THEUN HINBOUN POWER COMPANY

THEUN HINBOUN EXPANSION PROJECT

FINAL EIA/EMMP

Section 1 EIA

April 2008

Date of issue : April 30, 2008

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LIST OF ABBREVIATIONS/ACRONYMS

ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
BDP	Mekong Commission Basin Development Plan
BP	Bank Procedures
CA	Concession Agreement
Ca	Calcium
$CaCO_3$	Calcium carbonate
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species
Cl	Chloride
CO_2	Carbon dioxide
COD	Commercial Operation Date
DAFO	District Agriculture and Forestry Office
DFRC	Division of Forest Resources Conservation
DHM	Department of Meteorology and Hydrology
DO	Dissolved Oxygen
e.g.	exempli gratiae (for example)
EA	Environmental Assessment
EIA	Environmental Impact Assessment
EMD	Environmental Management Division
EMMP	Environmental Monitoring and Management Plan
EMO	Environmental Management Office
EMP	Environmental Management Plan
EMU	Environmental Management Unit
EP	Mekong Commission Environmental Programme
EU	Environmental Unit
FSL	Full Supply Level
GEF	Global Environmental Facility
GMS	Greater Mekong Sub-region
GOL	Government of Lao PDR
ha	Hectare
HCC	Head Contractor
IEWMP	Integrated Ecosystem and Wildlife Management Project
IFI	International Financing Institutions
IUCN	International Union for Conservation of Nature and Natural Resources
K	Potassium
km^2	Square kilometres
kV	Kilo Volt
M&E	Monitoring & Evaluation
m^3	Cubic metres

m^3/s	Cubic meter per second
MAF	Ministry of Agriculture and Forestry
masl	Metres above sea level
MCTPC	Ministry of Communication, Transport, Post and Construction
MEM	Ministry of Energy and Mining
Mg	Magnesium
MIH	Ministry of Industry and Handicrafts
MIH/DOE	Ministry of Industry and Handicraft / Department of Electricity
mm	Millimetre
MRC	Mekong River Commission
MW	Mega Watt
MWL	Minimum Water Level
Na	Sodium
NEC	National Environmental Committee
NG	Site 8 on the Nam Gnouang, proposed dam site for Expansion Project
NGO	Non-Governmental Organisation
NKD	Nam Kading (NPA)
NO_2	Nitrite
NO_3	Nitrate
NPA	National Protection Area
NT 1	Nam Theun 1 Hydropower Project
NT 2	Nam Theun 2 Hydropower Project
NTFP	Non-Timber Forest Product
NTPC	Nam Theun 2 Power Company Limited
OP	World Bank Operational Policies
PA	Protected Area
PAFO	Province Agriculture and Forestry Office
PM	Prime Minister
PO_4-P	Orthophosphate-phosphorus
PoE	Panel of Experts
RAP	Resettlement Action Plan
RCC	Roller compacted concrete
SED	Social and Environmental Division
SIA	Social Impact Assessment
WREA	Science, Technology and Environment Agency
STEO	Science, Technology and Environment Office
t	Temperature
THPC	Theun-Hinboun Power Company Ltd.
THPP	Theun-Hinboun Hydropower Plant
THXP	Theun-Hinboun Expansion Project
TOR	Terms of Reference
Tot-N	Total Nitrogen

Tot-P	Total Phosphorus
TSS	Total Suspended Solids
UN	United Nations
UXO	Unexploded Ordnance
WB	World Bank
WCD	World Commission on Dams
WCS	Wildlife Conservation Society
WMPA	Watershed Management and Protection Authority
WREA	Water Resources and Environment Authority
WUP	Mekong Commission Water Utilisation Plan
WWF	World Wide Found for Nature

1 INTRODUCTION

1.1 Project Background

The existing Theun-Hinboun Power Plant (THPP) is a 210 MW run-of-the-river hydropower scheme owned and operated by the Theun-Hinboun Power Company Limited (THPC).

THPP was the first hydropower project in Lao PDR developed by the private sector under a concession agreement with the Lao PDR Government. Construction started in May 1995, and facilities were commissioned in March 1998 and continue to operate successfully.

As a result of the successful completion and operating experience with the existing plant, THPC has proposed a new scheme to regulate the inflow into the existing Headpond. The recommended scheme, known as the Expansion Project, involves an upstream dam and reservoir in the Nam Gnouang (NG dam site) and expansion of the generating capacity of the Theun Hinboun power station. The impending completion of the Nam Theun 2 dam upstream on the Nam Theun will reduce the power generation at Theun Hinboun. The effect of Nam Theun 2 on the THPC revenue has added impetus to the need to expand the Theun Hinboun facilities in order to mitigate the resulting decline in power generation.

In May 2006 THPC signed a Contract with SWECO International to undertake a Technical Feasibility Study of the Theun Hinboun Expansion Project, also referred to as THXP in this report. The results of this were presented in November 2006.

1.2 Development of the EIA/EMP

The consulting company Resource Management and Research (RMR) were in 2004 engaged to analyse the environmental and social impacts of planned project. More than 2 years of field work have resulted in several volumes of “Social Action & Environmental Management Plans” covering the relevant themes and impacts zones in much detail.

The original RMR reports are, however, written in a format, volume and level of detail that is incompatible with the prevailing Lao PDR EIA standards and requirements. The Norwegian consulting company NORPLAN AS was in October 2006 contracted by THPC to compile the required information and edit the EIA/EMMP and SIA/RAP documents for the prescribed consultation and approval process.

1.3 Available Information

The present report is largely based on previous reports and documentation. First of all the main information source has been the Social Action & Environmental Management Plans produced by RMR. In addition, information has been gathered for a number of thematic reports addressing environmental issues in the THPX impact zones. Information from the SWECO Feasibility and Hydrology Studies been

extensively used. Results from the THPC water quality and climatic monitoring programme have also provided important input data for the report.

As a background for recommendations related to catchment management and biodiversity protection the Lao PDR office of World Conservation Society prepared a report "Plan for Catchment Protection and Rehabilitation of the Theun Hinboun Expansion Project (WCS 2007). A specific ESIA report for the 230 kV transmission line element of the Project was carried out by Chareun and Associates (Chareun 2007).

1.4 Outline of the Report

The approach used in this study and the structure of the report is similar to a normal EIA process and contains the normal EIA elements as it is also prescribed in Lao PDR and ADB guidelines. The report is divided in 2 Sections. The first Section (Chapter 1-8) contains the main impact assessment part. The second Section (Chapter 9-18) contains the different elements which together make up the Environment Management and Monitoring Plan.

The chapters are as follow:

Section 1

- Introduction
- Legal and Policy Framework
- Project Description
- Physical Environment
- Biological Environment
- Project Impacts
- Analysis of Alternatives
- Cumulative Basin Impacts

Section 2

- Introduction to Environmental Management and Monitoring Plans
- Reservoir Clearance and Filling Plan
- Catchment Biodiversity Development And Protection Plan
- Water Quality Monitoring
- Fish Monitoring and Mitigation Plan
- Downstream Riverbed Management Plan
- Construction Activities Environment Plan
- Operation Environment Plan

- Transmission Line Environment Management and Mitigation Plan
- Environmental Awareness Training

2 LEGAL AND POLICY FRAMEWORK

2.1 Introduction

In the following a brief summary of the administrative and legal situation in the relevant national sectors, Lao PDR international commitments, and the environmental and social requirements of the International Financing Institutions is provided.

2.2 National Legal and Institutional Situation

2.2.1 Environment Protection

The basic legal framework is laid down in the Environmental Protection Law of 1999, which was approved by the implementation decree of 2002. The law includes provisions for EIA for projects and activities that might have impacts on the environment and regulations for all enterprises to control pollution and comply with environmental quality standards.

According to the Law the basic principles of environmental protection are:

- Environmental protection shall be the priority consideration and environmental mitigation and restoration are considered to be less preferable but also important activities;
- The social-economic development plans shall include provisions to protect the environment and national resources;
- All persons and organisations residing in the Lao PDR are obligated to protect the environment;
- Whoever causes damage to the environment is responsible for the impact under the law;
- Natural resources, raw materials and energy shall be used in an economical manner, which minimise pollution and waste and allows for sustainable development.

Executing agency

The executing agency of the Environmental Protection Law is the Science, Technology and Environment Agency (WREA), which is also responsible for reviewing EIAs. WREA has developed specific guidelines for the content and process of environmental assessment of hydro-power projects, including the preparation of environmental management plans.

2.2.2 Nature Conservation

The conservation of areas for biodiversity purposes has its legal basis in the Prime Minister's (PM) Decree of 1993 aimed at fulfilling the Lao PDR obligations under the Convention of Biological Diversity. Through this decree 20 National Protected Areas (NPAs) have been

established. The administrative responsibility for the management of the NPAs has been placed at the Ministry of Agriculture and Forestry.

2.2.3 Forestry

The Forestry Law of 1996 provides general provisions for the management of all forest related resources, including all plants, wildlife, watercourses, etc. The Department of Forestry, Ministry of Agriculture and Forestry, has the overall responsibility and is responsible for allocating the use of forestland and forest resources. Forests are grouped into the following five categories: Protection, Conservation, Production, Regeneration, and Degraded, each with their specific management policy.

2.2.4 Water Management

The Law on Water and Water Resources of 1996 is intended to assure sustainable use of water. Water use is categorised into small, medium and large-scale use. The legislation prescribes the rights and procedures for the different categories of water use. Development of a large-scale user projects will require the preparation of an EIA. The administration of the Water Law is located in the Water Resources Coordination Committee under the Prime Ministers Office.

2.2.5 EIA Guidelines

Based on the provision in the Environmental Protection Law that development projects and activities that have the potential to affect the environment shall require an EIA, WREA have issued National EIA regulation for Lao PDR (2000). This regulation specifies the overall principles for the EIA effort and prescribes the thematic issues to be covered and the outputs expected at the different stages the EIA process.

WREA has also instructed the Ministries to develop sectroral guidelines for the project categories within their respective area of responsibilities. The Ministry of industry and Handicraft - now the Ministry of Energy - responded promptly to this request and have issued the following guidelines for power and transmission line projects:

- Regulation on Implementing Environmental Assessment for Electricity Projects in Lao PDR, No. 447, 20.11.2001
- Power Sector Environmental Policy, No. 581, 4.10.2001
- Environmental Management Documents for the Department of Electricity, No. 582, 4.10.2001
- Department of Electricity Environmental Records Management, No. 583, 4.10.2001
- Environmental Management Plans for Electricity Projects, No. 584, 4.10.2001
- Environmental Management Standard for Electricity Projects, No.0366/ MIH.DOE,2003

2.3 International Commitments

2.3.1 Mekong River Commission

Lao PDR is one of the four signatory parties to the 1995 Agreement on the Co-operation for Sustainable Development of the Mekong River Basin and one of the members of the Mekong River Commission (MRC). The Commission succeeded the Mekong Committee, which, among other things, was instrumental in the planning of Nam Ngum, the first larger hydropower project in Lao PDR. Whereas the Committee was primarily focussed on hydrology, navigation and hydropower, the mandate of the Commission is more oriented towards co-operation for the promotion of sustainable development, utilisation, management and conservation of the water and related resources of the Mekong River Basin.

The primary purpose of the Agreement is to promote economic and social well-being of the people in all the riparian countries through the protection of the environment, improvement of navigation and the co-operation in the maintenance of flows and intra-and inter-basins diversions. MRC has initiated several basin-wide planning and research programmes, including the Water Utilisation Plan (WUP), the Environmental Programme (EP), the Basin Development Plan (BDP) and the Fisheries Programme. Lao PDR has its own National Mekong Secretariat in Vientiane.

2.3.2 ASEAN Membership

Lao PDR became a member of the Association of Southeast Asian Nations (ASEAN) in 1997. ASEAN countries have adopted an agreement on the Conservation of Nature and Natural Resources. However, this agreement has been ratified by only three countries since it was adopted in 1985, and is therefore not in force. ASEAN also has provisions to assist member countries to establish transboundary nature reserves.

2.3.3 Greater Mekong Sub-region (GMS) Initiative

In 1992, with the assistance of ADB, Cambodia, Lao People's Democratic Republic, Myanmar, Thailand, Viet Nam, and Yunnan Province in the People's Republic of China entered into a program of sub-regional economic cooperation, designed to enhance economic relations among the countries. The program has contributed to infrastructure development and better use of the resource base in the sub-region.

2.3.4 International Conventions and Treaties

Convention on Biological Diversity (CBD)

Lao PDR became a signatory to the CBD in 1992, following up the ASEAN Agreement of the Conservation of Nature and Natural Resources, which was signed in 1985. The obligations of CBD have been fulfilled in terms of new policy and legislation and by establishing NPAs.

Convention on the Protection of World Cultural and Natural Heritage

This UNESCO convention was ratified by GoL in 1987. The convention addresses the protection of both cultural and natural objects and sites of high national and international value.

Convention on International Trade in Endangered species (CITES)

Lao PDR ratified this convention in early 2004. Prior to the ratification, the Ministry of Agriculture and Forestry (MAF) issued a regulation that banned all hunting for trade. Hunting for consumption was still allowed. This is a signal that GoL is now committed to increasing efforts to halt the extensive trade in wildlife from Lao PDR to its neighbouring countries.

2.4 Development Bank Guidelines

2.4.1 EIA process

The process of Environmental Impact Assessment is a method used by many International Financing Institutions (IFIs) including the Asian Development Bank (ADB) to ascertain the environmental risks and benefits associated with their lending operations and other financial support to development projects. The Environmental Policy of the ADB dates from November 2002 and forms the basis for environmental requirements and interventions for project implementation. The Environmental Assessment Guidelines (2003) describe procedures and methodology to be used to investigate environmental and social impacts of projects to be considered for funding. The WB's environmental assessment procedures are described in OP/BP 4.01 (Operational Policy, Bank Procedures). This policy is considered to be the umbrella policy for the Bank's "safeguard policies", which includes specific requirements and policies

In both ADB and WB projects Environmental Assessment (EA) plays a key role in improving decision-making and in ensuring that project options under consideration are sound and sustainable.

2.4.2 Safeguard Policies

In total six safeguard policy papers have been issued. Three of these are primarily addressing social issues and are addressed in more detail in the SIA/RAP. These policies cover:

- Involuntary Resettlement
- Indigenous People/Ethnic Minorities
- Cultural Property

The other three policies have more relevance to the preparation and content of the EIA

Safety of Dams (OP/BP 4.37)

For large dams (15 meters or more) it is a requirement that the borrower adopts and implements certain dam safety measures for the

design, bid tendering, construction, operation and maintenance of the dam and associated works.

International Waterways (OP/BP 7.50)

The policy does not allow financing of a project on an international waterway until all the riparian countries are notified of the project. If there is an objection from one of the riparians, the Bank will assess and confirm that the project will not cause appreciable harm to the interests of the other riparians.

Natural Habitats (OP/BP 4.04)

The World Bank does not support projects that, in the World Bank's opinion, involve the significant conversion or degradation of critical natural habitats.

2.4.3 IFIs Project Preparation and Consultation Process

The ADB is committed to ensure that key stakeholders are systematically identified and involved in project planning and implementation. Early consultations have to be held with affected groups to guide project decision making, and their views and preferences has to be reflected in the plans developed as an integral part of the project.

3 PROJECT DESCRIPTION

3.1 Introduction

The Theun Hinboun Expansion Project is composed of two main parts:

- A storage reservoir and a power plant on the Nam Gnouang upstream of the Theun-Hinboun Headpond; and
- Expansion of the Theun-Hinboun Power Plant capacity to take advantage of increased dry-season flows facilitated by the improved seasonal storage by the reservoir.

The Nam Hai and Nam Hinboun river channels downstream of the Theun Hinboun Power Plant will have to convey an increased water flow volume.

3.2 Project Location

3.2.1 River Basins

The planned reservoir is located on the Nam Gnouang which is one of the major tributaries on the Nam Theun/Nam Kading river system. As for the existing Theun Hinboun Power Plant the expansion will divert water from Nam Theun/Nam Kading basin into the Nam Hai/Nam Hinboun river basin to the south. The location of the main project features in relation to landscape and infrastructure elements are shown in Figure 3-1.

3.2.2 Project Zones

For the purpose of the impact assessment and presentation the area potentially impacted by the project can be divided in different zones. The need for specification of the zones differs from topic to topic, with the most detailed specification used for the purpose of social impact assessment and resettlement planning. The zones used in both the Environmental Impact Assessment and the Social Impact Assessment are described in the sections below and mapped in Figure 3-2.

Zone 1: Reservoir

This zone includes the area that will be inundated by establishing the NG Reservoir.

Zone 2: Headpond

This zone includes the Headpond and the surrounding land of the existing Theun Hinboun Hydropower Project, which is partly on the Nam Theun and partly on Nam Gnouang.

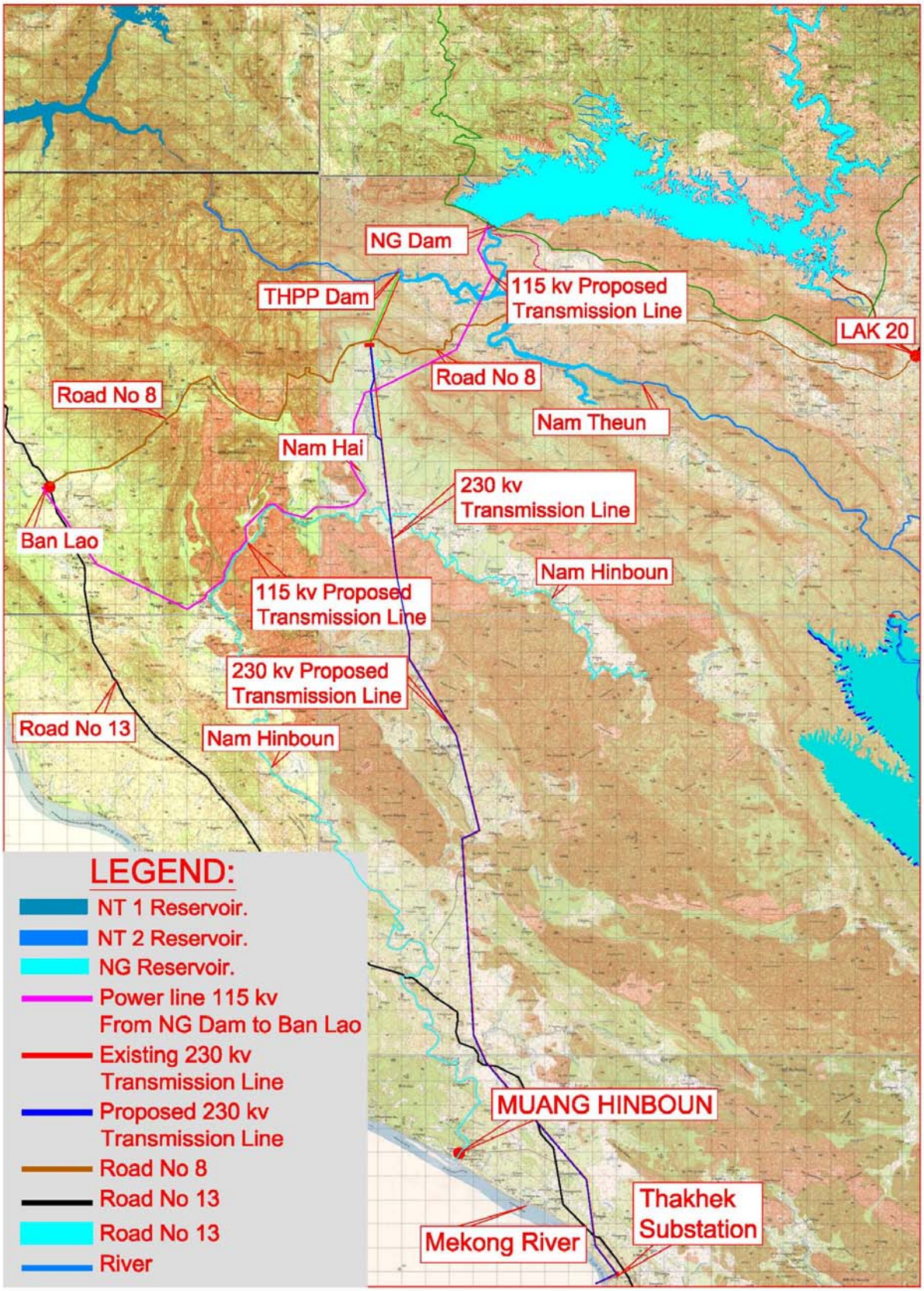


Figure 3-1. Overview of the project area with some major project element indicated (Source THPC)

Zone 3: Recipient Rivers

This Zone is divided into several sub-zones:

- Nam Hai and confluence with Nam Hinboun Area
- Upper Nam Hinboun Area
- Middle reach of Nam Hinboun Area
- Lower Nam Hinboun Area
- Downstream of THPP Dam within the Nam Kading NPA and will be affected by reduced water flows
- Pakkading Area.

Zone 4: Project Construction Lands

- This Zone includes:
- Project construction land at NG Damsite
- Project construction land at THPP Damsite
- Upper Nam Hai: Kounkham / Nahin
- 230 kV Transmission Line Corridor
- 115kV Transmission Line Corridor

Zone 5: Upstream Areas

This zone includes the upstream of the NG Reservoir including the Nam Gnouang and its tributaries, tributaries to the Lower Nam Hinboun, including the Nam Paten and the Nam Pakan, and the upper reaches of the Nam Hinboun not impacted by additional flooding.

Zone 6: Resettlement Areas

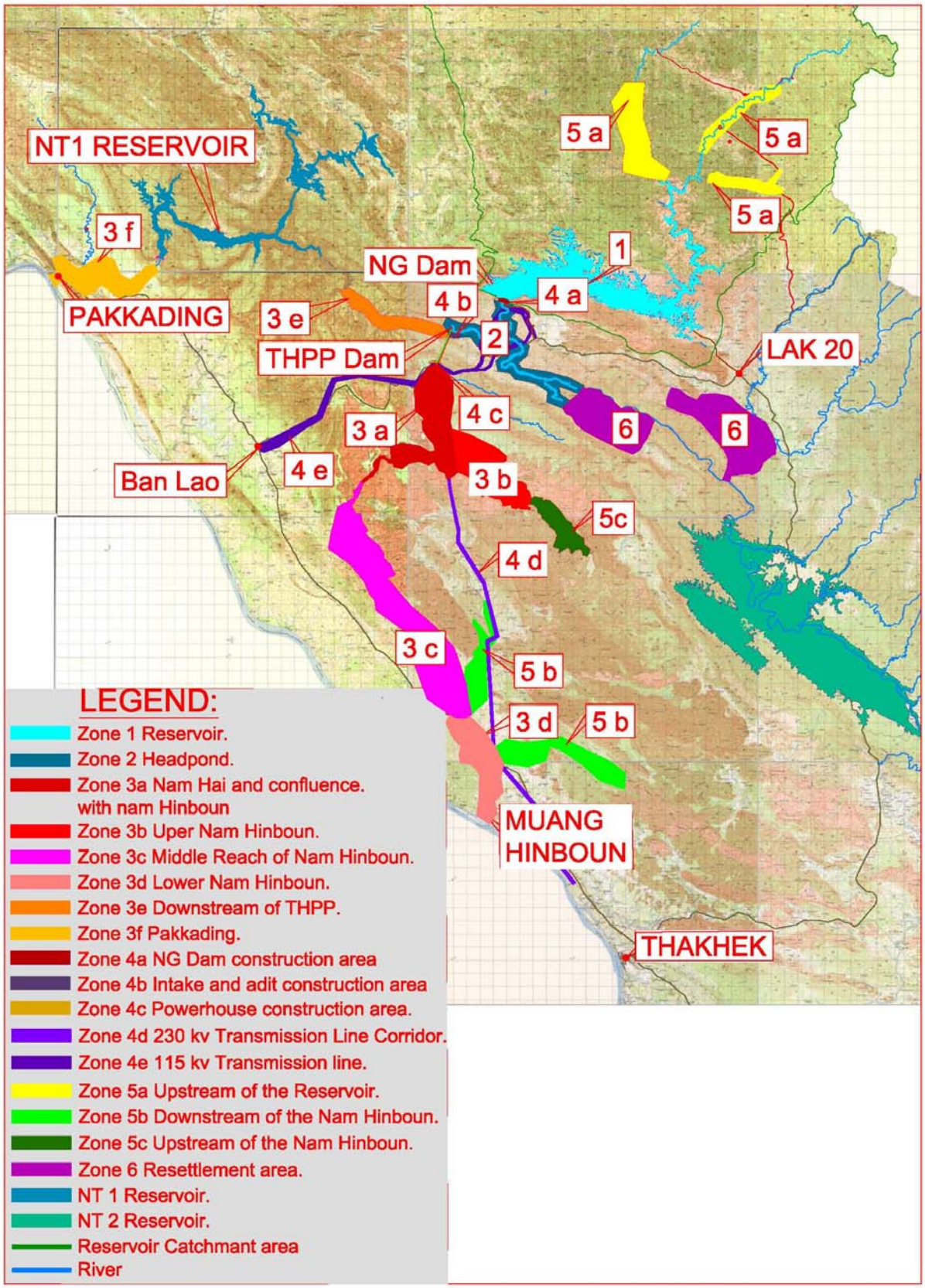


Figure 3-2. Project impact zones

3.3 Power Project Features

3.3.1 Dam and Reservoir

Site

A 65 m high dam will be built about 1 km upstream of Ban Thasala (462000E 2021500N). The dam site (referred to as NG) is located on the Nam Gnouang arm of the Theun Hinboun Headpond about 27 km upstream of the existing THPP diversion weir. The NG dam will create an upstream reservoir on the Nam Gnouang reaching at its maximum storage capacity about 100 km up the headwaters of the river (Figure 3-3)

Reservoir

The reservoir is planned with a full supply level (FSL) of 455 masl. The reservoir upstream of the dam at FSL will cover an area of about 105 km^2 and have a gross storage capacity of 2,450 Mm^3. The reservoir will in most dry seasons draw down to an elevation of 420 masl. At that level the water volume will be 0,189 Mm^3 and the surface area about 15 km^2. This will give a live storage volume (water available for power production) of 2,262 Mm^3.

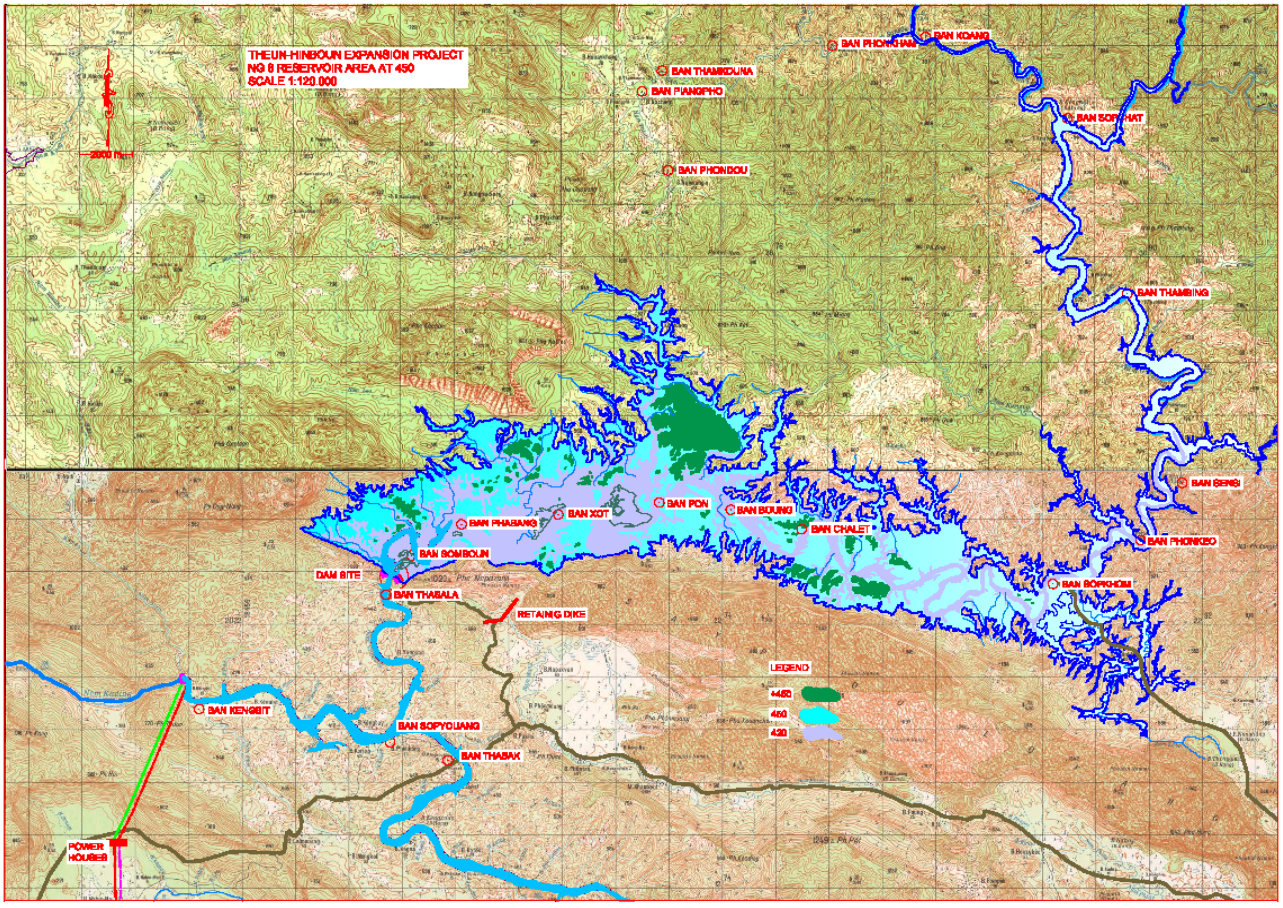


Figure 3-3. NG Reservoir

The dam

The dam will be constructed as a Roller Compacted Concrete (RCC) dam with a plunge pool and a spillway equipped with 5 radial gates. The reservoir water level will surcharge above the FSL during ex-

treme floods with the maximum water level during maximum floods being at 459.8 masl. Accordingly, a dam crest level at 460 masl has been selected with a 1.2 m parapet wall to be provided above the crest level.

3.3.2 NG Power Plant

A power plant will be integrated in the dam structure. This plant will have an installed capacity of 60 MW. Power from the NG facility will be routed from Ban Thasala to Ban Lao and be sold to EdL for consumption within Lao PDR.

3.3.3 Headpond Diversion Tunnel

A second diversion and headrace tunnel will have an intake integrated with the existing weir at Ban Kengbit. The arrangement will divert water from the existing THPP Headpond down to the extended THXP power plant at Ban Khounkhan. The new tunnel will be excavated on the right side (west) and in parallel with the existing tunnel. The new power station will be located immediately adjacent to the existing power plant building.

3.3.4 Downstream Power Station and Channel

The expansion of the power plant will consist of a single unit with a nominal capacity of 220 MW.

The existing tailrace canal, surge pond and regulating weir can accommodate the additional 110 m^3/sec (220 m^3/sec in total) from the expansion only minor modifications.

3.3.5 Auxiliary and Ancillary Features

Retaining dyke

The initial geological investigations indicate a possible seepage from the NG reservoir through the western part of the karstic formation of the Pha Kouanchan ridge. A seepage and surface runoff monitoring program is being implemented. Results and observations from this program together with planned early impounding of the partially completed reservoir will assist in determining whether a containment structure is required. The containment structure could consist of an embankment dike approximately 2.5 km long and 35 meter high built in the Nam Phadang catchment just south of the limestone ridge. This is structure will partly be located inside the Pha Kouanchan Provincial Protected Area (Figure 3-4).

The quarry, for providing materials for the dam construction will be located within the western limestone block of Pha Kouanchan PPA. The area of the quarry is determined to 104.1 ha.

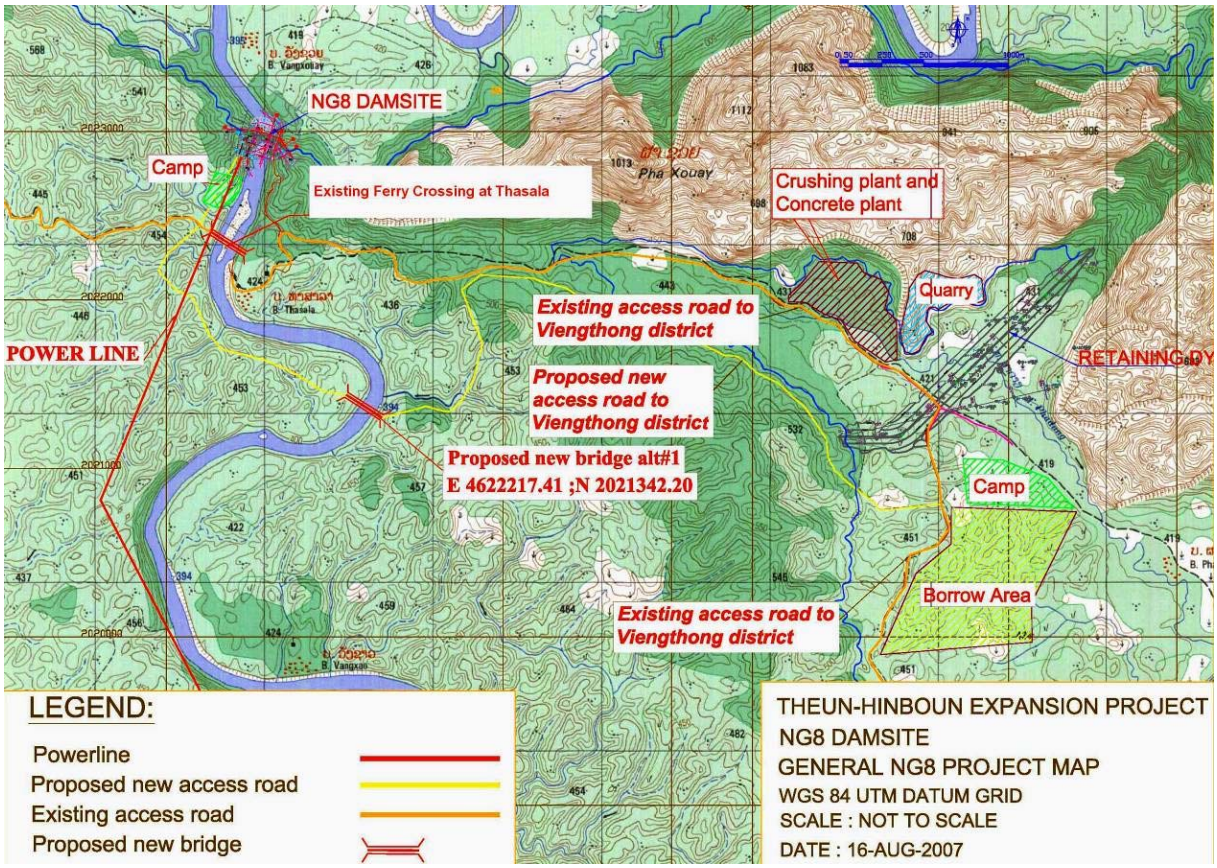


Figure 3-4. Auxiliary and Ancillary Project Features in the dam site zone. Quarries, spoil tips, retaining dyke, etc.

A borrow area for embankment fill will be located on the Nam Phadang Plateau within 2 kilometres of the retaining dike at Ban Naphavan. The borrow area is indicated to cover 248.6 ha. A crushing and concrete batching plant site will be located in the vicinity of the retaining structure on the southern face of Pha Kouanchan ridge (Figure 3-4).

Spoil areas for the THPP Intake and headrace waterways will be located in the areas previously used for the initial project. These are located at adit 1, at adit 2, at the surge chamber area and in the vicinity of the power house.

Internal transmission lines

A 115 kV transmission line will be constructed from the switchyard at the NG power house to the transformer station at Ban Lao near National Road 13. This line will follow NR8 and pass through some scenic areas nearby or just within the boundaries of the Nam Kadding NPA. The line corridor is about 21 km long (Figure 3-4).

A 22 kV line from the THPP switchyard to provide power to the construction activities in the NG area is foreseen. The line routing has not been decided but will most likely follow existing or new roads to the construction sites.

Access roads and bridges

An 11 km construction and access road from Ban Pakha on NR 8 to the dam site will be established. For most of the length this will be an upgrading of the existing road to Ban Thasala to an all weather class IV road. Some smaller new section of roads will be needed to cater for transport between the borrow pits, quarries, camps, etc. and the dam site (Figure 3-4).

The construction of the road includes a concrete bridge over the Nam Mang and a re-routing to a preferred site for a bridge over the Nam Gnouang some 800 meters below Ban Thasala. The bridge over Nam Gnouang at will replace the existing ferry on the road to Viengthong. The actual alignment of the road is not yet known but it will pass through or nearby the three villages of Pakha, Naphavan and Thasala.

The existing road to Ban Sopkhom and Ban Thongviengkham in the eastern part of the reservoir area are likely to be upgraded if needed as part of the mitigation measures and the implementation of the environmental and social management plans. It is however, likely that parts of the road will be flooded when the reservoir reaches FSL.

Camps and workshops

Major construction camps are foreseen on the right bank of Nam Gnouang at Ban Thasala for the NG dam and power plant construction. A camp will also be needed at Ban Khounkham for the works at the existing powerhouse area. Smaller workshops will be located at the THPP intake, at adit 2, at the surge chamber area and along the power transmission line routes.

Owner's Engineer and THPC staff will require expanded facilities at the THPP site. Housing is planned adjacent to the former Environmental Management Division (EMD) housing and office buildings.

A work camp will be established within the perimeter of the borrow area, serving as base for workers constructing the retaining dike.

3.3.6 Project Features in the Intake and Tunnel Zones

New Intake Structure

A new intake structure will be constructed next to the existing one near Ban Kengbit. The structure will be integrated into the existing weir. Although the land area needed for this purpose is rather small, there may be some minor additional land requirements adjacent to existing land already owned by the Company.

Diversion Tunnel

The intake structure will lead the water into a second diversion and headrace tunnel of about 7 km length through the Sayphou Mountain in parallel to and west of the first tunnel (see Figure 3-5). Most of the tunnel will be excavated underground. For the last about 500 metres the ground will be excavated, penstock put in and covered again.

Adits

In total, three adits will be made to facilitate the construction of the diversion tunnel. Two of these will be on the northern side of the Sayphou Mountain Range. Adit 1 will be located near Ban Kengbit, just south of the diversion weir. Adit 2 will be located on the Sayphou Mountain Range to the west of the tunnel, approximately half way between the intake and the power house.

Work Camp

A smaller camp will be established for the construction of Adit 2 consisting of an area of approximately 2.9 ha.

Access roads

Two access roads are planned for the diversion tunnel area:

- From NR8 to the Intake at Ban Kengbit; this will mainly be a widening of the existing dirt road; and
- From NR8 to Adit 2. For the major part of this road, the current road will be cleared but otherwise maintain its dimensions. However, the road will be extended by approximately 1,000 metres to reach the new Adit 2.

Spoils

Two spoil areas a planned for depositing of soil and rock material:

- One area in Ban Kengbit measuring 6.8 ha. located south of the access road; and
- One area near Adit 2 with an area of 9.9 ha.

3.3.7 Project Features in the Power Station Area

Power Station

A new power station will be located immediately adjacent to the existing power plant building on land already belonging to THPC. The expansion of the power plant will consist of a single unit with a nominal capacity of 220 MW.

Tailrace Channel and Surge Pond

The existing tailrace channel and surge pond can handle the additional 110 m^3/sec (220 m^3/sec in total) from the expansion without major modification. Minor excavation works will take place within the fenced area. Its function as a re-regulation pond will however, be limited.

Penstock

A penstock will be excavated for the last 500 metres of the tunnel before it reaches the power house. Once the penstock is in place, it will be covered with soil.

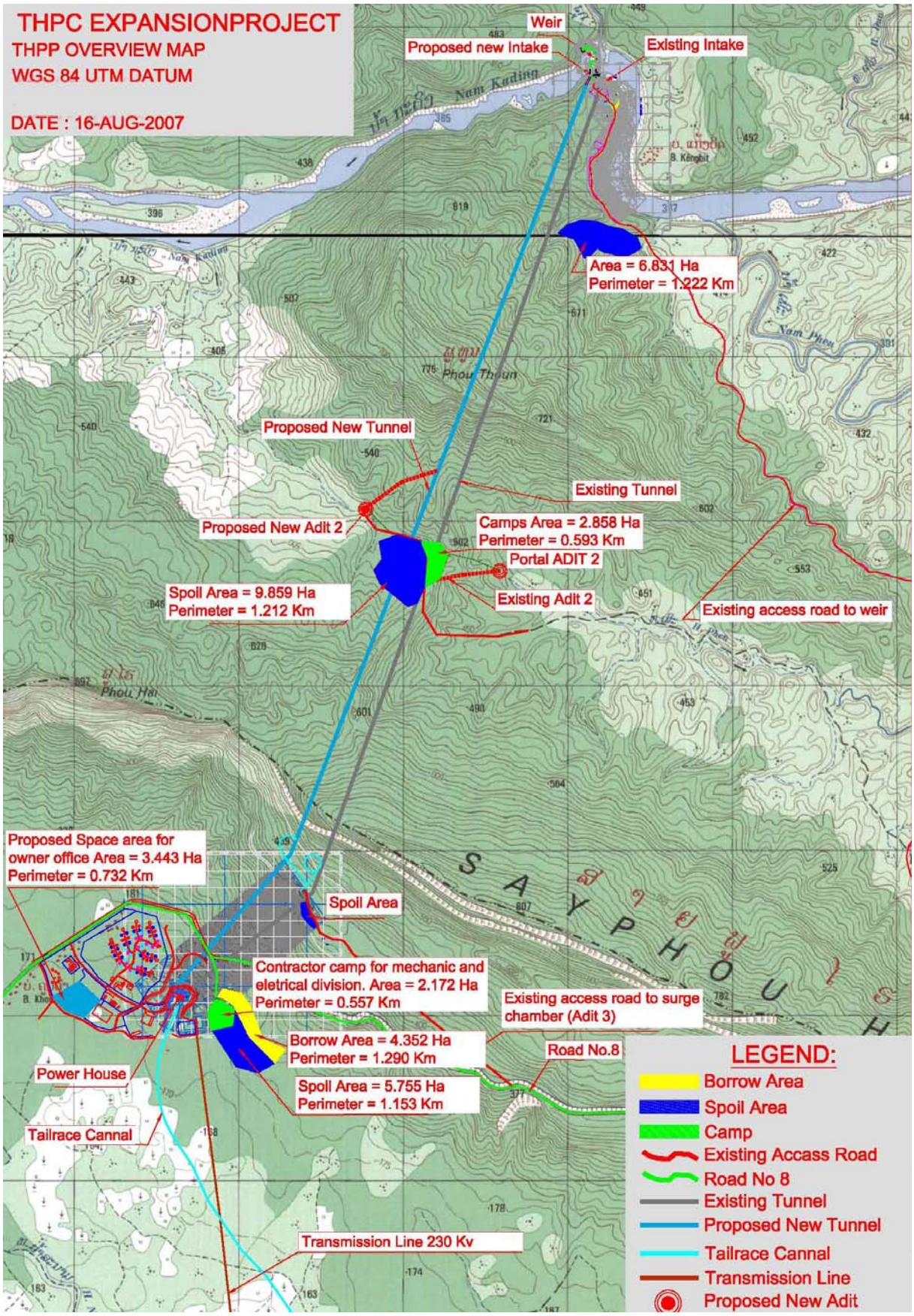


Figure 3-5: Location of Intake, Diversion Tunnel, Adits, Roads and Spoils for THXP.

Adit

Adit 3 will excavated between the top of the Sayphou Ridge and the power house.

Access Road

The access road used for the adit and penstock excavation for the THPP will be cleared and put in place again. There will not be any enlargement of this access road.

Work Camps

Two work camp areas are planned within the downstream power station Areas – both within the THPC compound:

- A camp for project staff covering 3.4 ha in the western part of the compound; and
- Three adjoining work camps, immediately east of the power station with a total area of 2.2 ha.

Borrow

A borrow measuring 4.4 ha is planned for the area further east of the power station, still within the THPC Compound.

Spoils

Two spoil areas are designed for this area:

- A relatively small area north of NR8 for the soil excavated from the diversion tunnel. This spoil measures 0.6 ha; and
- A larger area of 5.8 ha, southwest of and adjacent to the borrow.

A 22 kV line from the THPP switchyard to provide power to the construction activities in the NG area is foreseen. The line routing has not been decided but will most likely follow existing or new roads to the construction sites.

3.4 Project Construction and Operation

3.4.1 Construction Schedule and Milestones

The priority construction programme assumes an award of the engineer-procure-construct (EPC) contract in mid 2008. This contact will be terminated in mid 2013 given that the retaining dyke has to be build. The Commercial Operation Date (COD) of the extended THPP will be in September 2011 and for the NG power plant in January 2012.

3.4.2 Reservoir Filling

The filling of the reservoir will start in 2011. The level of 439 masl will be reached in June/July 2011 and the full supply level of 455 masl is

assumed to be reached at the time of COD for NG in late 2011 or beginning of 2012.

3.5 Reservoir and Power Plant Operation

3.5.1 Reservoir and NG Power Plant Operation.

The THPP power plant is in effect operated by EGAT. EGAT dispatches the plant according to their energy needs for the day with a 24-hr planning period.

The NG dam will be built to create a seasonal storage reservoir upstream of the THPP facility. The reservoir will operate mostly during the dry season to complement the unregulated flows from the Nam Phao and compensate for the water diverted by the Nam Theun 2 project, and thus ensuring maximum energy production at THPP. The power plant at NG will operate when water is released to THPP. Approximately 70% of the energy will be produced during the dry season (mid-November to mid-June). Very little spill is expected. It is calculated that over a 18 year period only 1.8% of the annual flows will spill over the NG dam.

100% of the energy produced at the NG (60 MW) power plant will be sold to EDL.

3.5.2 Operation of the Extended THPP

With the expansion the THPP facility will become more of a base load plant than today. The provision of more sustained dry season flows will give flexibility in capacity for longer periods.

Production regimes during the wet season will be similar to the situation today although the capacity will be doubled. There is the likelihood that the plant is operated sporadically during latter parts of some exceptionally dry years. On average, the energy production will be distributed evenly with 50% being produced during the wet season and 50% during the dry season. At the moment the distribution is 44% and 56%.

Spills are expected to be in the order of 10% of the annual flow at THPP headpond weir with an additional 2% representing riparian releases (5 m^3/sec constant) and 3% being attributed to large floods of short duration.

100% of the energy produced at the extended THPP will be sold to EGAT.

EGAT will be required to take all energy available. This means that they will operate during most days of the year (probably all days). The capacity at which they will operate will vary from wet to dry season. Maximum discharges of 220 m^3/s are expected during most of the wet season while fluctuations between full capacity and minimum capacity area expected during the dry season. Discharge flows will vary between 220 m^3/s and 90 m^3/s for short durations during the latter parts of the wet season.

The regulating pond (surge pond) attenuates the incremental flows from maximum to minimum during the operation regime of the plant. The pond will not be able to fully regulate the flow, but it will buffer the otherwise abrupt changes in discharge volumes. This means that increases in flow from 0 m^3/s to 220 m^3/s (max) will be seen over a few hours in the Nam Hai and Nam Hinboun. The same phenomenon occurs when the plant is shut down as the flows will gradually decrease to 0 m^3/s over hours rather than instantaneously.

3.6 High Voltage Transmission Line

The increased power production at the Theun Hinboun Power Plant will require a doubling of the capacity of the transmission of the generated power to the link up with the Thailand transmission network.

This will require a second 230 kV transmission line in addition to the existing Theun-Hinboun transmission line from the THHP switchyard to the Mekong crossing at Thakhek (Figure 3-6).

The existing switchyards at the THPP facility and at Thakek will be extended to accommodate for a 230 kV single circuit transmission line.

The new transmission line will for most of the reach be routed using the same corridor as the existing line. A 230 kV line will normally require a 30 m wide corridor between lines for short circuit protection. In addition, a minimum of 30 m on either side of the lines should be maintained for public safety reasons. Combining the two lines will minimise the landtake as the combined safety width of the lines Right-of-Way will be only 90 m.

There will in a few sections of the line be necessary to separate the two corridors. This is when passing rocky outcrops where the terrain does not allow for two lines and in cases where the line will come too close to dense settlements.

More details on the routing and technical specifications of the transmission line can be found in the separate document on the Transmission line ESIA. (Chareun and Associates 2007)

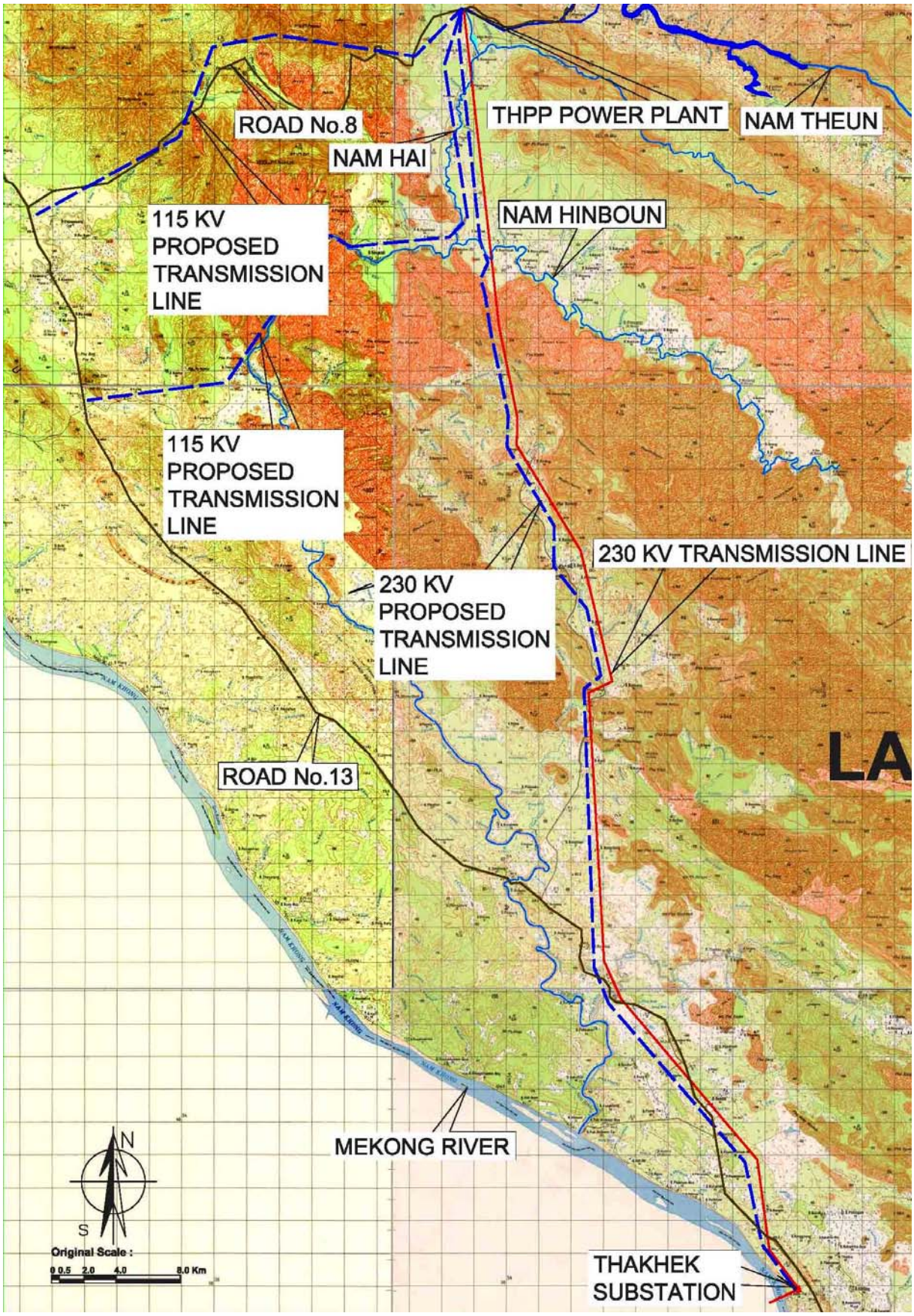


Figure 3-6. High voltage transmission line corridor

4 PHYSICAL ENVIRONMENT

4.1 Climate

The headwaters of Nam Theun and Nam Gnouang are located in the Annamite mountain chain which forms the border between Lao PDR and Vietnam. Elevations of some high mountains in this chain are over 2,000 meters above sea level. The headwaters of Nam Hinboun are located west of the Nam Theun catchment at about 400 masl. The Mekong River at the confluence with Nam Kading is located at an elevation of about 140 masl and the confluence with Nam Hinboun at 138 masl.

The profiled topography of the catchment determines the patterns of air temperatures and rainfall resulting in large differences in temperature and rainfall frequency and intensity.

4.1.1 Temperature

Air temperatures are measured on a daily basis by the THPC Environment Monitoring Division (EMD) at the Headpond and at the power house at Ban Khounkham.

Average temperature

The calculated average monthly air temperatures at the Headpond site (Figure 4-1) and at the powerhouse (Figure 4-2) are based on the EMD measurements from 1999 to 2006. Average minimum monthly air temperatures range from 16.0 ^{0}C – 23.9 ^{0}C at the Headpond and from 17.4 ^{0}C – 23.9 ^{0}C at the powerhouse. Average maximum monthly air temperatures range from 30.1 ^{0}C – 36.3 ^{0}C at the Headpond and from 31.9 ^{0}C – 36.6 ^{0}C at the powerhouse.

Air temperatures are highest from April to October and lowest from December to February. During the wet season (April – September) little difference is seen in the temperatures at the two sites. In the dry season the minimum measurements at the dam site are about one to two degrees below the powerhouse measurements. The difference in temperature can be attributed to the difference in elevation of the two stations. The Headpond station is located at 400 masl and the powerhouse station at 170 masl.

Max and min.

Measured maximum air temperatures at the Headpond and the powerhouse have been as high as 45 ^{0}C. The maximum temperature at the Headpond is measured in September and those at the powerhouse have been measured in April.

Minimum temperatures occur in the months of December and January. The measured minimum air temperature at the dam site has been as low as 5 ^{0}C, but at the powerhouse no air temperatures lower than 11 ^{0}C were measured.

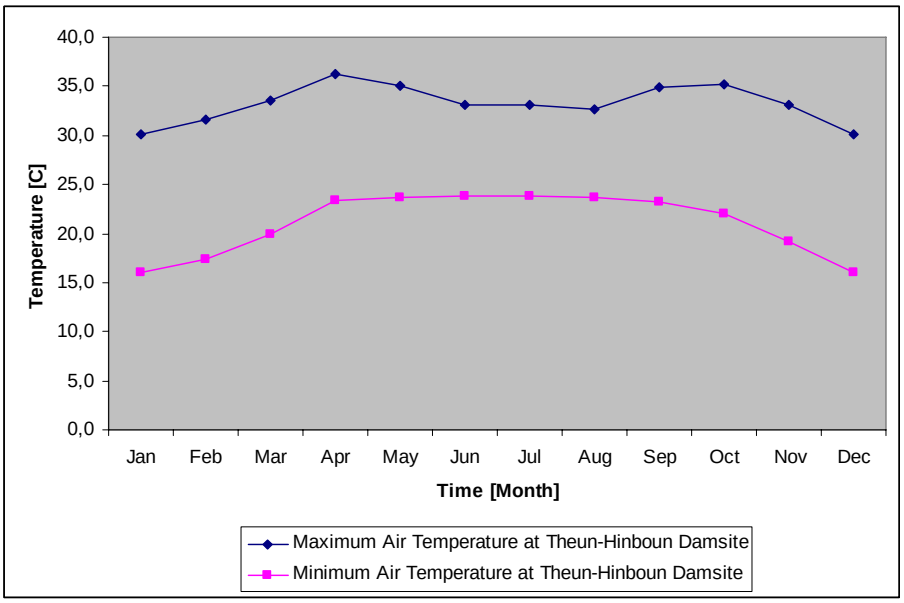


Figure 4-1. Average maximum and minimum monthly air temperatures measured at Theun-Hinboun dam site from 1999 to 2006 (THPC-EMD)

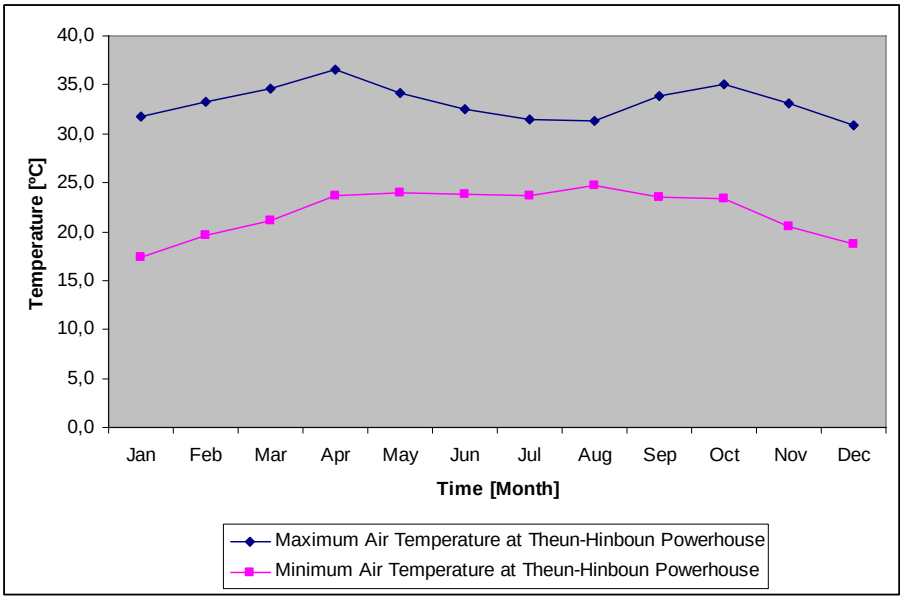


Figure 4-2. Average maximum and minimum monthly air temperatures measured at Theun-Hinboun powerhouse from 1999 to 2006 (THPC-EMD)

4.1.2 Rainfall

The local rainfall of the Nam Theun basin is very complex and significant efforts have been made to understand the rainfall pattern in the project area. The catchment's north–east boundary comprises the divide between the rivers emptying into the South China Sea and the rivers emptying into the Mekong. The rainfall on each side of this divide is dominated by different weather systems. During the south–west monsoon the winds bring humid air from the Indian Ocean caus-

ing the wet season to peak in July-August in Lao PDR. In central Vietnam, however, much rain falls in the transition period between the south–west and the north east monsoons (which carry humid air from the south China sea) giving a peak rainy season in September–October. It was found that the heavy rainfalls in Vietnam during these months also spill over to the upper mountainous part of the Nam Theun basins in Lao PDR. The rainfall in the Nam Theun basin is therefore a mix of both the south western and eastern water systems.

To add to this complex situation, the mountains along the border between Lao PDR and Vietnam affect the local climate. The steep slopes and mountains ridges cause rainfall due to orographic effects on one side, but create a rain shadow on the other side. Besides giving very large local variations this phenomenon causes a dip in average annual rainfall along the centre of the Nam Theun basin. Annual rainfall is higher at the water divides because of orthographic effects during either the south–west or the north-east monsoon, while the central parts suffer from the rain shadow. This effect is especially prevalent in Nam Phao and Nam Gnouang tributaries, which receive the least amount of rainfall within the Nam Theun Basin. The complex rainfall pattern is illustrated in Figure 4-3.

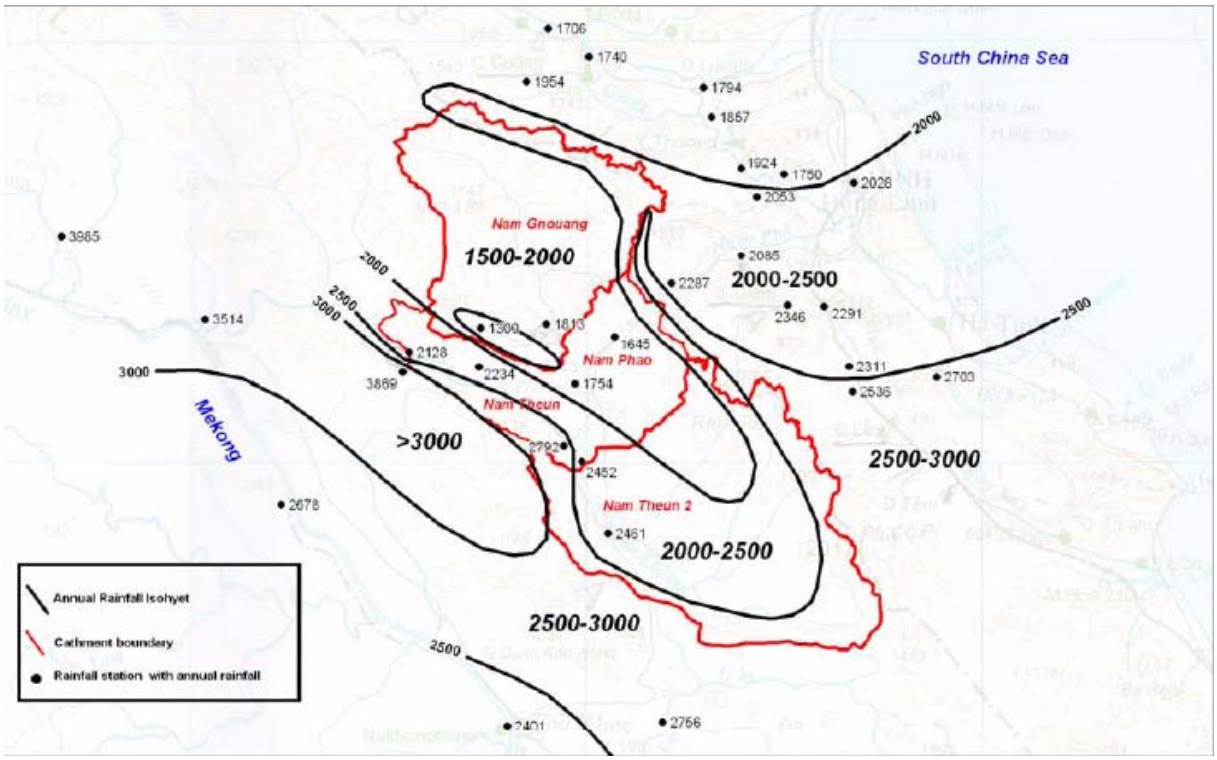


Figure 4-3. Isohyet map of the project area (SWECO 2006)

Of major importance is also the fact that the Nam Theun basin is regularly affected by typhoons. The river basin is located in the direct path that typhoons normally take during the months of September and October. The typhoons may cause extreme rainfall and runoff and historic records show that large floods in the Nam Theun are often related to such events. Typhoons must therefore be taken into

account for estimation of floods in the Nam Gnouang, Nam Phao and Nam Theun rivers.

THPC-EMD has measured rainfall at the Headpond area and at the powerhouse from 1999 onwards. At Ban Sensi, in the upper part of the Nam Gnouang reservoir area, rainfall has been measured from 2005.

Figure 4-4 shows the average monthly rainfall at the THPP Headpond, and powerhouse and illustrates the distinct difference between the dry season and the wet season rainfall. The average yearly rainfall in the measured period was 2.6 m at the dam site and almost 4 m at the powerhouse

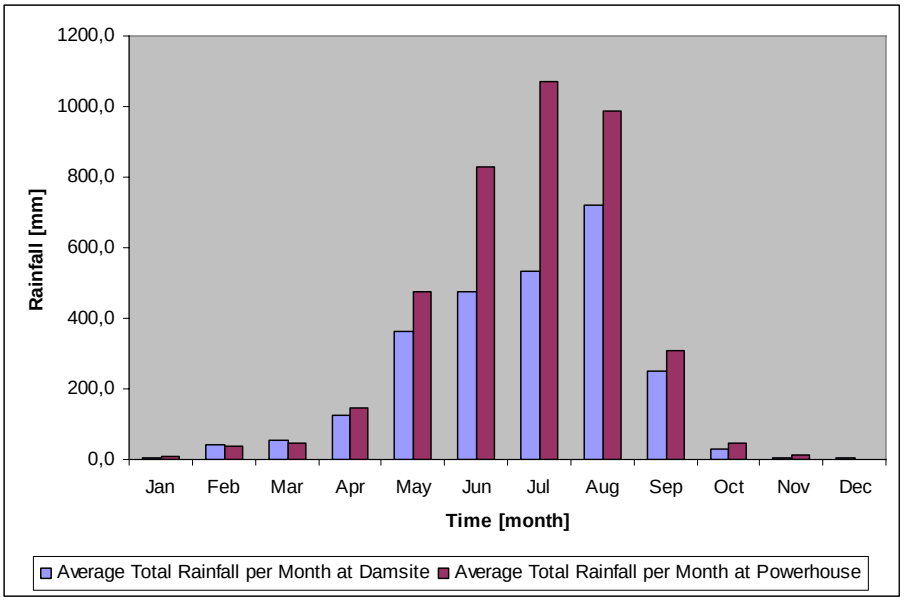


Figure 4-4. Average monthly rainfall measured at Theun-Hinboun damsite and powerhouse from 1999 to 2006 (THPC-EMD)

Figure 4-5 shows the monthly average rainfall at Ban Sensi. Again a clear difference can be noticed between the dry season from October to April and the rainy season from May to September. At the powerhouse and at the Headpond maximum rainfall peaks in July, but at Ban Sensi maximum rainfall is skewed to the end of the rainy season in August and September.

The average rainfall per year at Ban Sensi is 1.7 m per year, which is less than half of the rainfall at the powerhouse.

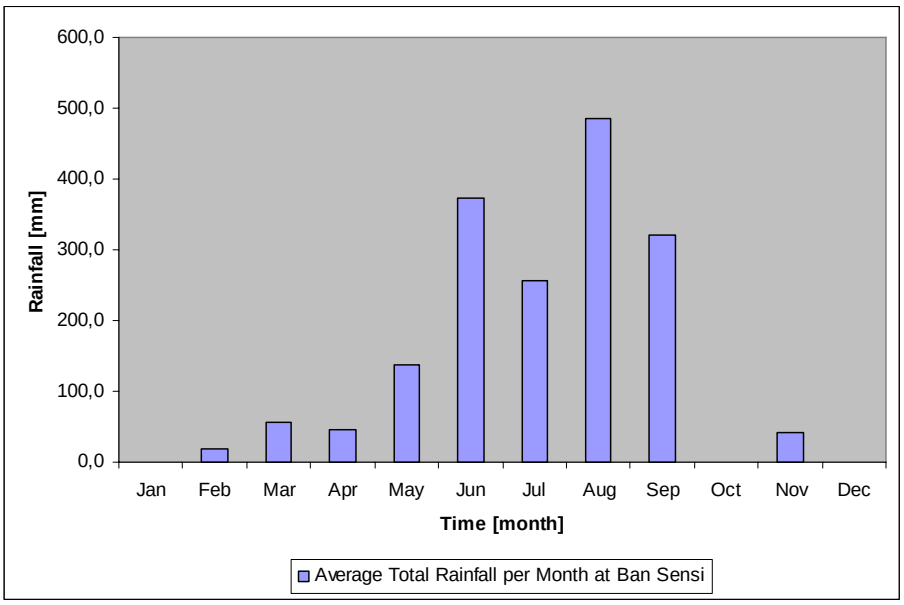


Figure 4-5. Monthly rainfall 2005 and 2006 at Ban Sensi (THPC-EMD)

In September, 2002, a typhoon caused extremely high daily rainfall. Water levels in Nam Gnouang raised more than 9 meters in one day and huge landslides occurred at the headwaters of Nam Gnouang.

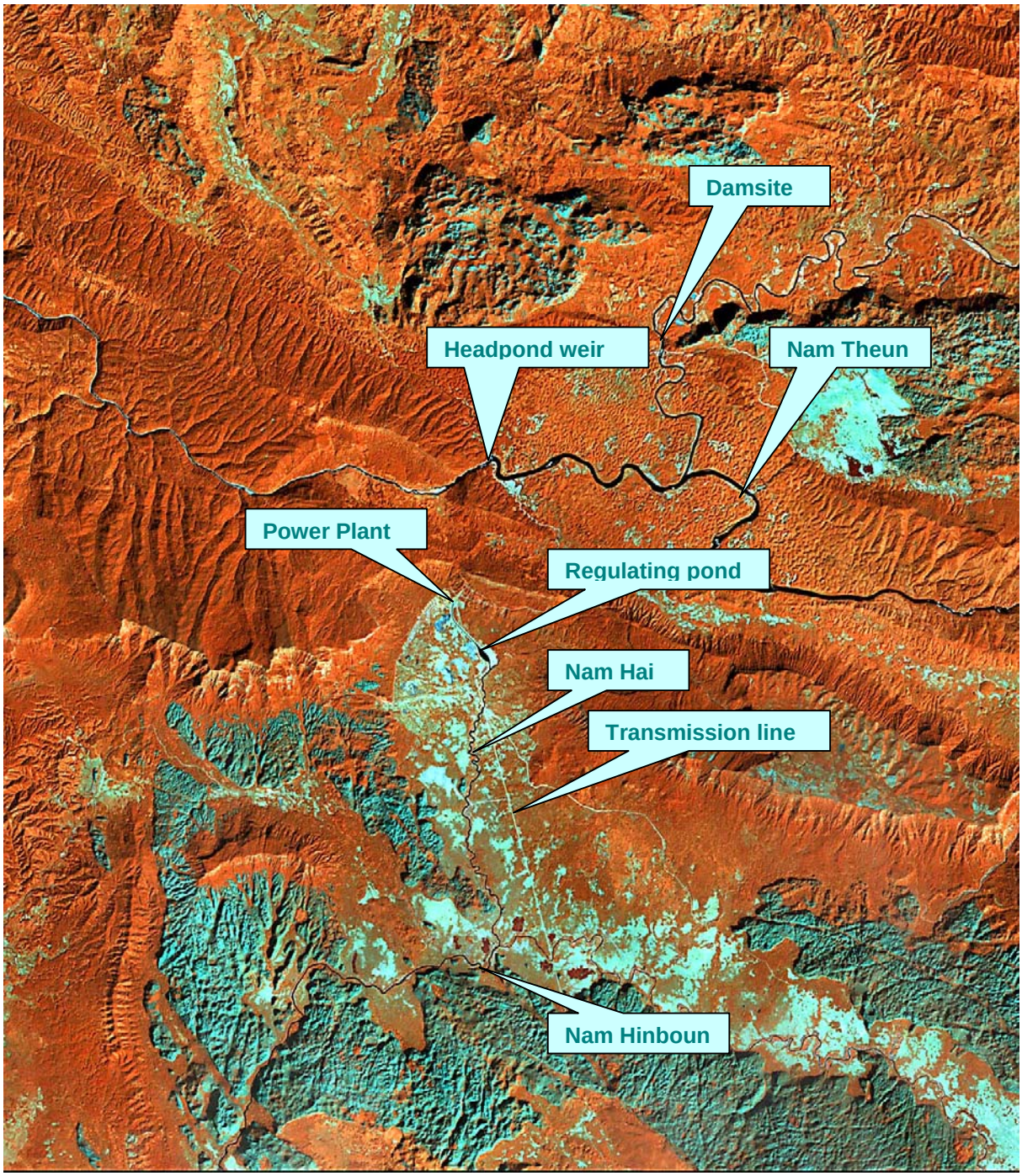
4.1.3 Evaporation

Evaporation data have not been collected for the impacts zones of this project. The closest available evaporation records are from Ban Phaeng and Nakhon Phanon in Thailand. These two stations in Thailand give annual figures for basin potential evaporation values of 1,084 and 1,000 mm/year respectively.

For Nam Hinboun catchment it is believed that evaporation is relatively similar to the Thai figures. The evaporation has two peaks during the year with the highest values in March to May and another peak in October to November. Normally potential evaporation decreases with altitude. Thus, for the Nam Theun and Nam Gnouang catchments the evaporation figures are believed to be less than 1,000 mm/year.

4.2 Topography

Absolute elevations of the catchment range between about 140 m on the Mekong Flood Plain to about 2300 m along the Annamite watershed. Many mountains in the watershed, and isolated mountains within the catchments, have summit elevations of 1500m to 1900m. The most notable features of the relief are the scarcity of flat land (Figure 4-6). There are high average slope values and the occurrence of long cliffs and escarpments of 200 to 500 m height along the WNW-ESE alignments of the sedimentary systems, marking the boundaries of different sedimentary rock types.



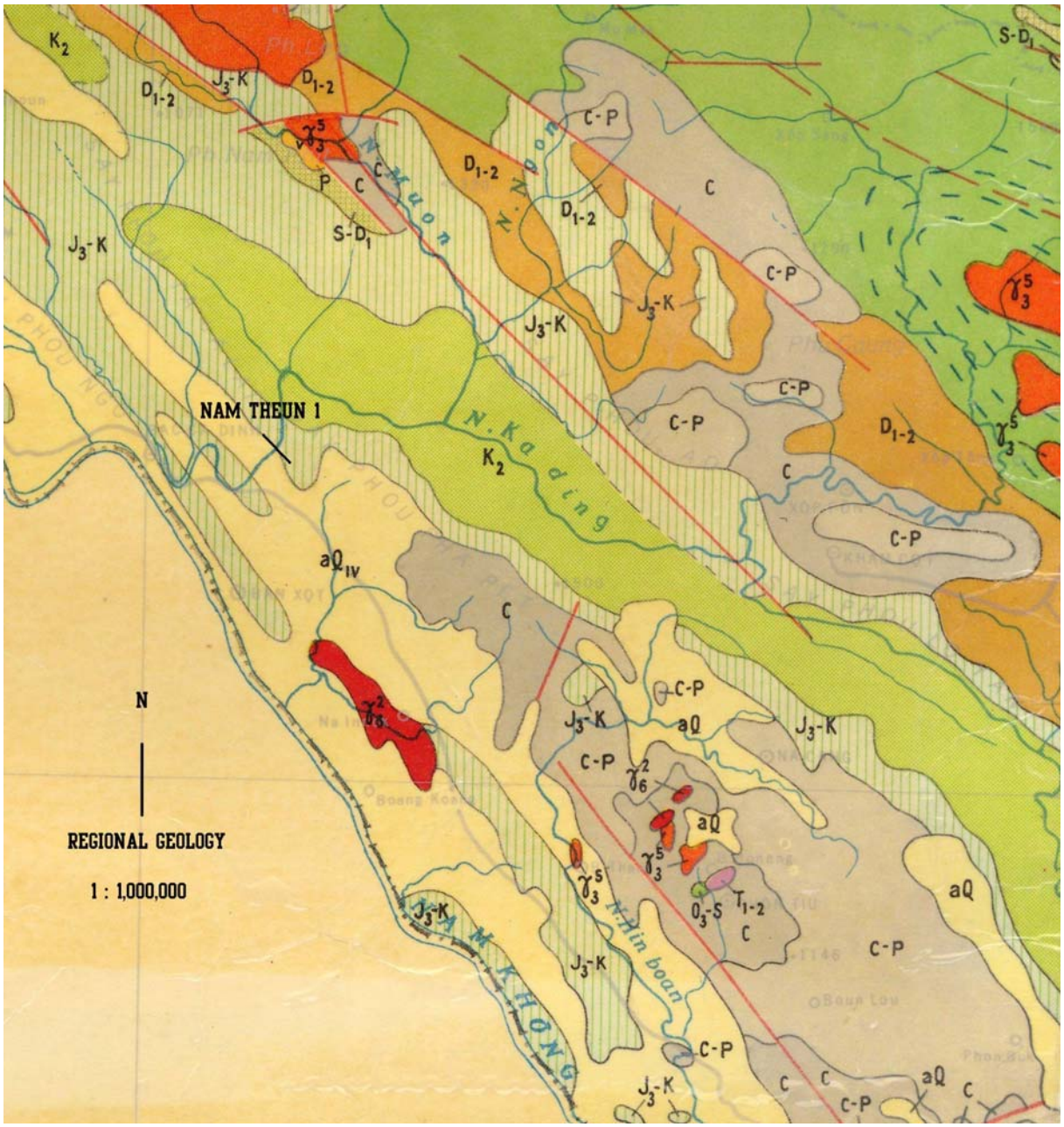
Light green: Agricultural land and grassland
Darker blue-green: Barren rock
Red-brown: Wooded

Figure 4-6. Landsat Image of parts of the project area

4.3 Geology

4.3.1 General geology

The the geology of the region covering the project area is shown in Figure 4-7. The map section is taken from the Geological Map of Kampuchea, Lao PDR and Vietnam.



aQ_{IV}: **Quaternary** (sand, silt, clay)
K2: **Upper Cretacerous** (red conglome-rate, sandstone, claystone)
J3-K: **Upper Jurassic- Cretaceous** (red conglomerate, sand-, silt-, claystone
C: **Early- Middle Palaeozoic** (carboniferous)
C-P: limestone
D1-2: siltstone

Figure 4-7 Regional Geology

4.3.2 *Nam Theun – Nam Kading*

The Nam Theun catchment is geologically diverse, with rocks of alluvial, sedimentary and igneous origin. A corridor of red conglomerated sandstone, siltstone and claystone runs on each side of the Nam Theun/Nam Kading main stream channel from the source to the confluence with the Mekong. Parallel to this, to the north and south, are

Carboniferous and Devonian pavement and karst limestone uplands, with isolated granite extrusions.

4.3.3 *Nam Hinboun*

The Nam Hinboun catchment lies predominantly in the limestone zone, coming off the extremely steep Nakai-Nam Theun Plateau, descending through limestone uplands and down through quaternary alluvial sandstone, siltstone and claystone of the Mekong main stream floodplain.

4.3.4 *Nam Gnouang Reservoir and Dam Site*

Reservoir

The reservoir area consists of Jurassic sandstone and Carboniferous karstic limestone. The majority of the limestone is found bordering the southern shores of the reservoir. The reservoir water is in most areas separated from contact with the limestone by an underlying layer of relatively impervious siltstone rock overlain by deeply weathered impervious residual material.

Damsite

The planed NG damsite is located at a point where the Nam Gnouang breaks through a ridge of Carboniferous limestone, schist, shale, & siltstone, which includes karstic limestone of the Bacson series, to enter younger Jurassic-Cretaceous sandstones, conglomerates and siltstones. The Dam Site is located over impermeable Jurassic sandstones.

4.3.5 *Mineral Resources*

Nam Theun/Kading

Deposits of gold, lead, graphite, and tin are believed to be present in the Nam Gnouang and Nam Theun catchments. And some small scale commercial mining is taking place.

Some alluvial panning for gold is practised by villagers during low water levels (at the end of the dry season) on the Nam Gnouang and Nam Kading. Alluvial deposits are dredged by hand or mechanised dredgers from the bottom of pools and then panned for gold. In particular the villagers of Ban Kengbit on the Theun-Hinboun Headpond, and Ban Phonsi in the lower Nam Kading are involved in alluvial panning of gold deposits.

Alluvial gold is also found in Nam Kata, a stream entering the Nam Theun tributary, Nam Phao, downstream Lak Xao. Prospects exist for commercial exploitation. At present gold is extracted by artesian means, which includes the use of mercury. THPC is presently monitoring these rivers due to the locations of proposed resettlement sites along the Nam Phao and Nam Phiat.

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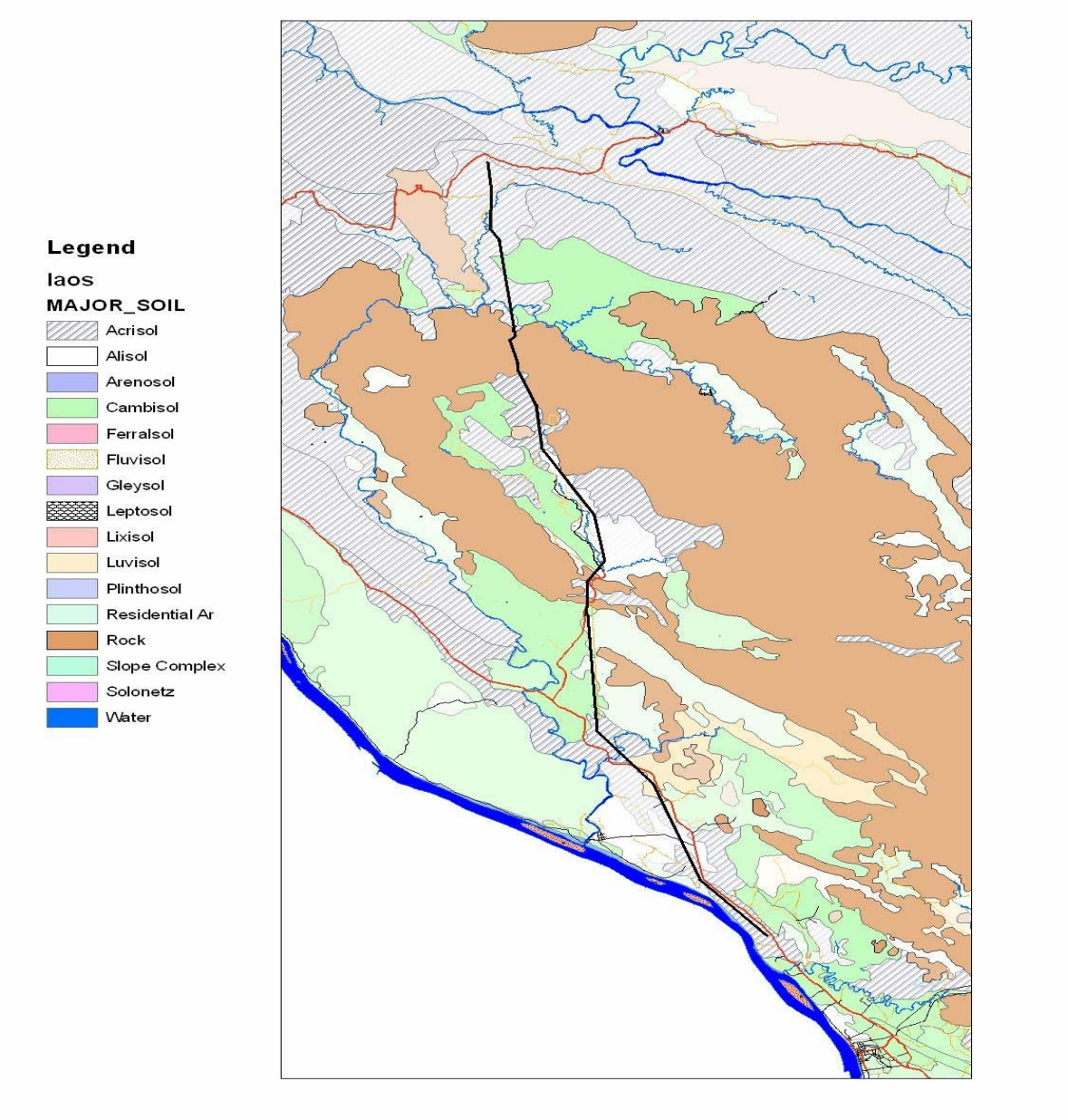

Figure 4-8. Soil types in the Nam Hinboun catchment (Chareun 2007)

Nam Hinboun

Located on the Nam Pathaen, a tributary of the Nam Hinboun is the Maouang Kai tin and lead mine. The mine has been worked since about 1930, originally established under the French colonial regime. It is a typical small washing and screening process applied to a local lead ore deposit in silt. It uses water pumped from the Nam Pathen stream to wash out the ore. There are no settling ponds, and the sediment rich water is fed directly back into the Nam Pathen leading to downstream water quality problems. Some of the discharge water also enters Nam Thak through an underground river.

Several unexplored and un-mined iron and tin deposits are known to occur in Khammouane Province, and small scale operations have already started at some of these sites.

4.4 Soil

In general, hill soils are shallow, acidic and strongly leached. Silts and fine sands are chiefly found on slopes. Finer particles are accumulated on valley floors and here deeper clay-dominated soils have developed. The Nam Hinboun catchment is dominated by Acrisol and Cambisol (Figure 4-8) in addition to large areas coverd barren with calcareous rock

4.5 Contaminated Sites and UXOs

Compared to the situation in other parts of Lao PDR (for instance, along the Ho Chi Minh trail or the Nakai Plateau), there a low risk of encountering Unexploded Ordinances (UXO) in the NG dam site and reservoir areas. No areas are reported to be contaminated by warfare related use of chemicals.

Drop report map

This fact is supported by the information on UXO contained in the "Atlas de la Republique Democratique Populaire Lao", and US Air force Ordinance Drop Report Map (Figure 4-9). The map shows very few drop reports in the reservoir area and its catchment. This is confirmed by the residents of reservoir villages. However, the road to Viengthong has been a target for bombing and therefore many drops have been reported along the road between the Route 8 and the ferry crossing at Ban Thasala.

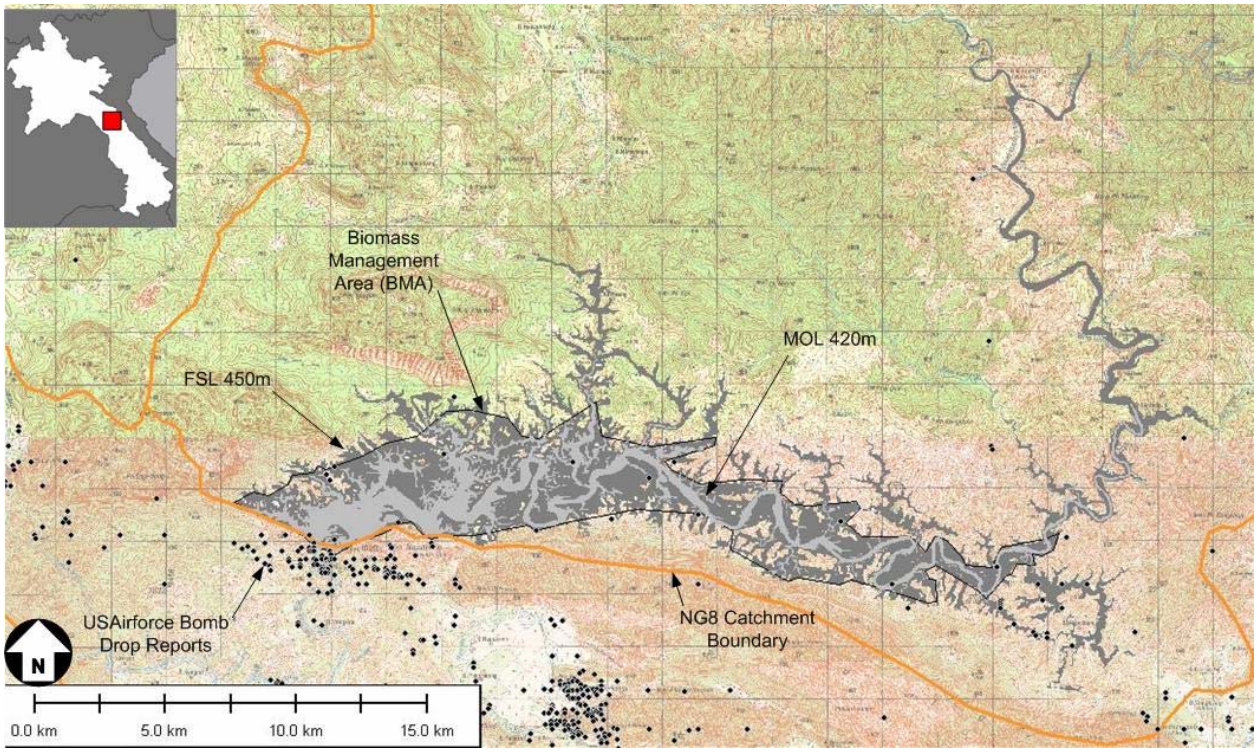

Figure 4-9. Bomb drop reports in the project area (RMR 2006a)

4.6 Seismicity

The seismic earthquake conditions have been studied in the Nam Theun catchments in connection with the different plans for hydro-power dam construction. The studies indicate that the maximum horizontal surface acceleration for a maximum credible earthquake would be in the range of about 0.1 to 0.12 g (SWECO 2006). A well designed and constructed RCC dam type does not require any special construction measures to withstand this value of seismic shaking.

Milisearch study

The specialised company, Milsearch-BPKP EOD, has carried out on-the-ground search for indications of UXO in the for project construction area. (Milisearch 2006)

Retaining dike

The investigation at the proposed retaining dike construction concluded that the potential for UXO contamination and the attendant risk is relatively low. However, the presence of UXO buried at depths exceeding the sampling parameters could not be discounted.

Dam site

The assessment of the proposed NG dam site concluded that UXO contamination had occurred during former military activities in the area. The level of contamination could not be determined by the limited sampling conducted during the UXO assessment. However, from the evidence to date it is recommended that all activities involving the disturbance of soil either during preliminary testing or subsequent construction be preceded by UXO clearance.

Riverbed

The river bed close to the proposed NG dam site construction area was not addressed during sampling activities. However, the riverbed is considered to have the potential for UXO contamination because of the recorded density of aerial bombardment in the area during military activities.

4.7 Hydrology

4.7.1 Introduction

Two major river systems will be impacted by the planned project, the Nam Theun/Nam Kading catchment (which also includes Nam Gnouang) and the Nam Hinboun/Nam Hai catchment. The outline of the catchments can be seen in Figure 4-10 below.

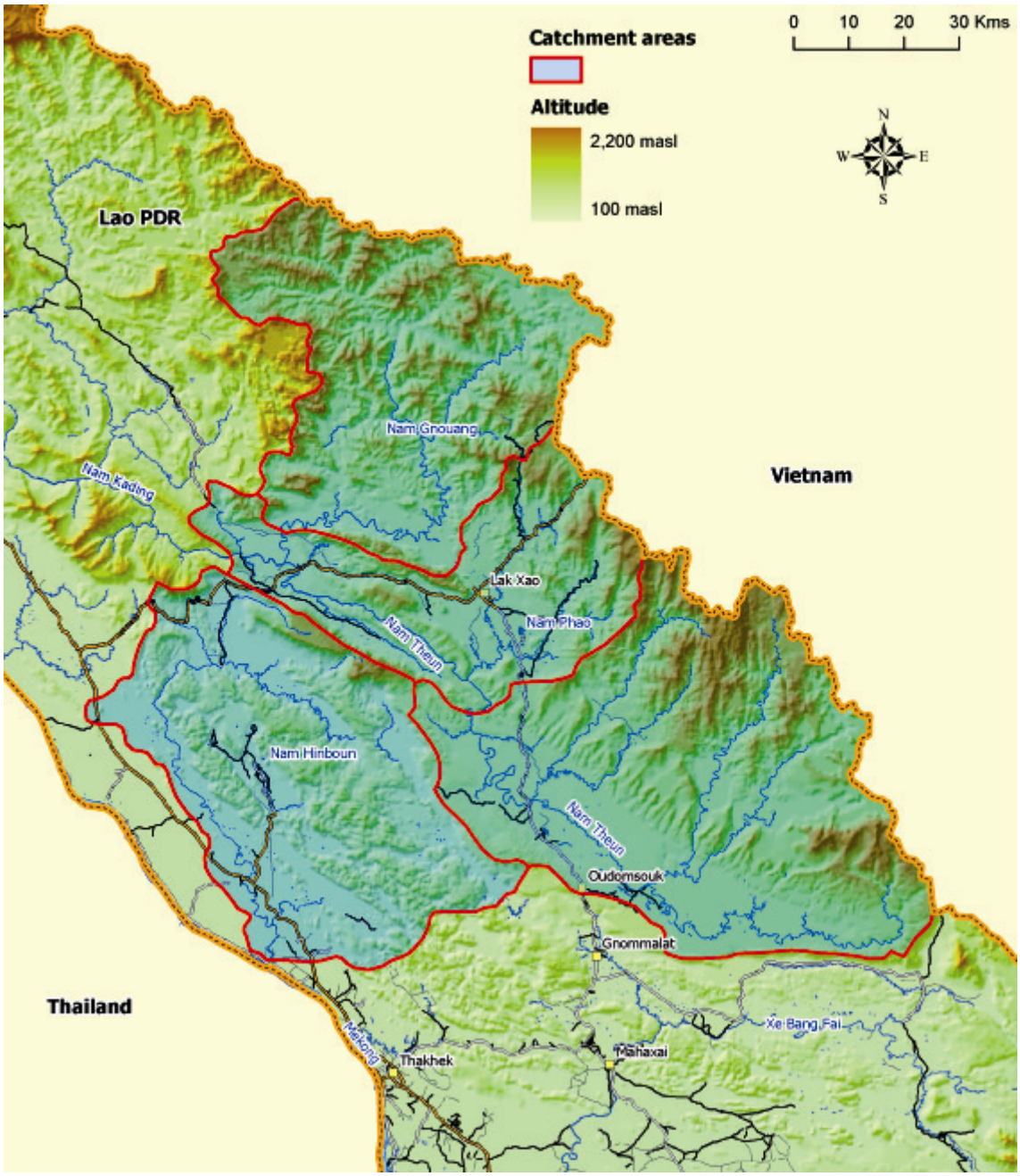

Figure 4-10. Relevant catchments and sub-catchments.

4.7.2 Nam Theun/Nam Kading

The natural Nam Theun/Nam Kading catchment covers a total area of 15,269 km^2. 8,937 km^2 (59%) is upstream of the present Theun Hinboun weir. In relation to the existing THPP and the planed expansion this catchment can be considered as the "Upstream River Catchment".

Changes

Below the THPP weir the river system has been modified by the THPP diversion of flow into the Nam Hinboun/Nam Hai River Basin. This has significantly reduced the dry season flow downstream in the Nam Kading. Further reduction in the downstream flow will result from the implementation of THXP. Effective from 2008, the runoff from about a half of the Nam Theun catchment will be diverted into Xe Bangfai from the Nam Theun 2 reservoir on the Nakai Plateau. Only a 2 m^3/s compensation flow will be discharged from the dam except for possible reservoir overspill in extreme flood situations. Thus the situation in about 2 years time will be that the catchments at the THPP diversion weir will consist of the residual Nam Theun catchment (with the major tributary Nam Phao) and the Nam Gnouang catchment.

Inflows model

As an input to the power generation simulation model, SWECO (2006) has modelled the inflow of the two catchments, using the latest data on rainfall and taking into account evaporation and rainfall on the planned reservoir and the Headpond. The results are seen in the table and the duration curves below.

Table 4-1. Catchment runoff (SWECO 2006)

Inflow	Catchment area	Mean runoff	Maximum weekly runoff	Maximum weekly runoff	Coefficient of variation
	km^2	**m^3/s**	**m^3/s**	**m^3/s**	
NG 8	2,942	92.1	1,389	8,4	132%
Nam Theun*	1,961	86,5	1,007	5,1	135%
Total	4,903	178,6			

* Only sub-catchment below NT2 dam included.

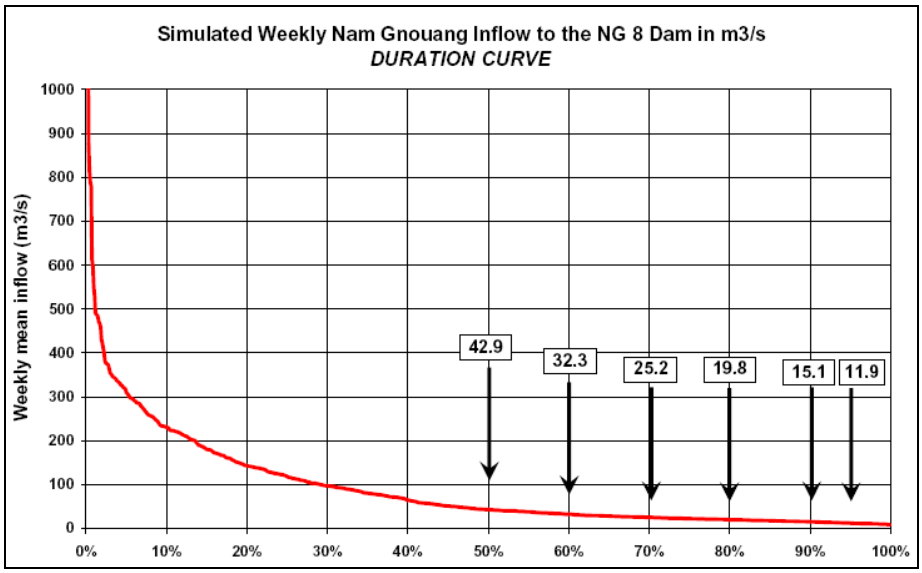

Figure 4-11 Reservoir inflow duration curve (SWECO 2006)

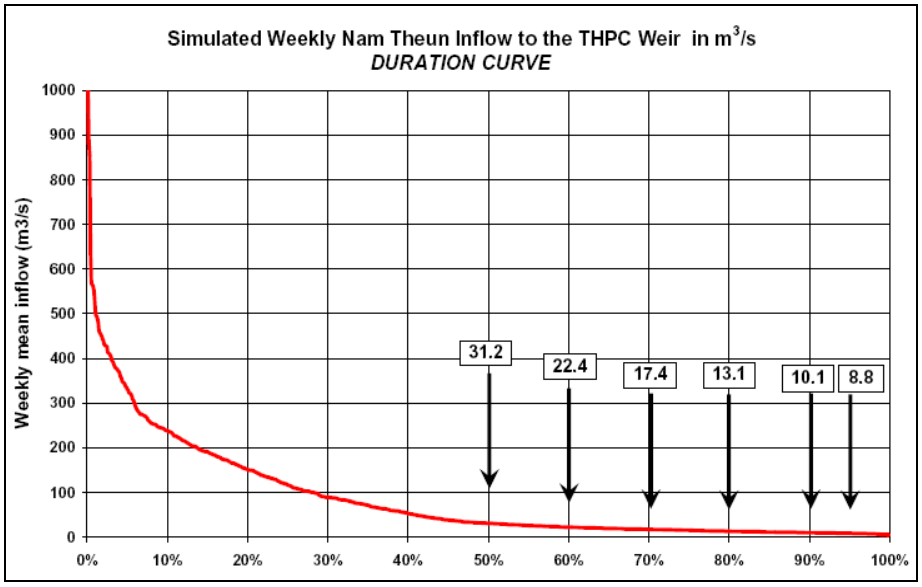

Figure 4-12. Headpond inflow duration curve (SWECO 2006)

Floods

Assessments made in the SWECO study indicate that earlier studies have underestimated the events of extreme floods. The reason for this is that these events are mostly caused by typhoons coming from the east and the existing rainfall stations do not cover the border areas well. By using Vietnamese rainfall data and calibrating these data against the extreme flood experienced in September 2002 the extreme flood satiations were computed (Table 4-2).

Table 4-2. Estimated extreme runoff to the NG dam site (SWECO 2006)

Return Period	Peak magnitude (m^3/s)
100	8,700
1,000	13,500
10,000	18,600
PMF	21,400

4.7.3 Nam Hinboun/Nam Hai

Some key figures describing the natural hydrological features of the Hinboun/Nam Hai river systems are shown in Table 4-3.

The Nam Hai catchment receives extreme rainfall. The annual average is about 4000 mm and maximum intensities are 260 mm/day and 115 mm/hour have been observed. The Nam Hai River thus experiences rapid fluctuations in water levels and flows. The flood peaks are high and normally have short duration.

The Nam Hinboun shows slower response. The catchment is much larger and the extensive limestone areas that provide good infiltration capacity which buffers the rainfall events. Nam Hinboun, therefore, shows a distinct seasonality in flows with high flows during most of the rainy season and a significant base flows throughout the dry season.

Table 4-3. Natural hydrological characteristics of the Nam Hinboun / Nam Hai Rivers (SWECO 2007)

Site	Catchment area km^2	Mean flow m^3/s	Mean annual Low Flow m^3/s	Mean annual Flood m^3/s
Nam Hai at Ban Namsanam	87	9.0	0	250
Nam Hai at confluence with Hinboun	181	19	0.03	330
Nam Hinboun at Ban Khen	1,086	106	2.7	870
Nam Hinboun at confluence with Mekong	3,099	226	8.7	1,650

The natural base flow and mean flow levels in the lower parts of Nam Hai and Nam Hinboun has however, been significantly altered by the operation and releases of water from the THPP. In the Nam Hai River the present releases also have a considerably effect on the peak flood levels, while in the Hinboun River downstream Nam Hai the influence on floods is more limited.

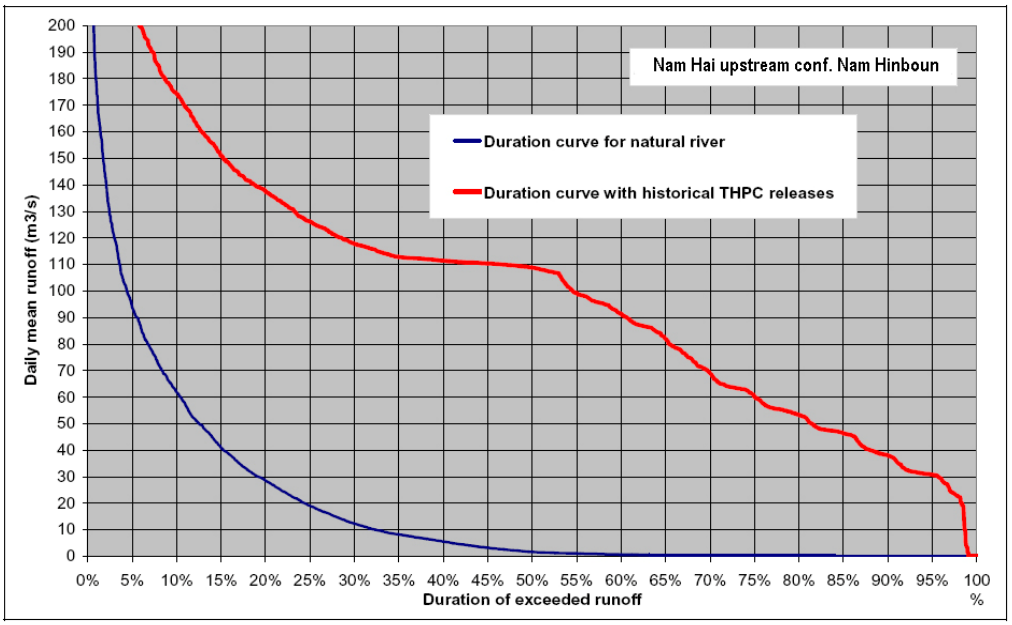

Figure 4-13. Flow duration curve at Nam Hai before its confluence with Nam Hinboun with and without the THPP operation (SWECO 2007)

Figure 4-13 shows the comparison of flow durations in natural conditions and with the present releases from THPP. The effects of the power plant operational regime are significant in the Nam Hai. Dry river conditions which normally occurred about 40-45 % of the time now only occur 1-2% of the time, while the duration of flows above 110 m^3/s has increased from 3% to 50% of the time.

In the Nam Hinboun at Ban Khen (just upstream the narrow gorge through the mountain ridge) the effects of the THPP releases are significantly less than in the Nam Hai (Figure 4-14). Here the natural flows of more than 110 m^3/s occurred in 30% of the time and activities around the river were thus probably accustomed to these high levels during the rainy season. With the THPP operation the flows above 110 m^3/s now occurs 58% of the time. A significant change from the normal situation, however, is that also at Ban Khen the levels of mean annual low flow (2.7 m^3/s) have become very rare due to THPP operations.

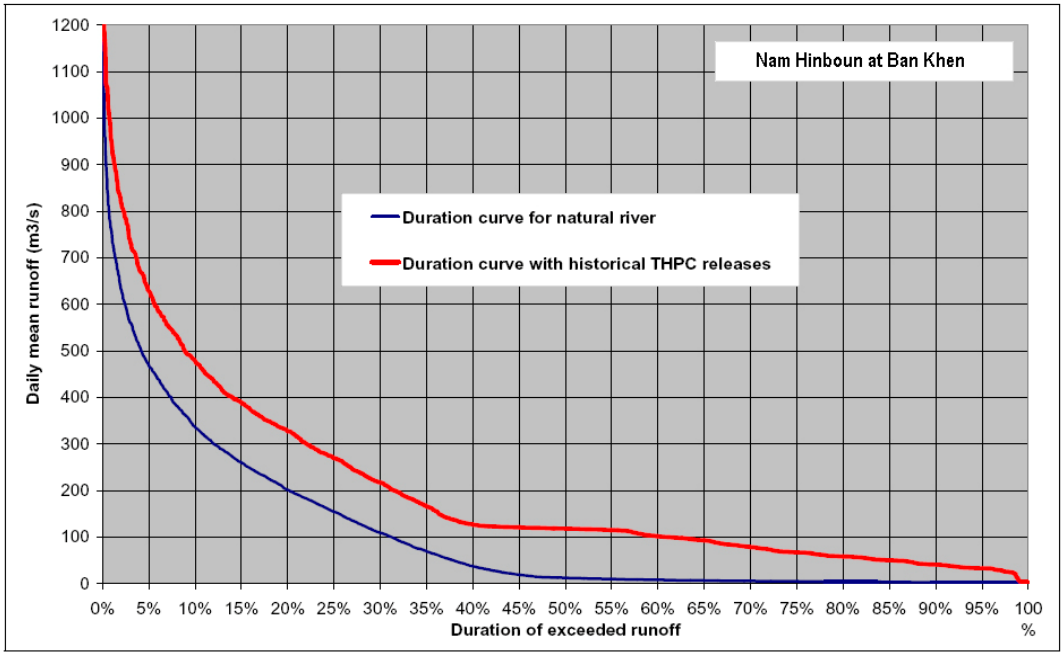

Figure 4-14. Flow duration curve of Nam Hinboun at Ban Khen with and without the THCP operation (SWECO 2007)

The results of the hydrological assessment further indicate that the strongest impact of THPP operation peak flows are found in Nam Hai. The peak flow is the hydrological parameter which is most important for judging impacts on the river morphology. Here the mean annual flood is presently increased by 30-50% compared with natural conditions, while the 100-years peak is increased with about 15-25%.

In the Nam Hinboun, the effects of THPP releases are considerably lower. The mean annual flood is today only increased with some 10% and the 100-years flood by some 5%.

4.7.4 Flooding

As a result of the monsoonal distribution of rainfall, flash floods occur almost each wet season in all catchments in the region. Such floods take water levels over the banks of streams in upper river reaches for a few hours or days at a time. More prolonged and regular over-bank flooding occurs every year in the lower river reaches. This is caused partly by the backwater impact of high Mekong flood levels. Periodic flooding is necessary for the maintenance of distinct riverine habitats, fisheries and agriculture along the river channel. Extreme flood events might, however, have serious negative impacts on the same river functions.

The diversion of water into the Nam Hai-Nam Hinboun has increased the duration, depth and frequency of natural floods, and associated backwatering in rivers and streams draining into the Nam Hai and Hinboun river sections. The magnitudes of these effects, are discusssed in Chapter 6.

4.7.5 Groundwater

Little is known about the groundwater situation in the project area. The karstic nature of the geology in both reservoir area and in the Nam Hinboun catchment makes it very difficult to determine groundwater movements and volumes. It seems obvious that there are underground water movements crossing normal topographic borders between catchments. This situation has made it difficult to prepare precise hydrological models and forecasts for project impacts zones and has also left some uncertainties about the risk of leakage of the reservoir trough the Pha Kouanchan ridge and the need to construct a retention dike.

4.8 Water Quality

4.8.1 Introduction

Monitoring

A number of water quality analyses are available for the river systems upstream and downstream of the THXP. Most of these studies have been made as a part of the planning and assessment of hydropower developments. Therefore they have often been ad. hoc in character and few long times series of data exist.

For the Theun Hinboun project area older data series are found in NORPLAN (1995). The NORPLAN analysis covers December 1994 and March, April and July 1995.

The most consistent time series have, however, been collected by Theun Hinboun Environment Management Division (EMD), which since July 2002 has carried out water monitoring for key water quality parameters at 12 stations in the basin. (Figure 4-15)

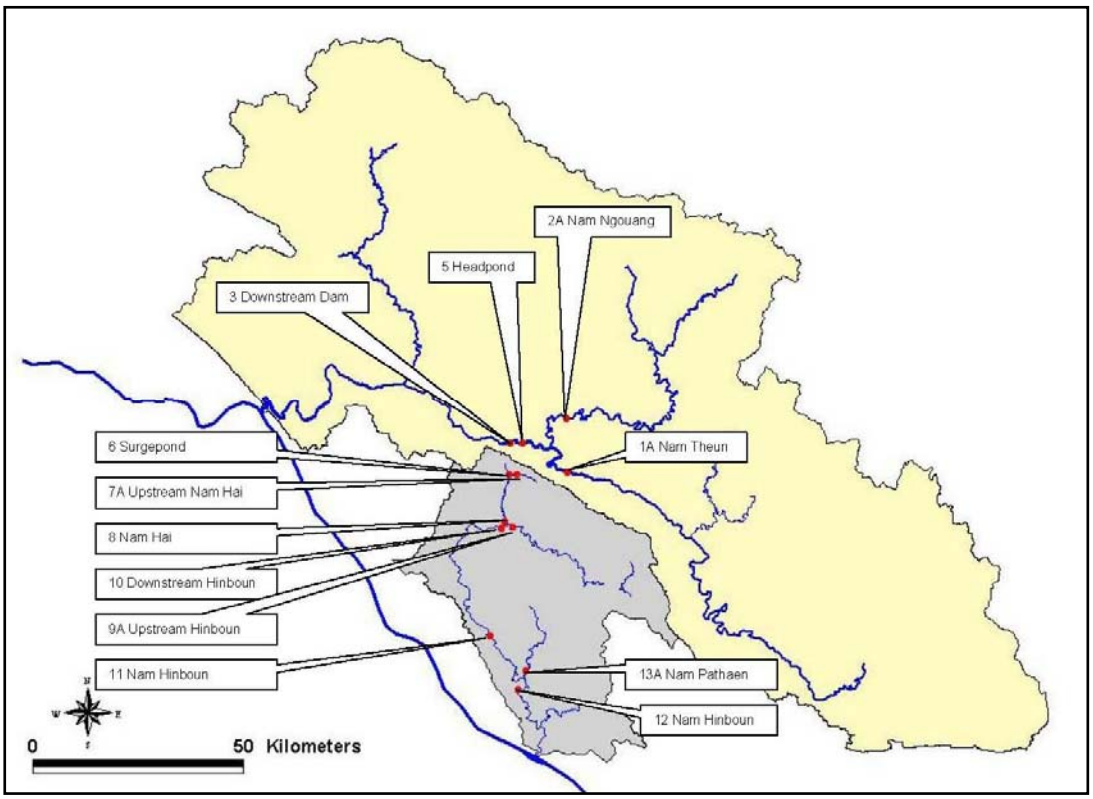

Figure 4-15. EMD water quality monitoring stations (Schouten et al. 2004)

Stations

Of the 12 water quality stations measured by EMD, 5 stations are not impacted by the establishment of THPP and the diversion of water from Nam Theun to Nam Hinboun. These 5 stations are Nam Theun (1A), Nam Ngouang (2A), Nam Hai upstream of the confluence with the regulating pond water (7A), Nam Hinboun upstream of the confluence with Nam Hai (9A), and Nam Pathaen (13A). The other 7 stations are in reaches which have water qualities impacted by the diversion and fluctuations in water flow caused by the operation of the existing power plant.

Additional 3 stations have been established at the confluence between Nam Phao and Nam Theun (2 upstreams and 1 downstream) for monitoring water quality in Nam Theun during construction of Nam Theun 2 dam.

Parameters

The water quality parameters measured by EMD have been: temperature, dissolved oxygen (DO), oxygen saturation (DO %), pH, total dissolved solids (TDS), total hardness, conductivity, salinity, suspended solids (SS), turbidity (NTU), Secchi disk reading, ammonia (NH_3-N), nitrite (NO_2-N), nitrate (NO_3-N), total phosphate (Tot-P), chemical oxygen demand (COD), fecal coliform bacteria, and total coliform bacteria. The data are available in a database format, but have not always been consistent.

Fluctuations

It is important to recognise that there are dramatic seasonal and yearly fluctuations in water discharges in Nam Theun, Nam Gnouang, Nam Hai and Nam Hinboun. Several of the water quality parameters

are functions of flow. Some pollutants will be diluted at high flows but heavy rains and resulting high floods might cause flushing and mobilising of pollutants and sediments.

4.8.2 Sub Basin Characteristics

Below is a brief summary of some of the features of the relevant subcatchments influenced by the Project. The presentations in Table 4-4 to Table 4-8 are based on a synthesis of the data from the EMD monitoring from 1998 to 2006, supplemented with some information from other sources (i.e. RMR 2006 and Schouten et al 2004). In addition to the general status of the river reaches described below a more detailed discussion of the priority issues turbidity and oxygen is provided in separate sections.

The figures in the summary tables show that the reaches studied in most cases have satisfactory levels of the most parameters measured. Except for the diversion of water from Nam Theun into the Nam Hinboun catchment and the erosion induced by swidden agriculture practises and the water diversion, impacts on water quality from human activities are very modest.

It is striking to see the great variation in the maximum and minimum readings of most parameters. This reflects the dramatic changes in water quality over the year caused by very high variations in wet season and dry season river flow. Seen in light of the large variation between the maximum values and the minimum values, the differences between river reaches are minor. It is probable that some of the more systematic chemical differences between the rivers seem negligible compare to the seasonal variation and the extreme maximum and minimum values.

Nam Gnouang

The water quality in the Nam Gnouang is generally high, with neutral pH, low conductivity, no salinity, low values of nutrients and no measurements showing significant levels of organic micro pollutants, heavy metals or coliform bacteria.

Nam Gnouang has at times experienced extremely low water temperatures. In January 1975, when air temperatures dropped below 0 ^{0}C at night a massive fish kill affecting numerous fish species was observed because of the resulting low water temperature.

Heavy rainfall in the upstream reaches sometimes causes landslides which contribute to high concentration of Suspended Solids (SS). The very high maximum values for SS can be attributed to such events.

Table 4-4. Summary of 1998-2006 water quality data from at Nam Gnouang dam site (EMD 2A).

Parameter	Maximum	Average	Minimum
Temperature (^oC)	32.3	24.8	16.7
Dissolved Oxygen (DO mg/l)	9.9	7.4	4.5
Total Dissolved Solids (TDS mg/l)	131.0	52.8	27.0
Total Hardness (mg/l)	135.0	45.4	5.0
Suspended Solids (SS mg/l)	685.0	56.2	5.0
Nitrogen (NO_3-N mg/l)	2.70	0.41	0.10
Phosphorous (Tot-P mg/l)	0.46	0.09	0.01

4.8.3 Nam Theun and Upper tributaries

Water quality in the Nam Theun, in particular the upper reaches which will be diverted into Xe Bang Fai by the NT2 project, is uniformly high, with neutral pH, low conductivity, no salinity, low values of nutrients and negligible pollutants. The sediment transport is low in the dry season since the larger part of the upper catchment is inside the NPA. Even in this relatively "unpolluted" river, the measured minimum values for dissolved oxygen are very low (below the Thai standards for fisheries). This happens in the wet season when transport of organic materials is high and light penetration in water bodies low.

Table 4-5. Summary of 1998-2006 water quality data from Nam Theun upstream Headpond (EMD 1A).

Parameter	Maximum	Average	Minimum
Temperature (^oC)	32.9	25.3	16.5
Dissolved Oxygen (DO mg/l)	11.5	7.9	4.4
Total Dissolved Solids (TDS mg/l)	48.0	20.8	7.6
Total Hardness (mg/l)	48.0	17.4	3.5
Suspended Solids (SS mg/l)	327.0	39.2	5.0
Nitrogen (NO_3-N mg/l)	1.70	0.35	0.10
Phosphorous (Tot-P mg/l)	0.36	0.08	0.01

At the resettlement site (Nam Phao) and upstream (Nam Phao and Nam Kata) a special monitoring should be necessary to insure the good quality of water and food from the Nam Phao. Upstream Nam Pan, a Nam Phao tributary, there is a goldmine. Observations from this site show that they use to treat rocks from the mine with mercury and maybe cyanide. Three new stations have been selected:

- On the Nam Phao at Ban Phontong, near the resettlement site,
- On the Nam Phao upstream near the Nam Pan,

- On the Nam Kata at Ban Pakho.

Mercury and heavy metals (Pb) will be monitored in carnivores fishes. Water quality data will be collected also and cyanide, arsenic and mercury will be measured. This monitoring should cover a year to monitor evolution of concentrations depending on rainfalls and flows during dry and rainy seasons.

4.8.4 THPP Headpond

The Headpond has to some extent the appearance of a lake with some of the characteristics of lake ecosystems. However, retention time in the pond is short and thus the surface water monitoring shows little difference in monitored values compared with the upstream rivers. The main difference seems to be that it has less variation in temperature than the rivers.

The oxygen situation is similar to the rivers but measurements from the deeper layers of the Headpond indicate more significant oxygen deficiency below 10 m at the end of the dry season.

Bed load and coarse sediment transport is being retained in the Headpond, but in the flood season water with high concentration of finer fractions are channelled into the Nam Hai/Nam Hinboun or discharged over the spillway into the Nam Kading.

Table 4-6. Summary of 1998-2006 water quality data from Headpond (EMD 5).

Parameter	Maximum	Average	Minimum
Temperature (^oC)	31.8	25.0	18.5
Dissolved Oxygen (DO mg/l)	10.6	7.5	4.2
Total Dissolved Solids (TDS mg/l)	53.2	28.2	2.9
Total Hardness (mg/l)	90.0	26.6	5.0
Suspended Solids (SS mg/l)	341.0	35.9	4.0
Nitrogen (NO_3-N mg/l)	1.70	0.33	< 0.005
Phosphorous (Tot-P mg/l)	1.00	0.08	0.01

4.8.5 Nam Kading.

The quality values of the water in the riparian release and flood season spill downstream the Nam Kading show many similarities with the upstream river reaches. One striking point from the monitoring data is, however, the very high maximum figures for Dissolved Solids and Suspended Solids. The most likely explanation for this situation would be that the riparian flow releases are drawn from a sediment rich deep layer in the Headpond.

Low minimum values of dissolved oxygen have been found, but it is assumed that the oxygen is quickly replenished in the river rapids in the upper Nam Kading.

Table 4-7. Summary of 1998-2006 water quality data from Nam Kading below Headpond (EMD 3)

Parameter	Maximum	Average	Minimum
Temperature (^oC)	31.5	24.8	17.6
Dissolved Oxygen (DO mg/l)	11.9	7.5	4.4
Total Dissolved Solids (TDS mg/l)	261.0	34.2	13.3
Total Hardness (mg/l)	90.0	28.2	12.0
Suspended Solids (SS mg/l)	327.0	38.3	3.0
Nitrogen (NO_3-N mg/l)	1.60	0.32	< 0.05
Phosphorous (Tot-P mg/l)	0.39	0.06	< 0.005

4.8.6 Nam Hai and Nam Hinboun

The Nam Hai and Nam Hinboun water flow and water quality has undergone significant changes since 1998 when the THPP commenced operation. From being rivers with large seasonal variations in flow and quality (as seen in the upper reaches of the rivers today), there is a high year around flow but with very large daily fluctuation. The dramatic increase in dry season flow and the intermittent discharge, varying from 0 to 110 m^3/s in one day, have started extensive erosion processes, in particular along the Nam Hai. This process is still ongoing and river morphology does not yet seem to have been stabilised.

The measured maximum figures of Suspended Solids and Dissolved Solids (which are seen in the wet season) is not higher than in the upstream rivers but the average figures and minimum figures are higher reflecting significant sediment transport also in the dry season, when the rivers are usually “clean”.

Table 4-8. Summary of 1998-2006 water quality data from the Nam Hai and Nam Hinboun impacted by the present power plant (EMD 8 and 11)

Parameter	Maximum	Average	Minimum
Temperature (^oC)	32.1	25.0	13.4
Dissolved Oxygen (DO mg/l)	11.9	7.7	3.5
Total Dissolved Solids (TDS mg/l)	145.2	48.0	16.0
Total Hardness (mg/l)	162.0	46.7	13.5
Suspended Solids (SS mg/l)	230.0	64.3	18.0
Nitrogen (NO_3-N mg/l)	2.60	0.46	< 0.05
Phosphorous (Tot-P mg/l)	1.00	0.10	0.01

Heavy metals

A particular water quality problem is encountered in the lower part of Nam Hinboun. In the Nam Pathaen tributary of the Nam Hinboun there are mines producing heavy metals like tin, lead and zinc. There is presently high activity at the mines, and this contributes significantly to pollution problems in Nam Pathaen and subsequently in the lower Nam Hinboun.

High levels of turbidity can also be observed. Regular monitoring is not carried out but one sample taken in Nam Phaeten in July 1995 shows high levels of several heavy metals including lead, zinc, tin and cadmium. The content of iron was extreme (18,700 μg/l compared to the WHO and Lao PDR standard of 300 μg/). In the same period the iron concentration in the lower Nam Hinboun also exceeded the water quality standards (NORPLAN 1997). There is a concern that the mining activity might be causing high concentrations of heavy metals in fish and other aquatic organisms.

4.8.7 Oxygen Status

Ecological Mechanisms

The oxygen content of water bodies is important for the ecological status of the water. Oxidation of organic (and other reactive) materials in the water and on the bottom of rivers and reservoirs will consume dissolved oxygen. The replenishment of oxygen takes place by aquatic plant photo synthesis, thermal turnover, diffusion from the surface and by water and air mixing in streams and rapids and by wind action in lakes and reservoirs.

If the water is stagnant or if the input of organic material is too high the concentration of oxygen in the water column will be diminished and in some cases reach zero (anoxic conditions) in the deeper stagnant layers.

Stratification

In lakes and reservoirs under stable conditions stratification in temperature and oxygen concentration might develop. In Lao PDR this will happen in the dry season when the inflow is low. The reservoir then develops a cooler bottom layer depleted of oxygen (hypolimnon) and an upper warmer layer (epilimnon) where oxygen is replenished by diffusion, plant photo synthesis and mixing. Adding to the problem of stratification is the factor that plants produced in the epilimnon will die and sink down to the hypolimnon and thus provides more organic materials to be digested. Unless the reservoir is deep, the inflow of large quantities of water in the wet season will cause a turnover of the whole water column and thus bring oxygen to the deep layers of the reservoir.

Biodiversity

Biodiversity comes under stress when the oxygen content in the water is reduced. Some species are more sensitive to the reduction than other and the species composition might change. Under anoxic conditions the ecological situation changes completely and the oxidation process shift into other chemical pathways and produces for instance H_2S, ammonia and methane, which are toxic to most organisms. Anoxic situations will instantly lead to death of all fish species and other higher animal organisms. When, however, the water is again exposed to oxygen the chemical process is rapidly reversed and the organisms might re-establish themselves.

Causes

A common cause of oxygen depletion is pollution from domestic or industrial waste water with high organic content (food processing, paper mills, etc.). No significant sources of that kind are found in the impact zones of this project.

Oxygen monitoring and standards

The oxygen monitoring data in the project area are given as Dissolved Oxygen (DO). No specific Lao PDR water quality standards exist for oxygen status. However, in Thailand the standard requirement of surface water suitable for conservation of aquatic organisms and fisheries are set at DO 6 mg/l occurring for at least 20 % of the number of measurements.

Nam Theun and Nam Gnouang

Most of the upstream tributaries in the project area are rapid flowing (good oxygen mixing) and with relatively low traces of organic material. Therefore the dissolved oxygen status at most of the stations are characterised as high (6-8 mg/l) or very high (> 8 mg/l).

On the EMD monitoring stations of in Nam Theun and Nam Gnouang (both stations located in slow flowing water close to the THPP Headpond), Dissolved Oxygen levels fell between 4 and 5 ml/l in September and October (Figure 4-16). During these months rainfall and run off are very high. This brings detritus and organic material from the land into rivers and streams causing a decline of DO in Nam Theun and Nam Gnouang. However, no DO concentrations lower than 4.5 ml/l have been measured during the rainy season.

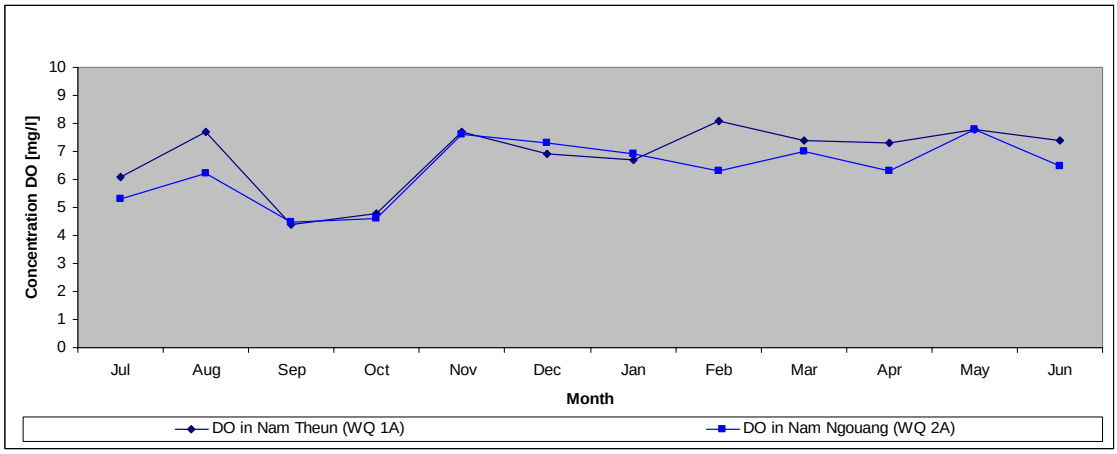

Figure 4-16. OD values for one year (July 2002 to June 2003) in Nam Theun and Nam Gnouang (Schouten, et al. 2004)

In May hyper-saturation can be noticed as a result of increased phytoplankton and algae growth in the slow flowing rivers at the end of the dry season. Phytoplankton and algae produce oxygen during day time by photosynthesis. Over saturation of DO during day time gives an indication of the density of phytoplankton and algae blooms.

Nam Hai and Nam Hinboun

As indicated in Figure 4-17, DO concentrations at a station on Nam Hai upstream of the power plant tail water discharge and in the upstream part of Nam Hinboun (upstream the confluence with Nam Hai and the THPP tail water) are not only below 6 mg/l in the wet season, but also sometimes during the dry season.

Many villages are located along the Nam Hai and the Nam Hinboun use the river for washing and bathing and utilize riverbanks for vegetable gardens. Their water-buffaloes, cattle, pigs, goats, and chickens roam the riverbanks for food, use the river for drinking and bathing, and leave faeces in the river. Livestock is one of the main contributors of organic waste in the Nam Hinboun. As dry season water discharge is very low (Nam Hinboun 4-5 m^3/sec), people and livestock easily impact water quality. As a result of the intensive water use of the river, DO concentrations in Nam Hinboun are often lower than 6 mg/l, but do not drop below 4.2 mg/l.

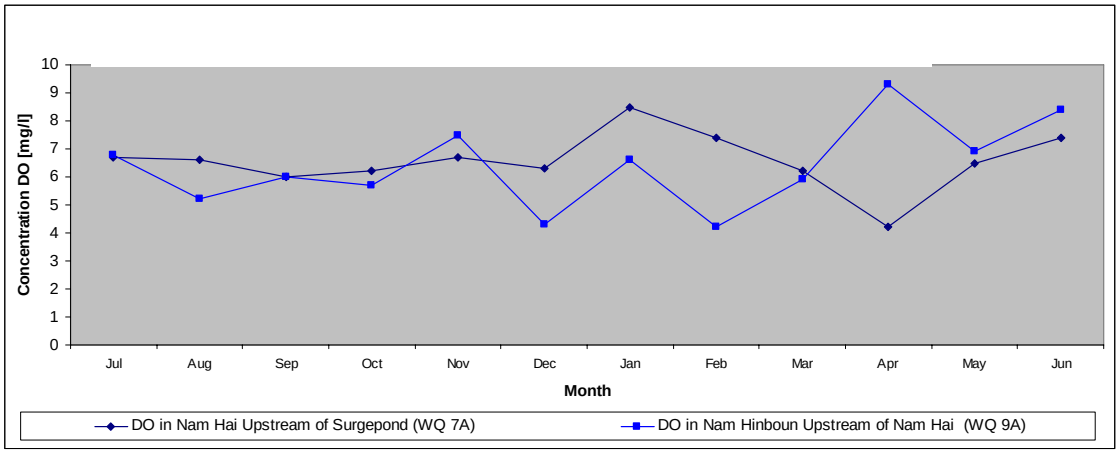

Figure 4-17. OD values for one year (July 2002 to June 2003) in Nam Hai and Nam Hinboun (Schouten, et al. 2004)

4.8.8 Turbidity

The turbidity describes the amount of particles and dissolved materials in the water. High turbidity is negative in many ways. It reduces the light penetration through the water and thus reduces the growth of plankton and bottom algae and other plants which in turn reduces fish and other aquatic fauna diversity and production. In addition, high levels of sediments in the water may in some cases clog the gills and respiratory organs of fish and other aquatic animals.

The amount of dissolved and suspended particles in the water is measured in several ways; Total Suspended Solids (TSS) Nephelometric Turbidity Units (NTU) and the Secchi debt being most used.

Nam Theun

The Nam Theun and its tributaries show very high fluctuations in the content of particles and dissolved materials. Its upper reaches are in most cases very clean in the dry season because of the well protected catchments. During flood events, however, very high turbidity levels have been measured, caused by bank erosion, sediment flushing of the riverbed and soil slips. Nam Gnouang has reasonable low turbidity for most of the year but has been prone to incidents of soil slips which have resulted in extreme levels of turbidity.

Nam Hai

In the Nam Hai-Nam Hinboun catchment, measurements of Total Suspended Solids (TSS), Turbidity (NTU) and the Secchi dept have

been taken covering a period from 2002 to 2006 by EMD and RMR. These results have been combined and summarized for the periods June to November (high flows with little intermittency, December & January (moderate flows, some intermittency), February to mid April (low flows, high intermittency) and mid April to May (flow range between low and high, very high intermittency mixed with low intermittency). The turbidity data are presented in Figure 4-18.

The results clearly show the erosive effects of the release of diverted water from the power plant into the Nam Hai. Whereas the upstream reaches, which is not influenced by the power plant operation might have very high loads of sediments in flood periods, the water downstream the tailrace has a rather constant high turbidity. This is caused by the generally higher and seasonably more constant flow but amplified by the peaking procedure which causes riverbed and bank erosion in particular in the Nam Hai reach. The discharged tailrace water is rather low in turbidity. Only in floods does the water diverted from the Nam Theun have high turbidity, but this is mostly non-colloidal material which settles out on its passage downstream.

During periods of continuous high flows turbidity levels reach 60 NTU about 4 km downstream of the tailrace. During intermittent flows turbidity levels fluctuate between 10 and 50 NTU's with an average value around 25 NTU's. Depending on the pattern of intermittency, these fluctuating levels of turbidity pass down the river between 5 and 7 km/hour, with the same hydraulic attenuation characteristics.

Examination of the bank material along the Nam Hai showed it to have more of the fine and very fine particles than the river bank material from the Nam Gnouang and Nam Theun. This is to be expected in alluvial terrace soils laid down over long periods by infrequent floods. Such soils differ profoundly from the banks of upper catchment rivers and streams, from which very fine particles have been washed out.

Turbidity levels in the Nam Hai and Hinboun downstream of the tailrace never fall below about 10 NTU. For the period December to mid-April turbidity fluctuates between 20 and 30 NTU. In contrast natural rivers in Lao PDR have very low turbidity (0 to 2 NTU) in the period December to mid-April. From June to November turbidity in natural rivers ranges between 20 and 50 NTU with occasional flood peaks of over 100 NTU. The Nam Hai Hinboun is by contrast consistently higher at between 50 and 75 NTU from June to November.

The lower tributaries of the Nam Hinboun, Nam Thuk and Nam Pathen, also have a rather high constant level of Suspended Solids. This is a result of the mining activities that takes place in these sub-catchments and where processed water from the mining is released without treatment into the rivers.

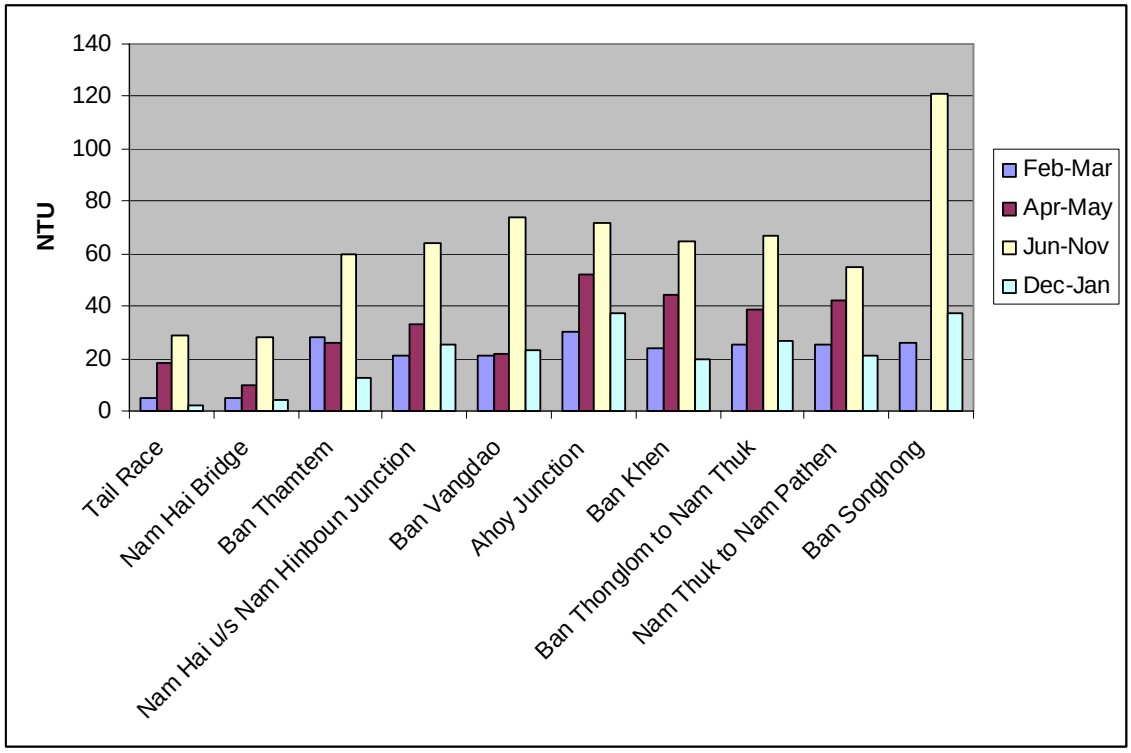

Figure 4-18. Turbidity measurements in NTU for 10 stations from tailrace down to Mekong floodplain (based on RMR 2006d)

5 BIOLOGICAL ENVIRONMENT

5.1 Vegetation and Land Use

5.1.1 Nam Gnouang Catchment

The Nam Gnouang catchment is situated in the Annam Bio-geographic Sub Unit (5B). The catchment is a mosaic of habitats and forest types. The entire area is crisscrossed by small rivers and streams and features impressive limestone outcrops rising to 1600 masl. The area also contains impressive limestone outcrops covered in mostly deciduous species. These outcrops contain many caves that are suitable for cave-dwelling wildlife such as bats, birds, and small mammals.

A large percentage of the area is covered with agricultural land and vegetation heavily modified by human activities. However, the upper reaches of both the Pon and Khamang tributaries contain what appear to be good quality forests. This is most likely due to the large distance these areas are from villages and their inaccessibility.

In areas of original forest cover mixed deciduous forest is the most prominent (Figure 5-1 A). This forest type is located along streams and up onto hillsides. Patches of evergreen forest persist in gullies at higher elevations and there are stands of deciduous and bamboo forest.

Figure 5-1. Different habitats along the Nam Pon River. A. Mixed deciduous forest. B. Evergreen forest. C. Deciduous forest. D. Bamboo forest

Areas close to villages located along the Nam Gnouang could be regarded as un-stocked forest or upland field re-growth. These are previously forested areas where crown density has been reduced to less than 20% (or in some cases 0%) due to heavy disturbance from shifting cultivation practices. These agricultural practices have led to a loss of forest structure, species diversity, and the ecological processes that characterize natural forests.

Areas currently being used for upland agricultural practices are virtually devoid of vegetation aside from whatever crop that is planted there (Figure 5-2). Many villagers have stated that approximately 1ha of upland field is used per family each season. For the NG area this would put the estimate of land used in any one rotation of crops at around 736 ha.

Upland shifting agriculture has been practiced for many years in the area and due to varying fallow periods (3-10 years) the disturbed landscape is a mixture of re-growth stages. Areas in fallow for 1-3 years are dominated by grasses and herbaceous perennial plants such as *Imperata cylindrica*, *Themeda triandra, Eupatorium odoratum, Ageratum conyzoides,* and *Erianthus arundinaceus.* In areas that have been in fallow for approximately 3-6 years it is evident that pioneer tree species have begun to regenerate and previously dominant grasses and herbaceous plants have declined. In areas that had been in fallow for 8-10 years trees have started to form an open canopy, although, bamboo species are prominent.

Figure 5-2. Upland field currently in use along the Nam Khamang River

Despite the level of natural regeneration that is occurring there are large areas north of the Nam Khamang River that could be best described as anthropogenic grasslands. Villagers report that they have not practiced upland agriculture in these areas for decades. Fires used in the process of preparing other adjacent fields have burnt out of control and repeatedly scorched vast hillsides. This has meant that tree species have not been able to establish themselves and grasses and herbaceous perennials dominate (Figure 5-3).

Although no official calculation of the amount of land that is currently under use or in the various fallow stages has been conducted it is large proportionate to the inundation area. Many ridgelines and valleys that divide upland agricultural areas are still forested. The fact that these patches of forest are intact is encouraging. They may act as reference sites for any future assisted forest rehabilitation and they may aid in facilitating natural succession by providing seed inputs and habitat for seed dispersing.

Figure 5-3. Large areas of deforested land dominated by grasses, Nam Khamang.

5.1.2 *NG Reservoir*

Reservoir land categories

The land planned to be inundation by the NG reservoir contains the most degraded land in the catchment. As can be seen in Table 5-1 and

Figure 5-4 hardly any natural dense forests can be found within the area. Analysis of vegetation maps from the 10 and 20 year back indicates the rapid transformation that has taken place from natural forests into young and degraded forest and open land vegetation types.

Table 5-1. Vegetation and land-use in the reservoir area (Revised from RMR 2006a)

Vegetation and land use classification	**Area at FSL 455 (ha)**
Mature dense woodland and bamboo > 25 years since clearing or logging.	33
Young woodlands and bamboo >15 years since clearing or logging	483
Low woody vegetation 4 – 15 years since clearing or logging	1,744
Poldered Rice Fields	20
Sand & gravel	330
Rock	3
Non-irrigated croplands (mostly hill rice) and fallows for 3 years	5,823
River Bank & Terrace Gardens	1,317

Open water	594
Village residential site and gardens	161
EMD assisted and irrigated gardens, terraces and orchards	192
All Reservoir	**10,700**

Thus the vegetation types in the NG reservoir area now represent the highly degraded remains of the forests which covered a larger part of the area until the mid-1960s. The main reason for this has been the in-migration of Upland Tai and Hmong groups in late 1960s and 1970s, and the swidden farming practises as a result of population increase. Woodlands of the NG reservoir today do not represent tropical forests of any significant conservation or biodiversity value.

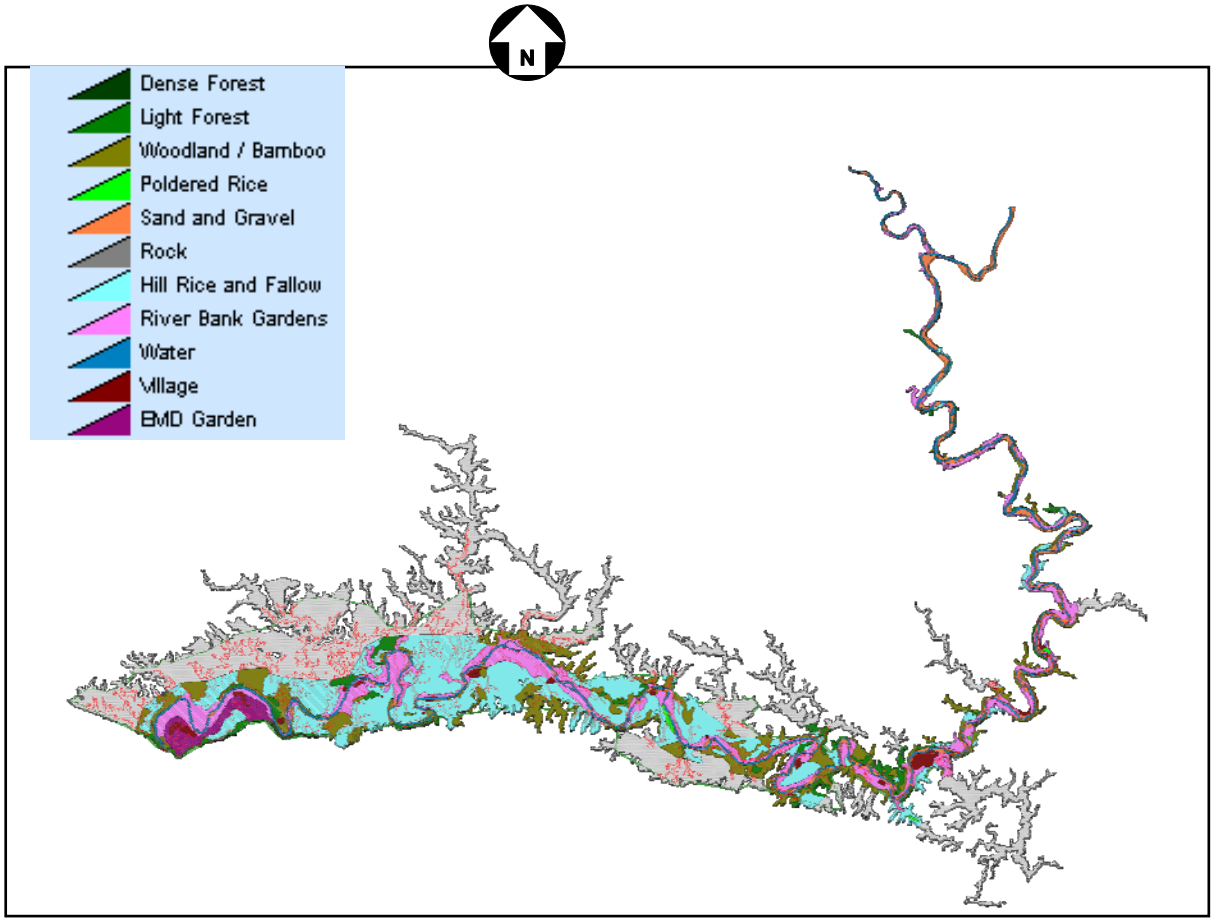

Figure 5-4. Vegetation and land-use in the reservoir area as mapped by RMR in 2005-2006.

Timber Resources

Following from the above and confirmed through field investigation, very limited volumes of valuable tropical timber in the future reservoir area were found. The average density and timber volume in the "forest like" and the "cultivated" land categories is shown in Table 5-2.

Table 5-2. Estimates of the tree volumes and densities in the reservoir area (RMR 2006a)

	Forests and Woodlands	Other vegetation categories
Reservoir coverage	*20%*	*80%*
Commercial timber volume (m^3/ha)	14	4
All timber volume (m^3/ha)	63	19
Number of trees > 4m crown diameter (no/ha)	53	15
Number of trees 2-4m crown diameter (no/ha)	83	29

Compared with what has been measured for other reservoirs in Lao PDR the volumes of timber (and hard biomass) in NG are very low. The calculated figure is 58 t/ha in the woodland and forest lands for NG reservoir, whereas it was 352 t/ha in the Nam Leuk reservoir and 134 t/ha for Nam Ngum 3.

Reservoir Biomass

RMR (2006a) have carried out detailed calculations of the amount of organic material (biomass) presently found in the reservoir areas (Table 5-3). The potential contribution to the oxygen consumption in the reservoir water of different fractions of biomass has also been calculated.

The data shows that the densities of soft biomass and tree foliage inside the future reservoir are similar to the average figure found for other reservoirs in Lao PDR. Also the density figures for the “below the ground roots” are similar to the average of earlier studies. The “hard biomass” figures, however, are far below the average for Lao PDR and other tropical forests, illustrated from the data of timber resources shown in Table 5-2 above.

The highest figures of biomass (organic materials) are found in the soil, i.e. the “below ground organic materials” down to 25 cm. Few studies of the below ground organic materials have been carried out in Lao PDR so it is not possible to compare the figures for NG with other projects. The contribution to oxygen depletion from the different fractions of biomass will have to take into consideration the speed of decomposition of the fractions and how accessible they are for decomposition.

The most easily degradable component is the soft biomass which will decompose in a few months up to 2-3 years. On the other hand the hard biomass will take decades to fully decompose in a water environment. There is uncertainty about how far into the reservoir floor surface the degradation of organic material will penetrate. Examination of other reservoirs in Lao PDR has indicated that the degradation will penetrate only a few mm into the soil. Thus the huge potential source of organic materials found in the root system and in the fine organic substances in the soil will be of little importance for the oxygen degradation on in bottom water of the reservoir.

Following this, it is evident the most important measure to reduce the oxygen depleting substances in the reservoir will be to reduce the

amount of soft biomass. However, since a significant part of the soft biomass is found in the canopy branches and leaves of the trees it will also be necessary to cut the larger trees found in the area.

Table 5-3. Summary of biomass distribution in the reservoir area (RMR 2006a)

	Forests and Woodlands	**Other vegetation categories**
Reservoir coverage	*20 %*	*80%*
Soft biomass (t/ha)	77	47
Of this: Tree foliage (t/ha)	(11)	(3)
Hard biomass (t/ha)	58	17
Below ground roots to 25cm (t/ha)	63	45
Below ground organic material down to 25cm (t/ha)	211	226

5.1.3 Nam Hai and Nam Hinboun Catchment

The catchment of Nam Hai and Nam Hinboun is dominated by barren limestone rock and alluvial plains. The plains are to a large extent cultivated. The direct affected land close to the river and the transmission line is dominated by agricultural land of which rice paddy cover close to 50 % of the total and in addition contains substantial areas of gardens and swidden. The forests (Mixed Deciduos) and bush land cover only about 10-15 % direct impacted areas.

5.2 Wildlife

5.2.1 Regional Status

Most of the attention of conservationists in the last decade has been directed at the biodiversity of the Nakai Plateau area, which is beyond the impact zones of this project. The most relevant study covering the relevant impact zone were commissioned in 1995 from the Wildlife Conservation Society (WCS) in connection with the initial THPP. The study concluded that at least 5 globally threatened birds and 12 globally threatened mammals occur within the area affected by the original Theun Hinboun Project. In addition, 22 other important species were found to have populations in the affected area. A number of habitats were identified as being vulnerable to damage or destruction by the Project. The definition of the impact area also includes the Nam Kading National Protected Area which is located on each side of Nam Kading downstream the THPP Headpond.

The animals listed by the WCS as at risk of experiencing significant impairment from the Project's impact events are shown in Table 5-4 below:

Table 5-4. Animals at risk of significant impairment by Theun-Hinboun Project (WCS 1995)

Species	Status
Oriental Darter	Globally Near-Threatened
Lesser Fish Eagle	Globally Near-Threatened
River Lapwing	National Long-term Decline
Long Billed Plover	Globally Near-Threatened
Small Pratincole	Regionally At Risk
Pale-Capped Pigeon	Globally Threatened
Crested Kingfisher	Regionally At Risk
Blythe's Kingfisher	Globally Threatened
Red-Collared Woodpecker	Globally Threatened
Wire-Tailed Swallow	Regionally At Risk
Rufous-Throated Fulvetta	Globally Near-Threatened
Rhesus Macaque	Regionally At Risk
Dhole	Globally Threatened
Large otters (2 spp.)	Regionally At Risk /Globally Threatened
Asian Small-Clawed Otter	Globally Threatened
Asian Elephant	Globally Threatened
Gaur	Globally Threatened

A further 38 species of birds and mammals were listed as being at risk of experiencing a slight impairment. Dominant in the list of mammals and birds that were suspected to be negatively impacted were water related species which might be impacted by the reduced water flow in Nam Kading.

It has been observed that a significant reduction in the occurrence of some species in and around Nam Kading NPA. How much of this reduction can be attributed to the THPP and how much is caused by other developments for instance increased hunting pressure, has not been established.

The WCS study recommended certain mitigation and compensatory measures to reduce the impact on wildlife. Most of the mitigation measures recommended by WCS were not effectively adopted, and there has been no follow-up survey to determine the impact of extent of damage to the animal populations at risk. Some of the initial management actions have recently been proposed to be included in the Environment Management and Mitigation Plan for the NT1 Hydropower Project.

5.2.2 Nam Gnouang Catchment

The Nam Gnouang reservoir and catchment area contains a great diversity of wildlife species. Numerous surveys have been conducted in surrounding areas by various teams. A summary of recent observations of birds and mammals species is given in Table 5-5. The list is compiled from direct observations and interviews with informants

from villages during the field visits. The table is limited to "Key Species" of conservation concern, as defined by Duckworth et al. (1999). As the the information was gathered opportunistically, and can not be regarded as a comprehensive list of Key Species in the area.

Table 5-5. Comments on Key Wildlife Species in the upper Nam Gnouang catchment. Based on Robichaud,2005 and WCS 2007.

Birds	
Crested Argus (*Rheinardia ocellata*):.	Reported present (but less common than formerly) in the vicinity of Ban Sopchat
Bar-backed Partridge (*Arborophila brunneopectus*	One caged bird seen in Ban Phonekham
Crested Kingfisher (*Megaceryle lugubris*)	Just one was seen along the Nam Gnouang. Although Tizard (1996) reported 4-5 pairs on the Nam Gnouang and Nam Heung.
Great Hornbill (*Buceros bicornis)*	Casques of Great Hornbill (one each) were seen in Ban Sensi, Ban Phonekham, and Ban Sopchat. Villagers said the species still occurs in the general area.
River Lapwing (*Vanellus duvaucelii)*	Just one pair was observed during the survey, on the Nam Gnouang, within 2 km upstream of Ban Sensi. Tizard (1996) reported eight pairs on the same stretch of the Nam Gnouang.
Large-billed Crow (*Corvus macrorhynchos*)	A maximum of 2 were seen one-way along the Nam Gnouang and 3-4 along the Nam Heung
Mammals	
Macaques	Residents of Ban Phonekham reported that three species inhabit the area; the description of one fits Rhesus Macaque (*Macaca mulatta*). In Ban Phonekham, a freshly butchered primate carcass was seen, and villagers' description of the live animal corresponds to Bear Macaque (*Macaca arctoides*).
Douc Langur (*Pygathrix namaeus*)	Reported to be very common locally by residents of Ban Sopchat.
Phayre's Langur (*Semnopithecus phayrei*)	A grey monkey (called "chang" in Khmu) that most likely equates to Phayre's Langur was reported present locally by residents of B. Phonekham.
Gibbons	All villagers questioned reported gibbons present in the area
Bears	Two species reportedly present, fitting Asiatic Black Bear (*Ursus thibetanus*) and Sun Bear (*Ursus malaynus*).
Otters	Two species ("bouan" and "nak") reportedly still inhabit both the Nam Gnouang and Nam Heung, but apparently less commonly than before.

Asian Golden Cat (*Catopuma temminckii*)	A juvenile golden cat was seen captured by a villager in the upper reaches of he Nam Khamang
Tiger (*Panthera tigris*)	Tiger may survive at very low density in the area. Ban Kuang villagers believe one might still inhabit the upper Houay Kao on the east side of the Nam Heung, north of the village.
Asian Elephant (Elephas maximus)	None occur in the area, and have not for a very long time – at least 20-30 years.
Heude's Pig (*Sus bucculentus*)	Villagers consistently reported that two species of pigs inhabit the area, and that both are common and crop pests. Presumably, Eurasian Wild Pig (*Sus scrofa*) and the Indochinese endemic, *S. bucculentus*
Saola (*Pseudoryx nghetinhensis*)	This species is extremely rare and known to occur in the area relevant to the NG.
Muntjac	Villagers collectively reported three species of muntjacs in the general area, the descriptions of which apparently correspond to Large-antlered Muntjac (*Muntiacus vuquangensis*), Red Muntjac (*M. muntjak*), and Truongson Muntjac (*M. truongsonensis*).
Sambar (*Cervus unicolor*)	Antlers (one set each) were seen in Ban Sensi and Ban Sopchat. Villages variously reported one (Ban Sensi) or two (Ban Koang and Ban Sopchat) species of "khouang" present.
Gaur (*Bos gaurus*)	Probably absent from the area of Ban Sensi. Elsewhere, vague but conflicting information was given
Banteng (*Bos javanicus*)	More than one village reported the presence of a remnant herd (numbering fewer than ten individuals) of wild cattle that, based on their descriptions, is probably Banteng, around the upper Nam Kamang.
Serow (*Naemorhedus sumatraensis*)	Generally reported to occur in nearby mountainous, rocky areas.
Black Giant Squirrel (*Ratufa icolour*)	Two partial tails said to be from, and consistent with, this species were seen in the house of the vice-chief of Ban Sopchat.

Of these species particular focus has been on the extremely rare and endangered Saola (*Pseudoryx nghetinhensis)* which is endemic to this part of Laos PDR. This animal is regarded as having the highest priority for conservation in the Lao PDR (WCS 1999). The consensus of the villagers interviewed is that Saola may remain in the area, but in very low numbers due to hunting. It seems unlikely that they occur close to Ban Sensi today, although Tizard (1996) mapped a small area of occurrence just east of the village nine years ago. The remaining Saola are probably found further up the Nam Gnouang/Heung/Chat basin.

Fauna also includes the Laotian rock rat or *kha-nyou* (*Laonastes aenigmamus*), sometimes called the "rat-squirrel" which is found in the inaccessible limestone mountains of Pha Kouanchan Provincial Protected Area. This large rodent belongs to the ancient fossil family *Diatomyidae*, and was first scientifically described in 2005.

The following Key Species were reported to have disappeared ifrom the area: Green Peafowl (*Pavo muticus*), Golden Jackal (Canis aureus), Dhole (*Cuon alpinus*), Asian Tapir (*Tapirus indicus*) and rhinos. The only surprise amongst this list of absentees is Dhole. It apparently occurred formerly but few or none survive in the area today.

5.2.3 Nam Hai and Nam Hinboun Catchment

The Phou Hin Poun NPA which covers a substantial prat of the catchmet and transmission line corridor was decleared a NPA (NBCA) in 1993 (PM Decree 164). The NPA is reported to habour over 20 species of Mammals including Asian Elephant, Gaur, Sambar, Bear, several big cat species, etc. It also contains significant number of vulnerable bird species, 81 species of Reptiles, and 47 species of Amphibians.

5.3 Aquatic Ecology

5.3.1 River Ecology

The main rivers and tributaries in the project impact zones offer a variety of ecological conditions, which again determines the aquatic fauna and flora. The most important features are the river profiles and morphology and the seasonal fluctuations in river discharges, water levels and water quality.

The most important habitats for fish and other aquatic organisms' biodiversity are:

- floodplains
- deep pools
- rapids

Flood plains

Flood plains are found on level land where the river overflows large areas of land in the wet season. The most significant floodplain areas are found on lowland rivers such as Nam Hinboun and the lower part of Nam Kading. In these rivers, floods in Mekong will give backwater effects and cause flooding of low-laying surrounding land upstream the confluence. The organic materials found in these flooded areas create spawning and breeding grounds for many fish species and give rise to fisheries both in the flooded fields and in the rivers when water resides. Several fish species found in the main Mekong migrate to spawn in the tributary floodplains in the wet season.

Deep pools

Deep pools are features found in both slow flowing reaches and in reaches with rapids. Such pools serve as dry season refuge areas and spawning grounds for many fish species and are the most important fishing sites in both Nam Theun/Nam Kading and Nam Hinboun river systems. Deep pools are formed by scouring just upstream and just downstream of rapids. An important pool area is found downstream the Keng Vang Fong rapids on Nam Kading 38 km upstream the Mekong confluence (at the dam site of the planned NT1 hydropower project). An agreement has been reaches to protect this pool area as a Fish Conservation Zone.

Deep pools are also found in slow flowing river reaches in Nam Gnouang, Nam Hinboun and lower Nam Kading. On sandy substrate bottoms these pools might change in form and depth by the process of erosion and sediment transport. The intermittent flow release from THPP has significantly reduced the number of pools in the down-stream part of Nam Hinboun.

Rapids

Rapids form habitats with ecological conditions very different from that found in the main river reaches and provide feeding and spawning grounds for species particularly adapted to such conditions. The often rocky substrate and high currents also give good conditions for benthic plant growth and invertebrates that are a source of food for some fish species.

Flow fluctuations

In addition to the different morphological features, the ecological conditions for fish and other aquatic organisms are very much determined by the seasonal and daily water level fluctuations. Data series from the period before the THPP was constructed show that the average maximum and minimum water levels differs with as much as 16 m from the dry to the wet season in Nam Theun/Nam Kading and as much as 12 m in Nam Hinboun. The maximum change in water levels from one day to the next has been measured as high as 9 m in both Nam Theun/Nam Kading and Nam Hinboun.

Due to seasonal fluctuations of river discharges and water levels, and subsequent changes in water quality, the conditions of aquatic habitats differ seasonally. As a result of dynamic natural changes in aquatic habitats, the species composition of aquatic life, the abundance of aquatic populations, fish production, and fish catch change seasonally and annually as well. Floods can flush out certain fish species from rivers, floodplains can be inadequately flooded affecting fish recruitment, and flow, temperature and water quality factors that trigger migration might fail. During some years, aquatic habitats provide the right conditions for spawning. In other years there is little recruitment of particular fish species due to unfavourable conditions of aquatic habitats. Landslides, erosion, and subsequent sedimentation particularly affect spawning habitats such as riverbanks, deep pools, and rapids. Sedimentation is aggravated by extreme floods and land and water uses by a growing human population. Fish that were abundant one year might be totally absent the next.

Migration

Migration between different aquatic habitats has often triggered flow conditions that change concentrations of suspended solids and water transparency. Such factors affect the availability of food for fish, and the spawning migrations of fish being strongly related with concentrations of suspended solids. Most fish species that migrate upstream in September when suspended solids are high, searching for upstream rapid reaches where the water levels recede and concentrations of suspended solids decline. In the beginning of the rainy season when suspended solids increase, spawning migration aims for floodplains where sediments settle or clean upstream reaches of ephemeral streams.

5.3.2 Aquatic Biodiversity

General

The Mekong Basin supports a rich aquatic diversity. The Fisheries Program of the Mekong River Commission estimated that about 1,200 fish species might be found in the Mekong River Basin but only a part of these have been identified and scientifically described. The biology and ecological requirements of the fish species are even less known.

Particularly in the headwaters of many tributaries to the Mekong, fish species with geographically limited distribution areas or confined to specific rivers (endemic species) are frequently found. The reasons for this are both isolation though geological processes and the diversity of natural river habitats as a result of the dynamic annual, seasonal and spatial differences in climate, hydrology, and water quality.

Nam Theun – Nam Kading

The fish biodiversity of Nam Theun/Nam Kading has been studied several times in connection with the planning of hydropower developments in the basin. All studies found a large number of species but there are some differences in the number and species reported. This is partly caused by the seasonal and yearly changes in occurrence and lack of clarity in the taxonomy of the registered fish species in the region.

As an input to the Environmental Assessment of the Theun Hinboun Hydropower Project (Norpower 1993) a “Study of Aquatic Life” was prepared (Department of Livestock and Veterinary & Burapha Development Consultants 1992). This study reports 102 fish species in Nam Kading below Keng Vang Fong. Further upstream in Nam Kading and in the reach which is now the THPP Headpond 79 species were found.

To assess the impacts on fish species of the planned Nam Theun 2 Hydropower Plant, the fish taxonomist Maurice Kottelat carried out several fish surveys in Nam Theun/Nam Kading River Basin (Kottelat 1996, 1997 and 2002). In total 71 fish species were identified of which a large percentage was not previously recorded from Laotian waters.

11 fish species were registered as new to science. These species were:

- *Bangana elegans*
- *Danio fangfangae*
- *Rhodeus laoensis*
- *Scaphognathops theunensis*
- *Nemacheilus arenicolus*
- *Schistura atra*
- *Schistura nudidorsum*
- *Schistura obeini*
- *Schistura tubulinaris*

- *Rhinogobius lineatus*
- *Tor ater*

The populations of some of these endemic species are to some extent impacted by the dam and Headpond of the THPP, but none of them seem to have disappeared. They can still be found in the Nam Theun upstream of the Headpond.

Fish species in the Nam Kading river reach downstream of Keng Vang Fong are similar to the fish species that can be found in the Mekong mainstream. The composition of species in the upstream and rapids flowing through part of Nam Kading and in the Nam Theun differs greatly from those found in the slow flowing lowland reach.

Biologists and taxonomists, who carried out their fish surveys in Nam Theun/Kading only during the dry season, assumed that the Keng Vang Fong and the numerous rapids in Nam Kading formed an obstacle for upstream fish migration from the Mekong even before the construction of the Theun Hinboun weir. However, at least one aquatic species belonging to the long distance migrating fish family *Pangasiidae* swims from the Mekong mainstream up into tributaries in August/September to spawn in rapids. With the establishment of the Headpond weir the upward migration of fish has been blocked for most of the year. However, in the peak of the wet season (September) the weir is submerged and some long distance migrating fish is able to pass to upstream waters. This opportunity will be more or less lost when NT2 comes into operation and the flow into the Hadpond is reduced.

Nam Gnouang and Theun Hinboun Headpond

The 25 meter high Theun Hinboun Weir has changed part of Nam Theun and Nam Gnouang rives into a “lake like” water body with a surface area of 6.3 km^2. The water level of the Headpond is maintained at 397-400 masl but reaching 410 masl during high floods.

A habitat change has resulted in the disappearance of many of the original fish species but allowed the proliferation of others. Presently the introduced fish species, common carp (*Cyprinus carpio*) forms an important part of the fish yield of Theun Hinboun Headpond.

The carp has invaded the Headpond after disappearance of more than 1/3 of the originally occurring fish species. The carp is confined to the slow moving water of the Headpond and has not been able to establish populations in the fast flowing rivers further upstream.

The fish species composition of Nam Gnouang upstream the Headpond does not seems to have been significantly changed by the THPP. In the first years after filling of the Headpond upstream reaches an increased in fish caches due to upstream movement of from the Headpond area was observed, but this situation has now stabilised.

Nam Hai and Nam Hinboun.

The Nam Hinboun river system is found to be even richer in species than the Nam Theun/Nam Kading. In the "Study of Aquatic Life" (Department of Livestock and Veterinary & Burapha Development Consultants 1992) 118 fish species are listed from the Nam Hinboun. Due to the level and slow flowing character of this river, the species composition of Nam Hinboun is more similar to the Mekong mainstream and the lower part of Nam Kading than to the Nam Theun.

5.3.3 Fish Production

General

The fisheries of Nam Theun/Nam Kading and Nam Hinboun river basins are to a great extent influenced by the fish migration patterns of refuge, spawning, and feeding areas. Fish migrate between deep pools, floodplains, rapids, tributaries, ephemeral streams, ponds, paddies, and backwaters. Long distance migrating fish species migrate upstream from the Mekong particularly in the months of August/September when water levels in tributaries are high.

While extreme floods may result in reduced fish catch at upstream locations, the area, duration and frequency of flooding caused by the Mekong mainstream are largely determining the total annual fish production of the Mekong Basin as a whole, including the Nam Hai/Nam Hinboun River Basin. Since the annual floods fluctuate significantly, annual fish production and fish yields differ accordingly. Recruitment and production of *Pa Soy* (*Pa Soy* is the local name for mix of juveniles from about 25 different fish species) in the Nam Hinboun floodplain depend on the level, duration, and frequency of floods. *Pa Soy* are caught when they migrate from the floodplains and streams up in to Nam Hinboun.

The complex situation with many fish species, large natural changes in ecological conditions and changes in use of fishing gears and level of total fishing efforts makes it difficult to analyse the developments in fish production and fish catch. For instance, the impacts on fisheries of the THPP have been difficult to isolate from changes caused by natural causes and other development factors.

Nam Kading Nam Theun

Nam Kading

In the Nam Kading, significant fishing takes place only directly downstream the Headpond weir and in the reach between Kang Vang Fong, at the border to the Nam Kading NPA, and the confluence with the Mekong. The lack of permanent settlements and difficult access restricts the fishing activities inside the NPA.

Villagers who fish the Nam Kading in the first few kilometres downstream of the weir have reported a reduction of abundance of certain fish species in their catch after the construction and operation of THPP. However, they did not notice any disappearance of specific fish species in their catch.

Downstream of Keng Vang Fong the changes caused by the THPP in hydrology and water quality are observed mainly in the dry season.

The flow volume and the water velocity have been reduced and have resulted in the deposition of finer sediments. Two bottom dwelling fish species have disappeared from the reach most likely because of change from sandy to muddy conditions. The change in substrate has, however, led to the establishment of new aquatic plant species and new mussel species. Annual village fish yields have reportedly decreased significantly downstream of Keng Vang Fong. However, the total fishing effort in this stretch of the river has increased considerably since the operation of THPP. The decreased annual village fish yields are more likely to have been caused by the increased fishing efforts than by the diversion of water caused by the THPP. (Schouten, et al. 2004).

Nam Mouan

In the parts of Nam Mouan outside the NPA local fishermen report that their annual catch has changed little. The impact of THPP has on this reach has only caused a slight decrease on water levels during the dry season.

Upstream Headpond

The blockage of migration opportunities by the THPP weir does not seems to have had any significant impact on the species composition downstream and upstream of the weir. The upstream fish species appear to be able to fulfil their complete life cycles upstream of the dam. Villagers at upstream locations of the Headpond have reported a decrease in annual catch in last years. However, the fish yields appear to have decreased mostly as a result of increased fishing efforts with increased access to markets to sell fish and as a result of background impacts on aquatic habitats and water quality. Ongoing large scale fishing practices in Nam Katha and Nam Phao and ongoing destructive fisheries with explosives and use of pesticides in Nam Theun do not contribute to the sustainability of annual village fish yields.

Nam Gnounag and Theun Hinboun Headpond

Due to the reduction on number of fish species it would have been expected that the fish yields from the Headpond area would have declined. However, the loss in species seems to have been more than compensated by the proliferation in the Headpond of the carp (*Cyprinus carpio*). This exotic fish species has become the most common species in the annual village fish yields along the Headpond and has largely compensated the reduction of annual village fish yields resulting from loss of fish species.

The rather stable increase in water depth has caused a loss of aquatic vegetation from the Headpond area. People living around the Headpond used to harvest such aquatic weeds for consumption. On the other hand one snail that normally occurs in stagnant waters and paddies, has proliferated in the Headpond. People harvest this snail for consumption and it also serves as the main food source for the carp.

What is said about the Nam Theun and its tributaries upstream the Headpond is also valid for Nam Gnouang. Also here destructive fisheries with explosives and use of pesticides take place.

Nam Hai and Nam Hinboun.

At upstream locations of Nam Hai, the annual village fish yields stayed more or less the same or have even increased after THPP came into operation. The positive changes have been seen in the dry season. Before the power plant was established this reach went almost dry, and now the power plant has provided more perennial flow through it year-round releases of water into the Nam Hai.

Further downstream Nam Hai and in Nam Hinboun down to the Mekong River, the village fish yields have reportedly shown a significantly decline. The discharges from the power plant have caused riverbank erosion, downstream sedimentation, drastic morphologic changes and extreme water level fluctuation (average of 2 m in dry season). High turbidity and high flows which earlier only occurred as a wet season phenomenon are now permanent features of the river and will be increased by the NG dam. It also seems that the increased sediment transport in Nam Hinboun caused by the intermittent flow releases have “filled” the deep pools of the river and thus destroy important fish production habitats and fishing sites.

This has resulted in a situation where local people can no longer harvest aquatic vegetation or collect snails, mussels, and shrimps from the Nam Hinboun mainstream. These items represent important parts of the aquatic food chain and thus resulted in a decline in fish productivity and village fish catches. Discharges of suspended solids and heavy metals from tin mines into Nam Theuk and Nam Pathaen and subsequently into the Nam Hinboun have exacerbate the negative impacts on fish yields in the lower reaches of the Mekong.

In the Nam Hinboun, upstream of the confluence with Nam Hai, the Project induced backwater effects are recorded up till the village of Nasangkham. The annual village fish yields in this stretch of Nam Hinboun have increased after the power plant started operation due higher water levels during the dry season. However, the annual village fish yields in villages along Nam Hinboun upstream of Nasangkham have declined. This indicates that, similar to the lower Nam Kading, the decrease in fish catches in the Nam Hinboun basins can be partly be attributed to factors such as over-fishing and unsustainable fishing methods in addition to the morphologic and flow changes due to the THPP.

5.4 Protected Areas

5.4.1 Biodiversity Conservation

Lao PDR ranks as one of the richest countries in South-East Asia when it comes to biological diversity. Unfortunately, the increasingly degradation of the country’s forest resources and wetlands, combined with an intense (illegal) hunting pressure and trade in endangered species continues to put undue pressure on the diversity of plants and animals. In order to counteract this negative trend, Lao PDR has initiated several important actions in biodiversity conservation.

5.4.2 NPAs

In 1996, Lao PDR ratified the Convention on Biological Diversity (CBD). The obligations of CBD have been followed up with legal and institutional development (see Chapter 2), as well as by the establishment of 20 National Protected Areas (NPAs), previously labelled National Biodiversity Conservation Areas (NBCAs), covering more than 33 100 km^2 (14 % of the land area). In addition to the NPAs, a number of provincial and district protection areas has been established.

There are three NPAs in the direct or indirect impacts zone of the THXP (Figure 5-5). These are:

- Nakai Nam Theun NPA covering 353,200 ha of the headwaters of Nam Theun
- Nam Kading NPA covering 169,000 ha of the Nam Kading valley downstream of the existing Theun Hinboun dam.
- Phou Hin Phoun or Kammouan Limestone NPA covering 150,000 ha of the southern and eastern catchment of Nam Hinboun.

As a compensation measure of the barrier effect of the Nam Theun 2 reservoir on the Nakai Plateau, a Forest Corridor (Nam Theun Corridor) linking Nam Kading NPA with the Phou Hin Poun NPA has been established. This area coves the forests on each side of Nam Theun downstream of the NT2 damsite.

5.4.3 PPAs

In addition to the NPAs, two Province Protected Areas (PPAs) are found within or close to the project impact zones (Figure 5-5). These are:

- The Nam Chat/Nam Pan Provincial Conservation Forest consisting of 45,000 ha largely undisturbed forest. It is located to the east of the planed reservoir area covering the parts of the catchment of Nam Gnouang bordering Vietnam. The area contains large stands of Wet Evergreen Forest and is considered important habitat for rare and highly endangered wildlife species such as the Saola (*Pseudoryx nghetinhensis*).

- The small Pha Kouanchan PPA covers most of the inaccessible limestone ridge separating the Nam Gnouang reservoir area and the Nam Theun catchment. The most characteristic species found in this PPA are species adapted to steep rock and cave environments, in particular reptiles and bats. The fauna also includes the Laotian rock rat or *kha-nyou* (*Laonastes aenigmamus*), sometimes called the "rat-squirrel". This large rodent, belonging to the ancient fossil family *Diatomyidae*, was first scientifically described in 2005.

5.4.4 *Saola Management Area*

The Pou Kadoung Saola Management area was proposed in 1996 (WCS/ IUCN 1999). It encompasses the northern section of the Nam Ngouang River and the head waters of the Nam Chat, Nam Pan and Nam Heung Rivers. This area is considered to be of high importance due to the presence of Saola (*Pseudoryx nghetinhensis).* Despite its apparent importance, no action has been taken to establish or manage this area.

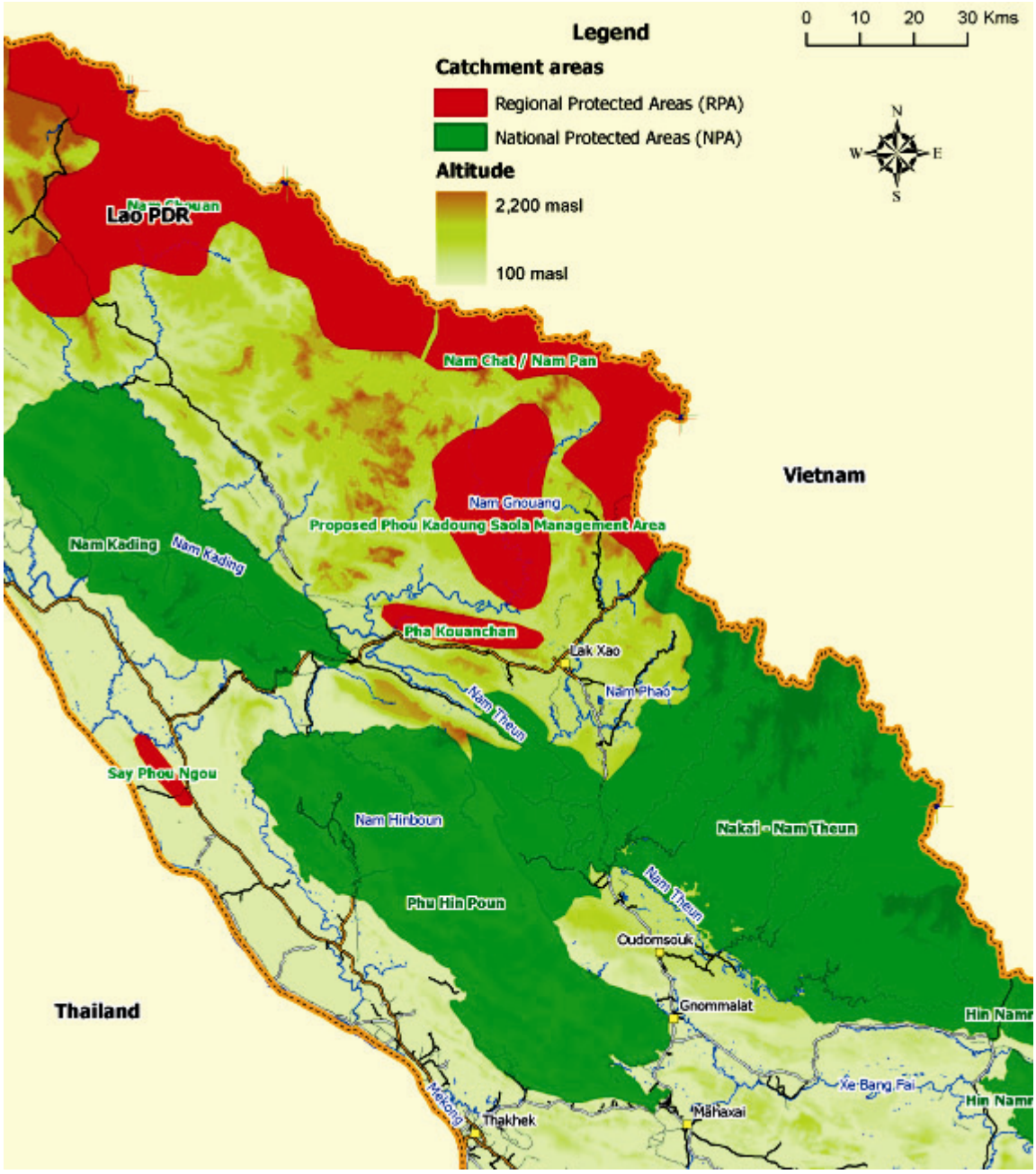

Figure 5-5. Biodiversity Conservation Areas

5.4.5 Management Challenges

Similar to the general situation in Lao PDR, the unique value of the biodiversity in the Bolikhamxay and Khammouane Provinces is under serious threat. In general for the NPAs in Lao PDR, unsustainable logging and deforestation for agriculture are seen as the most serious threat to biodiversity. In these two provinces, however, and in particular in the western parts, the trade in wildlife is seen as an even more acute problem (IUCN 2000). The centre of this trade is supposed to be Lax Xao and about 60-70 % of the goods are assumed to go to Vietnam and eventually to China.

The NT2 Project will provide the Nakai-Nam Theun NPA with annual funds of US$ 1 million. This will be an important contribution in order to protect this globally important NPA against further encroachment from loggers and poachers.

At the present time there is almost no control of logging or hunting in these NPAs, mostly responding to pressure from rapidly expanding markets for timber, wild animals and “wild medicines” in Vietnam and China. It cannot be expected that this situation will change in the near future. Theoretically, plans to extend and link NPAs to form more effective ecosystem assemblies are sound. However, the core problem of how to protect habitats and species in Lao PDR has not yet been solved. The most promising event in recent years is the emergence of ecotourism. It may be possible to initiate effective conservation by empowering enterprises and communities benefiting from tourism revenues to protect the wild resources on which the tourism is based. This will inevitably be on a small scale, and it may be necessary to scale down the ambitious expectations triggered when the NPAs and PPAs were established.

6 PROJECT IMPACTS

6.1 Introduction

Potential Impacts

This Chapter presents predictions of potential impacts from the proposed THXP development. Some of these impacts cannot be avoided and should be compensated for in one way or another. Other potential impacts can be prevented by applying good environmental practice in construction and project management or mitigated through specific actions.

The assessment presented in this Chapter is limited to the identification of what will happen if the project is implemented without any mitigation measures.

Recommendations

Mitigation and compensatory measures and actions are not described in this Chapter but are dealt with in Section II "Environmental Management and Monitoring Plan".

No-action

The impacts on various sectors are measured against the development of this sector under a "no-action" scenario, i.e. the environmental and socio-economic situation without the project. It should be remembered that the "no-action situation" will not always be identical with the baseline condition as presented in Chapter 4 and 5. There might be a dynamic situation (for instance demographic changes or catchment/soil erosion changes), where the "baseline" is constantly changing over time. In such cases, the assessment will discuss the project-induced changes in relation to the changes that will result from other dynamic factors in the project area. In this regard, the changes in baseline conditions caused by the NT2 development will be particularly important.

6.2 Impacts on the Physical and Chemical Environments

6.2.1 River Flow

Nam Gnouang and Nam Theun

Reservoir

A major part of the lower Nam Gnouang will be turned into a reservoir with a normal seasonal fluctuation of water between 420 masl. and 455 masl.

In extreme flood situations the maximum water level might rise to 459.8 masl. In addition there might be some backwater effects in the tributaries to the reservoir. This can cause flooding of land and settlements upstream also above the 459.8 masl level.

The reservoir will behave more or less like a lake with a central current following in the middle part of the reservoir. The strength of this current will depend on the level of drawdown and the release pattern from the NG dam.

Upstream

Except some potential backwater impacts during high floods the flow pattern of the Nam Gnouang and tributary river reaches upstream the reservoir will not be altered.

Nam Theun

The reaches of Nam Theun and the tributaries upstream the Headpond will not be hydrologically impacted by the THXP. However, compared to today, the situation will be significantly different when the NT2 reservoir starts filling partially in 2007 and fully in 2008, and the NT2 power plant comes into operation in 2009. In regular operational mode only the agreed riparian flow of 2+ m^3/s and some possible overflow at the end of the wet season will be released down Nam Theun from the NT2 dam.

Nam Kading

The water release from the Theun Hinboun weir will be altered both as a consequence of the NT2 project and the THXP. The seasonal flow pattern will change as the reservoirs will store water and reduce the inflow into the Headpond in the wet season. In addition, more water will be diverted to the THPP and discharged to the Nam Hinboun catchment as a feature of THXP operation. This will further reduce the amount of water that would otherwise been spilled over the existing weir and into the Nam Kading. The excising riparian release will be the same as today: 5 m^3/s.

The resulting total change in Nam Kading flow is discussed in Chapter 8 – Cumulative Impact Assessment. The change in flow distribution over the year in Nam Kading downstream the THPP Headpond is illustrated in Figure 8-2.

Nam Hai and Nam Hinboun

The water flow in Nam Hai and Nam Hinboun downstream the Theun Hinboun Power Plant tailrace has already been significantly changed from the normal pattern by the existing powerplant operation. (see Section 4.7.3). The changes are most pronounced in the Nam Hai reach. Here the mean annual natural flood is presently increased with 30-50%, whereas the 100-years peak is increased with about 15-25% (Table 6-1).

With implementation of the THXP the volume of water discharged from the power plant will be two times the present volume. This will give a corresponding increase in the mean annual flow in Nam Hai of about 60-90% compared with the natural flow and about 35-45% increase in the 100 year flow compared with the natural runoff (Table 6-1).

Table 6-1. Nam Hai flood volumes at Ban Namsamam (SWECO 2007)

Nam Hai at Ban Namsamam – downstream tailrace discharge					
Re-turn Period	**Natural flow**	**With existing power plant (THPP)**		**With expansion project (THXP)**	
Years	*m^3/s*	*m^3/s*	*%*	*m^3/s*	*%*
2 (MAF)	250	360	+ 44	**470**	**+ 88**
10	350	460	+ 31	**570**	**+ 62**
20	390	500	+ 28	**610**	**+ 56**
50	440	550	+ 25	**660**	**+ 50**
100	490	600	+ 22	**710**	**+ 45**

In the Nam Hinboun, the effects of THPC releases and the planned addition of THXP are relatively lower. With the planned expansion the increases in the mid Hinboun are about 25% in the mean annual flood and about 13% for the 100-years flood (Table 6-2).

Table 6-2. Nam Hinboun flood volumes at Ban Khen (SWECO 2007)

Nam Hinboun at Ban Khen – upstream gorge					
Return Period	**Natural flow**	**With existing THPP**		**With expansion project (THXP)**	
Years	*m^3/s*	*m^3/s*	*%*	*m^3/s*	*%*
2 (MAF)	870	980	+ 12	**1090**	**+ 25**
10	1050	1160	+ 10	**1270**	**+ 21**
20	1200	1310	+ 9	**1420**	**+ 18**
50	1330	1440	+ 8	**1550**	**+ 16**
100	1650	1760	+ 7	**1870**	**+ 13**

Mekong

The NT2 Project will significantly reduce the total amount of water discharged from Nam Kading into the Mekong. The THXP project will divert more water into Nam Hinboun catchment and will thus cause a further reduction. A more detailed assessment of the cumulative hydrological impacts of the cascade of hydropower power project on the Nam Theun/Nam Kading can be found in Chapter 8 covering cumulative impacts.

6.2.2 *Flooding*

Nam Hai and upper Nam Hinboun

Table 6-3 gives some of the results of the hydraulic modelling of the Nam Hai and upper Nam Hinboun (SWECO 2007). (Upper Hinboun

is referring to the river before it reaches the narrow gorge below Ban Khen) It can be seen from the table a similar pattern as for the flood events with increased frequency of flooding with the same rainfall event when the THPP discharge is included in the analysis. For example, the 10-years flood event without any power plant discharges (natural flow) will flood approximately 47.2 km^2 of the river floodplain. With the THXP in operation the same area of inundation will occur roughly every 2-5 years.

Table 6-3. Flooded area around Nam Hai and Nam Hinboun upstream Ban Khen (SWECO 2007)

Flooded area in km^2					
Scenario	**MAF**	**10 year**	**20 year**	**50 year**	**100 year**
With planned THXP	**38.0**	**66.6**	**72.7**	**81.5**	**87.7**
With existing THPP	23.0	58.7	66.6	75.7	82.4
Natural flow	14.6	47.2	59.5	70.0	76.7

The relative effect of the THPP and THXP releases decreases for the more extreme flood event (Figure 6-2 and Figure 6-2). The 100 year flood would in the natural condition inundate an area of 76.7 km^2 and will cover 87.7 km^2 in the THXP scenario. One of the reasons for this is that the floodplain areas are confined within the limited space of the steep, karstic limestone ridges and during extreme floods much of these areas are already inundated during natural conditions.

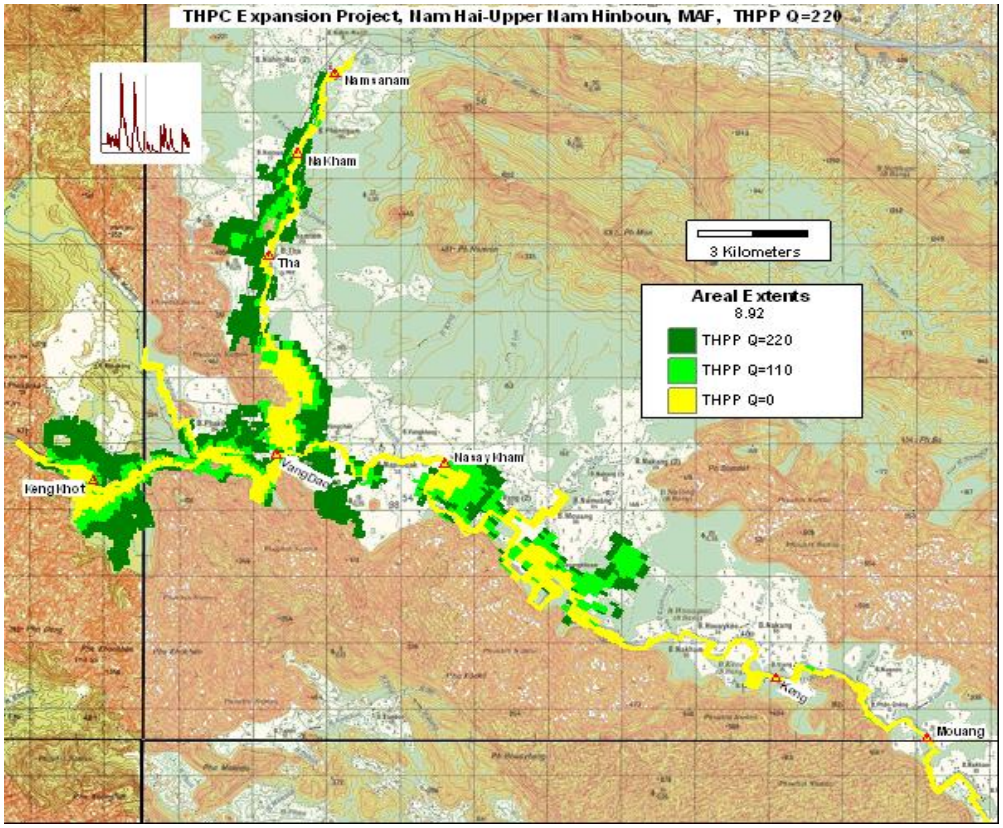

Figure 6-1. Calculated extent of the mean Annual Flood event (SWECO 2007)

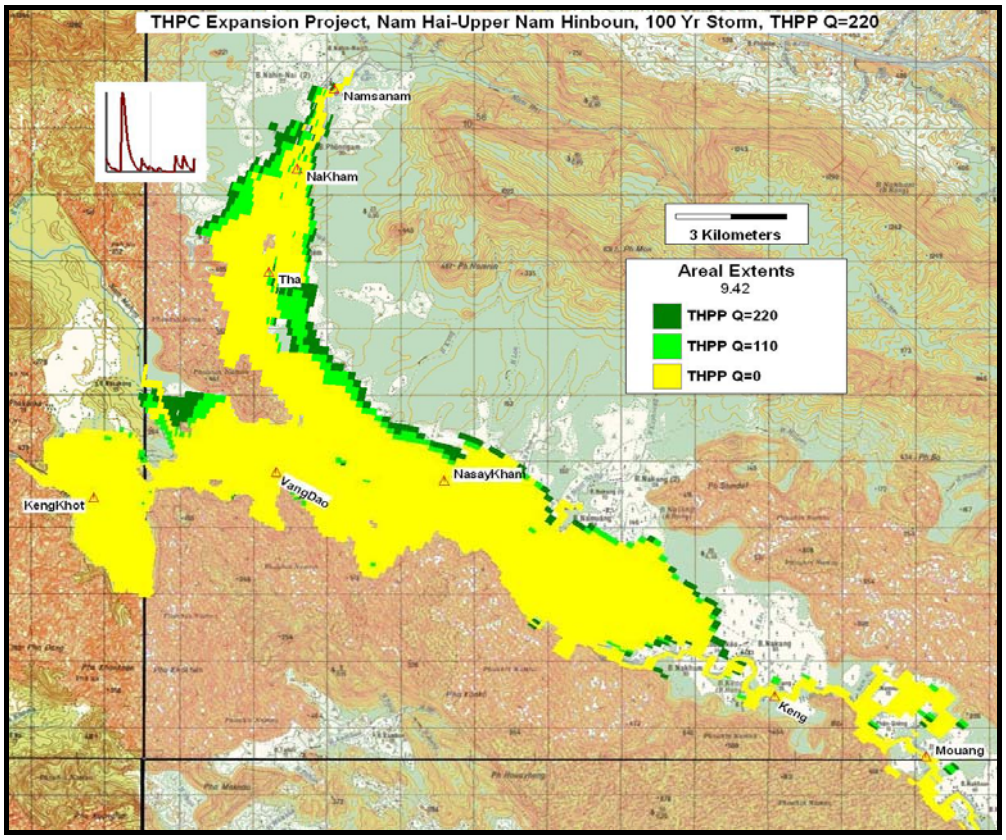

Figure 6-2. Calculated extent of the 100 year flood event (SWECO 2007)

The duration of flooding events will however, be changed. Consistent with both the hydrological and hydraulic modelling has shown a trend of increased flood durations when the discharges from the power plant increase (Table. 6-4). At Ban Namsanam the 100 year flood in average would last for about 5.5 days during natural conditions 10.5 days with the present power plant release and 19.5 days with the expansion project. At Ban Kengkhot the respective figures are 8 days, 9.5 days and 13.5 days.

Table. 6-4. Flood durations of present and future releases from THPC (SWECO 2007).

Flood duration in hours Ban Namsanam			
Return Period	***Natural***	***Present power scheme***	***Expansion project***
2 (MAF)	0	42	393
10	17	166	455
20	51	207	463
50	118	235	471
100	136	257	471
Flood duration in hours Ban Kengkhot			
Return Period	***Natural***	***Present power scheme***	***Expansion project***
2 (MAF)	0	79	162

10	114	133	245
20	132	176	297
50	162	211	314
100	182	226	324

Lower Hinboun

SWECO (August 2007) issued hydrodynamic model calculations for the extent of flooding in lower Nam Hinboun from Ban Ken down to the Mekong confluence. As can be seen from Figure 6-3 and Figure 6-4 and in Table 6-5 the impacts of additional release of water from THPP are modest compared to the natural occurring flood levels.

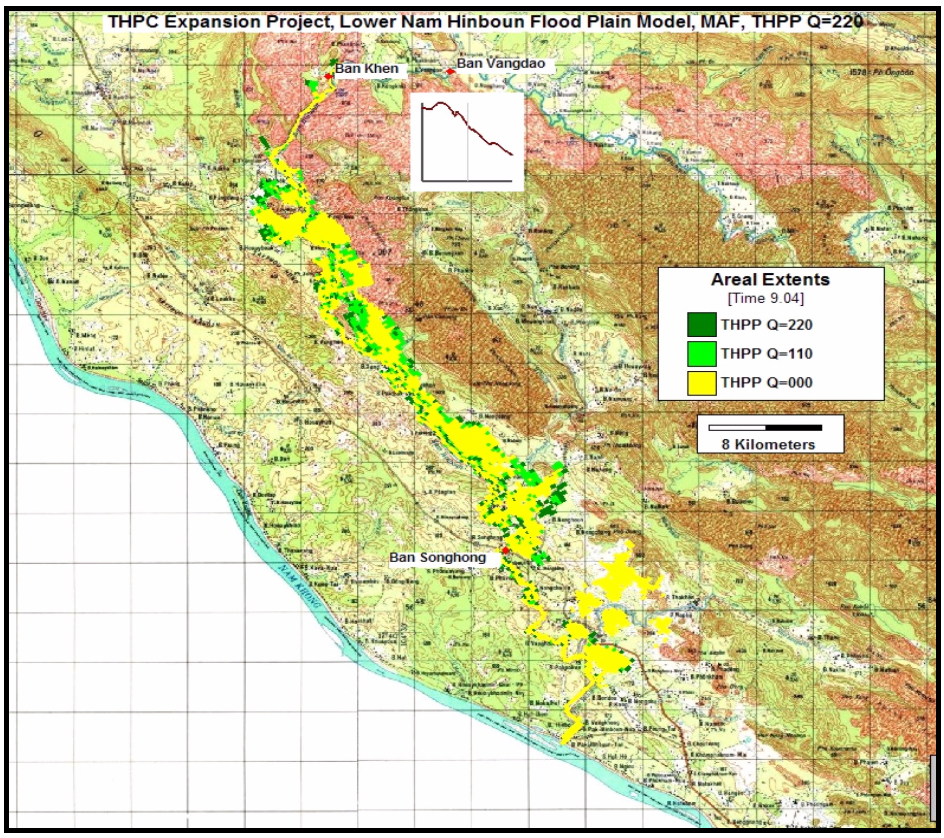

Figure 6-3 Mean Annual Flood in Lower Nam Hinboun for different THPP water releases

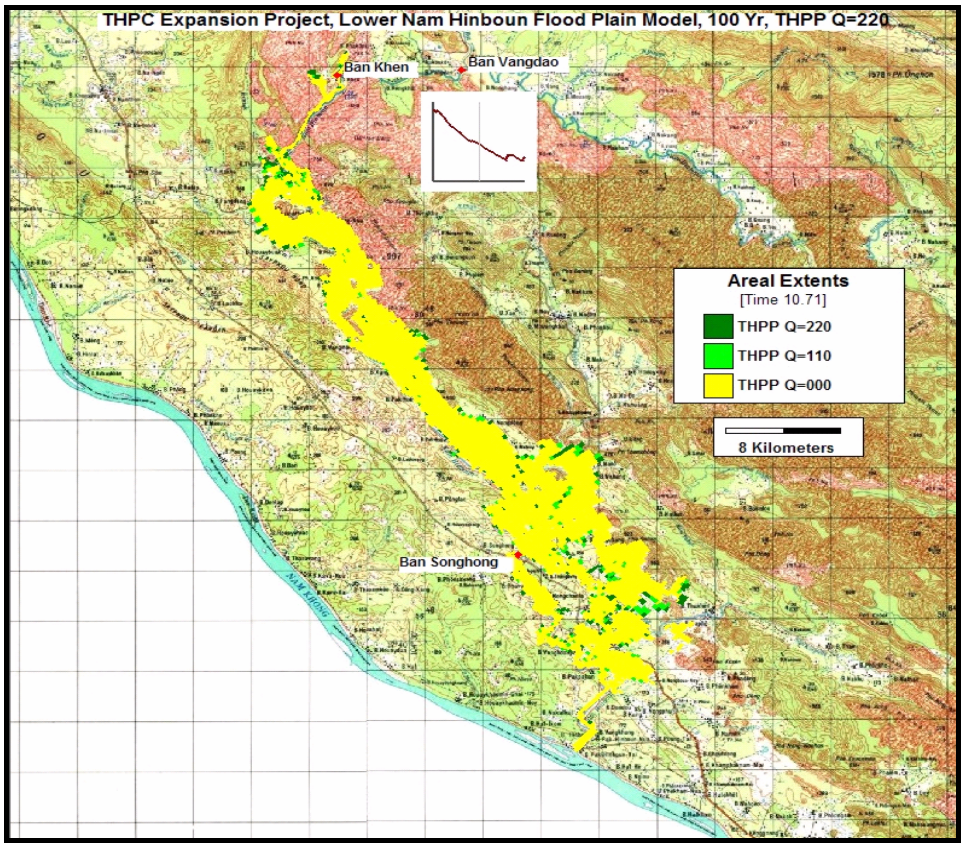

Figure 6-4 100 Year Flood in Lower Nam Hinboun for differnt THPP water releases.

Table 6-5. Inundated area in km^2 by flood event and THPP discharge scenario.

Scenario	MAF	10 Year	20 Year	50 Year	100 Year
THPP Q=220	126.4	172.2	182.9	194.7	203.3
THPP Q=110	113.4	157.2	173.7	186.9	195.1
THPP Q=0	94.5	144.0	159.3	177.7	187.5

6.2.3 *Operational Water Quality Impacts*

Nam Gnouang and Nam Theun

The water quality of the river reaches upstream of the reservoir on the Nam Gnouang and the Nam Theun upstream the Theun Hinboun Headpond will not be impacted by the THXP project. In the Nam Theun reach, however, the commissioning of the NT2 hydropower project in 2009 will significantly change the flow pattern and thus the water quality situation. The regular release of only 2 m^3/s from the NT2 dam and the variable spill-over at the end of the rainy season will have considerable impacts on water quality all the way down to the Headpond. The NT2 riparian release water in the end of the dry season is likely to have a reduced content of dissolved oxygen even though the release will be drawn from the epilimnon of the reservoir. Oxygen saturation is, however, expected to increase

a short distance downstream the NT2 dam where the river runs through several sets of rapids.

The main impact on the water quality will be caused by the relatively larger contribution to the flow from the tributary Nam Phao. In the Nam Phao catchment there is a higher population density and general level of polluting activities (agriculture, mining, wood processing) compared to Nam Theun. Consequently the lower reach of Nam Theun in future is expected to have a higher concentration of organic material, nutrients and suspended solids than today.

NT2 Reservoir Oxygen Status

The prediction of the future oxygen situation in hydropower reservoirs has been an issue raised in hydropower EIAs in Lao PDR. A major analytic effort and literature review of this issue were done in conjunction with the NT2 project. Simulations of the water quality of the NT2 reservoir were carried out under different operational and organic material input scenarios. A description of the model and the results can be found in the Environmental Assessment & Management Plan (NTPC, 2004).

Based on model calculations, it was predicted that the NT2 reservoir will be thermally stratified each year from the late dry season. Periodic episodes of low dissolved oxygen (< 2 mg/l) were predicted to occur in the deeper waters under thermally stratified conditions. Anoxic conditions will generally last for about 1 to 3 months but because of the shallow nature of the NT2 reservoir anoxic conditions are likely to affect less that the 3 % of the reservoir volume.

NT2 Release

There have been concerns that the NT2 project will also impact the oxygen content on the water released down to the THPP Headpond. Riparian-released water from the dam and into Nam Theun will be drawn from the epilimnon. The dissolved oxygen concentration in the dry season is predicted to be around 5 mg/l. However, in the first years of operation the oxygen content might be lower as decomposition of the inundated biomass will be high. Even with the release of oxygen deficient water it is not expected that this will have a negative impact on the river water quality far downstream. The rapids found in this reach will function as efficient aeration structures and the water quality will be modified by significant tributaries inflow. The occasional large discharges of undigested organic materials downstream might however, add to the deepwater oxygen depletion problems in the Headpond.

Experiences from other Lao Reservoirs

After 35 years of operation the water quality of the Nam Ngum 1 Power Project is fairly good. Some anoxic water is found at the bottom of the reservoir, but mostly below the intake of the power plant (in the volume of dead storage). Frequently the discharged water from the station has low dissolved oxygen concentrations (in average 3.5 ml/l). Downstream of the dam the concentration gradually increases. The methane concentrations have been low.

Nam Leuk reservoir was inundated in 1999. In 2001 water quality problems still existed. The reservoir was anoxic from about 10 m below surface down to the bottom of the reservoir. Discharges from the power station indicated ferric oxidation and smell of hydrogen

sulphide was reported. In the dry season the discharged water was mostly anoxic (OD < 0.5 mg/l) and with a fairly high concentration of dissolved methane (5 mg/l). After passing a simple weir downstream, however, the quality is significantly improved.

As mentioned before, it is reported that there are seasonally low oxygen levels in the deeper layers of the Theun Hinboun Headpond. It appears, however, that this situation has not had any impact on the quality of the water downstream the power plant surge pond.

NG Reservoir

In the new reservoir water quality will significant change from a situation characteristic for a slow flowing river to that of a lake.

Sediments

The reservoir will trap most of the inflowing sediments. This will settle on the reservoir bottom with the largest amount disposed in the up-stream parts of the reservoir. The sedimentation of solid materials and its impact on reservoir life and active storage capacity are discussed in detail in the THXP Technical Feasibility Study, Annex 1. (SWECO 2006). From a water quality point of view, the sedimentation will result in a reduction in surface suspended solid concentration and in less turbid water in particular in the downstream sections of the reservoir. Less turbidity will increase the light penetration in the water column and increased alga growth and generally increased biological production.

Oxygen

The other main impact will be the establishment of a thermal stratification in the reservoir each dry season. This phenomenon and the digestion of organic materials brought in from the tributaries, produced in the reservoir itself or left in the reservoir when inundated will result in oxygen depletion in the bottom layers of the reservoir. Experiences from other reservoirs in Lao PDR indicate that the oxygen depleted layer will be found at about 10-15m from the surface in the end of the dry season. In the wet season the inflow of water will cause mixing of the water column and bring oxygen to the deeper layers. The ability of this process is to “recharge” the deepest strata of the reservoir will be dependent on the total depth of the water. It is likely that the deepest parts of the reservoir will be constantly anoxic.

Oxygen levels of less than 3 mg/l are considered a minimum for fish production (The Thai water quality standard prescribes minimum 6 mg/l for fish production). Oxygen free conditions (anoxic water) are deadly to higher plant and animal life.

The most serious conditions will be experienced in the first 10 years of reservoir operation, when organic materials in the inundated area will be digested. This situation can be significantly reduced to by removing organic materials (soft biomass) from the reservoir area before inundation. Low levels of oxygen in the deeper layers will, however, be a permanent feature of a reservoir like NG. Downstream negative impacts can only be avoided by installing aeration structures.

Eutrophication

The more “lake like” ecological appearance of the reservoir compared to the river will allow for a eutrophication process to take place, causing increased biological production in the reservoir sur-

face layers. The human activities in the catchments are modest and the content of nutrients relatively low. Therefore, it is not expected that the hypotrophic levels that might become detrimental to fish production and human water use will be reached.

Theun Hinboun Headpond

The water quality in the Headpond will be influenced by the changes in flow pattern and water quality from the NG dam and powerplant. In addition, there will be impacts caused by changes in the volumes and quality of the inflowing Nam Theun water resulting from the NT2 project.

Sediments

The sediment load in to the Headpond will be significantly reduced because of the trapping of sediments in the NG reservoir. For many of water uses and the aquatic biodiversity this will be a positive change.

Oxygen

There is a risk for periodically reduction in the level of dissolved oxygen in the Headpond. Today the oxygen situation in the pond is good. (The average value of OD being 7.9 mg/l.) The released water from the NG reservoir will however, lead to some reduction in the oxygen concentration in the Headpond. The time periods when the oxygen depletion might be observed and how serious this impact will turn out to be cannot be estimated at this time. The final result will depend on the details of intake and tailrace arrangements at the NG power plant.

It can be assumed that without special aeration arrangements, some oxygen will be replenished but that some of the toxic elements (ammonia, methane and H_2S) might be carried down to Ban Thasala when the powerplant draws water from the anoxic layer at the end of the dry season. Exactly how the impact of impaired water will affect the Headpond is difficult to predict as the discharged water will also be colder that Headpond water and thus tend to flow as a sheet on the bottom and not mixing with more oxygen rich surface water.

The Nam Gnouang branch of the Headpond water might however become less suited for human consumption and fish production than today.

Other

Other water pollution problems are not foreseen as a result of the operation of the power plant. It is important, however, to organise and protect the Substation at the NT8 power plant in a way that the risk for accidental releases of oil components are minimised.

Nam Kading

It is not foreseen that the down stream water quality will significantly change from today's situation. The basic impacts induced by the existing plant (see Chapter 4) will most likely continue also with the NT2 and the THXP in operation. In periods of high floods, the oxygen status of the water in the Headpond and the water overtopping the weir is assumed to be quite good. In periods of low flow the water in the Headpond might have lower oxygen content than today

but the rapids just downstream the weir will serve as an efficient aeration structure and replenish the oxygen.

Nam Hai and Nam Hinboun

The water quality impacts of the Expansion project will generally be an increase in the impacts documented from the initial THPP. Except for the potential of reduced oxygen content in the water tunnelled into the power plant there will be no significant increases in discharge of polluting elements.

Oxygen

In periods of the year the water released from the NG reservoir into the Headpond and further into the Power Plant will have a reduced content of dissolved oxygen. On average, the water in the Headpond will have lower dissolved oxygen content. However, oxygen content of the water just downstream the tailrace is today high due to the functioning of the aeration weir. The aeration structure should be able to cater also for the water releases of the Expansion Project.

Sediments

Sediment content of the water released in to Nam Hai and Nam Hinboun will be approximately the same as today's situation. The increased water volume will, however, have the capacity to carry more sediment which will be eroded from the banks and bottom of Nam Hai and Nam Hinboun. The total volume of sediment carried will increase because of the increased water flow, but the concentration of sediments (mg/l) might be the same or less.

Heavy metals

Some of the tributaries to Nam Hinboun, not far from the confluence with Mekong, carry water with large concentrations of heavy metals. The overall increase in the Nam Hinboun flow will have a positive impact by diluting the pollution from these tributaries.

6.2.4 Water Quality Impacts from Construction Activities

Sediments

Negative impacts on the water quality will occur during the construction period if proper measures are not implemented. The sediment load to the Nam Gnouang and the Headpond will increase during construction of cofferdams and other river works. However, since the river often experiences events of very high turbidity, the existing ecosystem will adapt to such events, and it not expected that the additional load from construction activities will have any dramatic impact far downstream. It is also expected that most of the released materials will be trapped in the THPP Headpond.

Chemicals

Pollution due to accidents during handling and use of oil and fuel and other chemicals used in the construction process is a potential hazard to the water quality. However, the high flows of the river will have a strong dilution effect on any pollution.

Domestic waste

The concentration of people at certain work places and camps during construction might generate large quantities of domestic wastewater and solid waste containing polluting elements leaking into water sources. To what extent this will cause significant water pollution problems depends on how the sanitary features and how the waste collection and disposal will be organised. The present capacity for

waste water treatment at the power plant site at Kounkham village will not be enough to cater for extended activities at this site. Without proper management the microbiological contamination of water sources might be serious.

6.2.5 Erosion and Soil Degradation

Potential project impacts related to soil degradation and erosion might be experienced in several impact zones. The basic cause for such impacts might either be hydrological changes, changes in land use and construction activities.

NG Reservoir and THPP Headpond

Slides and slips

The Nam Gnouang has been known to experience landslides and slips which has caused loss of land and dramatic increases in the sediment content of the water. The planed reservoir will introduce a new element influencing these problems as the drawdown and filling the reservoir will create unstable conditions. RMR identified and mapped areas around the reservoir which might be such problem areas (Figure 6-5). The landslide prone areas will mostly be found in the upper narrow parts of the reservoir. The negative impact on water quality by such events will most likely be small as the released sediments will to a limited extent be transported downstream and mostly settle in the reservoir.

With the increased capacity of the main power plant the water level of the Headpond will see larger fluctuation than today. This might cause a slight increase in the erosion of river bank soil.

Nam Hai and Nam Hinboun

Serious river bank erosion impacts have been observed as a result of the existing operation of the THPP. In particular, the impacts along the Nam Hai have been extensive, and this situation has not been stabilised even after almost 10 years of operation. The Expansion Project will double the water discharges into the Nam Hai and the Nam Hinboun, and it is likely that the erosion processes will also increase. It is, however, difficult to say how much additional impact will be caused by THXP.

The increase in flooding events and duration as calculated by Sweco (see Section 6.2.1) might also have a negative impact on the soil quality on the floodplains. Water-logging over more extensive periods will change soil structure and the natural vegetation cover.

Resettlement host village areas

The resettlement of people from the reservoir area will cause increased pressure on the land in host village areas. If traditional land use practices continue, the increased population are likely to expose more land to erosion processes. On the other hand, the catchment closest to the main reservoir will hopefully recover some of its natural vegetation structure when villages are moved out. This will result in a decrease in the erosion impact from the near reservoir catchment.

Construction sites

Soil erosion will occur as a result project construction activities, such as clearing of the damsite, building new roads, improvement of existing roads, opening and the operation of quarries, disposal of stone and soil, and a number of other project related activities. The general wear and tear on vegetation cover and soil will also contribute to increased erosion. Some of these problems will be of limited time duration but others might cause more permanent problems if not actively counteracted.

6.2.6 Seismic Risk and Rockfalls

Seismicity

There are two categories of seismic risks related to large dams. The first is the risk of dam rupture in a seismic active area. The other is earthquake induced by the weight of the dammed volume of water and consequently dam rupture. It is indicated that the risk of reservoir induced seismicity is generally associated with the combined effect of a reservoir of over more than one billion m^3 and a dam over 100 m height. The storage of NG is planned for 2,451 Mm^3 with a dam of 60 m height, and is thus below these risk criteria. The feasibility study, moreover, concludes that with the geological information available and the chosen dam design and construction criteria the risk for dam rupture or other seismic damage is minimal.

Rockfalls

The high and steep rock walls formed by the limestone blocks along the southern rim of the reservoir could cause water waves to be created in the case of large limestone rock falls into the reservoir (Figure 6-5). Also, the stability of the limestone walls could be decreased due to the impounding of the reservoir water as reservoir water comes into contact with large areas of the nearly vertical limestone rock walls. Additional instability of the rock walls could be caused by rapid drawdown of reservoir water levels trapping perched water levels in cracks in the limestone blocks. These perched water columns could form zones of un-drained water forces that could induce rock falls.

Natural or reservoir operation induced rock falls entering the reservoir will cause water waves to be formed. The height of the water waves will depend on the volume of the rockfall, and the water depth into which the rockfall occurs. These water waves will spread out inside the reservoir and could eventually reach the dam, which could be overtopped if the waves are high enough.

A possible limestone rock fall into the NG reservoir can be exemplified with a limestone cliff of 40 m x 60 m x 5 m = 12,000 m^3. The resulting landslide would induce a wave in the reservoir of about 6 m height.

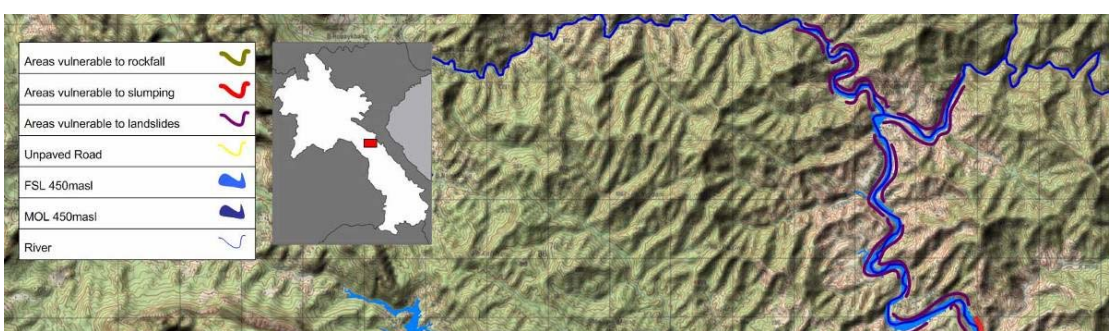

Figure 6-5. Areas of the reservoir rim with highest risk of rockfall and landslides (RMR 2006b)

The risk of rock falls into the NG reservoir has been an important consideration when selecting the type of dam to be built and determining the height of the dam crest level (460 masl). A flood wave caused by a rock fall of the size described above will in most cases be contained within the reservoir. The RCC structure can be overtopped by this magnitude of landslide induced water wave without significant damage to the structure. However, such larger rockfalls and the following wave spread in the reservoir might cause impacts on shores near activities and structures and be a hazard to people visiting the shores. The damage will be largest if the rockfall happens in a situation of maximum reservoir water level.

6.2.7 Climate

Climate

The reservoir will replace about 100 km^2 of forest and agricultural land. This will most likely result in some changes in the local temperature and humidity pattern around the reservoir.

During the south west monsoon the reservoir will be cooler than the average air temperature. This is assumed to last until the end of November. During the north-east monsoon the situation will be reversed but the difference is expected to be small. Over a 24-hour period the water temperature will vary much less than the air temperature and the reservoir will thus have a modifying effect on the air minimum and maximum temperature.

The differences in air and water temperature can produce microclimatic changes. The changes that might be observed would be; wet haze, fog, local winds and possibly precipitation enhancement.

The south rim of the reservoir is close to the limestone walls formed by the Pha Kouanchan PPA. Here down slope winds might be

formed when the mountain air is cold and the reservoir is warm and up-slope winds when the reservoir is cold and the mountains heated by sunshine.

Greenhouse gasses

It has been documented that dams and reservoirs can release significant amounts of gasses contributing to global warming. The highest data for CO_2 and methane discharges from hydropower reservoirs have, however, been from reservoirs with very high initial content of organic materials (in particular wetlands and swamps) combined with a very high annual inflow of degradable substances. The biomass and organic material present in the future NG reservoir area and the organic materials transported into the reservoir from upstream reaches are modest and should be further reduced by proper management actions and biomass removal. It is, therefore, expected that there will be only minor production and release of CO_2 and methane, and thus a much lower contribution to the global climate change process, from this reservoir, compared with thermal power plants producing the equivalent amount of power.

6.2.8 Air Quality and Noise

Construction impacts

Increased exhaust emission and noise from works and transport during the construction period are the direct foreseeable negative effects related to air pollution and noise problems. The activities that will have the highest potential for creating such problems are stone crushing and the initial phase of tunnelling, which will include blasting.

The main construction sites are situated in areas with relatively low population density which will diminish the problem. The stone crushing areas and the tunnelling sites are not within areas with high density of wildlife. Thus the negative impact of construction disturbances on wildlife will also be minimal.

Operation impacts

There will be no significant air pollution or noise emission from the operation of the power plants.

6.2.9 Traffic

The project will induce increased volumes of traffic in the project area.

Construction

Most negative impacts related to traffic will be experienced during the construction period. For the purpose of building the dam large quantities of rock and sand from the sites east of Ban Thasala to the construction site will be moved by heavy trucks.

At the tunnel sites both at the Headpond and at the THPP powerhouse, large quantities of spoil rock will have to be transported to designated spoil tips.

Noise, dust, exhaust and in particular road safety would be a concern in connection with construction phase traffic.

Operation

There will be traffic increases on a permanent basis from road no 8 to the NG dam and power plant site. The permanency and quality of the road needed for that purpose will also lead to an increase in the use of the road for the people in the area. An additional factor for increased traffic will be the replacement of the ferry at Ban Thasala with a bridge across Nam Gnouang. This will likely increase the traffic volume between road no. 8 and Viengthong.

6.3 Impacts on the Biological Environment

6.3.1 Loss of Land and Vegetation

Reservoir

The forest types and land use characteristics within the area covered by the reservoir FSL have been described in Section 5.1.3 of this report and illustrated in

Figure 5-4.

All the land listed (Table 6-6) will be lost of or changed. This area is predominantly degraded low woody vegetation (bushes, young trees, and bamboos), river gardens associated with villages and upland agricultural land used for rice and other crops. More than half of the land has been categorised as “Hill rice, annual crops and fallows”. The inundation zone does, however, contain some small areas of dense and open forest. In addition, the reservoir will flood the natural course of the Nam Gnouang River and main tributaries, which contains some riverine gallery forest.

Table 6-6. Land lost to reservoir

Land type	Land lost by inundation (ha)	%
Dense forest	33	0,3
Open forest	483	4,5
Low woody vegetation, bushes & young trees, bamboo	1,744	16,3
Poldered rice fields	20	0,2
Hill rice, annual crops and fallows	5,823	54,4
River bank gardens	1,317	12,3
Villages and gardens	353	3,3
Sand & gravel	330	3,1
Rock	3	0,0
Open water	594	5,6
Total	**10,700**	100

About 15 km^2 of this will be permanently inundated. The rest of the 107 km^2 will be seasonally inundated with the maximum coverage at the end of the wet season. The development of natural vegetation in the reservoir drawdown zone will depend on the length of the period of flooding and the initial soil conditions and gradient. In slopes with sandy soil the wave action will most likely create inert sandy shores where vegetation will find it difficult to establish. In more level land with higher organic content annual vegetation might establish itself in the dry season. In the higher levels of the reservoir, where the inundation period is short, trees and other perennial species are likely to survive from year to year.

In some level places it might be possible to establish some gardens and rice fields in the upper part of the reservoir drawdown zone.

Headpond

It has been decided not to extend the height of the THPP weir as part of this project. The future Headpond will therefore not inundate more land than the present situation. However, the increased storage capacity of water created by NG and the additional capacity of the THPP will result in less seasonal fluctuation but larger daily fluctuations in the Headpond water levels and thus reduce the periods when the banks are available for gardening by local villagers.

Nam Hinboun Flooding Impacts

THXP will under normal flow conditions not have an impact on the terrestrial vegetation and land use along the Nam Hinboun. Most of the year the water will be confined within the existing river channel and the vegetation is already adapted to wet season flooding events. However, as discussed in Section 6.2.2, the new flow regime will cause more frequent large flooding and the flood duration will increase. This might cause some changes in the natural vegetation by favouring species better able to survive longer periods of inundation. In general, it would favour opportunistic pioneer plant species and seasonal grasses. More important is the risk that extended flood periods will be harmful to some of the traditional agricultural practises (i.e. rice production).

There is also a risk that the increased flow volume caused by the intermittent release from the powe plant will increase the downstream river bank erosion problems. This will especially be a problem in the Nam Hai reach. This process has already diminished the gallery forest bordering the river and the new project will most likely accelerate this process.

Loss of Land to Project Structures and Roads

Project facilities

An overview of the site service facilities, quarries, stone crushing and concrete plants, dumps and roads are given in Chapter 3. All these will require land and change the present land use and vegetation pattern. A summary of the anticipated land requirement for the main facilities is presented in Table 6-7.

The vegetation lost for these facilities are for most parts already heavily modified by human use. No significant natural forest will be impacted. The borrow area, labour camp and concrete plant planed

close to the retaining dyke site will be partly in young bush land and grassland.

Table 6-7. Land requirement for some of the construction facilities (except access roads)

Facility	Area required ha
Camps, offices etc at power plant site	8.5
Spoil tips at headpond, adit and power plant	22.5
Main quarry	104.1
Borrow area at dam site	248.6
Borrow pit at power plant	4.4

6.3.2 Wildlife

Loss in Reservoir

Compared to adjacent areas of the reservoir which are less transformed by human activities, the loss of wildlife habitat and wildlife by the NG inundation are very modest. However, even if it is relatively low in biodiversity value, these habitats are likely to contain a diversity of species. Both the habitats within the inundation zone and the terrestrial and aquatic wildlife that occupies it will be directly impacted by the creation of the reservoir.

As the reservoir fills hundreds of temporary islands will form in the main reservoir basin. Non-flying animals in the reservoir area will move upwards to keep out of the rising water and some will become trapped on islands. Most of the animals which become trapped will be able to swim or wade to the reservoir shore or another island. Small animals, and animals which become trapped on particularly isolated islands will however be drowned during filling. Although the majority of these animals will be of no special biodiversity interest, and although the biomass clearance works and logging will have driven most large and medium sized mammals out of the reservoir area before the filling event, some interesting species could become trapped.

Increased poaching and wildlife trading

The NG Reservoir and other developments in that area might provide increased opportunities for wildlife and NTFP trade in the area. These activities are considered one of the greatest threats to wildlife biodiversity in this region.

At present, vehicular and boat access to certain parts of the Nam Gnouang catchment are seasonally limited due to poor quality roads and seasonal fluctuations in water levels. The access will be easier once the reservoir is created. The land surrounding the reservoir is seriously impoverished in terms of biodiversity and the total negative impact is assumed to be minor. However, the reservoir will also provide better access to major tributaries (Nam Heung and Nam Chat / Nam Pan) and small rivers (Nam Khou, Nam Pon, Nam Khamang,

Nam Thong) and streams which might have a higher potential for NTFP and wildlife.

Habitat fragmentation

The creation of the reservoir will also indirectly affect wildlife via the fragmentation of habitats. The reservoir will be a barrier to species that seasonally migrate or frequently move between habitats within the Nam Gnouang catchment. For example, species that inhabit limestone areas such as the Pha Khouan Chan PPA on the southern side of the reservoir will have reduced access to other parts of the Nam Gnouang valley. This aspect will be most significant in the lower part of the Nam Gnouang valley where the reservoir will be wide. The parts of the reservoir reaching up into the tributaries are narrow and will not constitute a serious obstacle for larger animals.

A particularly high number of species of conservation concern is found in Pha Khouan Chan PPA. This reflects the high observation of many limestone (cave) species, particularly flying and gliding mammals. Some might be dependent on the transition zone of between the limestone and the surrounding woodlands. How the fauna will react on the changes in the surrounding habitat is difficult to predict.

Construction Phase Impacts

During the construction period impacts on wildlife might be caused by the disturbance of the construction activities as such but primarily by the increase in the number of people in project construction areas. The disturbance impacts are likely to be limited to the areas closest to the construction sites.

There is a risk that that workers or camp followers near construction camps will hunt wildlife in the area for either consumption or trade. This impact might be felt beyond the construction sites themselves. Areas that are especially vulnerable will be parts of the Nam Kading NPA near Ban Kengbit and Ban Kounkham where there is already evidence of illegal hunting and trapping. Potential host village areas in the Nam Ngoy and along the Nam Phao are also close to the newly declared Nam Theun Corridor. There could be impacts from resettlers and host villages during the livelihood establishment phase if there is not increased patrolling, environmental awareness and proper supervision of resettler activities.

The most significant disturbance to wildlife in this phase will, however, be the activities related to the reservoir biomass clearance programme. It is unavoidable that this will cause loss of wildlife in the cleared area, in particular small mammals and reptiles.

6.3.3 Aquatic Ecology

This section should be read with reference to the section on River Flow (6.2.1) and Water Quality (6.2.2).

Upstream Reaches

The flow pattern of the Nam Gnouang and tributary river reaches upstream the reservoir will not be altered, except for some potential backwater effects during heavy rains in a full reservoir situation.

The reaches of Nam Theun and the tributaries upstream of the Headpond will not be impacted hydrologically and thus ecologically by the THXP. However, compared to today the situation will be significantly changed when the NT2 reservoir starts filling partially in 2007 and fully in 2008, and the power plant comes into operation in 2009. The riparian release of only 2+ m^3/s will significantly reduce the extent of aquatic habitats in this reach.

NG Reservoir

The lower part of Nam Gnouang and surrounding land will be turned into a more than 100 km^2 large lake ecosystem. This will lead to fundamental changes in the ecosystem structure and its fauna and flora. An eutrophication process will start increasing the general productivity in the water body. An increase in numbers of plankton algae and zoo plankton will also change the species composition of fish in favour of the plankton feeders.

In contrast to normal lakes, the reservoir will have a very large drawdown zone. The annual drawdown will restrict the establishment of lakes-shore ecosystems and species and result in a zone of very low productivity. Shallow water bottom fauna and shallow water feeding fish species will suffer.

The risk of invasive aquatic plant species “invading” the reservoir and obstructing fish production and transport is minimal.

Nam Kading

The reduced wet season flow over the Theun Hinboun weir caused by the combined effects of NT2 and NG will not have any fundamental impact on the aquatic ecosystems downstream compared to the situation with the existing regime based on a riparian release of 5 m^3/s throughout most of the year.

Nam Hai and Nam Hinboun

In the reaches of Nam Hai and Nam Hinboun, impacts from the intermittent discharge of water from the powerplant have already caused fundamental changes in these aquatic ecosystems and biodiversity. The Expansion Project will reinforce these impacts. The most important change has been the loss of benthic (bottom living) organisms. These are the basis of much of the fish production but have also been important food sources in their own right.

There is a risk that the increase in intermittent discharges will increase the bank erosion of the Nam Hai reach in particular. This will result in a further increase in the silting down of bottom organisms. It will also cause damage to the stands of riverine trees which are important providers of organic materials to feed river organisms.

6.3.4 *Fish and Fish Production*

Upstream Reaches

Compared to the existing situation and even more if the NT1 dam is realised, the blockage of migration routes upstream of Nam Gnouang by the NG will have a minor additional negative effect on fish migration patterns. Long distance migratory fish has already been on blocked fromusing this part of the catchment.

NG reservoir

Species composition

A fundamental ecological change will result from the conversion of the lower part of Nam Gnouang from a river into a reservoir. This will change the river ecosystem into an artificial lake ecosystem. Some of the indigenous fish and other aquatic life forms will be able to adapt to the new conditions, but for the most part, a dramatic shift in species composition and population density of various species will be seen.

A large decline in the number of aquatic species will occur. However, as a result of the increase of water volume the total aquatic productivity is assumed to increase (at the sacrifice of terrestrial production). The Common Carp has been introduced in the Theun Hinboun Headpond and has displaced indigenous species, but on the other hand provides the basis for significant fisheries. It can be expected that this species – even without any human interference – will find its way to the new reservoir. Smaller pelagic fish species might also establish a sizable population in the reservoir.

Fish production

The evolution of tropical reservoir fisheries and their productivity have been subjects of intense research. Based on data from other reservoirs in the region RMR (2006 f) has calculated that the NG reservoir with an average surface area of 70km² might support a potential annual sustainable catch at 315 to 595 tons/year, (= 860kg/day to 1,600kg/day). There will, however, be difficulties in realising these yields as access to the shore is very limited, resident populations are sparse and winds will at some periods create unsafe wave conditions. A reasonable average daily catch would more likely be in the range of 200 kg to 400 kg.

In the first period after inundation (up to about five years) the fish production will, due to the eutrophication effect of the inundated biomass, fluctuate and periods of very high yields might be seen. When the ecosystem stabilises the catch will settle on a more stable level.

It is unlikely that a situation of over-fishing will develop and protection of breeding areas is judged unnecessary. When the catch level has stabilised and the fishery activities have matured this issue may need to be revisited.

Nam Kading

The fish biodiversity and production in Nam Kading below the Theun Hinboun Headpond has been significantly impoverished by the present flow regime. This impact will be even more significant as the

wet season flow will be reduced to some extent from the THXP development but even more so from the operation of the NT2.

Nam Hai and Nam Hinboun

According to recent assessment of the fish biodiversity and fisheries in the reaches of Nam Hai and Nam Hinboun receiving discharges from the THPP, the previous fisheries in these rivers have already been significantly impacted in a negative manner. (RMR 2006e and Schouten 2004). To some extent this is due to changes in flow patterns and year around high levels of suspended solids which has destroyed aquatic plants and bottom fauna. Equally important is the impact of high and fluctuation flows which as made it impossible to use traditional fishing techniques.

The impacts of the doubling of the intermittent water release resulting from the increased capacity of THPP, will increase the negative impacts on fish biodiversity and fisheries. As the value of these fisheries is already very low the incremental damage will mot likely be small. The most likely survivors in these rivers will be fish species adapted to very turbid water (catfish and others) and species favoured by increased flooding.

6.3.5 Conservation Areas

Some established and planned protected areas will be directly impacted by the project features and its operation (Table 6-8).

Saola Management

The proposed reservoir will reach into and have a slight backwater impact on the streams in the proposed Saola Management Area. This impact covers very little land and will have a negligible impact on the Saola habitat.

Pha Kouan Chan

The planned reservoir will only touch the border of the Pha Kouan Chan PPA, but the PPA will be isolated from parts of the terrestrial habitats on its northern side. This might have negative impacts for some animals which migrate seasonally or more regularly between the limestone habitats and the richer more vegetated habitats of the Nam Gnouang valley.

On the south side of the PPA is planned the quarry for extracting limestone to the dam construction and the construction of the retaining dyke. The demarcation of the PPA borders is not clear but bout of these is assumed to be located inside the PPA. An estimate of 200 ha is likely to be taken for these features.

Phu Hin Poun NPA

About one half of the existing – and planned parallel line - is within the borders of the Phu Hin Poun NPA. The impact on the limestone mountains and ridges, which is the main focus of the protected area will however be small as line is routed to avoid such difficult landscape.

Nam Kading NPA

A tunnel adit and an access road will be located inside the Nam Kading NPA on the ridge between the intake and the powerhouse. The access road used for the first phase THPP will be used. The total land take will be about 10 ha.

Table 6-8. Area of Protected Land Affected by the Project (RMR 2006b)

Impact classes	Protected area	Approximate impacted area
Areas of NPA or other classes of protected areas to be inundated	Proposed Phou Kadoung Saola Management Area	Area not established
	Pha Kouan Chan Provincial Protected Area	3 ha
Areas of NPA or other classes of protected areas to be impacted by other project features	Pha Kouan Chan Provincial Protected Area (quarry and retention dyke)	About 200 ha
	Phu Hin Poun NPA (transmission line)	Unclear definition of NAP borders.
	Nam Kading NPA (tunnel adits)	About 10 ha
Areas of NPA or other classes of protected areas to be fragmented by reservoir.	Proposed Phou Kadoung Saola Management Area	25,600ha if area is established
	Pha Kouan Chan Provincial Protected Area	10,800ha
Areas of NPA or other classes of protected areas to be made more accessible by reservoir waterway enhancements	Proposed Phou Kadoung Saola Management Area	64,400ha if area is established
	Nam Chad-Nam Phan Provincial Protected Area	65,000ha
	Nam Chouan Provincial Protected Area	140,000ha

Nam Chat - Nam Chouan

The reservoir will make the north-western sections of the Nam Chat-Nam Pan Provincial Protected Area and the eastern parts of the Nam Chouan Provincial Protected Area more accessible by providing easy waterway routes of access for boats and barges. At present access to the north-western sections of the Nam Chat-Nam Pan Provincial Protected Area and the eastern parts of the Nam Chouan Provincial Protected Area from the Lao side of the watershed is by a seasonal non-engineered road constructed over the period 1995 to 2003. The waterway improvements as far as Ban Sopkhom could stimulate increased movement into Muang Cham Special Zone by hunters and NTFP collectors. The overall impact of this improved access is not expected to be major, as there is already extensive logging taking place in the area.

Other Areas

The project is assumed to cause little impact from improved access the three NPAs in the river catchments of the project: Nakai Nam Theun NPA, Nam Kading NPA and Phou Hin Phoun NPA, but it should be borne in mind that any improvements in communications routes and urbanisation might accelerate the harvesting of animals and forest products, and the trade in animals and plants also from these areas.

6.4 Summary of Potential Impacts

Table 6-9 below summarises potential project impacts. It should again be noted that these potential impacts are ranked according to

severity/magnitude without taking into account the possibilities for reducing or avoiding the impacts by mitigation measures. The mitigation or compensation measures are discussed in the Environmental Monitoring and Management Plans (EMMPs) in Section 2 of this report.

In the ranking the impacts the following categories and symbols have been used:

- High negative **– – –**
- Medium negative **– –**
- Small negative **–**
- Insignificant **0**
- Small positive **+**
- Medium positive **+ +**
- High positive **+ + +**

Table 6-9. Summary of THXP impacts

Potential impact	Impact ranking*
Permanent and operational impacts	
Reservoir (Impact zone 1)	
Improved boat transport opportunities	**+**
Soil slips and risk of rock fall induced waves	**– –**
Eutrophication and algae bloom	**–**
Periods of oxygen deficiency and anoxic deep water	**– – –**
Reduced sediment content in water	**+**
Loss of agriculture land	**– –**
Loss of forest land	**–**
Loss of biodiversity	**0**
Loss of riverine aquatic habitats and fish biodiversity	**– –**
Risk of introduction of invasive water plants	**–**
New fisheries opportunities	**+ +**
Loss of Pha Kouanchan PPA buffer zone	**–**
Headpond area (Impact zone 2)	
Periods of oxygen deficiency in water	**–**

Larger water drawdown fluctuation	–
Impacts on water use and riverbank gardens	– –
Nam Hai and Nam Hinboun (Impact zone 3)	
Increased risk of flood damage	– – –
River bank erosion	– – –
Increased sediment transport	–
Periods of oxygen deficiency in water	**0**
Buffering of heavy metal discharges from downstream tributaries.	+
Water logging and degrading of floodplain vegetation	– –
Loss of bottom fauna and fish species	– –
Nam Kading (Impact zone 3e)	
Periods of oxygen deficiency in water	**0**
Changes in aquatic habitats from reduced overflow	–
Blocking of fish migration	–
Increased activities close to Nam Kading NPA	–
Construction sites (Impact zone 4)	
Loss of land for permanent facilities	–
Improved infrastructure	+ +
Catchment (Impact zone 5a)	
Improved transport opportunities	+
Blocking upstream fish migration	–
Increased human pressure on NBAs and PPAs biodiversity	– –
Construction Phase Impacts	

Risk of traffic accidents	– –
Noise and dust problems	–
Sediment flow downstream caused by construction and spoil disposal	–
Discharge of oil components or other hazardous chemicals to water	–
Spreading of hazardous and domestic solid waste	– –
Soil erosion from vegetation clearance and road construction	–
Increased pressure on wildlife and NTFP from labour force and followers	– –
Drowning of animals during reservoir filling	–

7 ANALYSIS OF ALTERNATIVES

7.1 Power Development Priorities and Goals

Lao PDR is the country in the Lower Mekong Basin with the largest hydropower potential. Only a small percentage of this potential is yet developed. The only other significant power resource available in the country is coal.

The policy of Government of Lao PDR is to develop these hydropower resources for the benefit of the country through the two primary strategies:

- *To provide reliable and affordable power to cover the national demand and thereby promote economic and social development.*
- *To develop part of the hydropower potential to generate export income for the country by selling power to neighbour countries.*

7.2 Power Export

Bilateral trading of power is already well developed in the region and Lao PDR has been a "pioneer" in this trade by already having two export oriented power plants in operation.

Various forecasts for the power demand in Greater Mekong Subregion (GMS) show very high figures. The reason for this is primarily a large, unsatisfied demand for more energy in Thailand. The main candidates for future supply in Thailand are:

- Import of hydropower from Lao PDR, Yunnan Province of PRC and Myanmar.
- Thermal plants based on imported coal.
- Combined cycle gas plants based on domestic and imported gas.

Environmental concerns make the use of coal less attractive. With gas, as the most realistic thermal alternative, Thai power generation would depend heavily on gas by for about 75 to 90 % of its installed capacity in 2020, the level depending on the contribution of imports, primarily of hydropower.

Measures, such as demand side management, are cost-effective means of easing the situation. However, in a situation where only a part of the population today has access to electricity, there will inevitably be growth as long as the electrification programmes are effective and the electricity tariff is affordable. Regional power strategies underline cost efficiency of an integrated used of the power sources in the Greater Mekong Sub-region comparred to a system dominated by each county's own sources.

7.3 Ranking of Hydropower Development Alternatives

The hydropower sector seems to be one of the most thoroughly planned sectors in Lao PDR from an economic and technical viewpoint. It can be observed, however, that over the last two decades the definition of what is a feasible project and the principles of project ranking have changed substantially. It seems, for instance, that the original plans for cascades of large power plants on mainstream Mekong are no longer considered realistic options.

In addition to EdL's own ranking of projects (Electricité de Lao Generation Expansion Plan, 2005–2020), the following 6 hydropower ranking studies have been carried out in Lao PDR over the last 10 years:

- Hydropower Development Plan for Lao PDR (HDP) in 1997
- Power System Planning in the MIH (PSP) in 1997
- Nam Theun 2: Study of Alternatives (NT2SOA) in 1998 (Lahmeyer & Worley)
- Se Kong, Se San and Nam Theun River Basins Study in 1998 (Halcrow et al.)
- Hydropower Development Strategy Study (HDSS) in 2000 (Worley & Lahmeyer)
- Power System Strategy Study (PSSS) in 2002 (Electrowatt & PA)
- Power System Development Plan (PSDP) in 2004 (Meritec & Lahmeyer)

The studies present development scenarios for national supply and export projects based on professional judgement of the following factors:

- Economics of the project and quality of the site
- Solidity of the sponsor
- Market conditions, including demand growth, reserve margin and political support for power trading
- Capacity of Lao institutions to manage the implementation of multiple projects

The latest of these studies included environmental and social parameters as factors in ranking and sequencing of the projects. The project ranking in these studies shows many similarities. Nam Theun 2, Nam Mo, Xe Kaman 3 and Nam Ngum 2 are in all studies among the highest ranked export projects. The Theun Hinboun Expansion Project (with NT3) also has been given high ranking in the latest studies. In earlier studies NT3, as a stand alone project, came out with a lower rating.

It seems, however, that the master plan priorities have limited impacts on project priorities. The NT1 project was not prioritised in the last master plan but is now in an advanced stage of project preparation. Likewise, none of the coal based power generation projects

have been given high priority in the latest strategy studies. However, the Hongsa coal-fired generation project seems to be proceeding ahead.

7.4 Alternative Design and Location Concepts

7.4.1 Damsite Selection

At an earlier stage a number of possible dam sites in Nam Gnouang and Nam Theun river basins were studied by THPC for the the purpose of the Expansion project. This included the previously identified Nam Theun 3 site further upstream Nam Gnouang (renamed NG 1) as well as the NG 8 site. The NG 1 site was at that stage given preference, however, more detailed studies of NG 1 proved that this site would not be less attractive froman technical and environmental point of view, and the focus was then shifted to the NG 8 site.

7.4.2 Reservoir Size and Dam Height

Optimization studies were preformed to calculate the optimum reservoir fill supply level (alternatives levels of 445, 450 and 455 masl), the minimum operation level (430 or 420 masl) and with alternatives for added installed capacity at the Theun Hinboun Power plant and at the NG power plant.

The result of these studies concluded that 455 masl supply level and a 420 masl minimum operational level is the clear economical optimisation for this project, and thus this has been selected for the proposed project.

7.5 Riparian flow arrangements

At one stage the option of diverting the Nam Ao, into the Nam Kading below the Headpond weir was considered. Nam Ao today discharges upstream of the weir. The advantage of this arrangement would be that inWREAd of the permanent riparian flow of 5 m^3/s the Nam Ao would better mimic the seasonal fluctuation in water release downstream.

Technical issues and power production concerns and some uncertainly of the minimum flow in situation in Nam Ao resulted in a decision to continue with the existing riparian release regime.

8 CUMULATIVE BASIN IMPACTS

8.1 Introduction

8.1.1 Perspectives

Cumulative impacts are the combined impacts of the THXP Project and other projects, as well as development trends envisaged in the year of commissioning for the THXP (2013) and for year 2020. Impacts have thus be predicted in a short term 6-year scenario and when relevant a long term 13-year scenario, for which the existing power master plans are valid.

8.1.2 Prediction of Trends, Impacts and Scenarios

The Cumulative Impact Assessment (CIA) is based on specific plans for development or trends seen for different sectors. One complicating factor is that some sectors do not have well defined and specific development plans while other sectors might have plans but no implementation mechanisms or funding to put the plans into practice.

The following analysis has in particular focused on the combined changes caused by the sequence of hydropower developments in the Nam Theun/Nam Kading catchment. The resulting changes in hydrology will in turn cause changes also in aquatic biology and fisheries. The combination of developments will also influence infrastructure and general economic activity in the region and is also addressed in this chapter.

8.1.3 Cause – Effect Relationship

It is important to note that it is sometimes difficult to determine to what degree the assumed impacts can be attributed to the THXP Project and which impacts are caused by other development projects or general trends in economic and social development. In any case, cumulative impact predictions reflect an effort to identify impacts from a combination of driving forces and should not be interpreted as the potential results of the THXP Hydropower Project alone.

8.2 Hydrology

8.2.1 Introduction

The analysis addresses the situation in the Nam Theun/Nam Kading and the Nam Hinboun basins. In addition, the impacts on the reach of Mekong between Pak Kading and Savannakhet have been presented. The basin and the main Sub-catchments are shown in Figure 8-1. Today the hydrology is impacted by the diversion of water from Nam Theun into Nam Hai / Nam Hinboun by the THPP and the release of only 5 m^3/s downstream the Nam Kading from the intake weir. In the 6-year perspective the THPP, NT2, NT1 and the THXP are supposed to be in operation. Thus there will be significant changes in relation to the present situation.

No significant further hydropower developments in this catchment in the 13 year perspective are foreseen.

Figure 8-1. Location of Hydropower Projects and Sub-catchments in the Nam Theun / Nam Kading River Basin

8.2.2 Upper Nam Kading

This impact zone will be influenced by three hydropower plants: the Nam Theun 2 (NT2), Theun Hinboun (THPP) and Theun Hinboun Expansion (THXP), which together create cumulative impacts in term of altered water flow regimes above the planned NT1 Reservoir in Nam Kading valley.

Apart from occasional spilling during floods, only 2 m^3/s will be released into the Nam Theun downstream the NT2 reservoir. The remaining water will be diverted out of the catchment and into the Xe Bangfai. This will significantly reduce the inflow to the Theun Hinboun Headpond. The storage capacity of the NG reservoir on Nam Gnouang will not significantly influence the total inflow into the Headpond but will provide a more stable inflow over the year, thus allowing a larger portion of the water to be diverted to the Theun Hinboun power station and the into the Nam Hinboun river basin.

In Nam Kading downstream Theun-Hinboun Headpond, the impact will be a substantial reduction of the discharge in the flood season June-October. The average reduction in August will be from 1030 to 160 m^3/s or 87% (Figure 8-2). This is a result of the cumulative effect of both upstream regulation of seasonal flow and diversion into other river basins.

Similar to the baseline situation, only 5 m^3/s will in the future be released from THPP Headpond in the dry season, meaning that the river flow in the upper part of Nam Kading will be unchanged in the dry season. However the flow is significantly reduced the wet season compared to the baseline situation. This is caused by the cumulative impacts of the upstream storage reservoirs and increased water diversion, which have significantly reduced the period of spill over the Headpond weir.

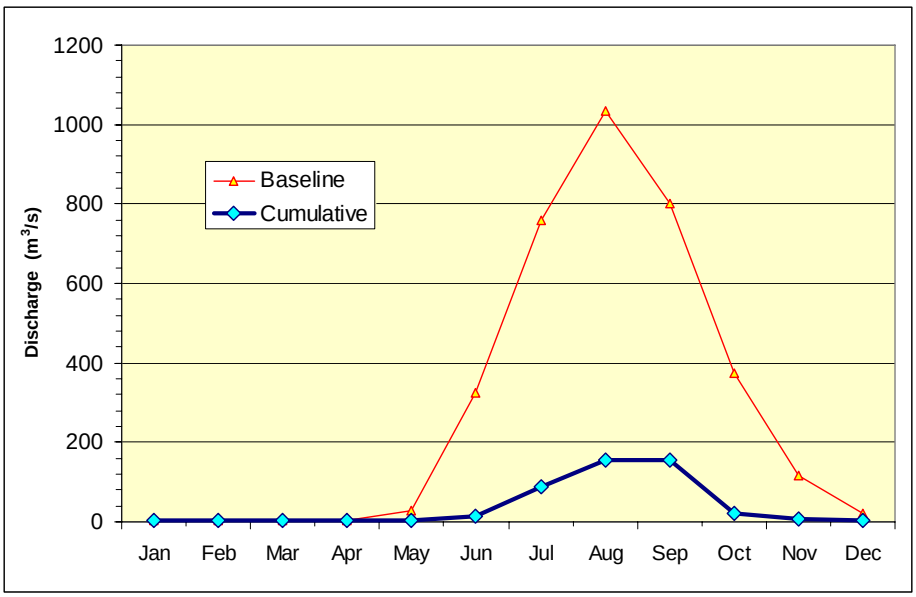

Figure 8-2. Impact on flow in Nam Kading just downstream the Theun-Hinboun weir.

As one moves downstream towards NT1, the discharges will increase above what is shown on Figure 8-2, due to tributary inflows.

8.2.3 Nam Hinboun

Figure 8-3 illustrates the effects of the diversion of water through Theun Hinboun power station before and after NT2 and THXP are brought into operation. The figure shows that during the wettest months the diversion will increase by 100%, managed by the planned doubling of turbine capacity.

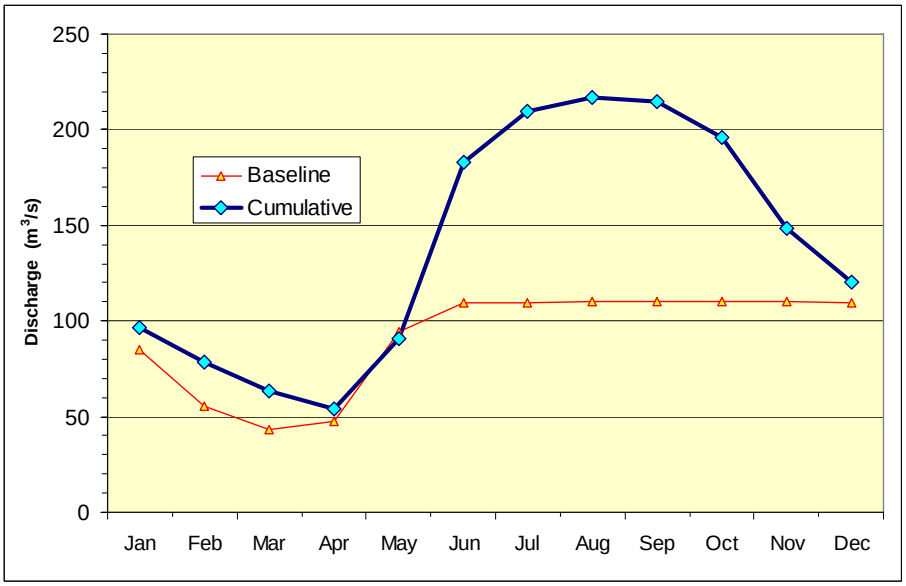

Figure 8-3: Cumulative impact on discharge through Theun-Hinboun Power Station.

8.2.4 *Lower Nam Kading*

In the lower Nam Kading, the cumulative impact in the 6-year perspective will be caused by the diversions of water from Nam Theun into other river basins as explained above and impacts from the seasonal storage impacts of NT1.

The impact a short distance downstream the NT1 dam is shown in Figure 8-4. One should note that the data only reflects the monthly average, not the daily and weekly intermittent release.

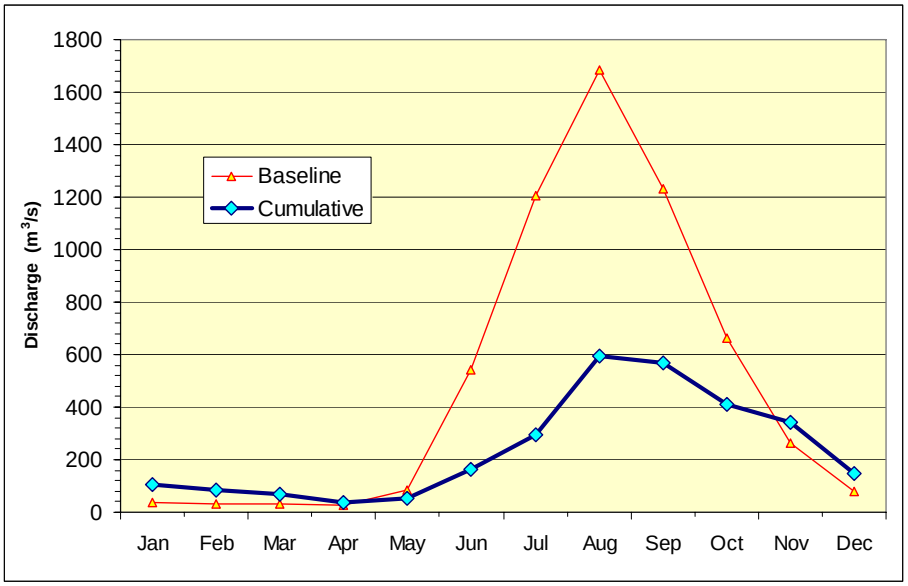

Figure 8-4. Impact on flow in Nam Kading downstream NT1 Dam.

In the wet season the discharge is reduced by 60-70 %; approximately from 1700 m^3/s to 600 m^3/s in an average year. In a large part of the dry season, however, the average discharge is increased due to the water release from the NT1 power plant. In the dry season the diversions at Theun Hinboun Expansion and Nam Theun 2 will not have a direct impact on Nam Kading flow, since the existing Theun Hinboun regulation today only releases 5 m^3/s in the dry season. The increase of dry-season flow in the Lower Nam Kading can therefore be attributed to NT1 operation only.

8.2.5 *Mekong*

The main focus of the analysis below is the combined effect of NT2, THXP and NT1, as well as the existing THPP, on flows and water levels in the Mekong. Mekong Hydrology will in the same period, however, be impacted by other planned hydropower developments in the wider catchment, including upstream project on the Mekong itself presently in operation or being constructed in Yunnan, China. Therefore, the impacts of Nam Theun/Nam Kading developments must be seen in relation to the impacts of the overall planned developments.

In the Mekong at Pak Kading (confluence with Nam Kading) the cumulative impacts of Nam Kading/Nam Theun hydropower developments will in the 6-year perspective show the same pattern as in

lower Nam Kading. The relative change will however, be much smaller since the Mekong flow is much larger than the Nam Kading flow. Thus, the August flow reduction of 1070 m^3/s in Nam Kading amounts to a reduction of only 8 % of the peak flow in Mekong. In the dry season the flows in Mekong will be increased by 3-4 % compared with today situation.

Further downstream, at Pak Hinboun, where the Theun-Hinboun diversion returns to the Mekong, the picture will be approximately the same as at Pak Kading. Dry season discharges will be increased by 4 - 5% and wet season discharges will be reduced by 7 %.

At Savannakhet, downstream of the Xe Bangfai confluence with the Mekong, all the water diverted out from Nam Theun/Nam Kading basin will be returned to the Mekong. Due to the NT2 seasonal storage, however, this is the section the Mekong where the changes in seasonal distribution of the flow is largest. The dry season flow in Mekong is increased by 14% and the wet season flow is reduced by 4 %. Figure 8-5 shows the annual variation of the discharges at this place.

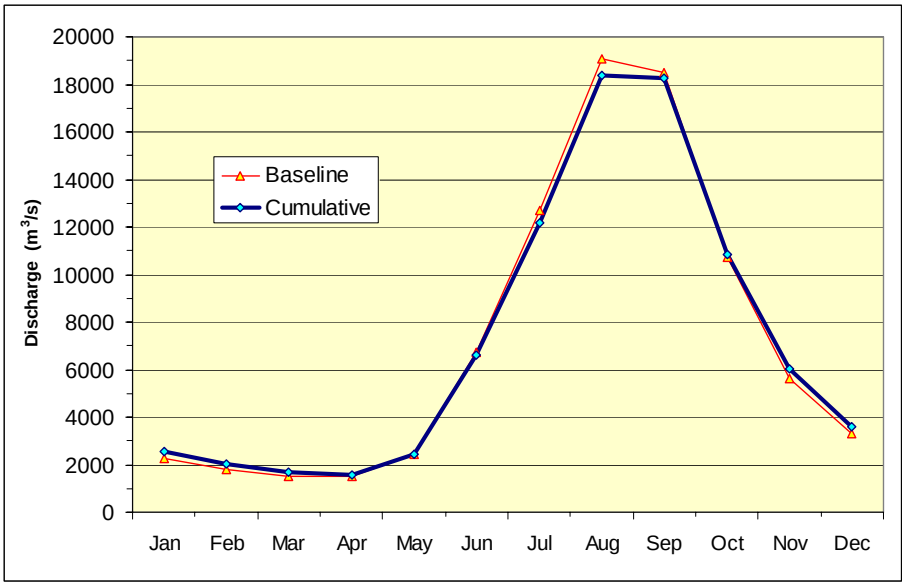

Figure 8-5. NT2, THXP and NT1 impact on Mekong discharges at Savannakhet, downstream the Xe Bangfai confluence.

In terms of water levels in the Mekong, these changes translate to an increase of the dry season water level of a 1-2 cm and a reduction in the flood season water level of 35-50 cm on the average between Pak Hinboun and the confluence with Xe Bangfai. At Savannakhet, where the stored water from NT2 has been discharged into Mekong largest change in dry-season impact will be seen. The dry season water levels will be increased by about 10 cm. The flood water levels will be reduced by some 25 cm, i.e. less than further upstream.

8.3 Flooding

With the new hydropower developments in the Nam Theun-Nam Kading catchment, the wet season flow in the lower Nam Kading will be

significantly reduced. This should result in a reduced risk of damaging flood events. In the Nam Hai / Nam Hinboun on the other hand the frequency of over bank flooding will likely increase. The last issue has already been discussed in more detail in Chapter 6.

In the dry season the lower Nam Kading will on average have a higher flow than today, but this situation will be overshadowed by the flow situation resulting from the intermittent operation of the NT1 power plant.

The changes in flow patterns caused by the cumulative impact of the Nam Theun/Nam Kading hydropower developments will have an overall positive impact by reducing damaging flood incidents downstream in the Mekong. The relatively largest impact will be seen in the reach between Pak Kading and the Xe Bangfai discharge point for the NT2 Project.

The increase in dry season flows might also be beneficial by providing more water for water supply and irrigation at higher levels, reducing pumping costs. Without the NT1 power plant the reach between Pak Kading and Pak Hinboun would have experienced a reduction in average dry season flow. This situation will be compensated for by dry season releases from NT1 so that also this reach will experience an increase in available water compared to the present situation.

8.4 Fisheries and Aquatic Biodiversity

8.4.1 Nam Theun/Nam Kading

Fisheries and aquatic biodiversity in the Nam Theun is impacted by the existing THPP Headpond weir diversions into Nam Hinboun. The cumulative impacts of the new dams and reservoirs and the change in water flow will aggravate the situation further. Cumulative impacts are created due to the fact that the NG and the NT2 reservoirs will shorten the periods of overflow over the Theun Hinboun intake weir, which may still allow some migratory fish to pass. At the same time, the NT1 dam will block all upstream migration of fish from the Mekong and lower reaches of the Nam Kading, and a large section of the Nam Kading will be turned into a reservoir with lake-like qualities.

The commissioning of the NT1 will initiate a process of change in terms of fish species composition in this reach of the Nam Kading between the NT1 dam and the THPP weir. Non-migratory fish species that are better adapted to the minimum water flows for a large part of the year will most probably become dominant at the expense of migratory species in the upper reaches. In the 6-year perspective the total fish biomass production in the river may fall before the increase of non-migratory fish species populations present in the river niche made absent by lack of migratory fish from the Mekong.

In the long-term perspective, the reduced water flow and the barrier of the NT1 dam for migrating fish species may lead to a permanent reduction of fish biomass production in this reach of the river. The presence and increase of populations of non-migratory species may have managed to compensate for some of the reduction in total fish popu-

lation caused by the establishment of the NT1 reservoir. However, it is likely that fish biomass production will stabilised at a lower level compared to the present situation.

8.4.2 Lower Nam Kading

In Nam Kading downstream of the NT1 dam, there will be impacts in terms of changed flow regime and oxygen content of the water. The dominant factor will be the NT1 alone, but the two upstream reservoirs will contribute to the reduction, both in terms of the amount and duration of overflow over the existing THPP weir. The water levels in the downstream reach of the Nam Kading will thus be a result of the combined effect of three reservoirs as well as the mode of operation of the NT1 power plant. In addition, a reduced overflow has the effect of decreasing the amount of oxygen rich overflow water that could have improved the quality of the oxygen poor turbine water that will enter the NT1 powerplant. However, although there will be a small cumulative contribution from the THPP/THXP and NT2, most of the effect on downstream fisheries and aquatic life can be ascribed to NT1.

In the 6-year perspective, after the commissioning of the NT1 Project, the downstream conditions for fish and aquatic life will start to change dramatically. The establishment of the dam will block any upstream fish migrations and the reduced water level along with reduced oxygen content in the downstream water will most likely start to reduce fish populations and fish catches. Other aquatic life in the river, such as macro invertebrates which many fish species feed on, will start to change in terms of species composition and occurrence. After commissioning of the NT1 in 2013 a process of adaptation, which may take a considerable time, will start.

In the 13-year perspective it is likely that the situation concerning fisheries and aquatic life will have stabilised to a certain extent. The species composition in the downstream reach may have changed considerably as some fish species may have stopped entering the Nam Kading from the mainstream. There is thus a possibility that the fish populations found in the downstream reach will now be more dominated by non-migratory resident species. Compared to the situation prior to commissioning of the NT1 dam, the fish catches may have been reduced substantially

8.5 Terrestrial Biodiversity

In the 6-year perspective, it is expected that the pressure on the natural resources and biodiversity caused by a combination of development projects, population growth and unsustainable forest and land utilisation will increase substantially. However, this will be counteracted by development and management activities implemented by the Watershed Management and Protection Authority for the Nakai-Nam Theun NPA, by implementation of the already existing management plan for Nam Chat/Nam Pan PPA and by the proposed PPA along the northern shores of the NG reservoir.

In the 13-year perspective, the pressure on terrestrial biodiversity will continue to increase due to a general population growth which will likely lead to reclamation of forested areas for agricultural purposes. Logging will most likely continue to diminish areas of high biodiversity value in the zone. Logging and hunting might also take place inside the protected areas so that the integrity of these could be threatened. To some degree the threat constituted by unsustainable collection of NTFPs and illegal hunting may be counteracted by a general rise in living standards and availability of other income sources for the local population.

8.6 Agriculture and Forestry

Except for a development into a larger variety of crops ,no large or significant changes in agriculture systems and practises are foreseen for the downstream area in the 6-year perspective. Agricultural development in the villages will mainly be affected by development initiatives and by general development trends such as population increase, both of which will probably result in a more intensified use of agricultural land.

Increased market opportunities for agricultural products will arise fromthe hydropower construction activities, improved infrastructure and population influx. More market oriented and commercialised production of more fruits and vegetables for supplying the workforce will arise in the villages in the vicinity of the construction sites and camps.

Development in the forestry sector in the downstream areas will entail an expansion of the already incipient plantation forestry including teak, rubber and eaglewood. Introduction of commercially and fast growing species for pulp and paper production (eucalyptus) will also intensify. The present remaining patches of natural forest and economically interesting tree species will largely have been logged and exploited beyond their carrying capacity. Unsustainable harvesting of NTFPs will likely lead to a reduction in these activities.

In the 13-year perspective the development trends will be reinforced and will lead to an agricultural system based on permanent cultivation of the uplands and an intensification of paddy cultivation. Agriculture will to a larger extent be commercialised but still subsistence production will play a significant role. Market opportunities will have experienced a slump after the cessation of hydropower construction but the general economic growth will have compensated for that by 2020.

In the forestry sector the logged areas will to a certain extent have been replaced by rubber, teak and eaglewood plantations as well as fast growing trees species intended mostly for pulp and paper production. Different fruit tree plantations may have expended considerably, potentially supplying both the local and more far away markets, including markets in Thailand.

The potential for developing irrigation may have been partly utilised along the Nam Theun and its tributaries. The largest increase is most likely going to take place along Nam Phao and Nam Kata, possibly

through the examples provided by the planned resettlement of villagers in these areas by the THXP.

The foreseen developments in the agricultural sector might cause an increase in the erosion but are not expected to have any significant impact the on hydrological regime and flow patterns in the basin.