a 4.6 km stretch of the Nam Kathang channel. All vegetation will be removed along the Downstream Channel. The Downstream Channel will pass through rice paddies and secondary forests and will impact a small wetland downstream of the tunnel (Figure 3.56).

Xe Bang Fai

Impacts to the terrestrial resources along the Xe Bang Fai are primarily attributable to the increase of discharge in the river to an average of 220 m³/s and the associated loss of land, in particular riverine forests, along the river through erosion. The increased discharge, particularly during the dry season could also prevent the migration of mammals and other wildlife across the river.

Transmission Lines

The clearance of vegetation (4,650 ha) for construction and access roads required for routine maintenance of the easements are the main impacts associated with the transmission lines. The majority of the 500 kV transmission line traverses agriculture land, scrub and degraded forest. However, approximately 62 km passes through lowland dry evergreen forest, secondary succession mixed deciduous and dry dipterocarp forest. The development of certain protocol will be required so as to minimise disturbance.

Threatened Species

Baseline Conditions

Currently, there are 35 mammal species, 14 bird species, and 10 reptile species recorded in the NNT NBCA and Nakai Plateau (Table 3.52) that are classified as globally threatened, near-threatened or data deficient according to the IUCN Red List of Threatened Animals (IUCN, 2004). In addition, there are 45 species comprising 17 mammal species, 21 bird species, and seven reptile species that are considered nationally at risk, potentially at risk, or little known in Lao PDR (Duckworth et al., 1999). Current threats, such as hunting, to some species or to the overall biodiversity are well documented in a number of reports, but detailed knowledge on their distribution and intensity is still limited.

Investigations into bats and rodents, in particular, are still limited, with new species still being identified. For example, Francis et al., (1996) have identified six range extensions (e.g. of bats previously only believed to occur in peninsular Malaysia and Borneo) and

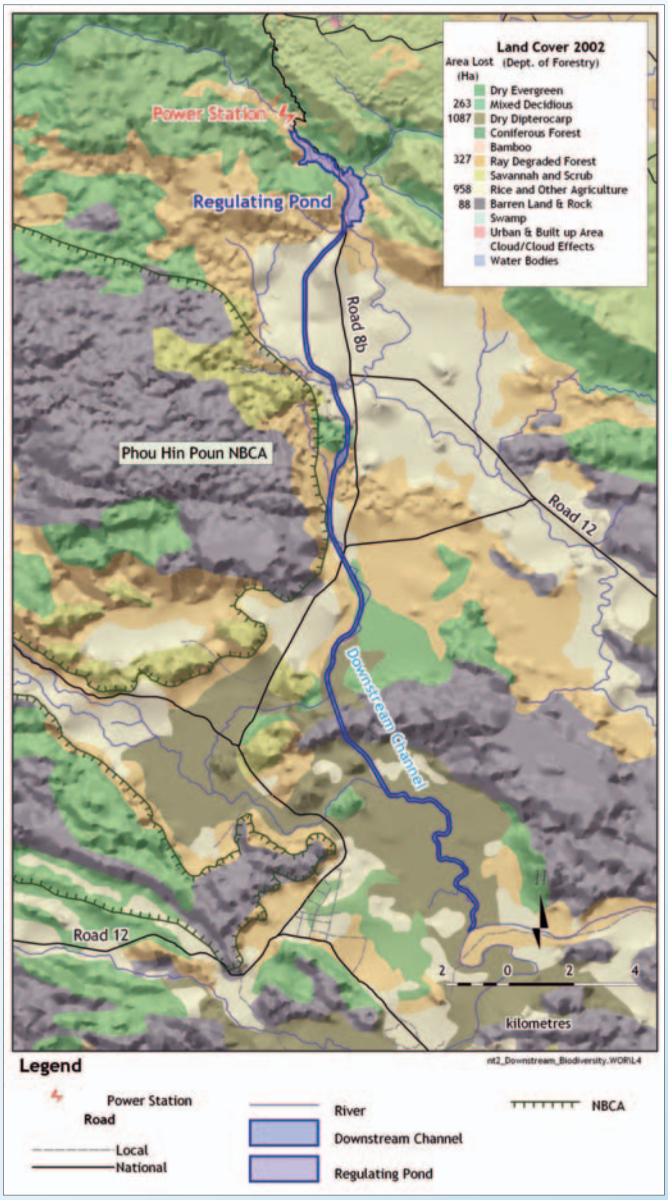

Figure 3.56: Downstream channel alignment and habitat/land use types

at least two new species (Francis et al. 1999, Robinson et al. 2003) among 44 species of bats captured. Thus, surveys and censuses of much longer duration and intensity, covering all habitat types at all seasons and using a wide range of methods for lengthy periods are needed to obtain a picture of species present, their distribution and abundance. Wildlife species recorded or provisionally recorded in the area, currently totaling over 100 mammals, over 400 birds, 38 reptiles, and 25 amphibians are listed in Annex J.

There are various mammals and birds that are strictly or nearly endemic to the Annamite mountains, some of which occur in the NNT NBCA and/or the Nakai Plateau, or can be expected to do so.. These include François's langur, douc, white-cheeked crested gibbon, Owston's civet, saola, large-antlered muntjac, Annamite muntjac, Heude's pig, Annamite striped rabbit, crested argus, short-tailed scimitar babbler. None of these is endemic to the Nam Theun basin and immediate surroundings. . In addition, other taxa very likely to have endemic representatives include the invertebrates, reptiles and amphibians as well as plants.

Management attention, including monitoring as indicators of the health of the wider environment, will be directed at least in part to specific species. The most obvious of these is the Asian elephant, because it is an umbrella species: by managing everything needed to retain elephants, many other species will persist. Other species can not readily be selected pending a baseline survey to assess what is still present. White-winged Ducks are so rare that they would merit specific attention, but it is not clear if there has been any record after 1995. However, it is likely that indicator species for directing management and monitoring attention should include some water-forest ecotone species (fish-eagles, fish-owls, Blyth's kingfisher), some sensitive to hunting (hornbills, fish-eagles), and some that are both typical of open wetland edge and sensitive to hunting (grey-headed lapwing, grey heron). If the reservoir creates suitable habitat for river lapwing, this would also be a good candidate to consider. Careful thought should be given in the baseline survey to select monitoring indicators where enough data can be gathered to indicate trends with some statistical confidence.

The White-Winged Duck

A population of five to ten pairs of white-winged duck was identified from the western end of the Nakai Plateau (WCS, 1995, Evans et al. 1997), which may not likely be viable on the long term. The nearest known population to the Nakai Plateau is close to the Cambodian border in the Xe Pian NBCA on the southern Bolovens Plateau. The area is a region of freshwater lakes, ponds, marshes and seasonally flooded grassland in Attapeu Province, approximately 130-150 km south southeast of the Nakai Plateau. Historically, the white-winged duck was widely distributed from northeast India and Bangladesh, through Southeast Asia to Java and Sumatra, Indonesia. However, it has since undergone a dramatic decline such that, in 1997, its global population was estimated at 450 individuals, and the total population for Lao PDR, Thailand, Vietnam and Cambodia was estimated at 130 individuals (BirdLife International, 2003).

It continues to decline throughout its range, largely attributable to widespread hunting and lowland deforestation, compounded locally by drainage and conversion of wetlands. The resultant small, fragmented populations are vulnerable to extinction from stochastic environmental events, loss of genetic variability, disturbance, hunting and collection of eggs and chicks for food or pets. Hydropower development, inappropriate forest management, and pollution are more localised threats (BirdLife International, 2003).

The white-winged duck inhabits standing or slow flowing natural and artificial wetlands, within or adjacent to evergreen, moist, deciduous or swamp forests, on which it depends for roosting and nesting, usually in tree-holes (Drilling, 2001, BirdLife International, 2003). Although lowlands (below El 200 m) provide optimum habitat, it is known to occur up to El 1,400 m, especially on plateaux supporting sluggish perennial rivers and pools (BirdLife International, 2003). The white-winged duck is very secretive, often only feeding at night, and although essentially sedentary, some birds make short dry-season movements in response to low water levels. In addition, the birds are relatively intolerant of human disturbance and may abandon an area after only a single contact with humans (Drilling, 2001), although this is evidently not so on the Nakai Plateau.

Besides being threatened by hunting, the Nakai Plateau white winged duck population will be impacted once the reservoir is inundated, and the loss of riparian habitat associated with inundation will likely result in their extirpation. However, given that the ducks are intolerant to human intrusion and given that there're no adequately protected sites within Lao PDR, neither translocation nor ex-situ conservation should be carried out. Nevertheless, alternative measures must be drawn up to give the ducks an opportunity to survive

The Elephant Population

There are reportedly two distinct sub-populations in the NNT NBCA. One is located in the northwestern part of the Nakai Plateau, where the Nam Xot drains into the Plateau, and the other is located in the southeastern part of the Plateau where the Nam Theun drains into the Plateau (Boonratana, 2000). Based on dung density estimation, Boonratana (2000) gave a conservative estimate of 94 individuals for the northwestern sub-population, but suggested that the area could support up to 450 individuals during the wet season. In a later study, Khounboline (2002) suggested that the northwestern sub-population was likely to comprise about 120 individuals from six groups.

The areas of concentration and the main travel routes of the northwestern sub-population during one wet season are primarily around Nong Pak Tok, Kouangten, Nam Gnalong, Ban Thalang, Nam Theun (between Ban Sopphaen and Kouangten), and at the mineral licks Poung Phai, Poung Ta-ee, Tha-Xang and Poung Mak Pat. Boonratana (2000) summarised the seasonality in habitat use as follows:

- Use of the northwestern part of the plateau throughout the year by the resident sub-population, and for some parts of the year by the southeastern sub-population;
- Use of the mineral licks throughout the year by the northwestern sub-population, and intermittently by the southeastern sub-population;
- Wider, but more intensive use, of the northwestern part of the plateau during the wet season by both the resident and southeastern sub-populations;
- High use of the Nam Theun riverine habitats (especially between Nam Gnalong and Nam Poungphai) during the peak wet season by both the resident and southeastern sub-populations;
- Use of parts of the central forest area in Phou Hin Poun NBCA, primarily at Kuan Xam, during the wet season; and
- Higher use of bamboo patches for feeding rather than any other habitats during the wet season.

Boonratana (2000) suggested that current observations were primarily due to a higher availability of food in the northwestern part of the Plateau during the wet season. In addition, frequent and regular visits to the mineral licks clearly indicate the importance of these resources to the Asian elephant. Hence, the species distribution and movement are also governed by the distribution of these mineral sources (Olivier, 1978, Davies & Payne, 1982, Sukumar, 1989, Boonratana, 1997 & 2000, Khounboline, 2002).

Constituents of mineral licks usually differ for di.erent mineral-between licks, therefore resulting in a tendency for elephants to visit as many mineral licks as possible (Lekagul & McMeely, 1997, Boonratana,2000, Khounboline, 2002). Furthermore, observations showed that mineral licks were visited more often during the wet season or after rain, when water dissolving the nutrients allows them to be easily consumed (Lekagul & McMeely, 1997, Khounboline, 2002).

In addition, peak rains most likely served as a trigger for different groups from both sub-populations to congregate along the Nam Theun, apparently to socialise and mate (Boonratana 1997, 2000).

The elephant population in the Nakai Plateau is currently threatened by poaching for ivory and by snares meant for other large mammals (possibly leading to death from injury-caused infections),and these threats will likely escalate with increasing demands for wildlife and/or their products. They are also threatened by habitat reduction due to agricultural encroachment, and from injuries caused by resident humans in their attempts to deter the elephants.

Human-elephant conflicts, as currently observed, apparently arise from habitat reduction, poaching, disturbance from past logging and related activities, and the elephants' acquired taste for agricultural crops. Khounboline (2002) documented a number of encounters between humans and elephants that resulted in three persons killed and one seriously injured. Without mitigation measures, human-elephant conflicts will likely escalate once the reservoir fills in, primarily through competition for the remaining severely reduced and fragmented habitats. This will require proactive human intervention that includes making available suitable habitats, ensuring abundant food supply, and avoiding the resettlement of dislocated humans to known elephant ranges.

Likewise, it is expected that the reservoir will disrupt and restrict the movements and gene flow of the elephants. Over time however, the reservoir may not necessarily form a barrier. Boonratana (2000) estimated that the over water distances, along some of the known travel routes are less than 1.5 km at the FSL, and not more than 400 m at the MOL. Nevertheless, this is merely an assumption, therefore appropriate mitigation measures must be developed and implemented, whether the elephants will swim across parts of the reservoir or not.

Potential Impacts

Potential sources of impact to the threatened and endangered at risk species are derived from the following sources: i) increased human population on the Nakai Plateau resulting in increased hunting pressure and increased competition for the same resources; ii) destruction of habitats for the threatened and endangered species; and iii) increased human access to habitats where the threatened and endangered species occur. The increased human population on the Nakai Plateau will engender considerable hunting pressure on wildlife and other natural resources. This is particularly true through the construction period and could likely continue through the operational period. The value of wildlife for the communities of the Nakai Plateau is considerably greater than that of domestic livestock. The former is considered a "free" resource or a source for additional income, and the latter is usually as maintained as the family's asset or kept for festive occasions.

A second source of impacts to the threatened and endangered species will be the destruction of habitats. To a large extent, habitats for the Asian elephants will be lost through the inundation of their mineral licks, forage areas and migration routes. Similarly, the increased human population on the Nakai Plateau and inundation of its habitat will likely cause the white-winged duck to disappear from the area.

A final threat will be the improved accessibility of the NNT NBCA to residents of the rese.lement resettlement areas and visitors, from the reservoir itself. The potential impacts to threatened and species include the extirpation of the populations from the Nakai Plateau and to some extent from the NNT NBCA.

Natural Habitats Accounting and Adequacy of Offsets

Interacting biophysical, climatic and anthropogenic factors have resulted in a complex mosaic of vegetation types in the Project area. A summary of the habitat types found in the Project area is presented in Table 3.58. Eleven habitat types are found in the maximum Project footprint of 130,589 ha. The maximum Project footprint plotted on the maps does not represent the actual area to be impacted, but rather the area within which the final construction zones will be located. In fact construction activities will probably impact less than 50% (in some case less than 10%) of the land required under the Concession Agreement, called here "Project Footprint". This is because the land requirement was defined at the stage of the Basic Design, when final location of Project infrastructure components was not finalized, and sufficient flexibility required. The actual area to be directly impacted will be significantly less (less than 50%) than the maximum Project footprint. However, as part of the project's precautionary approach, this maximum figure is used throughout this accounting document.

The most dominant habitat in the Project footprint is disturbed/regenerating forest. The second most dominant is mixed broadleaf and coniferous, followed by upper mixed deciduous forest. In total, 109,620 ha of forest habitat is represented with disturbed/regenerating forest making up 27% of this forested area. The remaining 20,969 ha is made up from non-forest habitat types, of which agriculture and swamp habitats cover an area of 11,995 ha (57%) and 4,682 ha (22%) respectively.

Natural Habitats of High Conservation Significance

The coniferous forest on the Nakai Plateau, probably the most extensive in Indochina, is dominated by *Pinus latteri* both in terms of stem density and biomass. *P. latteri* has been raised out of synonymy with *Pinus merkusii*. *P. merkusii* is found only in northern Sumatra and the Philippines, and *P. latteri* is distributed in Vietnam, Lao PDR, Cambodia, Thailand and southern Myanmar; also in extreme southern China (Hainan Island), but possibly introduced there. It is found from sea level to El 900 m, usually in open, savannah-like areas that are frequently burned by native peoples (de Laubenfels, 1988). *P. latteri* is listed as "threatened" by IUCN but in the lowest category of "low risk". On the Nakai Plateau, the tree density of the coniferous pine forest averages 58.6 trees per hectare, with trees exhibiting an average diameter at breast height of 57.1 cm, indicating that this is old growth forest (Robichaud, 2002; Margules Groome Poyry 1996), probably about 60 years old. The species is adapted to fire and is a light demanding, heat and drought tolerant tree, growing well on sandy soils, such as those on the Nakai Plateau. *P. latteri* does not regenerate under its own canopy unless there is fire. It is therefore likely possible that their presence on the Nakai Plateau is linked to human-set fires for agriculture. Though low in plant diversity in comparison to other tropical forested ecosystems, this natural habitat is a valuable ecosystem which is poorly represented in Lao PDR.

The riverine forest of the Nakai Plateau, which has yet to be ecologically or botanically characterised, is likely an ecosystem of high conservation significance. Similar natural habitats are found elsewhere in the Nam Theun catchment, along the Nam Choun and Nam Seng, but these are unlikely to be as extensive as on the Plateau.

Table 3.58: Summary of thematic habitats found in the Project Footprint (based on FIPD, 2002)

FIPD Forest Thematic Habitats	Area (ha)	% of Project Footprint Area
Forest		
Disturbed/regenerating or unstocked forest	29,236	22.4
Mixed broadleaf & coniferous forest	27,217	20.8
Upper mixed deciduous	21,688	16.6
Dry Dipterocarp	14,430	11.0
Upper dry evergreen	13,596	10.4
Lower mixed deciduous	3,140	2.4
Gallery/riverine forest	254	0.2
Coniferous forest	59	0.0
Total all forest	**109,620**	**83.8**
Non forest		
General agriculture	11,995	9.2
Swamp	4,682	3.6
Water	2,535	1.9
Grassland	846	0.6
Rock	717	0.5
Urban	194	0.1
Total non forest	**20,969**	**16.2**
Grand Total	**130,589**	**100.0**

Current Threats

A variety of threats to the integrity of the natural habitats and the survival of its biodiversity currently exist and are identified below. These threats are independent of the Project and would probably also exist in a no-Project scenario.

Logging

P. latteri is a medium-value timber that has been extracted from areas both within and outside the reservoir inundation area, and from the NBCA. This logging will continue – legally or illegally – unless proper management and enforcement is instituted (Salter *et al*, 1991 in Malaysian Environmental Consultants, 2003). GOL is making efforts to ensure that remaining stands outside the inundation area are conserved by imposing a total ban. Current controls appear to be effective, but the value and location of the remaining *P. latteri* stands puts them in jeopardy.

Fokienia hodginsii is one of the most valuable timbers in Lao PDR and grows in areas of high-altitude near the Vietnam border (Timmins and Evans, 1996). Logging within the NBCA took place in the mid-1990s, but appears to have ceased for now. In addition to the direct impacts that logging has on the forest, construction of logging roads facilitates access to critical natural habitats within the NBCA and leads to increased hunting and extraction of resources.

Commercial Extraction of Wildlife & Non-Timber Forest Products

The wildlife trade is currently a major drain on NNT NBCA resources (Robichaud, 2002), with a variety of mammal, birds and reptiles being hunted for consumption or medicine. Vietnamese traders regularly cross the border to hunt or purchase wildlife from villagers. These cross-border poachers are intensively snaring wildlife up to 20 km inside the NNT NBCA (IUCN, 1999). Considerable extraction of rattan and *Aquilaria malaccensis* (a fragrant resinous wood) has been observed in the interior of the NBCA (Timmins and Evans, 1996). With increasing population and commercial demand, these products and other NTFPs, are likely to be subjected to unsustainable collection.

Unsustainable Agricultural Practice

Long-term residents of the NBCA tend to use traditionally sustainable agricultural practices. However, it has been observed that recent arrivals to the NBCA practice a short-cycle, unsustainable form of farming (WCS, 1995). These swidden agriculture systems clear new land once their

present site is exhausted. This unsustainable agricultural practice, coupled with increasing population, is placing increased pressure on NNT NBCA natural resources.

On-going Land Development Activities on the Plateau

Natural habitats are currently being converted as a result of human activities. It is not possible to determine quantitatively what percentage of this ongoing degradation of natural habitat could be perceived as having occurred in anticipation of the Project. Clearance may well have been a continuation of practices not related to the Project; such as planned harvesting, collection by local communities or uncontrolled commercial logging.

Project Impacts

Project impacts on forest and forest biodiversity will occur during pre-construction, construction and operational phases, and are characterised as either direct or indirect impacts. Direct impacts are related to the clearance, degradation or disturbance of forest and forest biodiversity as a result of Project construction activities and operations. Indirect impacts may result from increased population and improved access to the forest, therefore generating increased pressures on forest resources. With the exception of fragmentation and buffer zones, the following account on natural habitat degradation focuses primarily on the direct impacts. A discussion on indirect impacts is earlier in Chapter 3.

Accounting for Degradation & Conversion

The impacts within the immediate footprint are taken to be absolute land-take; where degradation or conversion resulting from vegetation removal, construction, inundation or suffcient disturbance is considered as total degradation of the current habitat. However, in reality, with the exception of the Nakai Reservoir, the Project footprint is larger than the actual long-term requirement for construction and associated activities. The outstanding areas not required for construction may experience some disturbance in terms of temporary vegetation clearance, water quality, erosion, etc. For the most part, this disturbance will be temporary in nature and eventually, those impacted areas not required for direct construction might, in some instances, be able to re-establish their original natural habitat assemblage, although the duration will be determined by the extent of disturbance. Therefore, the extent of natural habitat degradation discussed below can be considered as a worst case scenario and an over representation of actual extent of impact.

Calculations indicate that of the 130,589 ha of maximum Project footprint, 62% will be natural habitat and the remaining 38% will be either non forest habitat, or disturbed/regenerating and unstocked forest. For specific habitat types, the ranked extent to be affected is presented in Table 3.59. The major habitat degradation will be in mixed broadleaved and coniferous (20.8%), disturbed/regenerating and unstocked (20.7%), and upper mixed deciduous (16.6%) natural habitats. Other habitats that will be significantly impacted are dry dipterocarp, upper dry evergreen and rice paddy, representing between 9-11% of the maximum Project footprint. Details

Table 3.59: Thematic habitat types ranked by area to be affected by the Project

Rank	FIPD Thematic Habitat	Total Area within the Project (ha)			Percentage of Respective Totals		
		Footprint	Fragments	Footprint + Fragments	Footprint	Fragments	Footprint + Fragments
1	Mixed broadleaved & coniferous	26,972	246	27,217	27.5	0.8	20.8
2	Disturbed/ regenerating & unstocked forest	18,667	8,340	27,007	19.0	25.6	20.7
3	Upper mixed deciduous	18,450	3,239	21,689	18.8	9.9	16.6
4	Dry dipterocarp	5,225	9,204	14,429	5.3	28.3	11.0
5	Upper dry evergreen	9,508	4,088	13,596	9.7	12.6	10.4
6	Rice paddy	8,617	3,291	11,908	8.8	10.1	9.1
7	Swamp	4,596	86	4,682	4.7	0.3	3.6
8	Lower mixed deciduous	441	2,700	3,140	0.4	8.3	2.4
9	Water	2,535	0	2,535	2.6	0.0	1.9
10	Ray	1,365	95	1,460	1.4	0.3	1.1
11	Grassland	838	7	845	0.9	0.0	0.6
12	Scrub	152	615	767	0.2	1.9	0.6
13	Barren land & rock	63	654	716	0.1	2.0	0.5
14	Gallery/riverine forest	254	0	254	0.3	0.0	0.2
15	Urban	194	0	194	0.2	0.0	0.1
16	Other agriculture	88	0	88	0.1	0.0	0.1
17	Coniferous forest	59	0	59	0.1	0.0	0.0
18	Unclassified	0	1	1	0.0	0.0	0.0
	Totals	98,020	32,567	130,588	100	100	100

of the habitat areas to be disturbed by individual components of the Project are presented in Annex I and discussed below.

Reservoir

The inundation of the 450 km^2 Nakai reservoir will submerge vegetation below El 538 m, covering approximately 38% of the total Nakai Plateau. For the majority of these habitat types, their value will be lost. The degradation of habitats on the Nakai Plateau due to inundation of the reservoir is an unavoidable consequence of the Project. However, not all habitats within the inundation area are natural habitats – some have already been extensively disturbed by human activity. Approximately 15% of habitats on the Nakai Plateau have already been disturbed, of which 12.6% is within the inundation area (Table 3.60).

Therefore 13% of the area to be inundated by the Nakai Reservoir has already been disturbed. Natural habitats remaining in the inundation area are mainly primary forest bordering slow-flowing rivers, small lakes and wetlands. These natural habitats to be affected by inundation include mixed broadleaf and coniferous (28%), upper mixed deciduous (18%) and upper dry evergreen (5%). An estimated 4,363 ha of swamp habitat will be affected to some degree, but depending on their location and the annual drawdown cycle of the reservoir these habitats may not be permanently lost.

Fragmentation

In addition to the 98,020 ha of land potentially directly occupied, 32,567 ha of land will be encircled by Project components. These encircled habitats will experience indirect impacts resulting from fragmentation. This fragmentation accounts for 25% of the total 130,588 ha in the Project area (Table 3.61). The majority of this fragmentation will occur in the Reservoir Zone. In terms of area, the predominant habitat types that will be impacted by fragmentation are dry dipterocarp (9,204 ha) and disturbed/regenerating and unstocked forest (8,340 ha), which respectively represent 28% and 26% of the total area to be fragmented. In terms of proportion fragmentation, for lower mixed deciduous and dry dipterocarp forest over 60% of the total impacted area is due to fragmentation. Approximately 30% of the total impacted area for upper dry evergreen and disturbed/regenerating and unstocked forest is also due to fragmentation.

Though these habitats are not directly replaced or altered, the Project will result in fragmentation of this once contiguous habitat area. The constraints made by Project components on the biological exchange between fragments are not quantifiable, and therefore the significance of this fragmentation is unknown. Nevertheless, the severity of impact will be less than the total loss caused by land-take for construction.

Table 3.60: Extent of natural habitats & disturbed habitats within & outside of the inundation area

Area	Natural Habitat Area (ha)	Natural Habitat % of Plateau	Disturbed Areas (ha)	Disturbed Area % of Plateau	Total Area (ha)	Total % of Plateau
Reservoir (Plateau land take)	32,128	25.1	16,103	12.6	48,231	37.7
NNT NBCA Plateau	76,802	60.0	3,051	2.4	79,853	62.3
Total Plateau Area	108,930	85.0	19,154	15.0	128,084	100.0

Impacts

Table 3.61. Fragmentation of habitats caused by the Project

Habitat Type	Area Fragmented (ha)	Total Area Impacted (ha)	Fragmentation as a % of Total Area
Barren land & rock	654	716	91.3
Lower mixed deciduous	2,700	3,140	86.0
Scrub	615	767	80.2
Dry dipterocarp	9,204	14,429	63.8
Disturbed/regenerating & unstocked forest	8,340	27,007	30.9
Upper dry evergreen	4,088	13,596	30.1
Rice paddy	3,291	11,908	27.6
Upper mixed deciduous	3,239	21,689	14.9
Ray	95	1,460	6.5
Swamp	86	4,682	1.8
Mixed broadleaved & coniferous	246	27,217	0.9
Grassland	7	845	0.8
Water	0	2,535	0.0
Gallery/riverine forest	0	254	0.0
Urban	0	194	0.0
Other agriculture	0	88	0.0
Coniferous forest	0	59	0.0
Total	32,567	130,588	24.9

Construction

Resettlement Area: The proposed resettlement area of 18,732 ha will be situated on the southwest side of the reservoir. Figure 3.72 (page 144) shows the 25 potential relocation sites and the habitat types in the resettlement area. The predominant natural habitats in this area are mixed broadleaf and coniferous (55%), upper dry evergreen (22%) and upper mixed deciduous (18%).

In total, only 750-1,000 ha will be degraded through conversion to agricultural land and house plots. The proposed sites for the agricultural land and house plots have already been cleared or degraded to varying degrees by past agricultural and logging activities. The majority of the remaining area indicated in the resettlement area is allocated to sustainable forest management, and as such the impact from the Project should be positive.

Nakai Dam: Approximately 1,325 ha has been allocated for the construction of the Nakai Dam and its access road. The main single natural habitat to be impacted for this construction will be in upper dry evergreen forest (35%). However, much of the habitats directly adjacent to the Nakai Dam consist of unstocked or disturbed/regenerating forest (51%). The construction of the Nakai Dam itself will only require 10-15 ha of clearance, much of which will be in the inundation area after the dam is closed.

Upgrade & Construction of Road 8B: On the Plateau, the upgrading of existing portions of Road 8B together with the construction of the new alignment will impact approximately 2,700 ha of habitats. Upper mixed deciduous, mixed broadleaf and coniferous, and upper dry evergreen natural habitats represent 70% of this area.

Power Station & Regulating Pond/Dam: Potentially, the construction of the Power Station and regulating pond/dam will impact a total of 900 ha. Much of the forest directly adjacent to the Power Station and regulating pond/dam construction areas is already degraded from past road construction and agriculture activities. This is reflected by the fact that over 60% of the area to be affected by the Power Station and regulating pond/dam comprises of either unstocked or disturbed/regenerating forest.

Downstream Channel: In the Gnommalat area, the construction of the Downstream Channel will affect over 1,650 ha of land, which, because of the greater presence of human population, predominately consists of rice paddy and agricultural land (48%). In terms of forested natural habitats, 550 ha of dry dipterocarp will be affected. Direct impact on forest in this area is therefore negligible. This impact includes the spoil areas as currently indicated.

115/500 kV Transmission Lines: Initially, the clearance of vegetation for the construction of both 115/500 kV Transmission Lines and their associated access tracks may affect up to 4,650 ha of land. This includes the section of the 115 kV Transmission Line from Mahaxai to Thakhek, under the responsibility of EDL. The Transmission Line alignments traverse rice paddy and agriculture land for 26% of the total area. These agricultural areas will not require clearing, other than the area occupied for the construction of the tower footprints. Other habitat types that will be affected by the construction of the Transmission Lines include dry dipterocarp (24%), disturbed/regenerating forest (19%) and unstocked forest (19%), which will require some degree of vegetation clearing. There is a degree of flexibility in the precise final alignment, and where possible the final route of the Transmission Lines will avoid areas of major vegetation.

During the operational phase, the Transmission Lines will impact a substantially smaller area than indicated above. The impact will be limited to the actual tower footprints themselves and routine clearing of vegetation within the easements. An estimated 782 ha of habitat will be cleared for the Transmission Line tower footprints and easement, over half of which will consist of lowland dry dipterocarp forest (Table 3.62).

These calculations are based on the assumption that no clearing would be required in rice paddy and agricultural land, and minimal clearing would occur in unstocked and disturbed/regenerating forests.

Table 3.62: Degradation of natural habitats in Transmission Line Easements

Vegetation Type	Easement			
	Segment 1 - 115/500 kV Line (ha)	Segment 2 - 500 kV Line (ha)	Segment 3 - 115 kV Line (ha)	Total (ha)
Lower dry evergreen forest	56	100	36	**192**
Lower mixed deciduous forest	42	100	12	**154**
Dry dipterocarp forest	126	240	16	**382**
Total	**224**	**440**	**64**	**728**

Buffer Zones

No direct construction is planned to take place in the buffer zones surrounding the Nam Kading and Xe Bang Fai. The primary impact associated with the Project will be the modification of hydrological regime.

Nam Kading: The buffer zone extends 270 m on either side of the Nam Kading and encompasses 11,377 ha of terrain. The major natural habitats present in the buffer zone include upper dry evergreen (25%) and upper mixed deciduous (11%) habitat, but the lesser valuable habitat types of unstocked and disturbed/regenerated forest together represent almost 40% of the total buffer zone. The main concern in this zone is the reduction in flow attributed not only to the Project but also to the operation of the Theun Hinboun Hydroelectric Project. Whilst severe impact on the vegetation is not considered likely, the dependence of key and threatened species of mammals on the aquatic ecosystem is an important element.

Xe Bang Fai: The Xe Bang Fai will experience almost a doubling of the annual discharge. The subsequent increases in erosion will, to some degree, impact the habitats surrounding the Xe Bang Fai. The buffer zone is similar in size to that of the Nam Kading, at 11,753 ha. However, due to the greater densities of human population in the area, the habitat types in the Xe Bang Fai buffer zone are predominantly rice paddy and agricultural land (44%). Dry dipterocarp (21%) is a prominent natural habitat that could be affected in this zone.

Significance of Natural Habitats to be Degraded or Converted

National Level of Significance

At a national level of significance, the maximum Project footprint will impact only 0.6% of the national area. In terms of natural habitats, the maximum Project footprint will encompass 10% of the national area of swamps , 0.8% of lower mixed deciduous area, and 0.5% of dry evergreen and coniferous forest (Table 3.63). Therefore from a national perspective the degradation of natural habitat is insignificant, with the possible exception of swamps.

The comparison on a national level requires cautious interpretation due to discrepancies in data. The national level assessment was limited to using the 1992 FIPD data for the whole country.

Sub-National Level of Significance

Terrestrial Natural Habitats: To minimise speculative accounting, details of the significance of the natural habitats to be degraded or converted at a sub-national level were generated for Bolikhamxay, Khammouane and Savannaket Provinces (Table 3.63). The total area of 130,586 ha that will be degraded or fragmented by the Project represents only 2.2% of the total area of these three provinces. The greatest impact will be on mixed broadleaved and coniferous forest, with a total of 27,217 ha being potentially affected. This represents 27% of the total habitat found in the three provinces. Swamp habitat (see footnote 1) degradation represents a 10% loss of the original provincial extent. Other important natural habitats that will register significant degradation at a sub-national level are gallery/riverine forest (6.2%), dry evergreen forest (3%) and coniferous forest (3.2%). Approximately 21,689 ha and 14,429 ha of upper mixed deciduous and dry dipterocarp will be lost respectively, but this represents only 1.5-2% of their total area in the three provinces, and should not be considered as a significant degradation. The degradation of already altered land such as rice paddy, agriculture and urban habitat types will affect between 1.4 and 2.2% of the provincial area but these are social rather than biodiversity conservation issues, and are covered in the RAP.

In summary, in terms of significance of the natural habitat lost the natural habitats ranked 1-6 are those of concern for offset measures. However, the following should be considered when interpreting the significance of the natural habitat degradation:

- The majority of the impact on the dry evergreen forest will not be land-take. This concerns the buffer area of the Nam Kading as it flows through the Nam Kading NBCA. Though inside the maximum Project footprint area, the buffer is not expected to experience significant impacts as a direct result of the Project;
- The majority of gallery/riverine forest is located in the lower reaches of the Xe Bang Fai. This is a naturally dynamic area changing shape over time, and so communities are able to adapt to periodic changes in river flow and exploit new habitat as it is made available. Increased dry season flow and erosion created by the Project may favour early colonizers of the gallery/riverine forest community;
- Swamp conditions may develop on the sandy soils of the Plateau's flooded valleys, currently covered by mixed broadleaved and coniferous forest; and
- The degradation of the lowland dry dipterocarp, lowland dry evergreen and lowland mixed deciduous forests may not be significant in terms of conservation value. These lowland forests exist in relatively densely populated areas and have been subject to much disturbance and exploitation. These forests have long been used for timber and firewood collection, hunting, and gathering of NTFPs – activities which have subsequently reduced the complexity, diversity and density of the forests. The clearing of the forest for agriculture has left fragmented remnants that do not have the habitat values associated with similar vegetation communities in less populated areas. Taking these factors into consideration, the proposed clearing in the lowland areas (for Power Station, Downstream Channel and Transmission Lines) will not pose a significant threat to natural habitats.

Therefore, at the sub-national level of significance the major natural habitat degradation will be in the mixed broadleaf and coniferous forest. This natural habitat class can be considered as a fire climax that has created a mosaic of broadleaf and conifers, with conifers dominating in areas that have been recently burnt, but unable to regenerate under their own canopy. In time they are replaced by broadleaf species. The conifers on the Plateau appear to have been selectively logged, which would leave organic matter in the soils of the logged areas, and thus favour broadleaf regeneration. The species of this community are expected to be relatively quick to exploit the opportunity. As a result of the Project land-take however, the areas with the necessary environmental conditions that

Table 3.63: Habitat occurrence and degradation for Bolikhamxay, Khammouane and Savannaket Provinces

Habitat Type	Total Provinces Area (ha) (FIPD 2002)	Total National Area (ha) (FIPD 1992)	NT2 Project Area (ha)	NT2 Project Area + Fragmented Areas (ha)	% of NT2 Foot-print + Local Provinces	% of NT2 Footprint + Nation	Habitat Degrada-tion Rank in the 3 Provinces
Mixed broadleaved & coniferous	100,838	0	26,972	27,217	27.0	na	1
Swamp	45,955	46,934	4,596	4,682	10.2	10.0	2
Gallery/riverine forest	4,091	0	254	254	6.2	na	3
Coniferous forest	1,849	12,333	59	59	3.2	0.5	4
Dry evergreen	459,383	2,566,847	9,508	13,596	3.0	0.5	5
Water	89,694	181,654	2,535	2,535	2.8	na	6
Rice paddy	544,133	923,020	8,617	11,908	2.2	1.3	7
Dry dipterocarp	716,417	1,444,411	5,225	14,429	2.0	1.0	8
Urban	10,788	20,064	194	194	1.8	1.0	9
Lower mixed deciduous	182,666	383,056	441	3,140	1.7	0.8	10
Ray	92,486	457,031	1,365	1,460	1.6	0.3	11
Upper mixed deciduous	1,480,886	7,203,863	18,450	21,689	1.5	0.3	12
Agricultural	6,128	113,204	88	88	1.4	0.1	13
Non-forest	2,056,982	8,643,727	19,657	28,619	1.4	0.3	14
Barren land & rock	211,072	217,082	63	716	0.3	0.3	15
Bamboo	20,111	835,979	0	0	na	na	16
Forest plantation	0	1,230	0	0	na	na	
Unclassed or cloud	1,547	0	0	0	na	na	
Total	6,025,024	23,050,433	98,020	130,586	2.2	0.6	

favour development will be reduced and these cannot be recreated or substituted elsewhere.

Aquatic Habitats: A total length of 673,135 m of river will be inundated by the reservoir out of a total length of 2,340,919 m found on the Nam Theun catchment above the Nakai Dam. This represents 29% of the total length and should be considered as a significant degradation. Outside the inundation area, the change in hydrology will alter the environmental equilibrium of river habitat. It is not possible at this stage to quantify the degradation of river habitats that might occur through sluggish river sections, rapids, pools, sand banks, etc.

Impacts on Protected Areas: It is anticipated that the Project will directly impact approximately 1,181 ha of land within the PHP – NNT Corridor. This represents only a 2.6% impact on a total corridor area of 45,123 ha. Figure 3.57 illustrates the areas of impact within the PHP – NNT corridor. It should be pointed out that the Project will not directly impact the NNT NBCA through construction activities: the only protected area to be directly impacted will be the PHP – NNT Corridor.

Overall an estimated 10,567 ha of protected area will affected by Project activities. The majority of this area is not subject to physical land-take. Over 85% of this total area will experience only indirect impacts, which include:

- The areas surrounded by fragmentation caused by Project roads and facilities in the PHP – NNT corridor on the Plateau – 4,317 ha or 40.9%; and
- River buffer around the Nam Theun and Nam Kading as it flows through the Nam Kading NBCA and the PHP – NNT corridor – 5,062 ha or 47.9%.

The significance of impacts on the protected areas needs to go beyond quantifying immediate land-take alone. The issues of concern for the NNT NBCA and neighbouring protected areas include the effect on function at a regional level, and at the local level the impact on biological functioning and movement of wildlife between the NNT NBCA and the PHP NBCA. Therefore the size of the fragmented area in the PHP – NNT corridor may be less important than its location in a critical area between the NNT and PHP NBCAs. The biological function of the corridor area is difficult to quantify, and it is hard to assign biological indicators to assess any changes in function. Concerns have been raised over the movement of elephants and the small remnant population of White-winged ducks (if still present) in the corridor.

In addition to direct land-take, the effects of reduced river flow on aquatic communities needs also to be considered. The proposed reduction in flow in the Nam Theun below the dam site to a minimum flow of 2 m^3/s will have a significant impact on the aquatic community, especially in the 12 km section of the Nam Theun between the dam site and the confluence with the Nam Phao. Further downstream, the effect on the flows of the Nam Kading in the Nam Kading NBCA will also be influenced by the management of the Theun-Hinboun dam.

Importance of Natural Habitat Degradation to Species

Assuming the principles of the planned salvage logging are followed, when the water level in the reservoir rises, few if any terrestrial animals will be either forced out of their natural habitat or trapped in isolated pockets. Natural habitat degradation will have an impact on biodiversity at the community, species and genetic levels.

Using the habitat criteria for species whose niche has a river type component, the following species will be affected:

- The White-winged duck will experience degradation of the existing habitat on the Nakai Plateau (but new suitable habitat is expected to be formed in the Special Conservation Areas north of the reservoir); and
- The fish eagles, the Crested and Blyth's Kingfisher, and the River lapwing, have ranges that cover higher elevations. Some 30% of their habitat will be degraded.

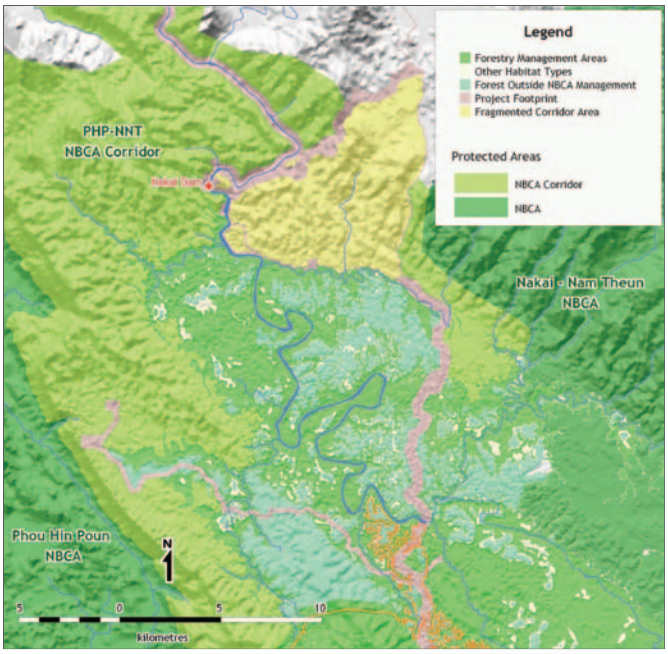

Figure 3.57: Habitat areas impacted within the NNT-PHP Corridor.

Inundated Areas & Wildlife Movements

The inundation area of the Nakai Reservoir will impact both natural habitats and wildlife. Some species that habitually cross the Plateau may continue to do so after inundation. During periods when the reservoir water level is at FSL, movement will be limited to flying and swimming species. The banks are steep in this area, and there will be little change to the surface area of the islands as the water changes depth. Species able to swim, such as elephants, will be able to island hop and swim across the corridor. In periods when the reservoir water level is low, constraints on movement may possibly be similar to those experienced before the Project.

In general, the terrestrial species that use the river corridor to travel will likely find the reservoir an impediment to their movements. However, the relatively shallow slopes of the dividing hills adjacent to the reservoir are not expected to be a major constraint to north-west/south-east movement.

White-winged Duck

The reported five to ten remaining pairs of White-winged duck select natural habitats below 600m (WCS, 1995). The length of river degradation below 600 m due to inundation totals 664,542 m. Comparing this degradation to that remaining in the NNT NBCA shows a shortfall of 27,216 m. Comparing the same degradation to just the area within the NNT NBCA, the shortfall rises to 370,535 m. This implies that the available natural habitat for the White-winged duck will decline to 30% of the current area when the reservoir is inundated, leaving only suitable habitat in a band between El 538 to 600m. However, new suitable habitat should form in the embayments and Thousand Islands parts of the reservoir.

Considering the low population numbers of the White-winged duck, this local degradation of its fundamental niche area may not be significant. In terms of resource needs, the reduced area may be sufficient to support the current population. There is however an issue is the viability of the remaining population (they have not been seen for nearly ten years) and preservation of the genetic diversity they contribute to the world population.

Elephants

The Asian elephant has been identified as a species of special interest to the Project, as natural habitat degradation will be extensive for the species, and there exists a potential for increased conflict with the human population. It is the key large mammal on the Plateau, and hence the conservation of this species can ensure the conservation of other species using the same natural habitats. Current threats are from hunting and natural habitat degradation. The main Project impacts on the elephant population include further degradation of natural habitats (including critical resources such as mineral licks), increased access for poachers, disruption of movement patterns, and increased conflicts with the resident human population (which can lead to injury and death to both humans and elephants). Elephants in the northern end of the Plateau range into the NNT NBCA and the PHP NBCA. Past experience with elephants in reservoir areas indicates that inundation may not alter habitual movements significantly, but the risk still remains that new routes may be adopted.

Creation of Habitats

The Project will create a host of habitats, primarily in the inundation zone of the Nakai Reservoir. Potentially, the habitats that will be created include:

- Lacustrine habitat of the reservoir;
- Island habitats with various forest types formed by the inundation;
- Ephemeral and permanent swamps adjacent to the reservoir;
- Smaller lakes, pools and sluggish streams created by the back water of the reservoir; and
- Mudflats and seasonal grasslands created by the annual reservoir drawdown.

The extent and connectivity of these permanent and ephemeral habitats will depend on both seasonal variations in rainfall and seasonal dynamics of inundation resulting from the operation of the Project. On an annual basis, these habitats will undergo both increases and decreases in size. There is a degree of scientific uncertainty attached to the creation and characterisation of these habitats as they have a broad possibility of becoming functional habitats supporting a wide array of both plant and animal diversity. The habitats created by the Project will take time to stabilize and support communities. Fluctuations in niche volume created by seasonal changes in reservoir level could cause a decrease in the population of some species that attempt to adapt to the new conditions. It would therefore be premature to speculate on the possible contribution of these habitats created by the Project in supporting certain communities or populations of conservation importance. The enclaves that will be created on the northeast side of the reservoir have the potential to form important habitats, such as wetlands and small lakes, for fish spawning and feeding and for other important species associated with these types of habitat. The potential of the northern part of the reservoir and the northern embayments to become appropriate/acceptable habitats for the ducks has already been mentioned. The feasibility of creating slow-flowing artificial wetlands close to the existing White-winged duck habitats but above the inundation zone, is worthy of investigation.

Area to be Protected by the Project

The principle offset for degradation of natural habitat by the Project is the financial assistance and management support for the conservation of the 338,718 ha NNT NBCA and adjacent protected areas. This management is under the control of the Nam Theun 2 Watershed Management and Protection Authority. To assist the operations of the WMPA, a management framework and detailed operational plan, the SEMFOP, has been developed. The framework and plan should ensure the long term sustainable manage-

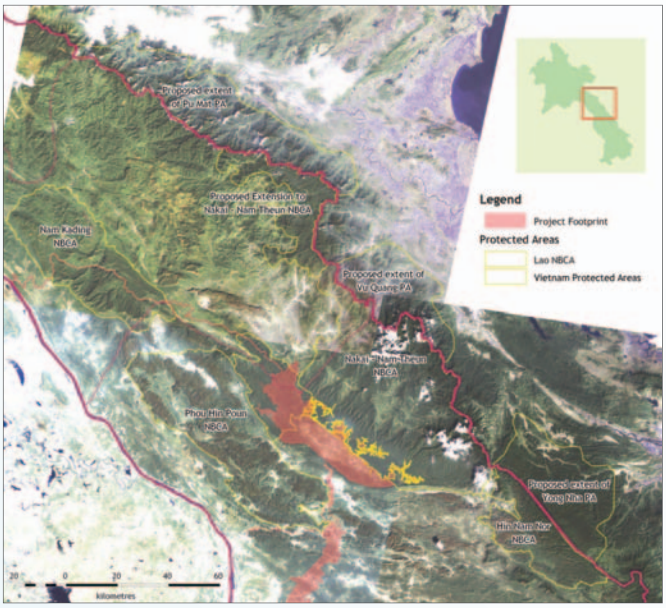

Figure 3.58: Regional Protected Areas.

ment of the area. The Project will provide initial funding of US$ 6.6 million for activities prior to the start of Project operations, and US$ 1 million for each year of the operating phase thereafter. GOL currently has few resources to devote to the conservation and management of conservation areas.

Adequacy of Offsets

Regional & Global Significance of the NNT NBCA: The northern Annamite Mountains are of outstanding importance in terms of global and regional biodiversity. In recent years, two endemic species of ungulates have been discovered – the saola (*Pseudoryx nghetinhensis*) and the large-antlered muntjac (*Muntiacus vuquangensis*), and Heude's pig (*Sus bucculentus*), long thought to be extinct, has been rediscovered in the area (Duckworth *et al*., 1999). Several species of fish, mostly new to science, were considered to be endemic to the Nakai Plateau – e.g. *Scaphognathops theunensis* and *Tor ater* – but now are known to inhabit headwaters of the Nam Theun catchment outside the zone of direct impact.

The NNT NBCA, within these northern Annamite Mountains, is the largest protected area in Lao PDR and is considered one of the most important protected areas in Asia (Robichaud, 2002) and of global significance (MacKinnon, 1997). On a regional level, the NNT NBCA has the country's most important forest cover in terms of extent and quality (Berkmuller *et al*., 1995), and is ranked the highest overall in terms of threatened bird and mammal species (Ling, 1999).

The NNT NBCA is contiguous with the Vu Quang Nature Reserve in Vietnam. The PHP – NNT and NNT – HNN corridors link NNT NBCA with Hin Nam Nor NBCA and Phou Hin Poun NBCA respectively (Figure 3.58).

The proposed northern extension of the NNT would link it with the proposed Pu Mat Reserve in Vietnam. As a result of its central location, the NNT NBCA is considered a linchpin for protected area systems in the region. The NNT NBCA acts as a core through which genetic material is transported between the surrounding protected areas. Apart from the value of the varied natural habitats for species richness, the biological functions of the NNT area are assumed to regulate populations and species distribution. From a management point of view, these biological functions provide a regulating mechanism to sustain biological diversity, and in the short term prevent local extinction. Without some form of management presence to protect the NNT NBCA from unsustainable human use and natural habitat degradation, biological diversity in all the region's protected areas will experience decline.

The current threats to the NNT NBCA, highlighted earlier in this annex, will continue unless adequate resources can be made available for its management and protection. Figure 3.59 shows that northern and central parts of the NNT NBCA have been disturbed, while the southern parts appear to have experienced relatively little human activity. Therefore it is imperative that successful management is implemented to prevent any further degradation of this globally significant area.

Adequacy on a Habitat Level: As Table 3.64 shows, with few exceptions, the areas of analogous forest and habitat type offset in the NNT NBCA significantly exceed those that will be lost as a result of the Project.

In particular, the natural habitat types of dry evergreen, upper mixed deciduous, coniferous and gallery/riverine forest are fully offset by the conservation of the NNT NBCA. However, not all natural habitat types will be represented in the offset area, and of those that are, their representation may not be equivalent to the area of impact in the maximum Project footprint. These exceptions include swamp habitats, mixed broadleaf & coniferous, lower mixed deciduous and dry dipterocarp forest.

In terms of aquatic habitats, the NNT NBCA will protect 859 km of river with slope < 5°, compared to the 622 km of degradation due to the inundation of the reservoir. This conservation of similar habitat can be considered as an adequate offset for the degradation of aquatic habitats due to the reservoir.

It has already been suggested above that using the uplands area of the NNT NBCA as an offset for impacts to lowland natural habitat types means that environmental impact at the regional and national levels shall be minimal. There is potentially a significant shortfall of mixed broadleaf and coniferous forest in the NNT NBCA offset compared to the area lost from inundation. However, despite concern about the potential loss of diversity of conifers at the genetic level, the degradation of the forest community and species population is not the main issue. The greater degradation will be the environmental conditions of the river in this area that constitutes a natural habitat for a number of species, including potentially the White-winged duck. This species, if its continued presence is confirmed on the Nakai Plateau, has restricted habitat preferences, and any habitat degradation would be of global significance.

Neither lower mixed deciduous nor dry dipterocarp natural habitats are represented in the NNT NBCA, and therefore the offset cannot be seen as adequate for these habitat types. However, at a national and provincial level the impact on both these natural habitats is not perceived as significant.

The decision on whether the degradation of one natural habitat area can be compensated by the conservation management of another is subjective and depends on the values assigned to the natural habitat degraded or protected. The fact that the security of the NNT NBCA has been made dependent on the Project is not a relevant issue. What is relevant is the possible loss of biological diversity through non-effective management of the NNT NBCA in a no-Project scenario. The security of the NNT NBCA is of critical importance for regional as well as global conservation. Thus any degradation of individual natural habitat elsewhere could be outweighed by the potential gains in improved regionally and globally important biological communities in the NNT NBCA. To use the White-winged duck as an example, the degradation of its existing habitat may be potentially severe, but as it is believed that there is currently only a small population, this may not be significant.

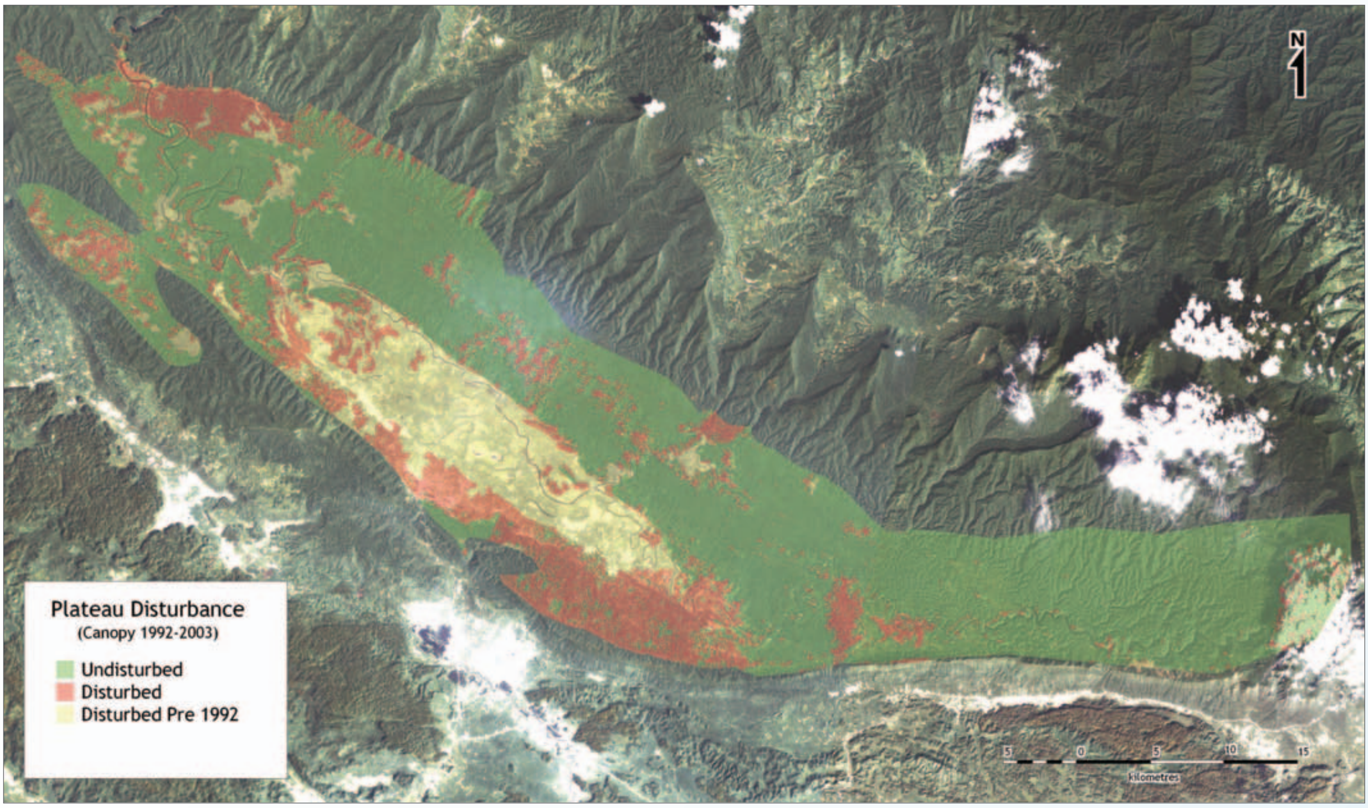

Figure 3.59: Historical clearing 1973-present.

All remaining individuals could be accommodated in the area available and if hunting and habitat disturbance (for this and other species) can be minimised, then it is possible that the area of suitable habitat can be increased even though the absolute size of the existing habitat declines. In this way, effective land resource management can more than offset degradation.

Conclusion

Natural habitats in the Project area are currently being converted as a result of human activities. From 1973-2003, forest cover within the area of the Nakai Plateau decreased by 11% to 60% cover, and forest cover within the inundation zone decreased by 13% to 48%.

Table 3.64 Adequacy of the NNT NBCA as an offset for Project impacts (ha)

Habitat Type	Maximum Project Footprint	Maximum Project Footprint + Fragmentation	NNT NBCA	% of Immediate Area Offset in NNT NBCA	% of Immediate & Fragmented Areas Offset in NNT NBCA
Dry evergreen	9,508	13,596	189,219	100	100
Upper mixed deciduous	18,450	21,689	48,513	100	100
Gallery/riverine forest	254	254	934	100	100
Coniferous forest	59	59	51,262	100	100
Non-forest	19,657	28,619	43,813	100	100
Ray	1,365	1,460	2,124	100	100
Agricultural	88	88	1,052	100	100
Urban	194	194	63	32.5	32.5
Rice paddy	8,617	11,908	1,507	17.5	12.7
Swamp	4,596	4,682	181	3.9	3.9
Mixed broadleaved & coniferous	26,972	27,217	45	0.2	0.2
Lower mixed deciduous	441	3,140	0	0	0
Dry dipterocarp	5,225	14,429	0	0	0
Barren land & rock	63	716	0	0	0
Water	2,535	2,535	0	0	0
Total	**98,020**	**130,586**	**338,718**		

Impacts

Of 130,589 ha of maximum Project footprint that could potentially be affected, 62% will be natural habitat and the remaining 38% will be either non-forest habitat, disturbed/regenerating or unstocked forest. The major habitat degradation will be in mixed broadleaved and coniferous (20.8%), disturbed/regenerating and unstocked (20.7%) and upper mixed deciduous (16.6%) natural habitats. Other habitats that will be significantly impacted are dry dipterocarp, upper dry evergreen and rice paddy, representing 9-11% of the maximum Project footprint. An estimated 10,567 ha of protected area will be affected by Project activities. The majority (85%) of this area is not subject to physical land-take but indirect impacts of fragmentation or river buffer.

From a national level perspective, the degradation of natural habitat is insignificant, with the exception of swamps (see footnote 1). The Project will encompass 10% of the national swamp area. From a sub-national perspective the greatest impact will be on mixed broadleaved and coniferous forest and swamps, with 27% and 10% of the total habitat found in the three provinces potentially impacted. Other natural habitats that will register significant degradation at a sub-national level are gallery/riverine forest (6.2%), dry evergreen forest (3%) and coniferous forest (3.2%).

The areas of habitat types offset in the NNT NBCA significantly exceed those that would be degraded as a result of the Project. Dry evergreen, upper mixed deciduous, coniferous and gallery, gallery/riverine forests are fully offset by the conservation of the NNT NBCA. Lower mixed deciduous and dry dipterocarp natural habitats are not adequately offset by the conservation of the NNT NBCA. However, the impact on these natural habitats is not perceived as significant at either the national or provincial level.

Mitigation Measures & Enhancements

The following are recommendations for further evaluation of the species, and potential measures for improving their habitats and managing the populations..

Monitoring for Wildlife

Although not exhaustive, basic baseline information on the Nakai Plateau wildlife is available from various studies (Delacour 1929, Francis et al. 1996, WCS, 1995b, 1996a, Timmins and Evans 1996, Evans et al. 1997, 2000, Evans and Timmins 1998, Duckworth et al. 1998a, 1998b, Thewlis et al. 1998, Boonratana, 2000, Khounboline, 2002) that could be used to initiate a monitoring programme. Furthermore, the programme needs only to focus on certain indicator species (e.g. elephants, primates, hornbills) to monitor wildlife and habitats, and to focus on certain human activities to monitor impacts on wildlife and habitats. Detection of as-yet unrecorded species and confirmation or refutation of hitherto provisionally recorded species can be simultaneously carried out with the monitoring programme. More species would likely be added to the list of monitoring indicators once monitoring has been continuously carried out for several years.

A rigorous monitoring programme would obtain data that could detect actual changes and trends in populations, and data that could be statistically tested. Rigorous methods would produce realistic census data and density estimates, important for conservation and management. However, they would require very large time investments by competent human resources to monitor the ecological parameters and to manage the data.

Minimisation of Impacts During Construction

To minimise the impacts of work camps related to the construction of the dam, a priority will be to ensure that the HCCEMMPs are well advanced before construction begins. In addition, WMPA personnel must acquire the relevant competence, in particular, patrolling must be in place.

GOL has recently adopted the protected area competence standards developed by the ASEAN Regional Centre for Biodiversity Conservation. These will serve as important guidelines in developing the capacity of WMPA personnel. A training needs assessment, intensive capacity development and on-the-job training programmes would be required. The management would need to develop a proactive, highly organised and well co-ordinate patrolling plan, possibly with additional human resources from the district military and police, and the local communities.

Zonation will be required, and locations of work camps and the carrying capacity of the campsites will be determined to minimise impacts on wildlife and their habitats. To minimise impact on the Plateau, the majority of the proposed work camps are located in the lowland Gnommalat plain, with possibly a single work camp located northeast of the Nakai Dam, adjacent to Road 8b, to provide workers for dam construction (the location of work camps is given in Figure 2.18). Waste disposal facilities will need to be developed for both human waste and garbage, to prevent transmission of diseases to wildlife and littering.

Minimisation of Impacts During Impoundment

During the construction phase, prior to impoundment of the Nakai Reservoir, a wildlife specialist will analyse known and potential threats to animal populations in the Nakai Reservoir area, and prepare a detailed plan to minimise impacts on animal populations when the Nakai Reservoir is formed. While it is recognised that the NNT NBCA is a large area of protected habitats, some animal populations may already occupy many of the suitable habitats. In addition, problems may arise in relocating some species from the Nakai Plateau because habitats in the NNT NBCA are significantly different. Although some populations of threatened species will likely stabilise once hunting is managed, habitat suitability in the NNT NBCA will nevertheless need to be evaluated prior to filling the Nakai Reservoir, in order to identify suitable habitats for these species.

In addition, an important precautionary measure to undertake prior inundation is with respect to human resettlement. Resettlement of affected villages should neither be anywhere near the elephants' known range nor near any critical wildlife habitats (feeding patches, mineral licks, and leks). The former is to avoid the likelihood of displaced elephants seeking food in or near human settlements and/or agricultural lands, therefore effectively preventing escalation of human-elephant conflicts.

When the reservoir fills, wildlife will be drowned, displaced or stranded on the islands formed. Gradual filling of the reservoir to resemble natural floods may eventually cause many animals to move to higher ground. However, specialists will need to be identified at least a year before the planned inundation, and a wildlife rescue plan will have to be established and fully operational at least six months before the planned inundation. This includes establishing and training teams, identifying viable and potentially viable islands, establishing holding areas, acquiring appropriate equipment and drugs, and identifying release sites. As new islands will be formed each year, the training component should include the training of locals to manage the operations as and when the needs arise.

In addition, animals stranded on islands will be vulnerable to poachers. Hence, there needs to be intensive and extensive patrolling of the reservoir islands, and this will likely require additional human resources and equipment (speedboats, electric outboards, radios, and spotlights) for the first few years. Patrolling before inundation would comprise a combination of boat, o.-road bike, and foot patrols. After inundation, focus of patrolling would be on the use of boats, and occasionally on foot for some of the larger islands.

The proposed investigation will focus on:

- Potential methods for early mitigation to encourage animals to move before filling of the reservoir;
- Developing an understanding of how the Nakai Reservoir will fill and how and where islands will form;
- Comparing data with past and current wildlife surveys;
- The need for communication and co-ordination between NTPC, GOL, WMPA, district and provincial authorities and villagers;
- Development of measures to manage organised hunting parties; and
- Identification of methods for enforcement activities to minimise hunting and wildlife trade.

In addition to these pre-emptive measures, a decision regarding physical rescue of animals stranded on the islands will include:

- Identification of competent specialists to lead and manage the operation;
- Identification and training of field teams involved in the rescue operation;
- Selection of equipment and methods for wildlife capture, transport and release;
- Fulfilling specific requirements for equipment and resources for rescue efforts;
- Establishment of criteria for euthanasia of injured animals;
- Establishment of animal handling procedures;
- Development of a programme schedule; and
- Necessary training for field teams to prevent hunting of vulnerable animals;

Management of Key Wildlife Species

As mentioned above, about 40% of the plateau will be inundated and of the remaining area, about 50% of the forests are in relatively good condition. There may be sufficient habitat to maintain viable populations of most of the Nakai Plateau fauna. However, some wide-ranging predators (e.g. tiger) are territorial and they may require an area the size of the reservoir just to maintain a few breeding males. Other animals such as elephants move seasonally between widely dispersed resources or ephemeral resources like bamboo, and therefore require special mitigation and management measures. The primary management programme to be developed and implemented for the key bird and mammal species, identified earlier as presently found on the Nakai Plateau, will be based on proactive patrolling and enforcement, not only for the plateau but also for the NNT NBCA.

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Elephant Conservation Programme

The Asian elephant is the key large mammal on the Nakai Plateau, hence any programme designed to conserve this species will very likely benefit other species using the same habitats. Thus, there needs to be a clear understanding of the area for the elephants, including the assessments of: i) population size and distribution; ii) migratory patterns; iii) current suitability of habitats and resource use for elephants; and iv) how future habitat suitability will change as a result of inundation.

Boonratana (2000) has made recommendations, which included:

- Carrying out a study on the ecological importance of mineral licks to the elephants and other herbivores. This study was conducted by Khounboline (2002), who examined the composition of mineral licks in the Nakai Plateau and provided some insight into the nutritional value of mineral licks to the elephants, and their influence on the elephants' ecology, behaviour and ranging patterns; and
- Carrying out a long-term study on the ecology and behaviour of the Asian elephant on the Nakai Plateau, for at least three continuous years before the reservoir fills and for at least three continuous years after that.

Thus, efforts must geared towards maintaining or achieving high quality habitat, which is characterised by: i) proximity to water, foraging areas, and mineral licks; ii) availability of a mosaic of habitat types; iii) availability of preferred food plants; iv) low levels of habitat fragmentation and alienation; v) contiguous areas of habitat sufficiently large to support a viable population; and vi) retention of seasonal movement corridors.

In addition, Khounboline (2002) suggested testing known methods (detection methods, passive deterrents, and active deterrents) for protecting crops from elephant raids, with the aim of developing practical tools that can be used by the local rural communities. This study will be incorporated into the elephant programme to help reduce the impact on elephant-human conflict once the reservoir fills.

The mitigation measures to conserve elephant populations will need to take into account the population dynamics and the extensive use of resources on the Nakai Plateau. In addition, the potential for increased interactions with human populations must be incorporated into the management plan. In terms of mitigation measures against the impacts of habitat loss, escalated human-elephant conflict and other related issues arising primarily through creation of the reservoir, Boonratana (2000) proposed the following:

- Creation of artificial mineral licks in the NNT NBCA, with the aim of drawing the elephants away from the currently existing mineral licks to alternative mineral sources on the northern side of the reservoir; and
- Identification and habitat improvement of "elephant islands". There is a strong likelihood that within time, the elephants will reuse their traditional routes, thereby causing escalation in human-elephant conflicts. Thus, suitable "islands" should be selected for habitat improvement before their formation. Criteria for selection should include only those islands that are along the elephants' routes and those that are well distanced from human settlements.

Of equal importance is resettling affected villages well away from the elephants' known range, as displaced elephants are likely to seek food in or near human habitations. Thus, distancing the resettled villages (and where they are allowed to carry out agricultural activities) will lessen the chances of human-elephant conflicts.

NTPC has requested the assistance and expertise of WCS for the development and implementation of the elephant programme. This programme, to start in the dry season of 2004, is to design and test management plans that could serve to reduce potential human–elephant conflict along the south shore of the reservoir. In order to do so, it is necessary to accurately determine the size and distribution of the elephant populations across the entire Plateau, assess the current habitat/resource use, identify seasonal movement patterns and the quality of habitat that will be available to elephants after inundation, including the presence of other mineral licks. A Nakai District conflict response team needs to be trained and mobilised to gather systematic data on human–elephant conflict across the entire Plateau, so as to provide district authorities an understanding of conflict. The programme will work with villagers to test low-cost crop protection methods that have proven to be successful in preventing human–elephant conflicts.

Compensatory Forestry

A forest area of approximately 28,000 ha will be lost as a consequence of the Project, mainly in the area to be inundated by the reservoir (Singh, 2004). No endangered and endemic tree species are expected to be lost.

Project will restore a similar area of currently degraded forest, under a compensatory forestry programme. If necessary, GOL will provide the required land for compensatory forestry activities at no cost to the Project.

Different areas with a crown cover less than 20% and which could qualify for this programme have been earmarked. There are (i) the degraded forests within the NNT-NPA; (ii) the area reserved for the sustainable forestry component of the resettlement action plan;(iii) degraded forests on the Nakai Plateau that will not be affected by the inundation. If these areas are not sufficient, then degraded forests outside of the area affected by the Project could be considered.

A rapid assessment of degraded forests in the Project area gives approximately 32,000 ha of degraded forest within the NNT-NPA (Singh, 2004), out of which 28,000 ha could be set aside for natural regeneration. It is believed at this stage that several hundreds hectares could qualify under the sustainable forestry component of the RAP. A preliminary estimate gives approximately 15,000 ha that will qualify for natural regeneration with very limited interventions. Based on the available data, preliminary assessment indicates that the above regeneration scheme would cost about$4.2 million.

Activities will start when the reservoir is created on the Nakai Plateau. During the five years after this date, GOL and NTPC will confirm the availability of areas eligible for the compensatory forestry programme, under the various options indicated above. Different activities will be undertaken, including inter alia, detailed surveys of the degraded areas, site selections, consultation with local people, development of management plans for these areas, preparation of groundwork, including development of nursery of suitable native species.

The second phase of the programme is expected to start from year six after the inundation, and will be a combination of assisted natural regeneration, enrichment planting, and other techniques that will be identi.edidentified during the first phase of the programme. A monitoring programme will also be set up to evaluate growth and conditions of the areas looked after. $5 million will be made available to undertake the compensatory forestry work ($4.2 million plus $0.8 million contingency) subject to confirmation of the detailed cost after completion of the detailed field surveys on the available degraded land in the NNT-NPA.

Impacts Associated with Construction

Generally, many significant impacts are observed during the construction of hydropower projects. Most construction activities will impact water and air, and will generate noise. Such impacts are presented with associated mitigation measures in the first part of this section. The second part deals with specific impacts associated with some specific construction activities, principally with construction of the Nakai Dam, quarries, spoil disposal areas, work camps and the labour force, the Headrace Channel and the upper and lower portions of tunnels, the Power Station and substations, and the Downstream Channel. The third part of this section deals with impacts linked to other specific construction and Project developments, such as the initial filling of the reservoir at the end of the construction period, the construction of roads, the Transmission Lines, the impacts associated with resettlement, and potential impacts to physical and cultural resources within the construction areas.

Givven that some aspects of the design cannot be fully assessed until the construction techniques and requirements of the Head Construction Contract (HCC) are determined, the EIA of these components can only be preliminary in nature and limited to identifying the major areas of consideration. Although several areas have been identified, the precise location of the quarries, spoil disposal sites, construction work camps and work areas are yet to be determined. Before new quarries for, sand, laterite and sandstone are opened; an EIA is to be undertaken by the HC. For spoil disposal sites, quarry sites, construction work camps and work areas, a plan detailing the locations, designs and environmental safeguards will be prepared as part of the Head Construction Contractor's Environmental Management and Monitoring Plan (HCCEMMP), and will be prepared

A discussion of quarry sites, spoil disposal, and construction work camp areas is included below to present the framework within which the activities will be determined and to provide general information on locations which have been identified as possible sites. Atleast 3 months before construction activities are scheduled.

The HCCEMMP will be the main document for the environmental management of construction activities. The plan will include a number of sub-plans for implementing protection and mitigation measures addressing environmental impacts created by the construction activities. These sub-plans are listed in Table 3.65. Monitoring programmes will be developed to ensure that impacts during construction are effectively mitigated and controlled.

The HCC contains a number of environmental requirements relating to construction, termed the 'Owners Requirements' (OR). These requirements are presented in Annex L, and are designed to ensure implementation of measures that will mitigate or minimise impacts identified during the Project environmental assessment. The HCCEMMP must include all requirements specified in the Owners Requirements. The HCCEMMP is described further in Chapter 6.

General Impacts Generated by all Construction Activities

All construction activities have the potential to have impacts on water quality, air quality and noise. These impacts are described in this section.

Water Quality

Sources & Types of Impacts

The major sources of construction-related impacts on water quality will be from erosion of disturbed areas required for the construction activities (construction sites, concrete batch plants, material storage areas, vehicle maintenance areas, spoil disposal areas), from wastewater discharge at the construction camps, and from contaminated water (oil, grease, petrochemicals, cement, chemicals).

The consequence of these impacts is the potential for introducing sediments and pollutants to water bodies during construction, thereby affecting aquatic habitats, fishes and water sources for residents and wildlife downstream of the construction areas.

Mitigation

The HC will be required to prepare several plans, including an Erosion and Sediment Control Plan, and a Water Quality Monitoring Plan, incorporating the requirements presented in Annex L. The following mechanisms will be used to mitigate and minimise impacts on water quality:

1 – Management of potential erosion and runoff from disturbed areas around the construction sites, including the following measures:

- All runoff from construction areas, including concrete batch plants, will be directed to sedimentation basins. Erosion control facilities will be installed throughout the construction areas and will include silt traps, fences and sedimentation basins where appropriate, depending upon the size of the catchment. The sedimentation basins will have adequate storage capacity and are to be regularly inspected, with accumulated sediments removed throughout the construction period;
- Catch drains, diversion drains, table drains, windrows and associated drop-down drains will direct site runoff to established watercourses. These will be inspected regularly for any damage caused by scouring, sediment deposition, channel obstruction and loss of vegetative cover, and all erosion control measures will be maintained;
- Soil and spoil removed from the construction areas will be stockpiled separately and stabilised with grasses or other vegetation. This material will either be stored permanently at the spoil disposal areas, or if possible returned to the original construction areas. At the end of the construction period, construction areas will be re-graded to conform to the natural topography of the areas. After placement, the areas will be seeded with grasses or shrubs of an appropriate variety to stabilise the soil and promote re-vegetation. It may be possible in some cases to leave the area as graded and allow for natural invasion of plants into the area. The regrading and replanting of the area will restore wildlife habitat in the construction areas.
- Erosion and Sediment Control Design Plans will be prepared and comprise details of implementation of drainage works, sediment traps, diversions, culverts and other structures designed to treat water to an acceptable quality before discharge into the natural watercourses. All structures are required to be in place prior to commencement of construction;

2 – Treatment facilities to remove oils and grease from drainage water before discharge to adjacent watercourses will be installed. This is of particular importance for runoff from vehicle maintenance areas. Monitoring of oil and grease skimmers is required throughout the construction period.

3 – Refuelling of heavy equipment and machinery will be undertaken by a service vehicle, with appropriate safeguards and protection measures to prevent spillage or contamination by chemical wastes or maintenance oils and lubricants. All fuel and hazardous material will be stored to minimise the potential for spills (the requirements for the HC's Chemical Waste/ Spillage Management Plan and Emergency Plan for Hazardous Materials are presented in Annex L).

4 – Wastewater treatment plants will be installed to treat all wastewater generated from work camps and other facilities associated with the construction of the Project (the requirements for the HC's Waste Management Plan are presented in Annex L).

5 – Any use of synthetic chemicals, especially relating to vegetation clearance, is required to follow the HC's Chemical Waste/Spillage Management Plan, and in accordance with the Pest Management Plan

Air Quality

Source & Types of Impacts

Vehicles and stationary equipment will impact air quality at the construction sites through emissions from engines. Additionally, quarrying activities, concrete batch plants, construction work and movement of vehicles along unpaved roads will generate dust and impact air quality. The burning of waste will also affect air quality.

Mitigation

Maintenance of vehicles and stationary equipment in good working order will reduce negative impacts on air quality. Spraying water on the unpaved roads will be used to control dust. The burning of waste is discouraged and shall be done in designated areas away from settlements. Burning of any materials which produce toxic gases is not permitted. The HC will be required to prepare an Emissions and Dust Control Plan.

Noise

Source & Types of Impacts

Sources of noise will include vehicles, excavation equipment, concrete batch plants and crushers located at the construction sites. Other sources of noise will be explosives used for tunnelling and to prepare the foundations and abutments for construction of the dam.

Noise in and around the construction area is likely to affect wildlife and residents in nearby areas. Wildlife in the area is likely to move away from the noise and eventually return to the area when construction is complete.

Mitigation

Maintenance of the vehicles and construction machinery in good working order and installation of noise mufflers on all engines will

Table 3.65: Sub-plans of the HCCEMMP for implementing protection and mitigation measures

	Sub-plan
1.	Erosion and Sediment Control Plan
2.	Spoil Disposal Planning and Management Plan
3.	Quarry Management Plan
4.	Water Quality Monitoring Plan
5.	Chemical Waste/ Spillage Management Plan
6.	Emergency Plan for Hazardous Materials
7.	Emissions and Dust Control Plan
8.	Noise Control Plan
9.	Physical Cultural Resources
10.	Landscaping and Revegetation Plan
11.	Vegetations Clearing Plan
12.	Waste Management Plan
13.	Reservoir Impoundment Management Plan
14.	Environmental Training for Construction Workers Plan
15.	On-site Traffic and Access Management Plan
16.	Explosive Ordnance Survey and Disposal Plan
17.	Construction Work Camps and Spontaneous Settlement Areas Plan
18.	Manual of Best Practices in Site management of Environmental Matters
19.	Project Staff Health Program

reduce the noise nuisance. To reduce the impact of noise on wildlife, explosives will only be used during daylight hours when wildlife is less active than during night time. The HC will be required to prepare a Noise Control Plan that includes these measures

Impacts Associated with Specific Construction Activities

Construction of the Nakai Dam

Areas to be Cleared

The areas to be cleared at the Nakai Dam site are shown in Figure 3.60. Areas will be cleared and levelled to enable storage of equipment, materials and the placement of the concrete batch plant. An access road will be constructed to enable movement of vehicles to and from the construction site. The Nakai Dam construction will require the diversion of the Nam Theun from the dam site, through a tunnel. Materials excavated from the foundation area will need to be taken off-site for disposal.

Impacts of Clearing

Construction may impact air quality (dust and engine emissions), water quality (erosion and sedimentation, contamination), and wildlife and vegetation within the immediate vicinity of the construction area (destruction of habitats). Most of the activities and therefore the impacts associated with construction of the dam will occur during the dry season. For the most part, these disturbances will be temporary in nature and eventually the areas downstream of the Dam will be returned to forested areas.

Mitigation of Clearing

Because construction of the dam will only occur during the dry season, provision for maintaining the construction areas during the wet season will be necessary. A primary concern for the construction areas is the potential for erosion of soils from the disturbed areas. Mitigation of other construction impacts on water quality, air quality and noise are discussed above.

Diversion of Water

During the construction period, little impact to the hydrologic regime of the Nam Theun is anticipated: one cofferdam will be located upstream from the dam site and a concrete lined tunnel, six metres in diameter and around 200 metres long will enable diversion of water around the construction area. A second cofferdam will be constructed downstream from the dam site and will prevent backwater effects into the construction area. A drawing of this arrangement is shown in Annex D.

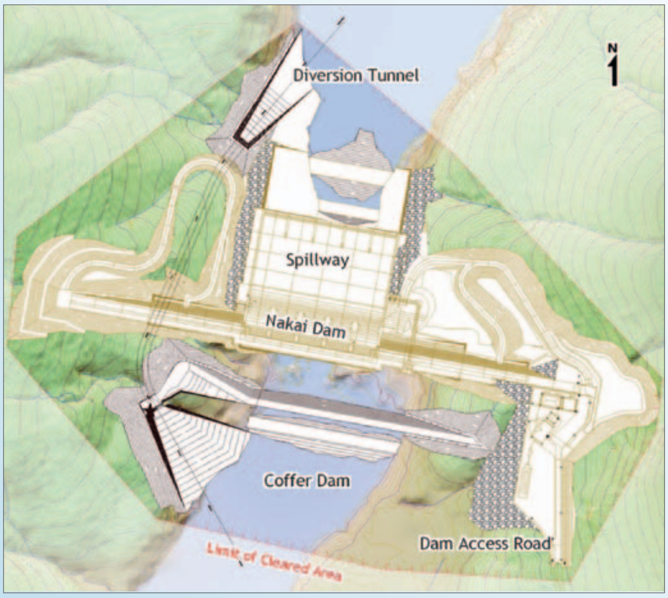

Figure 3.60: Area to be cleared for construction of the Nakai Dam

At the end of the construction period, the downstream cofferdam will be entirely removed and the cofferdam upstream will be partially removed to El 520 m. The diversion tunnel will be permanently plugged with 12 metres of concrete and the closure of the dam will then begin to fill the reservoir area and the minimum riparian release regime will begin. At this point, the discharge in the Nam Theun will be affected but flow in the Xe Bang Fai will not, until discharge from operation of the Power Station begins.

Impacts of Cofferdam & Diversion Tunnel Construction

Construction of the cofferdams and diversion tunnel will start prior to any construction activity of the dam itself. This is necessary to enable excavation of the foundation and abutment areas for the dam. The main impact associated with cofferdam construction is sedimentation that it will create in the Nam Theun during the period of construction, and then the diversion of water from the Nam Theun through the tunnel, which will impact the movement of fish through the area. The timing of the close of the diversion tunnel and dam will impact on the initial natural stocking density of the new reservoir.

Mitigation of Cofferdam Construction

Appropriate mitigation measures to limit sedimentation in the Nam Theun will be implemented.

At the end of the construction period, the cofferdams will be removed, and an appropriate location for the spoil will be selected (this will be included in the HCC Spoil Disposal Plan). Standard recommendations for minimising soil erosion will be followed, including grading if necessary and revegetation (HCC Landscaping and Revegetation Plan, HCC Erosion and Sediment Control Plan).

Scheduling of the closure of both the diversion tunnel and dam during the peak of wet season will allow early wet season upstream migrating fish to increase the initial stocking density of the reservoir. The timing of the closure needs careful consideration with other technical and economic aspects of the Project.

Quarries

Source of Impact

Limestone aggregate, sand, laterite and sandstone will be required for various Project uses, such as road base for the new roads, and for concrete for the Nakai Dam, regulating dam, saddle dams, Power Station, intake structure, tunnels and portions of the Downstream Channel.

Some potential quarry sites have been identified as sources of limestone, sand, laterite and sandstone. These areas fall within three main zones: i) Nakai Dam site zone: three potential sand sources and two potential sandstone sources are located in this area. In addition, a limestone quarry has been identified at Phou Pha Phen, north of the Nakai Dam site area and near Ban Lak Sao and Road 8B; ii) Road 12 to Thakhek zone: in this zone, three sand sources and three laterite quarries have been identified; iii) downstream zone: two laterite quarry sites have been identified near the Downstream Channel as well as a previously used, but currently not operational, limestone quarry located at Pha Thung, near the junction of Roads 12 and 8B.

Material from the quarries will be crushed to appropriate size for use in the concrete batch plant, and some material from the quarry will be used for riprap. Washing of the aggregate will also take place at the quarry sites.

Type of Impacts

Opening of the quarries will cause visual impacts because they will remove a significant part of the hills. Other impacts will be the noise generated during blasting and crushing, dust produced during blasting and crushing, transport of the aggregates, and transport of materials to the nearby rivers. These noise and dust impacts could affect wildlife in the area,

Recent studies of the ecology of karstic formations in East Asia, cited in Vermuelen and Whitten (1999) and Urwin and Berwick (2002), have confirmed that isolated karstic formations have the potential to harbour unique forms of life and create a different biological diversity, due largely to the possibility of localised endemism of species and sub-species. Vermuelen and Whitten (1999) recommend the exploitation of limestone resources within large tracts of karsts, rather than the destruction of an isolated karstic tower. The identified resource in the Phou Pha Phen area falls between these two options. It is an isolated outlier of a large consolidated karstic formation some thousands of square kilometres in extent

Mitigation

Standard mitigation measures against erosion and sedimentation, noise and air pollution will be taken, in particular for the use of explosives.

At the end of the exploitation, quarries will be rehabilitated. This will include re-establishment of vegetation, restoration of natural water courses, avoidance of flooding of the excavated areas, achievement of stable slopes, and avoidance of features which would otherwise constitute a risk to health and safety or a source of environmental pollution.

The HC will be required to prepare a Quarry Management Plan as outlined in Annex L, and other plans to address the construction impacts discussed above (erosion and sedimentation, dust). A specific Quarry Management Plan must be prepared for each quarry site.

Spoil Disposal Areas

Impacts

While some of the spoil material generated during excavation at all construction sites will be used in construction of roads, bunds, sediment traps, landscaping and resettlement village construction, the remaining spoil material will be placed in specific Spoil Disposal Areas. The total amount of spoil is estimated at approximately 15 million m^3. In addition to the destruction of habitats covered by spoil, other potential impacts could occur to water quality through erosion and sedimentation.

The locations of the Spoil Disposal Areas will be determined once the process of optimising the construction engineering and alignment options for the Downstream Channel and other Project earthworks is completed. Figure 2.17 shows a number of sites that have been identified as potentially suitable and Table 3.66 presents the potential sources of spoil, estimated volumes, and probable disposal sites.

Mitigation

The final sites for disposal will be determined through environmental studies and local consultations, to be incorporated into the HCC Spoil Disposal and Management Plan, as per the requirements specified in Annex L. A plan must be prepared for each site.

Work Camps, Work Areas & Labour Force

Four zones have been identified for potential construction camp development to accommodate a maximum construction worker population of approximately 4,000 workers. The selected areas are shown on Figure 2.18. Construction contraction will allow families of Lao workers to settle within the camps and will ensure that services are provided within these camp, preventing the development of spontaneons, eitherly that will not be allowed by GOL authorities in the proximity of the camps.

Impacts

Potential impacts from the workforce and of the spontaneous development, at the work camps in all construction areas, will be in terms of additional pressure on land and natural resources, including hunting near the camps and, directly and indirectly, on the NNT NBCA. The camps and the spontaneous development will generate solid and liquid wastes. Additionally, the spontaneous development near the construction camps could create public health risks, including an increase in the prevalence of sexually transmitted diseases, such as HIV/AIDS.

Without treatment, wastewater from the work camps and the spontaneous development could cause water quality problems in adjacent water bodies, and could affect local populations, the labour force, new communities, and fish populations. Inappropriate solid waste disposal could lead to the contamination of soil and rivers, and the spread of communicable diseases..

Mitigation

The environmental management of construction work camps will be specified in the Construction Works Camp developed within the HCCEMMP. Requirements for this plan are presented in Annex L. Of particular importance, GOL will enforce strict regulations preventing hunting in the Project area, including in the NNT NBCA.

Licenses to operate businesses, such as restaurants and bars, will be conditional upon appropriate disposal of wastewater, waste and good sanitary conditions. These licences will be established, reviewed and renewed regularly by GOL. Solid waste collection and proper disposal outside of the reservoir area will be established to ensure that solid wastes do not affect water quality in the adjacent water bodies (HCC Waste Management Plan).

A Project Staff Health Programme will be established to educate and provide health services to the workforce relating to the prevention and control of disease vectors, communicable and sexually transmitted diseases.

The same environmental provisions that apply to other construction areas will also apply to the construction work camps.

Construction of the Headrace Channel & Upper Tunnel

Construction of the Headrace Channel will occur on the Nakai Plateau between the Intake Structure and the Nam Theun. A section at the end of the Headrace Channel will be cleared of vegetation and overburden to enable free flow of water from the reservoir, at its minimum operating level (MOL), to the intake structure. The upper tunnel will be constructed between the intake structure and the Power Station. Construction will primarily involve excavation of materials from the Headrace Channel and the tunnel, and concrete lining.

Impacts

Excavation of the Headrace Channel and the upper tunnel to the Power Station will involve movement of vehicles and the use of excavating equipment, explosives and other types of machinery. A primary impact of this construction will be the placement of spoil removed from the Headrace Channel and the tunnel. Selection of

Table 3.66: Potential sources of spoil and disposal sites

Potential Location	Estimated Volume of Spoil Generated (m^3)	Description of Anticipated Spoil Disposal Sites
Nakai Dam	500,000	Spoil to be disposed upstream of dam, in dead storage of reservoir where possible, as well as stockpiled for road construction
Headrace Channel	3,100,000	Spoil to be used for construction of saddle dams, sediment traps, and the remaining would be placed in spoil deposit zones within reservoir
Headrace Tunnel, surge shaft & access adit	155,000	Spoil to be deposited in spoil location across from access adit on Road 8B, with total capacity for 230,000 m^3
Pressure Shaft and Tunnel, Power Station foundations, Tailrace Channel	1,300,000	Required for switchyard platform (~500,000 m^3), platforms for power station (60,000 m^3), and other areas around left bank of regulating pond, which have an approximate total capacity of 2,400,000 m^3
Regulating Pond	1,500,000	Spoil is to be used in construction of the Regulating Dam and deposited along edge of Regulating Dam and left bank of the regulating Pond
Downstream channel	8,700,000	Approximately 5,200,000 m^3 is estimated to be needed in construction of channel (banks as needed, access road parallel to channel as required). Preliminary sites have been identified along the downstream channel and further studies will determine their suitability for disposal of the 3,500,000 m^3

Note: * indicates following year

where the spoil materials can be placed will be a major consideration in the planning for the construction activities.

The clearing of the area between the intake structure and the MOL of the reservoir will be another source of impact.

Construction of the intake structure will require the installation of a concrete batch plant adjacent to the portal opening. The concrete batch plant will also be used to mix the concrete necessary for lining the upper tunnel and for the lining of the surge chambers. Placement of the concrete for the intake structure, tunnel lining and surge chamber will require movement of vehicles to the various locations. Installation of the concrete batch plant could also create some impacts associated with air quality, water quality and noise. Movement of vehicles bringing aggregate to the batch plant from the Pha Thung quarry could also create similar impacts.

Tunnel drainage water could also create impacts if discharged to adjacent water bodies without treatment.

Mitigation

Standard construction impacts will be mitigated as required by the various plans to be prepared by the HC (air quality, water quality, noise, spoil disposal). Tunnel drainage water will be collected and treated during construction of the upper tunnel.

Construction of the Power Station, Lower Portion of Tunnel & Substations

Construction of the Power Station and the lower tunnel will have similar impacts to those identified for the Nakai Dam site and the Headrace Channel. The main potential sources of impacts include: i) disturbance of lands; ii) disposal of spoil material; and iii) operation of construction equipment.

Impacts

A mixed deciduous and dry dipterocarp forest currently covers the area that will be disturbed for construction of the Power Station. Much of the forest directly adjacent to the construction area is already degraded by road construction and agriculture. The Power Station switchyard and substation construction will require the clearing of an additional two to three hectares of mixed deciduous forest.

Disposal of the spoil materials will require selection of an appropriate location. Indication of the locations of the spoil areas is presented in Figure 2.17.

The major potential impact at the construction and spoil disposal areas includes erosion and the runoff of cement, oils and grease, particularly during the wet season. This could result in damage to fish populations and pollution of water sources for residents living downstream from the construction areas.

As above, tunnel drainage water could also create impacts if discharged to adjacent water bodies without treatment.

Mitigation

Standard construction impacts will be mitigated as required by the various plans to be prepared by the HC (air quality, water quality, noise, spoil disposal). Tunnel drainage water will be collected and treated during construction of the upper tunnel.

Construction of the Downstream Channel

Impacts

Construction of the Downstream Channel will involve a 27 km corridor from the Regulating Dam to the Xe Bang Fai. In addition to the construction itself, the main sources of impacts to the downstream reach include the change in hydrology of the Nam Phit, disturbance of land and the placement of spoil materials.

As the Downstream Channel will parallel the Nam Phit in some sections, its construction will affect the hydrology in the Nam Phit. However, changes in hydrology are not expected to be significant during construction, as construction will only take place during the dry season when discharge in the Nam Phit is low. During the wet season, the discharge in the Nam Phit will likely be diverted to the finished sections of the Downstream Channel and then returned to the Nam Phit channel through a breach of the levees forming the banks of the Downstream Channel. The hydrologic change during the construction period will likely affect fish populations that migrate into the Nam Phit for spawning. Other potential impacts during the construction of the Downstream Channel relative to the changes in hydrology will be the interruption of irrigation systems along the margin of the Downstream Channel.

Mitigation

During the construction period, little mitigation is available for changes in hydrology.

Spoil Disposal Sites

While some of the spoil material will be used in construction of the roads, rim bunds, sediment traps, landscaping and resettlement village construction, the remaining spoil material will be placed in specific areas. The total amount of spoil is estimated at approximately 15 million m^3. In addition to the destruction of the habitats covered by the spoil, other potential impacts could occur to water quality through erosion and sedimentation. The locations of the spoil areas will be determined once the process of optimising the construction engineering and alignment options for the Downstream Channel and other Project earthworks is completed. Figure 2.17 shows a number of sites that have been identified as potentially suitable and Table 3.67presents the potential sources of spoil, estimated volumes, and probable disposal sites. The final sites for disposal will be determined through environmental studies and consultations, to be incorporated into the HCC Spoil Disposal Plan, as per the format of Schedule 12 of the Owner's Requirements (Annex L).

Other Impacts Associated with Construction Activities & Project Developments

This section presents other impacts associated with the initial filling of the reservoir, and impacts associated with construction activities and Project developments such as the roads, the Transmission Lines and the resettlement sites.

Initial Filling of the Reservoir

Filing Sequence

The length of time required to initially fill the Nakai Reservoir will depend on when filling starts. Table 3.67 indicates the rate at which the reservoir will fill, based on a computer simulation. If reservoir filling starts at the beginning of the wet season, the first hold point could be achieved in two to four months. However, if the reservoir filling starts at the end of the wet season, the filling process would not be achieved until the start of the following wet season, almost a year from the initial start of the filling process. During the filling it is assumed that the minimum riparian release of 2 m^3/s will be released from the Nakai Dam in compliance with the riparian release requirement.

Figure 3.60 shows the filling of the reservoir with a start time for each month of the year.

During the filling process, the water level of the reservoir will be controlled by the operation of the Nakai Dam. Several hold points will be observed for testing the power tunnels and the Power Station, as follows:

- Stage 1: the Head Contractor shall hold the level of the reservoir at elevation 527 m for three weeks to check the integrity of most of the Project structures (hold point number 1);
- Stage 2: the Head Contractor shall control the impounding of the reservoir from elevation 527 m to 533 m such that the maximum gradient of rise is never greater than 0.5 m/day. The Head Contractor shall hold the level of the reservoir at elevation 533 m for four weeks to check the integrity of most of the Project structures (hold point number 2); and
- Stage 3: the Head Contractor shall control the impounding of the reservoir from elevation 533 m to 538 m such that the maximum gradient of rise is never greater than both 0.2 m/day and one metre in ten days. The Head Contractor shall hold the level of the reservoir at full supply level for six weeks to check the integrity of the Project structures (hold point number 3).

Impacts

When the Nakai Reservoir is filled, 450 km^2 of land below El 538 m will be submerged. All existing vegetation and habitat types in the inundation zone will be lost, as will be their current economic, social and subsistence values.

During the filling process, some fuel wood and commercial timber could be recovered from the reservoir area. The original forest will not regenerate within the reservoir area because of the inundation.

With the rise of water level in the reservoir and the subsequent loss of terrestrial habitats on the Plateau, including the few remaining stands of *Pinus latteri*, resident and visiting wildlife, including birds, will need to find new habitats and territories. A large number of islands will form on the western end of the Nakai Reservoir and some animals might find refuge on these islands. However these habitats will not be large enough to accommodate all animals. Some animals, including some mammals and reptiles, might become stranded on these islands. It is also likely that animals on the islands will become vulnerable to hunting, including cats, primates, civets, wild cattle, and ungulates. The seasonal migration of large mammals, such as elephants, from the NNT NBCA to the Phou Hin Poun NBCA will be disturbed by the presence of the reservoir, resulting in potential conflicts between animals and the local population.

Mitigation

The loss of the stands of *Pinus latteri* on the Plateau will be compensated by the protection of the remaining stands above the inundation zone at several sites north of the proposed reservoir and in the southernmost sections of the Plateau.

A plan will be developed for the management of animal relocation in order to reduce potential conflicts with the local population.

An elephant programme that is currently being developed will assess elephant population size, migratory patterns and resource use to help provide recommendations on management strategies to prevent elephant-human conflict.

Table 3.67: Dates of water level meeting target levels for each calendar month

Target	EL 522 m		El 525.5 m		El 538 m	
Start	Average Year	Driest Year	Average Year	Driest Year	Average Year	Driest Year
01-Jan	29 Jan	15 Feb	20 Apr	21 May	23 Aug	12 Dec
01-Feb	17 Mar	8 Apr	20 May	6 Jun	25 Aug	1 Jan*
01-Mar	25 Apr	12 May	1 Jun	15 Jun	28 Aug	3 Mar*
01-Apr	14 May	1 Jun	5 Jun	18 Jun	31 Aug	4 Apr*
01-May	26 May	6 Jun	9 Jun	24 Jun	1 Sep	5 May*
01-Jun	6 Jun	13 Jun	17 Jun	1 Jul	4 Sep	5 May*
01-Jul	3 Jul	7 Jul	8 Jul	20 Jul	15 Sep	6 Jun*
01-Aug	2 Aug	8 Aug	5 Aug	21 Aug	3 Nov	7 Jul*
01-Sep	2 Sep	4 Sep	7 Sep	12 Sep	21 May*	8 Aug*
01-Oct	4 Oct	10 Oct	12 Oct	26 Oct	29 Jul*	9 Sep*
01-Nov	9 Nov	16 Nov	25 Nov	18 Dec	13 Aug*	10 Oct*
01-Dec	16 Dec	22 Dec	23 Dec	9 Mar*	18 Aug*	11 Nov*

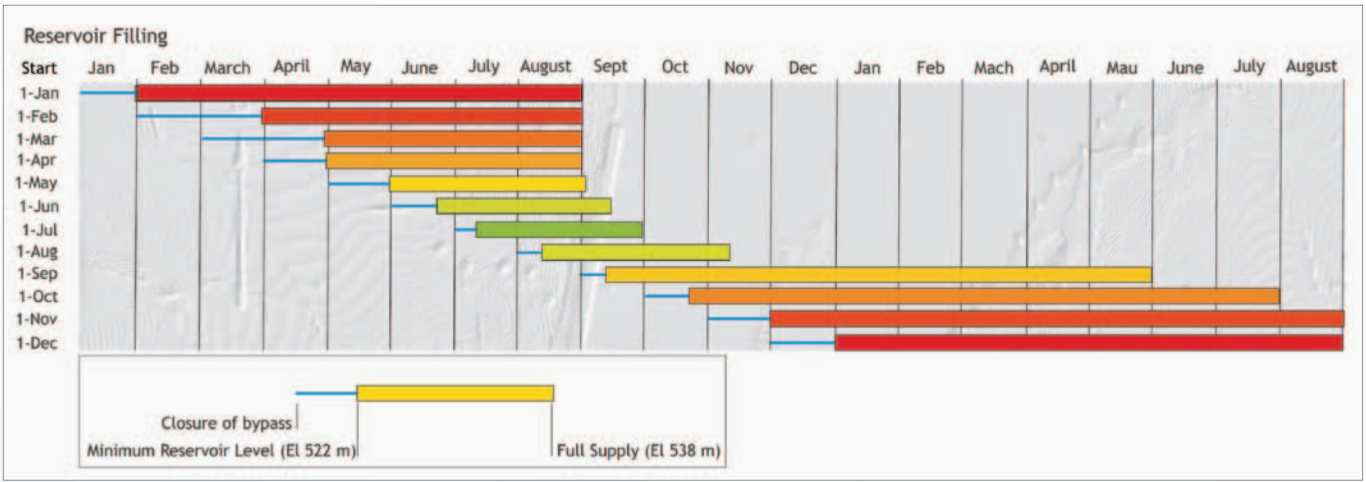

Figure 3.61: Reservoir filling

Roadways

The Project involves upgrading approximately 106 km of public roads and the construction of 56 km of new public roads. In addition, access roads and tracks, some of them of a temporary nature, will be constructed between public roads and Project facilities to enable construction, operation and maintenance. Some of the roads and tracks, especially along the Downstream Channel, will be left in place for possible future use as intermittent maintenance access.

This section presents: i) the design and construction requirements; ii) an assessment of the environment that will be impacted by road construction; iii) a discussion on the potential direct and indirect environmental impacts from the construction and use of the roads; and iv) mitigation strategies and measures.

The main focus of this section is on the two segments of new road alignments: i) the section of the road crossing the reservoir; and ii) the dam site access road. Upgrading of roads will not cause significant environmental impact over and above that of the existing roads, with the exception of impacts that will occur during the upgrading construction activities. Safeguards to ensure that road upgrades will not generate additional disturbance to the environment and will remedy any existing poor environmental performance will be included in various sub-plans of the HCCEMMP which cover erosion control, landscaping and best practices in drainage and earthworks.

Description of Roadworks

Description of Segments of Roads to be Upgraded & Constructed

Details of segments of roads to be upgraded and constructed can be found in Figure 2.16

Options Package

Should the agreed quotation submitted by the Contractor for works described for all the roads above be less than US $30 million, GOL may select items from the options package set out below in order that GOL Road Assets provided by NTPC reach the value of US $30 million. The options all involve upgrades to existing roads and do not include the construction of any new roadways. The options are:

- Further upgrade to applicable roads to include double bitumen surface treatment, rather than the gravel surface specified for Project category A roads;
- Ban Nam Niam to junction with dam access road near Ban Phonkeo: 12 km improvement to road to make it 7 m wide and conform to Project category B standards;
- Junction with dam access road near Ban Phonkeo to junction with Phou Phako quarry access road near Ban Phonxai: Upgrade of 8.5 km to existing road, to be 7 m wide and to conform to Project category B standards; and
- From the junction with Phou Phako quarry access road near Ban Phonxai to Ban Lak Sao: Upgrade of 14 km of road, to be 7 m wide and to Project category B standards.

As these potential upgrades are not yet finalised, they cannot be specifically discussed in this section. However, the same mitigation measures described below for the anticipated impacts of the known road works will also apply to any Options Package upgrades.

Design & Construction Requirements

Roads will be designed to the criteria shown in Table 3.68 All other design and construction requirements will be in accordance with the Lao PDR Road Design Manual as published by the Ministry of Transport, or to AASHTO standards where the Lao PDR Road Design Manual does not provide the necessary information. The design of the bridges and pavements will also comply with AASHTO standards.

Environment Crossed by the Road Works

Routing of New Roadways

The planning of design routes for the new roadways incorporated inputs from ground surveys to minimise social and environmental impacts and to provide for the best technical and financial solution. A formal alternatives analysis has not been conducted for the siting of the new roadways as the proposed routings have proved to be highly suitable, with expected low environmental and social impacts. An alternative for Segment 6, running between the escarpment and the reservoir before joining the dam site and Segment 7 (Figure 2.16) was rejected because of the disturbances it would have caused to the NNT – Phou Hin Poun NBCA corridor and because the route selected has less impacts on the corridor, which the road must unavoidably cross.

Resettlement & Compensation

It is not anticipated that resettlement will be required for the construction of the roads, as the areas crossed are sparsely populated. A survey using satellite interpretation and ground truthing is being conducted to identify if and how much of the land that will

Table 3.68: Design criteria for roads

Design Item	Category A	Category B	Category C	Category D
Traffic (vehicles/day)	<300	<300	<300	<100
Terrain	Flat	Mountainous	Mountainous	NA
Design Speed (km/hour)	80	40	40	40
Formation Width (m)	9	7	7	5
Number of lanes	2	2	2	1
Lane Width (m)	3	3	3	3
Carriageway (m)	6	6	6	3
Paved Shoulder (m)	NA	NA	0	NA
Unpaved Shoulder (m)	2 x 1.50	2 x 0.50	2 x 0.50	2 x 1
Max. Gradient (%)	6	8	12[1]	8
Min. Horizontal Curve (m)	250	60	60	60
Min. Vertical Curves:				
Crest (km)	5	1	1	1
Sag (km)	2	0.6	0.6	0.6
Max. Superelevation (%)	6[2]	6[3]	6[3]	6[3]
Crossfall:				
Paved (%)	NA	NA	2.5	NA
Unpaved (%)	3	4	NA	4
Paved Shoulder (%)	NA	NA	4	NA
Unpaved Shoulder (%)	5	5	5	5
Road Reserve (m)			40	
Bridge Design Live Load	HS - 25 – 44	HS - 25 – 44	HS - 25 - 44	HS – 25 - 44
Bridge width (m)	7	7	7	5
Bridges clearance (m)	4	4	4	4
Max. Pavement Axle Load (Tonne)	11	9.1	9.1	9.1
Flood Bridges (years)	100	100	100	100
Flood Culverts (years)	50	50	50	50
Pavement	Gravel	Gravel	Concrete	Gravel

Notes: 1. Generally < 8% up to 12% maximum locally; 2. Super-elevation may be increased to 8% in selected locations only; 3. Super-elevation may be increased to 10% in selected locations only

be crossed is currently used. Areas where compensation may be required can then be pinpointed. The details of this baseline survey and the framework for compensation are presented in the SDP.

Vegetation in the Area of Road Construction

The Nakai Dam site access road (Segment 7) will pass through evergreen forest for the majority of its length. This habitat type is uncommon on the plateau itself, occurring only in small parcels. It is widespread in the NNT NBCA and on the southern escarpment. In the area of the road alignment, this forest varies from semi-dense to dense forest (70% canopy cover) with trunk diameters of 20-60 cm. Floristically, the canopy consists of 80% non-deciduous trees dominated by *Dipterocarpus alatus* and *Hopea*, *Pterocarpus*, *Lagerstroemia* and *Anisoptera*, which are all valuable timbers. The understorey is dominated by ferns and palms.

Segment 6 will traverse a mosaic of mixed deciduous and dry dipterocarp forests, which are generally restricted to the rim of the inundation area. The forests along the road alignment are of open structure with 30-50% canopy cover. The dominant species are primarily *Dipterocarpus*, with *Lagerstroemia*, *Pometia*, *Schima*, *Stereospermum* and *Cratoxylon*, and to a lesser extent *Pterocarpus* and *Pinus latteri*.

As it crosses the inundation zone, Segment 6 goes through a small area of unstocked forest, where all valuable timber species have been removed, leaving a 20-30% canopy cover and an understorey dominated by *Cyperus* sp. and *Cimbopogon* sp. These open forest areas retain habitat value for many bird species, especially birds of prey and insect feeders.

Potential Impacts

Environmental impacts include both direct impacts at the road construction sites and in the immediate surroundings, and indirect impacts in the adjoining area, such as induced economic, social or environmental effects, whether planned or spontaneous, which are the results of increased accessibility and lower transportation costs.

Forest & Vegetation Clearing

An estimated 1,380 ha of forest vegetation will be cleared for road construction (refer to Figure 3.62). The largest area of clearing (580 ha) is within mixed broadleaf and coniferous habitat.

Change in Hydrology

The first 25 km of the new road alignment of Road 8B between Nakai and the point at which it turns northwards to cross the inundation zone will traverse the edge of the future reservoir. The road has the potential to intercept runoff water entering from the reservoir's southern catchment. In order to maintain access with the relocated villages of Ban Nakai Neua, Nakai (Oudomsouk) and Nakai Tai at the edge of the reservoir, the road will traverse the flanks of the slope of the plateau rim, separating approximately 5.5 km^2 of catchment surface area from the reservoir. The drainage towards the Plateau along this stretch is along numerous parallel gullies.

The new alignment, which crosses the inundation zone, will be a combination of multi-span bridges and causeways linking the multiple islands that are formed when the reservoir is filled.

Island Habitats

The new alignment of Road 8B across the inundation zone will be in the form of a causeway. Fill will link the high points, which will be islands in the completed reservoir (at FSL). The area the road will cross is currently classified as unstocked and disturbed mixed deciduous forests. When the area is inundated the high points will become islands and the vegetation may act as wildlife refuges.

Erosion & Sedimentation

Parts of the alignment of Segment 6 are high gradient, and mitigation measures will be incorporated to minimise impacts – particularly on steep slopes and uns soils, where runoff and drainage will be high. Excessive runoff and loss of soil can lead to vegetation damage, and thus deterioration of natural habitats and water quality.

Large-scale disturbance can also occur through slips and landslides in steep areas, particularly those involving high gradients such as the relocation of Road 8B between the escarpment and reservoir at FSL.

Dust

Dust raised from the road during construction, and subsequently raised by vehicles, can pose a health hazard and damage vegetation along the side of the road.

Construction Workers

The influx of new workers will add to the number of people in the area, potentially increasing hunting, fishing, and gathering of forest products in areas adjacent to the roads. If not managed properly, solid waste and waste water have the potential to contaminate soils, groundwater and nearby rivers and streams.

Disturbance to Crops

In areas near the roads, there is potential for crops to be disturbed, damaged, or raided by animals as a result of construction of the roadways. In the case of upgraded roads, no significant increased impact is expected to crops as animals can already access these areas on existing roads. With respect to Segment 8 (resettlement area roads) the roads will traverse through areas that are largely unused for agriculture. In the case of the two new road segments, Segment 6 is a relocation of an existing road. A large part of this segment of new road cuts through the reservoir and hence will not disturb crops.

Car Interactions with Livestock & Wildlife

Traffic on the roads during construction and during operation might cause accidents with livestock and wildlife moving on the roads.

Impacts on Natural Resources Linked with Economic Growth

The improved year-round access to the whole Project area from new and upgraded roads will enable people to settle in the area. Use of the improved access will enable movement from one area to another. This will translate into the development of roadside villages, and a potential increased pressure on the natural resources in the vicinity of the roads. The increased pressure will include uncontrolled logging, hunting and fishing, wildlife and non-timber forest product collection, livestock husbandry on the Nakai Plateau, shifting cultivation in forest areas and forest fires. These impacts are expected during the economic development of the Project area.

Public Health

The influx of people into the area is associated with an augmented risk of transmission of diseases, including sexually transmitted diseases, including HIV/AIDS. More traffic on the roads during construction and operation could increase accidents within communities living adjacent to the roads. Aquatic invertebrates known to be vectors of disease could inhabit stagnant water created during construction of roads. The increased prevalence of such diseases may impact the health of communities and the construction workforce.

Interference with Movements of Wildlife

Road construction, human presence and traffic will interfere with the natural movements of wildlife.

Mitigation

Potential impacts are summarised in Table 3.79. They are accompanied by recommended mitigation strategies designed to minimise the significance of impacts. The table also presents an indication of parties that will be responsible for their execution and monitoring. Mitigation of impacts commonly associated with other construction activities, such as erosion control, sedimentation, dust, pollution are not repeated here. They are detailed under the obligations of the HCC.

Transmission Lines

This section provides: i) a description of the activities to be undertaken to construct the transmission lines; ii) details of the existing environment along the transmission line routes; iii) a discussion on the potential environmental impacts from the construction and operation of the lines; and iv) detailed mitigation measures to minimise and/or eliminate adverse environmental impacts.

Description

Transmission Lines Characteristics

The Project includes the construction of three Transmission Lines. The planned routes for the 500 kV and 115 kV Transmission Lines are shown in Figure 3.63.

The first line is the 138 km-long double circuit 500 kV Transmission Line, to deliver electricity from the Nam Theun substation adjacent to the power station to the transfer point on the Lao-Thai border near Savannakhet. EGAT will take the electricity from the delivery point, through Mukdahan on the border, via a 500 kV Transmission Line to a new substation at Roi Et in Thailand.

The second line is the approximately 77 km-long double circuit 115 kV Transmission Line that will deliver electricity from the Nam Theun substation to the Thakhek substation. The Project will construct a double circuit 115 kV Transmission Line from the Power Station substation to just north of Mahaxai, then a single circuit 115 kV Transmission Line will be sent to Thakhek along existing towers. The responsibility of the Project for the 115 kV Transmission Line towers will be from the Power Station substation to north of the new Mahaxai. Lane Xang Minerals, operators of the Sepon gold and copper mining project, have constructed the section of the 115 kV Transmission Line from Mahaxai to Thakhek independently of the Project, and environmental impacts were analysed by Lane Xang Minerals separately.

The third transmission line may incorporate a section of an existing 22 kV line, from the substation near the Power Station to Ban Nakai (Oudomsouk). From this point, one line will extend to the resettlement area on the Nakai Plateau southeast of Oudomsouk. A second line will extend northeast to the bridge at Ban Thalang. The Thai length of the Transmission Line from the middle of the Mekong crossing up to the main substation at Roi-Et, approximately 161.2 km, will be constructed by EGAT.

The 500 kV and 115 kV Transmission Lines are expected to include self-supporting lattice steel towers and ACSR conductors, with the 500 kV towers being approximately 65-70 m in height and the 115 kV towers approximately 30 m in height. The normal spacing between consecutive towers is expected to be approximately 370 m for the 115 kV line and 450 m for the 500 kV line. The final design of the tower structures, conductor specifications and tower spacng

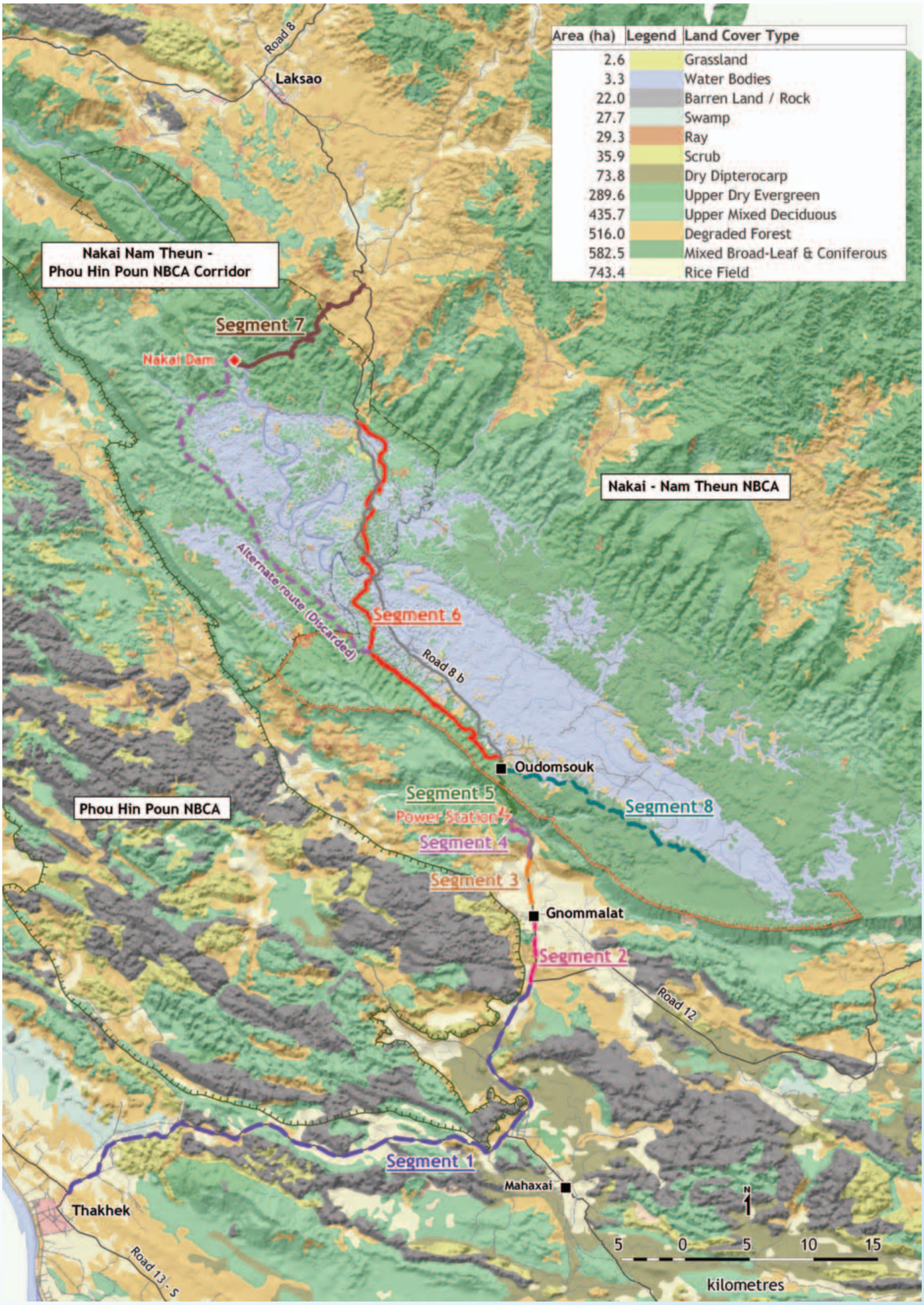

Figure 3.62: Alignment of roads to be upgraded (dashed) and new roads (solid) showing estimated loss of vegetation (estimated avg. road width: 16m)

Impacts

Table 3.79: Impacts and mitigation strategies for road construction and upgrading

Impact	Mitigation Strategy	Party responsible & Relevant HCC plans
Construction Phase Impacts		
1. Vegetation, habitat and other natural resources loss and disturbance from new road construction	a. Offset by the enhanced conservation management of the NBCA	WMPA
	b. Salvage logging arrangements	HCC Vegetation Clearing Plan
	c. Design alignment to generally minimize impacts on vegetation	HCC, design
	d. Construction management to ensure that disturbance is limited to the road easement	HCC under the control of NTPC and GOL
2. Potential change to reservoir water movement and surface mixing in reservoir by road crossing (segment 6)	Design road with adequate water movement structures to provide unimpeded water movement in reservoir.	HCC, design
3. Erosion and sedimentation	a. Restrict construction to dry season to the extent possible	HCC, Erosion & Sediment Control Plan
	b. Protection of susceptible soil surfaces with seeding and/or mulch	HCC, Erosion & Sediment Control Plan
	c. Protection of drainage channels with berms or fabric barriers	HCC, Erosion & Sediment Control Plan
	d. Installation of sedimentation ponds	HCC, Erosion & Sediment Control Plan
4. Spoil disposal	Road design will seek to balance cut and fill volumes, with maximum use of cut for roadbase construction.	HCC, Spoil disposal planning and management plan
5. Creation of stagnant water bodies in pits and drainage areas	a. Assessment of vector ecology in work areas	HCC, Project staff health programme
	b. Adequate drainage structures	HCC, Erosion and sediment control plan.
	c. Design drainage structures and bridges with minimum runoff coefficients	HCC, design
	d. Mosquito protection measures	HCC, Project staff health programme
6. Disturbance to aquatic habitats form erosion and stream blockage	Adequate erosion control measures	HCC, Erosion and sediment control plan
7. Hunting and fishing by construction workers	Fisheries and wildlife management	HCC, Environmental training for construction workers plan
8. Construction worker health and safety	Training	HCC, Project staff health programme
9. Dust, Noise	Dust and noise control measures	HCC, Emissions and dust control plan, Noise control plan
Contamination of soil, groundwater and river	Solid waste and waste water management	HCC, Waste Management Plan
Increase in road accidents	Enforce traffic regulation and Improve health facilities	NTPC, Resettlement and Regional health Programs. HCC, Project staff health program, HCC On-site traffic and access management plan
Operating Phase Impacts		
10. Interruption of drainage patterns	Installation of adequate drainage works	HCC, design
11. Threat to potential role of islands as wildlife refuges	Include impact of road in wildlife management studies and adaptive management responses	NTPC Wildlife programme and WMPA
12. Landslides, erosion	Erosion control measures	HCC, Erosion and sediment control plan
13. Creation of new pathway and habitats for disease vectors	Adequate drainage works	HCC, design
14. Erosion, vegetation loss from disposal of cut spoil	Avoid tipping cut spoil directly over edge of road	Construction Contract and HCCEMMP
15. Illegal logging in watershed	Implement regulation and controls	HCC, GOL, WMPA
16. Collection / depletion of non-timber forest products in watershed	Implement regulation and controls	HCC, GOL, WMPA
Livestock/car interactions	Signage, maximum speed on each section of roads	HCC, On-site traffic and access management plan
17. Hunting, fishing and disturbance to wildlife	Wildlife management	HCCEMMP
18. Spontaneous development	Implement regulation and controls	HCCEMMP

e known until negotiations are finalised with the relevant subcontractor under the HCC.

Preliminary estimates indicate that the "footprint" of each tower may be 10 m x 10 m. Suitable types of foundations will be designed for each soil class and tower type.

The Mekong River crossing will comprise one anchor and one suspension crossing tower on each bank of the river, and two intermediate suspension towers, on pier foundations, one on each side of the international border. Transmission Line towers will be painted to provide higher visibility in the Mekong crossing zone.

The 22 kV Transmission Line will be constructed on pre-stressed concrete poles.

The design of the Transmission Lines shall be based on reliability based design, and shall comply with the requirements of American Society of Civil Engineers Manual No.74, Guidelines of Electrical

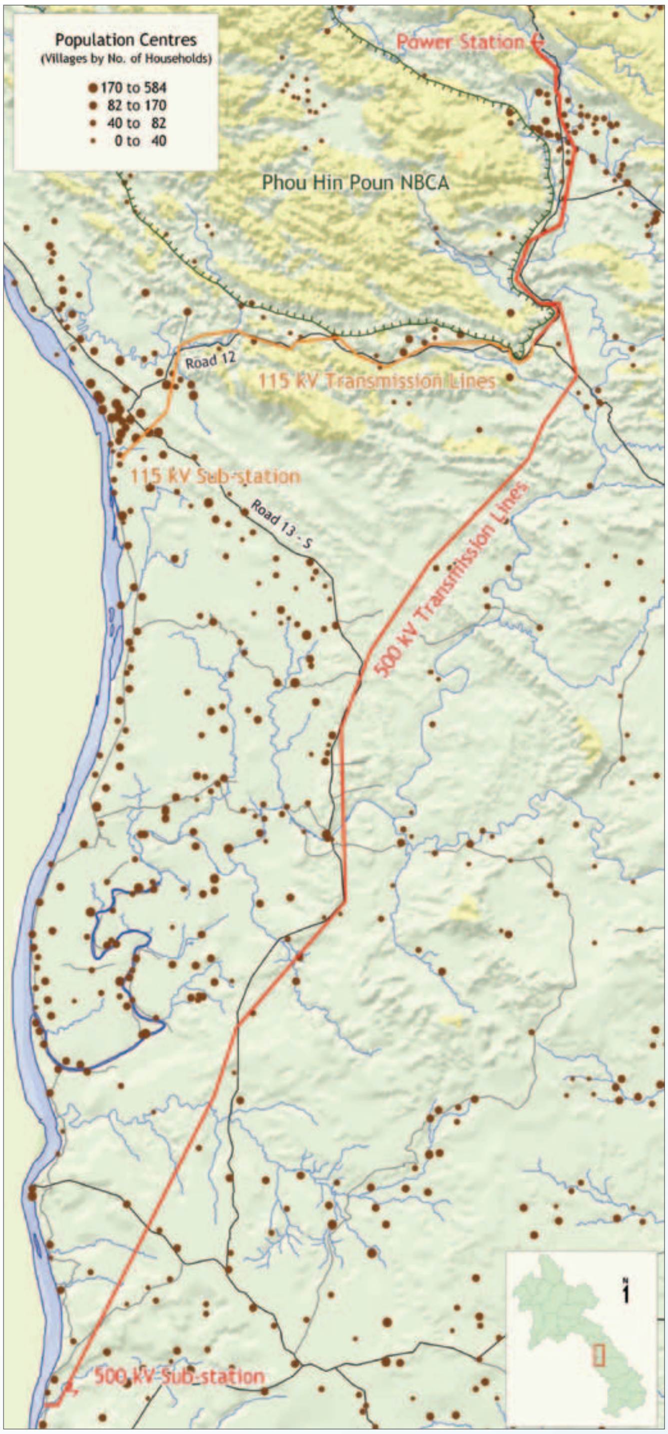

Figure 3.63: Alignment of the 115 kV & 500 kV Transmission Lines

Transmission Line Structure Loading, and ASCE Manual No.52, Guide for the Design of Steel Transmission Towers.

In addition to the activities required to construct the Transmission Lines, during the Operating Phase regular maintenance is needed that will require access tracks to the towers. These access tracks will be maintained and kept clear throughout the operating phase of the Project.

Substations

Substations, which include switchyards, will be constructed in several locations to support the transmission corridor. Two substations will be located near the Power Station, known as the 500/115 kV Nam Theun substation and the 115/22 kV Nam Theun substation respectively. The 115/22 kV Thakhek substation is being constructed by EDL. In addition, land has been reserved at Savannakhet for a substation that may be constructed by GOL at a later date. Although the technical configurations of each substation will vary, the general requirements for the substations include:

- Drainage systems and facilities (including oil/water separation and oil collection facilities);
- Water supply and water treatment systems and facilities;
- Wastewater treatment and disposal, and solid waste disposal systems and facilities;
- Building services, including lighting, power, ventilation and air-conditioning;
- Local monitoring, control, metering and protection systems and facilities for all substation auxiliaries and services, including interfaces to the Facility SCADA system for remote monitoring and control;
- Grounding systems and facilities, including interconnections with the power station grounding system;
- Communications systems linking the substations with the power station and other points as necessary;
- Buildings for housing all necessary control, monitoring, protection and auxiliary equipment, including the substation control room;
- Maintenance workshops, storage space, and other facilities to provide for convenient and effective on-site maintenance and repairs, and for ease of trans-shipment of plant and equipment for off-site repairs;
- Roads, pathways, drainage, hard stand, parking, maintenance and outdoor storage areas, security fences, gates, signage, security and work or task lighting and landscaping; and
- Facilities for operating and maintenance staff, including offices, services and shaded parking areas.

Routing of Transmission Lines

Design Process: The selection of the design routes for the Project 500 kV and 115 kV Transmission Lines incorporated input from ground surveys undertaken during the development phase of the Project. The selection of the route was made to minimise social and environmental impacts and to provide for the best financial and technical solution. A formal alternatives analysis has not been conducted for the route of the Transmission Lines as the original routing of the lines appears to be highly suitable, with low environmental and social impact.

On or prior to the Construction Phase Commencement Date, NTPC's rights in respect of the Concession Period Category 1 and 2 Areas will be redefined to reflect design progress. Both boundaries of the Transmission System corridor that form part of the Concession Period Category 1 and 2 Areas, may be moved outwards by up to one kilometre so long as such a move provides a clear net cost advantage to the Project and the relevant asset compensation provisions of the Concession Agreement are met. However, the total land area for the Concession Period Category 1 and 2 Areas for the transmission corridor cannot be greater than the total land area for the transmission corridor, as originally set out in the Concession Agreement.

In addition, within 12 months of the Construction Phase Commencement Date, NTPC will reduce the Construction Phase Category 1 and 2 Areas. The areas will be within the previously defined boundaries and to the extent reasonably practical to reflect further design progress and actual areas needed for Construction Works. All Construction Phase Category 1 and 2 Areas required by NTPC will be justified in terms of final design requirements, construction working space and material source requirements. In requesting

Impacts

areas for construction activities, NTPC will minimise land disturbance and avoid the disruption of the natural environment and people living within the Project Lands.

Where possible, the route of the Transmission Lines avoids areas of major vegetation. It should be noted that at no time will the Transmission Lines pass through a protected area or any part of an NBCA (Figure 3.63). The route has been carefully selected to minimise impacts and any modifications to the Transmission Line routing that may arise will ensure that this remains the case.

Resettlement: Ground surveys have been completed to avoid any need for resettlement necessary for the construction of the transmission lines. Should resettlement issues arise, the Nam Theun 2 Resettlement Policy will be followed. If land is required that is presently utilised, compensation will be paid as explained in the Resettlement Action Plan.

Thai Transmission Lines, impacts and compensation mechanisms

EGAT has powers under the EGAT Act of 1968 to purchase, occupy and use any land or property to construct transmission lines under, above, along or across any land belonging to any person. Only land under towers is permanently acquired. The rest of the land within the electric cable line area remains the property of the land owner but with restricted use (no structures or trees over three metres in height).

EGAT pays compensation at prevailing market rates for acquired land, for the use of land for erecting transmission posts, and for the land that is declared an electric cable line area. The tower base is compensated at full replacement value; land in the ROW (which can continue to be cultivated) is compensated at 50-90 percent of the replacement value. Houses and other assets are compensated at their replacement cost along with the affected residential land. Affected trees are compensated at a rate that takes into account the disruption in the income stream associated with the trees.

Routing of the Thai Transmission Line

EGAT has modified, and lengthened, its first proposed alignment to avoid a forest reserve traversed by the original alignment, therefore removing the need to have an IEE conducted under the current Thai environmental regulation. The current Thai Environmental Assessment Guidelines require that a proposed transmission line in Thailand needs an EIA if it falls in the area of Class 1B Watershed area, and an IEE if it traverses new forest reserve. In addition to the EIA/IEE requirement, EGAT would also need to obtain approval in the form of a permit from the Royal Forestry Department, before the clearing a public forest area.

Existing Environment

Terrain

The terrain through which the 500 kV Transmission Line will pass is moderately undulating for the first 40 km from the Power Station. The remainder of the route to the Mekong River crosses relatively flat terrain. The altitude along the Transmission Lines varies from El 180 m near the Power Station to El 105 m at the Mekong River crossing point.

The terrain through which the 115 kV Transmission Line section under the responsibility of the Project will pass is the same as the 500 kV Transmission Line until it ends north of the new Ban Mahaxai.

The terrain through which the 22 kV distribution line from the 115/22 kV substation and Ban Signo/Ban Thalang bridge passes is the same as the roads on the Nakai Plateau. The 22 kV line will follow the new alignment of Road 8B as it runs along the southern edge of the inundation area from Oudomsouk to the Ban Thalang Bridge. The line will traverse forest areas that are generally restricted to the rim of the inundation area. The forests along the road and transmission alignment are of open structure with 30-50% canopy cover, with *Dipterocarpus*, *Lagerstroemia*, *Pometia*, *Schima* being the main species and *Pterocarpus* and *Pinus* also present.

The second branch of the 22 kV distribution line proceeds to the southwest resettlement area. This line will also follow the roads to be constructed in that area. Alignment and, therefore, existing terrain is not known since road alignments are not final. However, the alignment will be designed to minimise impacts to vegetation and limit social disruption.

Geology

The areas proposed for placement of the Transmission Lines are not vulnerable to significant seismic shocks resulting from tectonic activity.

Climate

Transmission Lines and substations will be designed to withstand adverse climatic conditions prevailing along the routes, including wind, storms, pollution, humidity and temperature conditions, and will be consistent with the applicable standards, and good design, engineering and construction practice.

Vegetation & Habitat Types

Figure 3.64 shows the different vegetation types crossed by the Transmission Lines, based on the vegetation map prepared by the National Office for Forest Inventory and Planning (NOFIP, 2002). Vegetation types are described in Annex H.

The Transmission Lines passing through dry evergreen forests and mixed deciduous forest will require clearing of vegetation along the route. Transmission Lines passing through dry dipterocarp woodland will require some clearing of vegetation. However, the open nature of this forest will result in a lesser number of trees felled than in other forest types. Clearing of vegetation from an estimated area of approximately 100 m^2 will be required for the "footprint" or base of each tower.

Transmission Lines passing through areas of agricultural land will not require clearing other than the area occupied by the base of the tower.

Potential Environmental Impacts:

Environmental impacts for the Transmission Lines will occur predominantly during construction. The impacts are associated with the clearing of the easements and access roads, and earthworks for tower construction. During the operating phase, impacts will be limited to electromagnetic radiation, visual impact and impacts associated with the access and the maintenance of the lines.

Construction Phase Impacts

Disturbance to Vegetation for Transmission Lines: The removal of standing vegetation along the easements (Figure 3.65) and access roads will be a significant impact. Within the easements, NTPC will have the following rights during the Construction Phase:

- To remove or trim vegetation that may intrude in the Construction Period Category 1 Areas;
- To access the Construction Phase Category 1 Areas; and
- To support activities required to install, replace, or repair towers and/or transmission conductors of the Transmission System.

In the Category 2 land, located primarily under the Transmission Lines between the towers, public access will be for purposes primarily involving agriculture.

The methods to be used for clearing of vegetation have not yet been finalised. However, clearing will be in accordance with the HCCEMMP, in particular the Vegetation Clearing Plan (Annex L). In particular, indications for the preparation of this plan stipulate

Figure 3.64: Alignment of 115 kV & 500 kV Transmission Lines showing estimated loss of vegetation

that the application of herbicides shall be minimised to the greatest extent reasonable and practical. Use, application and storage of herbicides will follow the recommendations of the Pest Management Plan, presented later.

If major trees form part of the vegetation to be cleared, then internationally accepted safety precautions will be followed, and clearing will be carried out in accordance with the requirements contained in schedule 13 of the Concession Agreement on "Logging and Removal of Waste Forestry Products".

The limit of allowable clearing for the Transmission Lines in the construction phase is stipulated in the CA and can be summarised as follows:

Segment 1: 500 & 115 kV Line from the Nam Theun Substations to the Junction of Road 12, Near Ban Na Tung

The 500 kV and 115 kV Transmission Lines will run in parallel for approximately 22 km. Separation of the Transmission Lines will be approximately 52 m. The easement, which is Category 2 Land, will extend 58 m at ground level from the centre of each 500 kV tower and 30 m from the centre of each 115 kV tower. The total width of the easement, including the 52 m separation between towers, is 140 m. The width of Category 2 land increases with height to enable cutting of dangerous vegetation. Category 1 land will be the footprint of each tower plus a two-metre perimeter. This is shown on Figure 3.65.

Segment 2: 500 kV Line from the Junction of Road 12, Near Ban Na Tung to the Mekong Crossing

In this segment, Category 2 Land will extend for 50 m on each side of the towers, making the total width of the easement 100 m. The width of Category 2 land increases with height to enable cutting of dangerous vegetation. Category 1 land will be the footprint of each tower plus a two-metre perimeter. Refer to Figure 3.65.

Segment 3: 22 kV Line from the 115/22kV Nam Theun substation to the Resettlement Area on the Nakai Plateau

The 22 kV line will require very small clearance levels. Therefore, specific distances have not been prescribed in the CA as they have for the other segments of the Transmission Lines. It is anticipated that the alignment will follow the road routing and therefore will not require much additional clearing to that required for the road.

Calculations of Potential Vegetation Losses

The loss and perturbations of vegetation for the length of the various easements for the Transmission Lines in Segments 1 and 2, together with the section of the 115 kV Transmission Line from Ban Mahaxai to Thakhek (which is not under the responsibility of the Project) during the Construction Phase is presented in Figure 3.64.

Limited or no impacts are anticipated for Segment 3. More accurate data cannot be presented at this stage, as the final designs for the Transmission Lines are not complete.

The vegetation structure is variable. Including the 115 kV Transmission Line section from Mahaxai to Thakhek, the major vegetation losses will be in the dry dipterocarp forest (520 ha). The majority of the this forest is very open (20-40% projective canopy cover, Class 1) with a sparse or grassy understorey. Clearing of this forest is not expected to create a significant impact. The clearing of 160 ha of mixed deciduous forest will be in medium to dense forest.

These forest areas exist in a densely settled part of the Mekong piedmont and have been subject to much disturbance and exploitation. The long use of these forests for timber, firewood, hunting and gathering of non timber forest products has reduced their complexity and diversity. Consequently the habitat values are considerably less than those associated with similar vegetation in less accessible areas.

Additionally, the degree of settlement and agricultural activity in the Gnommalat Plain has resulted in extensive clearing that has left, in many cases, pockets of vegetation which are subject to intrusion and disturbance from all sides.

In most cases, the lines will follow the perimeter of a forest. In one stretch however, the 500 kV transmission easement will bisect a long narrow band of dense forest running east-west. This area is

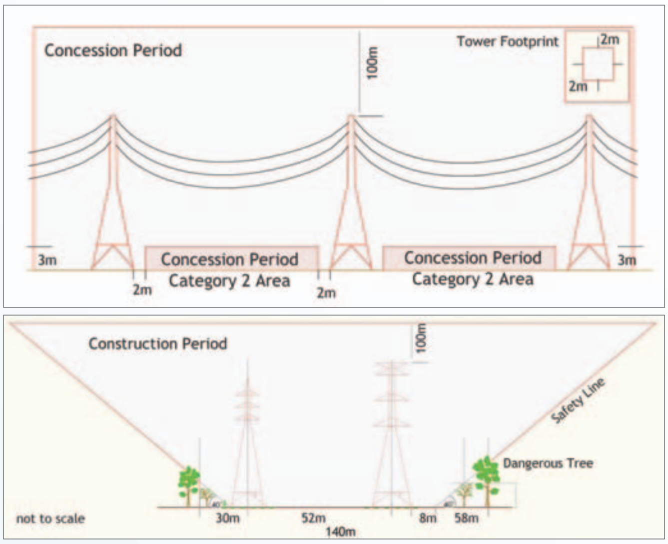

Figure 3.65: Category 1 & 2 potential area to be cleared for the 500 & 115 kV line

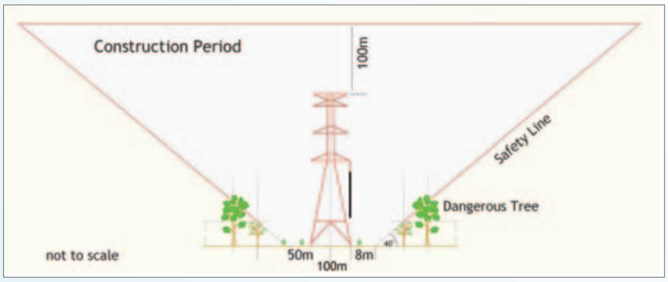

Figure 3.66: Category 2 potential area to be cleared for the 500 kV line

Between towers there is provision for clearing vegetation over 3 m in height for the 500 kV line during the Concession Period. The EGAT standard was adopted to allow the use of the land for agriculture purposes, but not for forest plantations. The limits of allowable clearing for the Operating Phase of the Project, as stipulated in the Concession Agreement, are presented on Figures 3.65-3.66.

EDL is responsible for the maintenance of the 115 kV Transmission Line section from Mahaxai to Thakhek. At this stage, no specific information is available on vegetation to be cleared for maintenance purposes.

The 22 kV distribution line will require very small clearance levels and specific distances have not been prescribed in the Concession Agreement. It is anticipated that during the Operating Phase, disturbance to vegetation will be minimal.

Substations: Impacts of substations in the Operating Phase will be minimal, and limited to the trimming of some vegetation and the maintenance of access tracks.

Electric & Magnetic Fields: Calculations of the expected electric and magnetic fields for the 500 kV and 115 kV Transmission Lines are presented below to assess the impacts of electric and magnetic fields caused by the Transmission Lines on human health.

<u>Electric field for the double-circuit 500 kV Transmission Line (Operating Voltage = 525 kV):</u> the results of calculations are presented in Figure 3.67 as the electric field profile across the easement at 1 m above the ground.

located within Segment 2, approximately 15-20 km south of Ban Na Tung. It is in this area that the major impacts on vegetation will occur and where mitigation measures to minimise the effects will be focused. The clearing in this area will be for a 100 m easement and may include the removal of the shrub layer in some sections, during the construction phase only. The 100 m cleared strip is considered sufficiently narrow to still allow passage by ground dwelling animals and safe flight path for birds. There will be no development within the easement that could cause alienation of the natural land surface and cover. Conversion to agriculture or grazing should not be allowed in this portion of the Transmission Line route.

Substations: The construction of substations will cause disturbance to vegetation and some earthworks will be required during the construction phase. Details of each substation are not known at this stage and therefore it is not possible to fully assess the impacts on the environment. All vegetation clearing must be done in accordance with the Vegetation Clearing Plan, to be prepared by the HC. Where the 115 kV lines terminate at the Thakhek Substation, EDL will construct a substation independently of the Project, and environmental impacts will be analysed by EDL separately as part of the substations planning and design process. Similarly, if EDL elects to construct a substation at Savannakhet, the planning process will include an environmental assessment of the land that will be used for the substation.

Access: Access trails to the Transmission System corridor may need to be constructed or improved. In order to access NTPC's Category 1 Project Land for the Transmission System corridors, NTPC may undertake construction to improve the quality of selected access trails. All existing access trails, roads and paths in or across the Construction Phase Category 2 Area for the Transmission System will be maintained and/or temporary routes established as close as is practical to the existing positions. In particular, several access routes have been identified to assist in the construction and maintenance of the 500 kV lines. A maximum of 23 ha of vegetation could be cleared to improve access trails to Segments 1 and 2 of the Transmission Line, including the 115 kV section from Mahaxai to Thakhek, with 16.8 ha in dry dipterocarp forests, 5.7 ha in mixed deciduous forests and 0.75 ha in dry evergreen forest. This assumes: i) one access road for every 6 towers, although NTPC does not currently have rights to land for a track for every 6 towers; ii) an average 1.5 km access track; and iii) a 4 m gravel track.

Earthworks: Earthworks associated with tower construction will be limited to four sunken concrete footings, one for each "foot" of each tower. While tower construction will require a considerable amount of ground level disturbance, it will not extend beyond the easements for the lines. Following construction, much of this land can be reclaimed for agricultural purposes.

Mekong River Crossing: To enable placement of an adequate foundation for the two towers that will be constructed in the Mekong River channel, some excavation in the river channel will be required. This excavation could create some increased sediment in the river. In addition, construction might have local impacts on navigation and fisheries in the Mekong River.

Operating Phase Impacts

Disturbance to Vegetation: Within the easements of the Transmission Lines, during the Operating Phase NTPC will have the rights to: i) remove or trim vegetation which may intrude into the Concession Period Category 1 Areas; ii) access the Concession Phase Category 1 Areas; and iii) support activities that require installation, replacement, or repair to towers and/or transmission conductors.

Electric field for the double-circuit 115 kV transmission line (Operating Voltage = 120 kV): Figure 3.68 presents the electric field profile generated across the easement at 1 m above the ground.

Magnetic fields for the double-circuit 500 kV Transmission Line: the results of the magnetic field calculation for different horizontal distances from the centre of the 500 kV double circuit Transmission Line, and at 1 m above the ground, are presented in Figure 3.69. The following line conditions were considered: i) load current of 2,000 A; ii) phases of the two circuits inverted (A, B, C and C, B, A from top to bottom for low reactance arrangement of phases); and iii) minimum conductor-to-ground clearances of 11 m and 14.5 m

Magnetic fields for the double-circuit 115 kV Transmission Line: Figure 3.70 presents the magnetic field profile across the easement of the 115 kV double circuit Transmission Line for different horizontal distances from the centre of the Transmission Line. The magnetic field profile was calculated at 1 m above the ground for the following conditions: i) load current of 645 A (based on the current rating of Hawk conductor at 75° C); ii) inversion of the phases of the two circuits (A, B, C and C, B, A from top to bottom for low reactance arrangement of phases); and iii) minimum conductor-to-ground clearances of 7 m, 9 m and 10.5 m.

Electric & Magnetic Fields for 22 kV Transmission Line: The use of 22 kV lines is standard international practice for power distribution in residential areas. It is therefore anticipated that the electric and magnetic fields for the 22 kV transmission line will be within acceptable international guidelines.

Health Effects of Electric & Magnetic Fields: Limits of exposure to electric and magnetic fields endorsed by the International Commission on Non Ionize Radiation Protection are presented in Table 3.70.

Levels for the electric and magnetic fields at the edge of the easements are acceptable. However, the electric field exposure characteristics for the 500 kV Transmission Line exceed the "up to 24 hours per day" guideline. This field is expected to exceed the recommended level at distances of approximately 3-17 m from the centre of the 500 kV Transmission Line (Figure 3.67). Mitigation measures will ensure that human habitation (and therefore 24-hour exposure) within the easement of the Transmission Line will not occur. Therefore, it is expected that no public health impact from electric and magnetic field will be associated with the Transmission Lines.

Mitigation & Monitoring

Compensation mechanisms for lands affected in Lao PDR by the Transmission Lines are presented in the SDP with the other Project lands.

Potential impacts associated with the Transmission Lines are summarised in Table 3.69, with an indication of mitigation strategies and parties responsible for execution and monitoring.

Resettlement Sites

The purpose of this section is to evaluate the impacts of the resettled people and their livelihood activities on the existing land and natural resources. Impacts of the 22 kV electricity distribution line and roadways crossing the resettlement area are addressed under the Transmission Line and Roadways headings.

Description

The proposed resettlement area of approximately 21,000 ha is situated on the southwest side of the proposed reservoir. Twenty-five potential village relocation sites adjacent to the reservoir's edge at FSL have been identified, each ranging in area from 30 to 306 ha, suitable to accommodate the 1,251 households (5,599 persons) (GOL Census Survey, 2003) eligible for resettlement. Figure 3.71 shows the existing village locations, as well as the currently preferred resettlement location for each of the villages, based on village initial preferences elicited during consultation sessions.

The sites identified cover a gross area of 3,400 ha, of which 800 ha will be in the draw down zone. As the reservoir recedes in the dry season, this zone is expected to be used for vegetable garden plots and grazing cattle and buffalo (RAP, 2002). Residential areas will form the core of the village, surrounded by gardens and fields with forests at a greater distance from the core. The actual plan of the new villages will depend on the specific location of each new site and discussions with villagers as to where the various households, buildings and fields should be located. NTPC will ensure that housing is located above the FSL of the reservoir. House designs have been developed through consultations with the villagers who are to be resettled. Houses will be elevated on posts and will be allocated an area of 14 m^2 per person, with a minimum housing area not less than their current existing area or 42 m^2 (whichever is greater). Each household will be entitled to 0.5 ha of land for their house and farming activities. Additionally, up to 0.15 ha of rice land will be allocated to each household in an off-lot location, to be developed and allocated on a community basis. Community infrastructure to be supplied includes: irrigation water to the house lot, irrigation to rice fields, year-round household water supply and

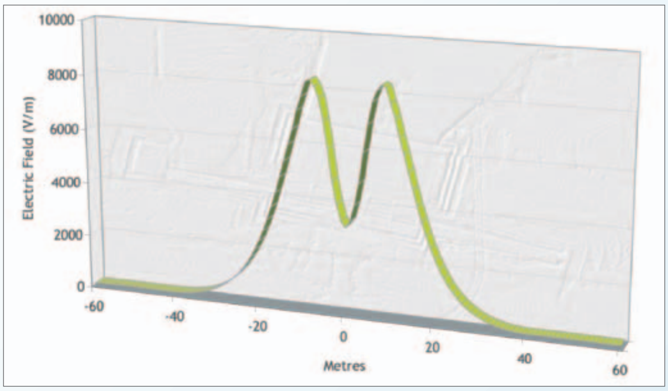

Figure 3.67: Electric fields double-circuit 500 kV Transmission Line

Assumptions made for modelling: Wire type – steel/aluminium, Ø = 11.36 mm, mid-span ground clearance = 42.2 m, horizontal distance from the centre of the line = 8.62 m. Assumptions are based on standard practice as final configuration has not been finalised.

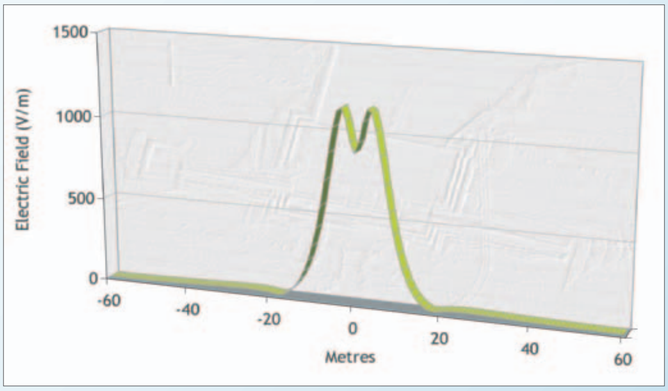

Figure 3.68: Electric fields double-circuit 115 kV Transmission Line

Assumptions made for modelling: Wire type – steel/aluminium, Ø = 10.5 mm, mid-span ground clearance = 18.9 m, horizontal distance from the centre of the line = 0.0 m. Assumptions are based on standard practice as final configuration is not finalised.

Impacts

Table 3.70: Limits of Exposure to Electric and Magnetic Fields

(source: Australian National Health and Medical Research Council, 1989, International Commission on Non Ionizing Radiation Protection, 1993)

Exposure Characteristics	Electric Field Strength (V/m)	Magnetic Flux Density (mG)
Occupational		
Whole working day	10,000	5,000
Short term	30,000[1]	50,000[2]
General Public		
Up to 24 hours/day[3]	5,000	1,000
Four hours/day[4]	10,000	10,000

Notes:

1. The maximum duration of exposure to fields between 10 and 30 kV/m may be calculated from the formula t = 80/E, where t is the duration in hours per work day and E is the electric field strength in kV/m
2. The maximum exposure duration is two hours per work day
3. This restriction applies to open spaces in which members of the general public might reasonable be expected to spend a substantial part of the day such as recreational areas, meeting grounds and the like
4: These values can be exceeded for a few minutes per day provided precautions are taken to prevent indirect coupling effects

electricity, community meeting hall, rice mill, access to house, and access to schools and clinics.

Existing Environment

Vegetation Types

The predominant vegetation type in the Resettlement Area is broadleaf and coniferous forest (52% of the total area). Other vegetation types represented are dry evergreen (18%), temporarily unstocked (10%), and mixed deciduous (16%) forests, with 1.7% of the entire area classified as urban (RAP, 2002).

Table 3.71 shows the vegetation/land use type within the Resettlement Area.

The broadleaf and coniferous forests are found in more open areas and are often associated with poor, dry soils. Much of the unstocked forests have been disturbed in the past by shifting cultivation and logging. Some have an overstorey of *Pinus latteri*, but the stocking is very low. Many trees are of poor quality, having been tapped for resin and burnt severely over time. The majority (61%) of the land has a slope of less than 15°.

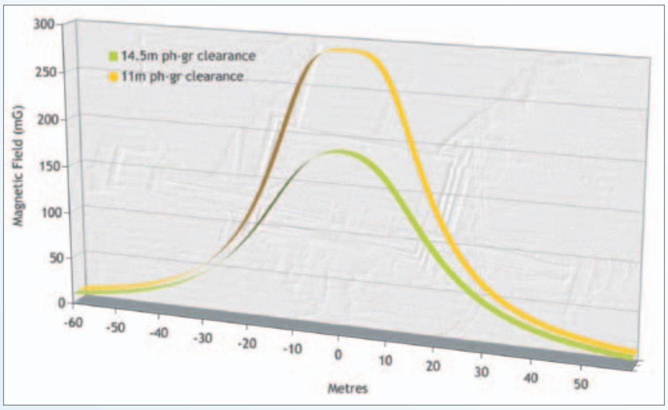

Figure 3.69: Magnetic field profile across the easement for 500 kV Transmission Line, based on a load current of 2000 A

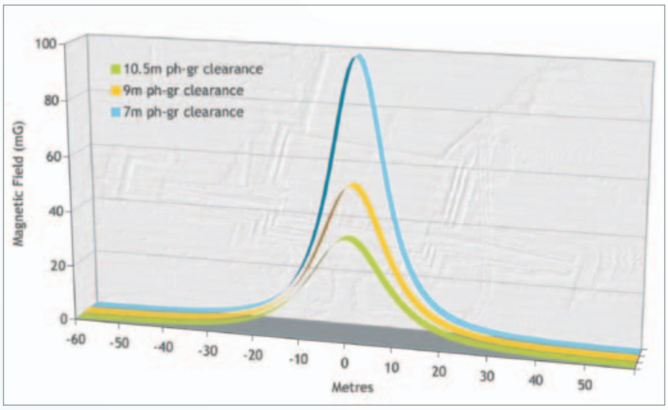

Figure 3.70: Magnetic field profile across the easement for 115 kV Transmission Line, based on a load current of 645 A.

Table 3.71 Impacts and mitigation strategies for the Transmission Lines

Potential Impact	Mitigation Strategy	Responsible Party & Relevant HCC Plans
1. Vegetation, habitat and other natural resources loss and disturbance from transmission lines construction	a. Avoid trees and clusters of vegetation as much as possible	HCC, design
	b. Limit use of chemicals for vegetation clearing along easements	HCC, Vegetation clearing plan
	c. Reclaim land under lines after construction	HCC, Landscaping & revegetation plan
2. Soil toxicity from application of chemicals used in clearing vegetation	a. Limit use of chemicals for vegetation clearing along easements	HCC, vegetation clearing plan
	b. Avoid application of chemicals in agricultural areas	HCC, vegetation clearing plan
3. Possible health risks associated with electric and magnetic fields generated from transmission lines	a. Prohibit dwellings, overnight houses, and businesses in the easements along the transmission lines	GOL
4. Risks of collision with vessels and aircrafts	a. Paint towers to provide higher visibility in the Mekong crossing zone.	HCC, design
5. Disturbance to vegetation from routine operational maintenance	a. Avoid maintenance in wet season whenever possible	NTPC
	b. Restrict operations to within the lines of easements	NTPC

Soils

The soils of the Resettlement Area, as on the Nakai Plateau, are generally heavily leached sandy loams, low in nutrients, shallow, and susceptible to erosion. These soils are poorly suited for intensive rice production or other forms of intensive arable agriculture. The land is best used for pine, combined with some NTFPs and low-intensity understorey grazing.

Current Livelihood Activities

Traditional livelihood activities are subsistence level rice cultivation, raising livestock, hunting and fishing for meat, and gathering of non-timber forest products. Livestock is traditionally regarded as a source of cash rather than raised as a source of food. In 2000, the dominant livestock type owned on the Nakai Plateau, buffalo, numbered 4,100 within the inundation area. This represents an average of 3.3 head per household, although the distributed is skewered with some households owning 30-40 buffalo and others owning none. A shortage of feed is reported by some from March through May. There is currently no supplemental feeding or management of forage (RAP, 2002).

Thai Transmission Line.

The proposed Thai 500kV transmission line would require a 60-metre wide right of way (ROW), consisting of 972 hectares of land. Eighty percent of the proposed ROW is mainly under paddy with some other crops also under cultivation. The remaining twenty percent is under fruit orchards and plantations. There is one house on the proposed alignment, which EGAT would make every effort to avoid. Construction of 300 towers would require permanent acquisition of 12 hectares of the ROW land of an estimated 2000 plots in private ownership.

Potential Environmental Impacts

Loss & Disturbance of Natural Habitats

The 0.5 ha multiple use home-garden lot will require intensive use of approximately 500 ha of the resettlement area. An additional area of approximately 200 to 250 ha will be used for the development of community infrastructure (schools, roads between houses, and irrigation facilities). In total, 750 ha is expected to be used intensively and to cause loss of the natural habitats and their resources in the resettlement areas. Villages will be mostly located within 500m of the reservoir maximum operating level; this area is characterised by unstocked and degraded forest. Much of the area has already been disturbed by shifting cultivation and logging activities, and therefore will require minimal clearance. During drawdown of the reservoir, some sites that would normally be islands will be available for understorey grazing, particularly near the villages Ban Nakai Tai, Nakai Neua and Nong Boua Kham.

Erosion & Degradation of Soil

Livestock paths have the potential to trigger erosion, particularly around natural water points. Dragging and skidding of logs can cause compaction of soil, and tree thinning and logging can cause

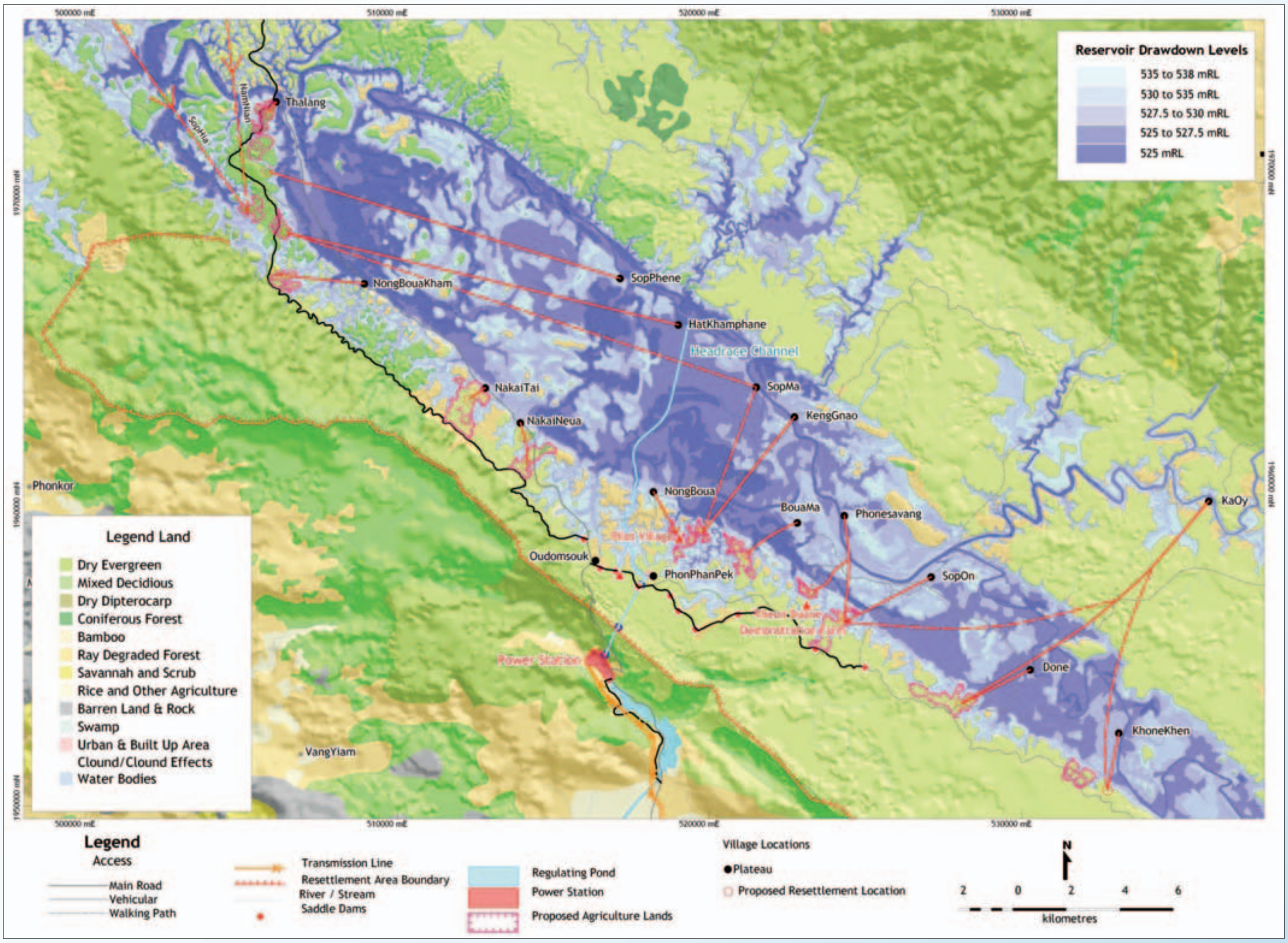

Figure 3.71: Vegetation types within and adjacent to proposed resettlement area, with existing village locations and proposed village resettlement sites

Table 3.72: Vegetation within the proposed resettlement area

Area (ha)	Description
14.8	Bamboo
101.7	Urban & Built-up Area
108.5	Other Agricultural Land
142.2	Water Bodies
263.8	Swamp
351.5	Coniferous Forest
500.7	Rice Paddy
609.8	Ray/Fallow Land
9,318.5	Unstocked/Degraded Forest
27,851.8	Mixed Deciduous
38,774.5	Dry Evergreen
117,227.9	Mixed Broad-leaf & Coniferous

erosion on steep slopes. Soil fertility can be lost from the excessive removal of vegetation, erosion, and soil compaction. Increased runoff as a result of vegetation clearing and soil compaction can decrease the infiltration capacity of the soil. Burning of the vegetation can in the long term deteriorate soil fertility and structure.

Wildlife & Aquatic Resources

In the Resettlement Area, wildlife and aquatic resources could potentially be subject to overexploitation. Interaction between the resettlers and wildlife is likely to be important for the protection of crops and livestock, in particular with elephants.

Water Quality

Adverse water quality could potentially result from activities in the resettlement sites. The potential impacts include increased levels of nutrients (nitrogen and phosphorus) in the reservoir from overuse of fertilisers for intensive forage plots and vegetable gardens, pollution of water by livestock grazing in the drawdown area, and inadequate wastewater disposal. Water quality could potentially be impacted by the misuse of pesticides and herbicides in relation to agricultural activities, vector control, insect and animal pest control and vegetation clearance in the resettlement area.

Groundwater

Groundwater will be developed for domestic use and irrigation, depending on availability. Once inundated, irrigation water will be sourced from the reservoir, so irrigation should not impact on groundwater quality and quantity. The long term extraction of groundwater should be sustainable, especially with the inherent recharge exhibited during the dry season.

Spontaneous Resettlement

The provision of new infrastructure, economic opportunities and services will draw spontaneous migrants to the area. Planning should anticipate some population increase in the area beyond the 5,684 persons affected by the inundation of the reservoir. Controls will be imposed on in-migration given the proximity of the NNT NBCA.

Mitigation & Monitoring

Potential impacts identified are listed in Table 3.73 They are accompanied by recommended mitigation strategies and indication of parties that will be involved for their implementation. It must be noted that the land available for resettlement has a limited capacity in terms of the number of people that can be supported through food self-sufficiency, it cannot support a subsistence livelihood economy for the 5,800 people. The resettlement will have to be accompanied by a shift from a subsistence economy to a market economy, to avoid resource exploitation and shifting cultivation in the surrounding area. This is discussed in the Social Development Plan.

Physical Cultural Resources

A number of physical cultural resources (PCR) within the Project Area will be impacted by Project activities. These resources are either part of the cultural traditions of the villages located within the reservoir area, and will be affected by inundation, or are resources within or adjacent to Project Lands that may be affected by construction activities. Surveys were conducted to determine the presence of PCR within the Project Area. A PCR Plan was developed with the aim to manage impacts and to ensure that PCR will be handled properly and in accordance with the relevant GOL regulation (Decree of the President of Lao PDR on the Preservation of Cultural, Historical, and Natural Heritage, 1997) and World Bank Operational Policy Note 11.03 and Operational Policy 4.11. A summary of the PCR Plan is outlined below with a more detailed discussion presented in Annex P.

Surveys and Studies

In the 1990's, two separate studies were conducted, in association with the MIC, to determine the presence of cultural resources within the Project Area. The first survey was conducted during the feasibility phase of the Project in 1990 (SMEC 1991) and concentrated on 26 locations within and around communities on the Nakai Plateau. A second survey was conducted in 1994-1995 and included the Downstream Channel as well as the Nakai Plateau (TEAM 1995). A team of archaeologists and social scientists further updated the field identification and consulted with the local communities about acceptable management measures.

An additional survey was conducted in 2004 to take into account more clearly defined land requirements of the Project and to adopt the definition of PCR to encompass not only sites of prehistoric, palaeontological and historic value, but also religious, sacred and unique natural values. Earth Systems Australia (ESA), in association with the Department of Museums and Archaeology, and the Institute of Cultural Research, within MIC, undertook a PCR Survey to (i) document all identified sites of PCR significance that will be potentially impacted by the Project; (ii) identify the impact; and (iii) present management and mitigation measures.

The Survey assessed PCR both within and adjacent to Project Lands and encompassed the Nakai Plateau, the Downstream Channel area and the impact corridors associated with the Xe Bang Fai, 500 KV Transmission Line and various road construction and upgrades.

The PCR Survey adopted the World Bank (OP 4.11) definition of PCR which covers movable and immovable objects, sites, structures, groups of structures, natural features and landscapes that have archaeological, palaeontological, historical, architectural, religious, aesthetic, or other cultural significance.

In summary, the methodology comprised of community consultations, satellite imagery interpretation, transects and walk-over surveys. All identified PCR sites and objects were documented and subjected to a comparative study and contextual analysis to measure their significance.

Baseline

The results of the ESA (2004) PCR Survey are summarised below. Locations of PCR are indicated in Figure 3.72 and examples of the types of the PCR are shown in Plates 25 to 30 a more detailed presentation of all sites of PCR can be found in Annex P including a physical and cultural description of each site and an assignment of the level of significance. The PCR context of the Project Area is also discussed.

Table 3.73: Impacts and mitigation environmental protection at the resettlement sites

Potential Impact	Mitigation Strategy	Parties Responsible
1. Vegetation, habitat and other natural resources loss and disturbance	a. Vegetation Clearance Plan to be submitted to the GOL b. Design siting of works to avoid large trees and dense vegetation as much as possible c. Sustainable management of 10000 ha of the Resettlement Area by the Nakai Plateau Forest Association.	NTPC
2. Erosion and sedimentation	a. Restrict construction to dry season b. Protection of susceptible soil surfaces with seeding and/or mulch c. Protection of drainage channels d. Installation of sedimentation ponds e. Avoid areas vulnerable to erosion for development of new villages	NTPC
3. Creation of stagnant water bodies in pits and drainage areas	a. Assessment of vector ecology in work areas b. Adequate drainage structures c. Mosquito protection measures	NTPC
4. Increased interactions between wildlife and resettlers	a. Grazing areas will avoid the proximity of intact forests. b. Development of a management plan for the population of elephants in the reservoir.	
5. Disturbance to aquatic habitats from erosion and stream blockage	a. Adequate erosion control measures	NTPC
6. Uncontrolled NTFP collection, hunting and fishing	a. Fisheries and wildlife management, in particular reservoir fisheries plan. b. Register guns in RA and in the NBCA c. Register boats in the reservoir area	GOL
7. Generation of solid and domestic waste	a. Proper waste treatment facilities and disposal	NTPC/GOL
8. Burning vegetation for brush control and shifting cultivation	a. Implement a controlled burning program b. Minimize the area of burning c. Prohibit shifting cultivation in resettlement area	NTPC/GOL
9. Exceeding the carrying capacity of grazing lands by high densities of livestock	a. Monitor and control forage quality, occurrence of unpalatable weedy species, and livestock density b. Avoid the use of soils susceptible to erosion for gazing c. Rotational grazing d. Control access of livestock with strategic placement of salt and water sources, and fencing	NTPC/GOL
10. Dragging and skidding logs, and increased traffic in agroforestry activities	a. Use regular tracks and loading areas	NTPC/GOL
11. Reduction in soil quality and nutrients from tree harvest and thinning for agroforestry	a. Plant cover crops between rotations b. Apply fertilizers where necessary	NTPC/GOL
12. Increased nutrient runoff to rivers and the reservoir from livestock grazing in drawdown zones, inadequate wastewater disposal, and the use of fertilizers in intensive forage plots, vegetable gardens, and forest plantations	a. Rotational grazing of livestock in drawdown zones b. Prohibit the use of fertilizers in the drawdown zones c. Provide adequate wastewater treatment facilities d. Locate homes above El 540 m e. Implementation of erosion control measures	NTPC/GOL
13. Uncontrolled logging from increased access to forested areas from development of new infrastructure	a. Implement regulation and controls on logging	NTPC/GOL
14. Spontaneous development from development of new infrastructure	a. Implement regulation and controls on spontaneous development	GOL
15. Threats to physical cultural resources	a. Survey the area for PCRs and recommend mitigation measures to minimize impact b. Employ good site selection techniques	NTPC/GOL

Prehistoric Sites

There is evidence of Neolithic and Palaeolithic human occupation in a number of limestone rock shelters and caves within the Pha Phen area (Plate 21). One cave of potential prehistoric significance was also identified in the Downstream Channel area. It is not anticipated that the Project will significantly affect the archaeological value of this site.

Historic Sites

Four historic, and potentially historic sites, were identified on the Nakai Plateau. The most significant of these sites is the abandoned temple in Ban Nakai Tai which is believed to be approximately 200 years old and may have been the centre of Buddhist influence on the Nakai Plateau. The temple location is outside of the inundation zone.

Sixteen historic, and potentially historic sites, were identified in the Downstream Channel area. From the end of the 17th century the Gnommalath and Mahaxai region hosted a prosperous society which built numerous Buddhist temples. The most significant sites identified are Kouan Ku, Wat Tha Pha and the abandoned temple of Wat That. All of the historic sites are located outside Project Lands however there is potential for increased access to result in the theft of movable objects and/or physical damage to historic structures.

In total nine sema stones were identified in a linear arrangement near Ban Na Nouang and adjacent to the Transmission Line Corridor. Traditionally sema stones were located at temple sites and as border markers for states of power, the stones offering protection against invaders. The sema stones are believed to predate the 18th century.

More than 50 abandoned lime kilns are located on the Xe Bang Fai embankments, both upstream and downstream of Mahaxai. It is believed that the kilns were established in the mid 1800s and production ceased in the 1950s. Lime was traded with settlements along the Xe Bang Fai and as far as the confluence with the Mekong River in Nakon Phanom. Isolated kilns have previously been identified in Lao PDR however the scale of lime production and how it may have influenced the historical development of the Mahaxai area is unique.

Spirit Sites

In total 39 territorial spirit sites were identified, typically comprising of a spirit hut located within a sacred forest. Twenty-nine other spirit sites were also identified, typically comprising unique natural features such as groundwater springs, caves and grasslands.

On the Nakai Plateau a number of the spirit sites identified are located inside or in close proximity to Project Lands, the most significant being ten territorial spirit (phi meuang) sites and two sacred salt licks (bor kua and bor sangtew).

In the Downstream Channel area eight territorial spirit sites were identified however all of these sites are located outside Project Lands and it is not anticipated that they will be adversely impacted by the Project. A number of other spirit sites are located inside or in close proximity including Tham Bong, located at the Phou Phathoung quarry site, and Tham Pha Thoung.

In the Impact Corridors, nine spirit sites including six territorial spirit sites, were identified as being located inside or in close proximity to Project Lands. There is potential for the spiritual amenity of these sites to be adversely affected by the environmental impacts associated with construction activities and the potential loss of land along the Xe Bang Fai due to an increase in the rate of erosion during Project operation. One of the most significant spirit sites is Pha Pet, located 400 m to the north of the Pha Phen Quarry.

Religious Sites

A total of 44 religious sites were identified, typically comprising of Buddhist temples and stupas but also a number of Christian churches. Temples were commonly identified as repositories for movable objects of PCR significance including Buddha images and manuscripts.

Twenty-four of these religious sites were identified as being located within or in close proximity to the Project Lands and thus may be subject to land loss, disturbance to religious amenity, physical damage to religious structures and/or theft of movable objects. Sites potentially incurring the most significant impacts include Wat Sibounheuang in Gnommalath Tai, Wat Sen Sayalarm in Mahaxai Kang, Wat Sibounheuang in Oudomsouk, and Wat Sen Sayalarm in Nakai Neua.

Cemeteries

A total of 81 cemeteries were identified, of which 41 are located within or partially inside Project Lands and may be subject to land loss, 26 are located inside the inundation area, and one is located on the bank of the Xe Bang Fai.Twentyone cemeteries are located outside Project Lands and therefore should not be adversely impacted by the Project.

Other Cultural Sites

A total of 26 other cultural sites were identified, most of which comprise of unique natural features such as groundwater springs or caves. Some of these sites are located inside or partially inside Project Lands and may be subject to loss of land. Further, there is the potential for the Project to increased access to these sites which, depending on how it is regulated, may have either positive or negative impacts on the cultural amenity.

Palaeontologic Sites

Palaeontologic sites were identified including fossilised animal bones of Quaternary age in cave floor deposits in the Pha Phen / Phou Phako area and a marine fossil assemblage, including crinoids and shells, within Carboniferous limestone in the same area. The Project activities are unlikely to have a significant impact on PCR at these sites.

Plate 25: Archaeological site AS-2, Pha Phen

Plate 26: Historical site HS-6, Kouan Ku

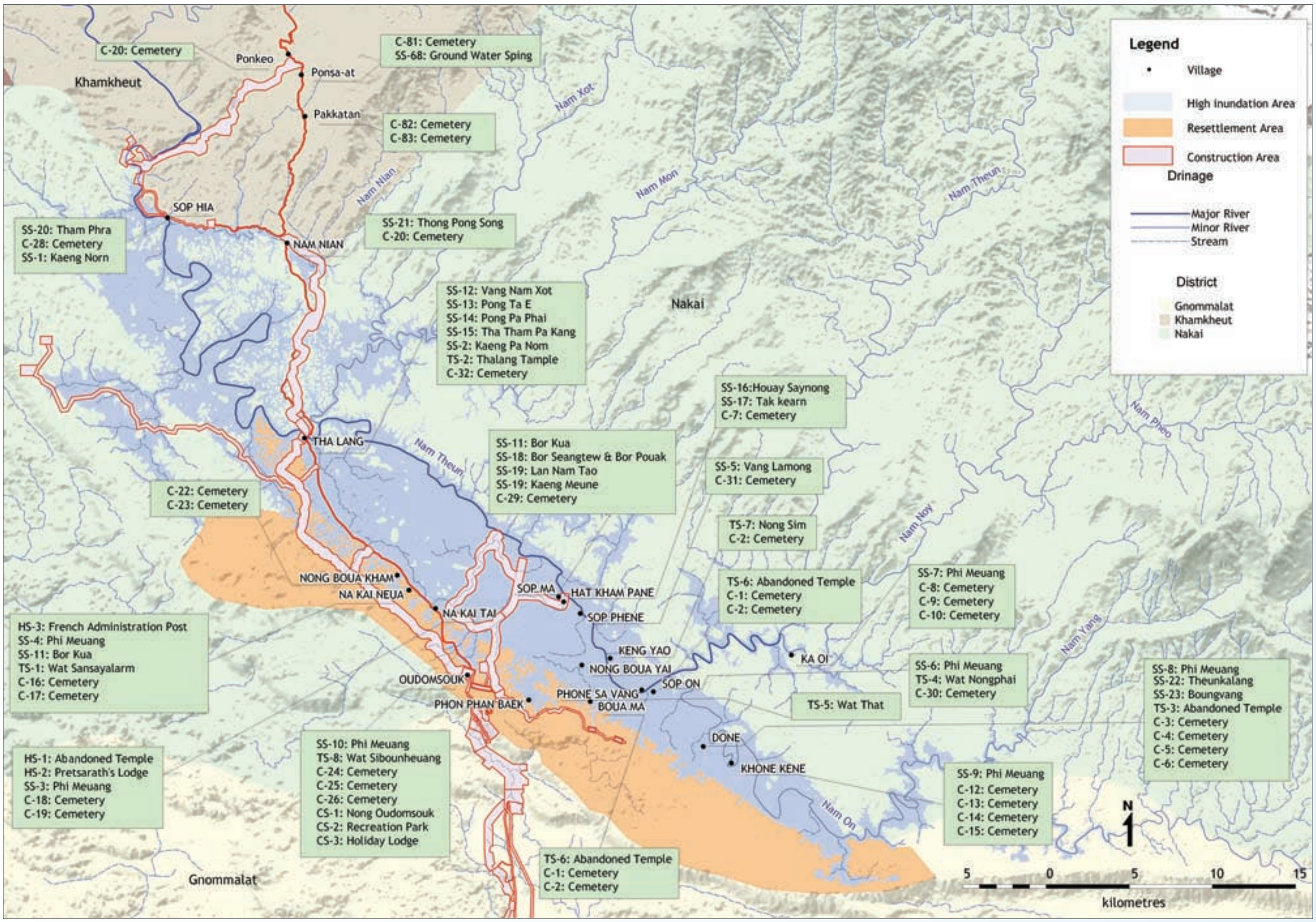

Figure 3.72: Plateau PCR Sites

Impacts

During Project construction and operation there is potential for PCR sites located within Project Lands to be either permanently or temporarily disturbed, and for the amenity or PCR value of these sites to be adversely affected. The general impacts that may result from Project construction or operations are outlined below. The site specific impacts for each PCR, which are too numerous to discuss here, are presented in the Annex P.

Construction

Impacts associated with construction activities include loss of land, alteration of air quality, noise, vibration, aesthetic degradation, change of water quality and restriction of access. PCR may also be adversely impacted due to the influx of construction workers and associated in-migration. Potential impacts of this in-migration include damage, deterioration and unacceptable exposure to historic sites, spirit sites, temples, and cemeteries.

Operation

The primary impact during operations will arise from inundation of the Nakai Plateau which will result in the abandonment and loss of some PCR sites. PCR sites impacted by the inundation include spirit sites and cemeteries. Increased pressure on land use in the resettlement areas, abutting the reservoir, may adversely affect PCR aready present in these areas. Other impacts related to operations include restriction or loss of access to PCR by the physical presence of Project infrastructure (e.g. Downstream Channel) and increased rates of river bank erosion which could impact PCR located on or close to the Xe Bang Fai. The improved access and tourist potential of the area may result in impacts related to the increase influx of people to the area.

Mitigation and Management

PCR Plan

Appropriate management and mitigation measures will be implemented for all sites potentially impacted by the Project. NTPC has developed a PCR plan to address or minimise any adverse impacts the Project may have on these PCR. Recommendations for the management of PCR are summarised in Table 3.75. Further details of the specific activities, together with an identification of responsibilities are presented in Annex P.

Area Affected by Construction Activity

The locations of the PCR will be provided to the HC. The HC will be requested to review these locations and make adjustments to the Project design, where practical and possible, to minimize impacts and risks to identified PCR.

If disruption of known sites is considered unavoidable, permission from GOL will be requested to implement the management strategy before any activity is undertaken with respect to the site of concern. After gaining approval from the GOL, NTPC will implement the management strategies.

For sites that are identified outside a construction area, but are in close proximity, those items may need to be visibly marked or

Plate 27: Spirit site, Phi Meuang

Plate 28: Religeous site, TS-6, an abandoned temple

active preservation measure such as fencing-off sites and relocation of items may be undertaken.

During construction it is recognized that new discoveries, or “chance finds”, of items or sites of physical cultural resources may be found. To address this, the HC is required to prepare, as part of the HCCEMMP, a Physical Cultural Resources Management Plan. The plan will include methodology for the following:

- Documentation and identification of any known locations of any objects or sites of physical cultural resource (i.e. those sites documented as part of the PCRS);
- Notification to the construction workforce of the need to be vigilant in the detection and reporting of, and the prevention of disturbance and damage to, objects and sites of physical cultural resource;
- In relation to previously identified locations of objects and sites of physical cultural resources , notification of the HC’s intention to commence construction activities at the locations should be given to the NTPC at least 28 days prior to the disturbance of such locations;
- Notification to the NTPC of any objects or sites of physical cultural resources encounted by the HC within the construction area; and
- Stopping work and securing the areas adjacent to the objects and sites of physical cultural resources to prevent damage to such objects and sites.

Chance Finds Pocedure

A chance finds procedure has been developed to assist, during construction activities, in the detection, reporting and prevention of damage to currently unidentified PCR. To facilitate the implementation of the procedure, a Lao PCR specialist shall be deployed at strategic construction areas to (i) assist the HC in his identification of PCR; (ii) to report the findings to NTPC; and (iii) where appropriate, conduct the mitigation measures to ensure the safety of the PCR item, but at the same time, prevent any unnecessary delays in construction. A diagram showing the activities of the chance finds procedure is presented in Annex P.

Nakai Plateau- Not Affected by HC works

The Resettlement Management Unit and Resettlement Office will incorporate the PCR Survey results into the resettlement programme for those areas which are not related to the HC’s construction activities. Specifically, items of physical cultural resources value, such as village, temples, stupas and cemeteries will be relocated to the new village or new buildings, if required.

During the resettlement process chance finds, of items or sites of physical cultural resources may be identified. Those working in

Plate 29: Cemetery site C-34

Plate 30: Cultural site CS-24, Tham Phra

Impacts

resettlement activities, especially involving infrastructure development, will be required to stop work immediately if any new item is discovered during works. NTPC will then seek guidance from GOL, and the District Information and Culture Office and MIC to develop an appropriate management strategy.

Xe Bang Fai Region – Not Affected by HC Works

For those items identified along the banks of the Xe Bang Fai, monitoring will be undertaken during the Operating Phase. This will ensure that if any of these items are in danger of becoming affected by the Project, due to increases in river bank erosion, mitigation measures are implemented in a timely manner.

Table 3.74 General mitigation measures of the PCR Plan.

	Mitigation Measures
1.	Conduct an awareness program in advance of construction activities to prepare communities for the potential impacts on PCR sites and to identify further site specific mitigation measures.
2.	Impacted PCR land and assets, most of which are communal, will be replaced, compensated or moved as identified.
3.	For spiritual and religious sites, compensation shall also include the provision of support for the conduct of 'appeasement' ceremonies.
4.	Ensure that movable PCR artefacts located in publicly accessible places (i.e. temples and rock shelters) are secured from theft and vandalism prior to the construction period, in a manner that does not adversely affect their religious / spiritual amenity.
5.	Give the communities primary responsibility, with support from NTPC and the MIC, for the relocation of movable structures such as stupas, and burial urns since they have the required knowledge of local rituals and procedures for moving such objects.
6.	Engage a Lao PCR expert specialising in cultural anthropology to conduct the community awareness programme, and to oversee mitigation measures where required.
7.	Implement the Chance Find Procedure for all construction and resettlement activities.
8.	Engage a Lao PCR expert to work along side the Head Contractor.
9.	Ensure that all construction workers receive a PCR induction programme.
10.	No cave or rock-shelter area should be disturbed without conducting an archaeological investigation, and if required, an archaeological salvage.

Pest Management Plan

Activities in the Project area may lead to a proliferation in the population of pests and a subsequent increase in the use of synthetic chemicals, such as pesticides and herbicides, to control these pests. Any proliferation in pest population may be detrimental to both agricultural productivity and human health. The subsequent increase in the use of synthetic chemicals has the potential to cause harm to the user, the public and the environment. To help address this potential problem NTPC has developed a Pest Management Plan (PMP). The aim of the PMP is to manage any potential pest problems that may develop and help ensure that the use of all pesticides, herbicides, fertilizer and any other synthetic chemical associated with the Project, will be handled properly. The PMP is based on an Integrated Pest Management (IPM) approach, which promotes good agricultural practices through the use of responsible and sustainable activities that will result in the reduction in pesticide use. A summary of the PMP is outlined below, with a detailed pest management plan being presented in Annex M for the following three areas: i) agriculture; ii) public health; and iii) construction. Budgeting, scheduling and monitoring requirements are included in the annex.

Agriculture

Baseline

In general, pest attack on agricultural crops and the use of pesticide in Lao PDR is low and rarely of economic importance. Current pests include: brown plant hopper (*Nilaparvata lugens*), stemborer (mainly *Scirpophaga incertulas*), gall midge (*Orseolia oryzae*), rice bug (*Leptocorisa oratorius*), armyworm (probably *Spodoptera mauritia acronyctoides*), golden apple snail and brown spot disease (*Cochliobolus miyabeanus*, alt. *Helminthosporium oryzae*) (Morton, 2003). Although across the country very little pesticide is used, the situation is changing, with the amount of insecticide use in rice having probably doubled in the last five years (Heong *et al.* 2001).

Impacts

Improved access to the NNT NBCA will facilitate access for traders of synthetic chemicals. On the Nakai Plateau, as the resettled communities adopt more intensive agricultural practices there will be increased potential for pest attack, especially as the ecology of the new crops finds a balance during the initial years. The poor state of the soil in the resettlement area will require application of fertilizer, both organic and inorganic. Uncontrolled application of inorganic fertilizers could lead to contamination of the land and reservoir. Increases in the amount of dry season irrigation along the Xe Bang Fai, a consequence of the additional Project discharge, has the potential to cause a proliferation in the number of pests, which may subsequently lead to reliance on pesticide to control outbreaks.

Mitigation

Integrated Pest Management

The Project intends to support the National Agriculture and Forestry Extension Service (NAFES) to implement an IPM training programme through Farmer Field School (FFS) activities in geographical areas relevant to the Project. Farmers will be trained when to use pesticides and to use only the correct pesticides; at the appropriate dose, at the right time, and not to pose a hazard to themselves, others or the environment.

A Pest Management Specialist (PMS) and an agronomist will provide training for the resettled villagers on the Nakai Plateau and authorise the use of pesticides and other synthetic chemicals. The PMS will be trained in IMP and thus will be able to strengthen the capacity of NAFES to run IPM FFSs.

The use of organic fertilizer will be encouraged, especially on the Nakai Plateau, to introduce organic matter into the soil. The Project has already established a compost plant on the Nakai Plateau to supply the pilot village. Although secondary to the importance of organic fertilizer, careful choice and planned use of the correct inorganic fertilizer will also be essential for successful agriculture on the Plateau.

Pesticides Acceptable & Not Acceptable to the Project

Given the limited size of the market in Lao PDR, when pesticide use is required the Project will adopt the registration and regulatory systems of Thailand and Vietnam. Pesticides acceptable for use where the Project has an influence must satisfy the following criteria: i) registered in Lao PDR and not on the Category I (WHO) list; and/or ii) registered in Thailand, and/or iii) registered in Vietnam; and iv) not banned in Lao PDR. Approximately sixty pesticides have been banned or subjected to restrictions throughout the world. Table 3.75 indicates the active ingredients with restrictions in Asia/Pacific countries and those banned in Lao PDR. These pesticides are not acceptable for use in Project activities. Regulatory control of synthetic chemicals in the NNT NBCA shall prevent any adverse impact.

Table 3.75: Active ingredients not acceptable to NTPC

Active Ingredients with Restriction in Asia/Pacific Countries		Active Ingredients Banned In Lao PDR		Active Ingredients on the PIC List But Not Banned in Lao PDR	
Active Ingredient	Country placing a restriction	Active Ingredient	Status	Active Ingredient	Status
Aramite	Thailand	2,4,5-T	X	DNOC	(X) Scheduled for PIC review
Azinphos-ethyl	Thailand	Aldrin	X	Methamidophos	Xf
Azinphos-methyl	Thailand	Binapacryl	X	Pentachlorophenol	X
Calcium arsenate	Thailand	Captafol	X	Phosphamidon	Xf
Chlordecone	Thailand	Chlordane	X	Benomyl	powder formulations >7% scheduled for PIC review
Chlorthiophos	Thailand	Chlordimeform	X	Carbofuran	powder formulations >10% scheduled for PIC review
Cycloheximide	Thailand	Chlorobenzilate	X	Thiram	powder formulations >15% scheduled for PIC review
Dichlorophen	Thailand	Cyhexatin	!		
Demefox	Thailand	Daminozide	!		
Demephion	Thailand	DDT	X		
Dinoterb	Thailand	Dieldrin	X		
Disulfoton	Thailand	Dinoseb	X		
DNOC	Thailand	Endrin	X		
Endosulfan	Thailand	Ethylene Dibromide	X		
Fensulfothion	Thailand	Ethylene Dichloride	X		
Folpet	Malaysia	Ethylene Oxide	X		
Fonofos	Thailand	Fluoroacetamide	X		
MCPA	Thailand	Gamma HCH	X		
MCPB	Thailand	Heptachlor	X		
Mecoprop	Thailand	Hexachlorobenzene	X		
Mephospholan	Thailand	Leptophos	!		
Methamidophos	Thailand	MEMC	?		
Methazole	Australia	Methyl Bromide	!		
Mevinphos	Thailand	Monocrotophos	Xf		
Mirex	Thailand and others	Parathion	Xf		
Paraquat	Malaysia	Parathion Methyl	Xf		
Paris Green	Thailand	Sodium Arsenate	X		
Phorate	Thailand	Sodium Chlorate	!		
Phosphamidon	Thailand	Sodium Fluuroacetate	!		
Prothoate	Thailand	TEPP	!		
Schradan	Thailand	Toxaphene	X		
Sulfotep	Thailand				
Tribufos	Australia				

Notes:
"X" = not registered in OECD countries and on the FAO/UNDP Prior Informed Consent (PIC) List; "Xf" = formulations subject to restriction and not the active ingredient;
"?" = banned but with unknown PIC status; "!" = poses risk to handlers, environment, in the treated produce and is subject to regulatory restriction in some countries.

Public Health

Baseline

Current diseases and their vectors that have been identified as important for the Project area include: dengue, malaria, Japanese encephalitis, Opisthorchiasis and Schistosomiasis.

For management of dengue, education programmes promote the need to minimize standing water, the habitat preferred by the larval stage of the *Aedes aegypti* mosquito vector. Larvicidal chemicals to control the vector mosquito such as temephos (Abate insecticide) are added to standing water, and adulticidal sprays of malathion or a synthetic pyrethroid are applied in houses.

With regards to malaria, the level of *Plasmodium* infected mosquitoes, *Anopheles dirus*, *A. minimus* and *A. nivipes*, in the entire Project area is not known but must be low. Current levels of human infection are very low on the Nakai Plateau (< 0.6% Khammouane Province, Dept. of Health) and also in the Gnommalat, Mahaxai, and Xe Bang Fai Districts. A Lao-EC project that ran for several years prior to 2002, included Khammouane and the districts of Nakai, Gnommalat, Mahaxai and Thakhek. The prime means of controlling malaria in Lao PDR is the use of bed nets. Levels of human infection have dropped dramatically since treated bed nets (IBN) were introduced in 1998 along with a campaign for Early Diagnosis and Treatment.

Japanese encephalitis is endemic in most rural areas of Asia. Its presence has been indicated in Khammouane Province, though the extent is not known (Vongsay *et al.* 1994). Although the main vector mosquito, *Culex tritaeniorhynchus*, is common, only a small fraction are infected. There is no specific treatment for infected individuals but general viral vaccines give short-lived protection. Preventing mosquito bites around dawn and dusk is effective in avoiding the disease.

This liver fluke, *Opisthorchis viverrini*, is picked up through eating infected raw fish and the residents of Gnommalat and Mahaxai are commonly infected. The intermediate host is the snail *Bithynia siamensis goniomphalus*, and a survey has identified infected snails in the area affected by the Project area, specifically in the Gnommalat District (Lohachit, 1997).

Schistosoma mekongi, a blood fluke, is only recorded around Kong Island in the south of Lao PDR. The intermediate host is the snail *Neotrichula aperta* gamma race and a survey has identified this snail in the area affected by the Project area, specifically in Ban Nakio and Ban Mahaxai. However these individuals were not infected (Lohachit, 1997).

Impacts

The Project will likely increase the number of breeding sites for the mosquito vectors of dengue, malaria and Japanese encephalitis, through increases in irrigation in the Project area and the reservoir itself. Although the Project will result in an increase in these habitats, there should be no significant impact on the prevalence of these diseases as long as the currently successful prevention measures against the vectors continued to be adopted.

Raw fish sauce may contain the disease Opisthorchiasis, and local communities and construction workers could be at risk from infection if they consume it. This is not different from the current situation and not a direct impact from the Project.

Although the uninfected snail vector is found in the Project area, Schistosomiasis is not recorded. In the opinion of local specialists, there is no reason to believe the Project will have any impact on the spread of this disease.

Mitigation

Through its resettlers' health programme and regional health programme, the Project will support local clinics and small hospitals on the Nakai Plateau and Xe Bang Fai area in continuing the already successful education of the population in prevention of dengue, malaria and Japanese encephalitis. This education programme will also include disseminating information on the dangers of eating raw fish and the prevention of Schistosomiasis. Such support and reinforcement of local medical facilities in providing preventative measures has been found to be lacking in schemes elsewhere in the world, and is now considered an essential prerequisite to international funding (Hunter J.M., in Sharp D., 2003).

Construction workers will be educated in the same prevention measures currently used by the local communities. Workers will also be supplied with bed nets which will help prevent the prevalence of mosquito borne diseases. Certain amounts of pesticides will be purchased to treat the bed nets, but the insecticides in use (synthetic pyrethroids) are of very low mammalian toxicity and there should be no danger to human health.

Construction

Baseline

The areas for the Pilot Village and the Theun Douane Demonstration Farm on the Nakai Plateau have already been cleared of vegetation utilising physical means only – no herbicides were used.

Impacts

During Project construction, land will be cleared of vegetation to facilitate building activities. Routine maintenance of the Transmission Lines will require periodic removal of any vegetation that may pose a danger during the operation phase. Any inappropriate use of herbicides to clear vegetation is likely to cause contamination of the land and nearby water bodies. Inappropriate use and storage of these synthetic chemicals may also cause harm to the users.

Mitigation

No chemical use is permitted for clearance of the resettlement area for the new villages, nor is the need envisaged. The resettled communities will participate in the preparation of their own land, clearing trees and undergrowth in the manual manner to which they are accustomed. The initial clearance of Project lands, such as for the Transmission Lines, will be done using physical means only. Maintenance of land under power lines in the existing Theun Hinboun hydroelectric project is through the use of labour and the Project will adopt the same methods. Certain situations may dictate occasional use of herbicides, and to prepare for this appropriate herbicides may be identified beforehand using the selection criteria detailed in Annex M.