VOLUME 1 – CHAPTER 2 PROJECT DESCRIPTION

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2 **PROJECT DESCRIPTION**

The following description of the physical components of the NT2 Project focuses on those aspects that have the potential to affect people and which raise the issue of resettlement or compensation. After presenting a brief description of the Project and the Project area, defined as those areas where people are expected to be affected, the physical components of the Project are discussed, along with their predicted impacts and mitigation. The quantity and quality of the water discharged to the downstream areas will then be discussed, along with the associated impacts and their mitigation.

For a more detailed description of the technical components of the Project's physical aspects, the reader is referred to the Chapter 2 and 3 of the Environmental Assessment and Management Plan (EAMP).

2.1 GENERAL OVERVIEW¹

The Nam Theun 2 Hydroelectric Project is to be built on the Nam Theun River (Nam Theun), a tributary of the Mekong River, in central Lao PDR. Key features of the Project include a dam on the Nam Theun at Keng None in Bolikhamxay Province. This dam will create a reservoir on the Nakai Plateau of maximum inundation of 450 km² at Full Supply Level (FSL), reducing in size to about 82 km² at its Minimum Operating Level (MOL). The Nakai Reservoir will have a catchment area of 4,013 km², most of which is in the Nakai Nam Theun NBCA, otherwise referred to as the NT2 Watershed.

Water from the Nakai Reservoir will be conveyed, via tunnels, to the power station, which will be located at the base of the Nakai Plateau near the town of Gnommalat. The elevation difference between the Nakai Reservoir and the power station is approximately 350m. Water will be conveyed from the power station via a tailrace channel to a regulating pond, located on the upper Nam Kathang River (Nam Kathang), designed to control variations in the flow of water released downstream of the power station. Water from the regulating pond will be diverted into both the Nam Kathang and the Xe Bangfai River (XBF). The water discharged to the XBF will flow via a purpose built 27 km long downstream channel, which will incorporate the reconfigured bed of a seasonal creek, the Nam Phit. The features of the NT2 Project are illustrated in Figure 2-1. The relationship of some of the main hydroelectric production features of the project are shown in the schematic diagram in Figure 2-2.

The total estimated cost of the NT2 is approximately US\$ 1.3 billion. Preliminary construction is scheduled to start in 2004, with main construction commencing in 2005 and is expected to take about four and a half years. It is expected that a peak labour force of approximately 4,000 people will be employed.

The final detailed design of the Project will commence following negotiation of financial terms with lenders and GOL. Any modifications to the current design resulting from the detailed design process are not expected to have any substantial effect on the resettlement or compensation requirements of the Project.

¹ See Volume 2 Chapter 4 and Volume 3 Chapter 2 for a detailed description of Project Area communities.





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Figure 2-2: Nam Theun 2 Hydroelectric Schematic Diagram

2.2 PROJECT REGIONS

The Project area covers two river systems in central Lao PDR, the Nam Theun and the Xe Bangfai Rivers, and extends from the lowlands along the Mekong River to the rugged Annamite Mountain Range along the Lao-Vietnamese border. Midway between the Mekong River and the Lao-Vietnamese border lies the Nakai Plateau, located approximately 350 meters above the adjacent plain. The proposed dam is on the Nam Theun situated on the Nakai Plateau, approximately 170 km upstream of its confluence with the Mekong River and 250 km east of Vientiane.

2.2.1 Nakai Plateau

The Nam Theun meanders along the relatively flat Nakai Plateau, to the Nakai dam site. There are wetlands, which include permanent and seasonal freshwater lakes, ponds and marshes. The Nakai Plateau also supports several areas of pine on its southern edge. Agricultural and forestry activities on the Nakai Plateau and associated road construction have had a significant impact on forests and wildlife, especially during the past decade. Other pressures on the plateau include the effects of shifting cultivation and fire, as well as hunting. Recent studies confirm that the area's wildlife abundance is severely diminished as hunting and trading in wildlife products in the area have become intense and sophisticated, and include incursions by armed hunters. While some good wildlife habitat remains, poverty amongst local communities is increasing demand for fuel wood and meat from wildlife.

2.2.2 From the Nakai Plateau to the Theun-Hinboun Dam

Just downstream of the proposed Nakai dam site, the river dramatically changes character from the slow, 75 m wide river of the Nakai Plateau to a 40 m wide series of alternating rapids and pools cutting through the sandstone and mudstone rock pocketed by holes and crevices. The only tributaries of size between the Nakai Dam and the Theun-Hinboun Dam are the Nam Phao and the Nam Gnouang Rivers.

At this time none of this stretch of the Nam Theun supports permanent settlement until the confluence with the Nam Ngoy is reached, which is within the Theun-Hinboun Project head pond. The banks of the entire reach of the Nam Theun from the Nakai dam site to the backwaters of the Theun-Hinboun Project are not permanently cultivated, although some swidden fields do exist. The first reach below the Nakai dam site of about 12 km to where the Nam Phao flows into the Nam Theun has no permanent shelters, but people from villages along Road 8B in Khamkeut District use the river in this region to fish.

2.2.3 NT2 Catchment

The catchment area of the NT2 Project is about 4,013 km², mostly of the upper and middle reaches of the Nam Theun, the rest surrounding the Nakai Plateau and proposed Nakai Reservoir. The upper Nam Theun and three major upper tributaries begin in the Annamite Mountains at elevation of El 2,286 and flow south down the mountains to the Nakai Plateau, which is at an elevation of about El 525. The mountains which form the watershed are forested and are largely in near pristine condition, except for enclaves of human populations along the main valleys.

Approximately 87% of the Nam Theun catchment has been designated as the Nakai Nam Theun National Biodiversity Conservation Area (NNT-NBCA). In addition, the catchment area includes a portion of what is now designated as the Nakai Nam Theun-Phou Hin Poun Corridor. The conservation

values of this area have long been recognized. However shifting cultivation has affected and continues to degrade forests and habitats. GOL does not have adequate personnel or resources to control this degradation of forest and wildlife. IUCN and WCS concur in the view that current threats to both habitats and species are so great as to make implementation of an effective conservation program essential if the area's wildlife and biodiversity values are to have any hope of being preserved.

2.2.4 XBF Area

The XBF catchment has a total area of 9,500 km² commencing at the spine of the Louang Chain Mountains on the Lao-Vietnamese border where the highest peak is just under El 1,650. The upper catchment is heavily forested with dense undergrowth in gullies and ravines, with a section comprising the Hin Nam Nor limestone karst area. In the river valley upstream of Mahaxai the slopes are gentle. The river channel meanders and is deeply incised in sandy banks. Downstream of Mahaxai the river flows through a well-defined channel until it reaches a V-shaped gorge through the Say Phou Xoy Range. The XB catchment downstream of bridge on Highway 13 is called the XBF plains. The plains are bounded by the Mekong River to the west and upland forest to the east. Flooding is common in the XBF plains mainly due to the backwater effect from high levels in the Mekong, and less so to the XBF's own discharge.

The XBF is typical of many lowland areas in Lao PDR with its community's dependency of paddy cultivation and fishing.

2.3 **PROJECT ZONES**

In order to facilitate an understanding and the planning of the NT2 Project, the project area has been divided into fifteen zones of activity and/or impact, as presented in Figure 2-3 and described below as follows:

- Zone 1: Inundation Area (Nakai Reservoir)
- Zone 2: Protected Area (Nakai-Nam Theun NBCA) and Corridor Areas
- Zone 3: Resettlement Area
- Zone 4: Nam Theun Downstream to Theun-Hinboun Dam
- Zone 5: Theun-Hinboun Dam to Next Major Tributary
- Zone 6: Road 8B, "Lak Sao Road" and Phou Phako Quarry
- Zone 7: Power Station, Regulating Dam and Operator's Village
- Zone 8: Downstream Channel from Regulating Dam to Nam Phit / Xe Bangfai Confluence
- Zone 9: Nam Kathang / Nam Gnom
- Zone 10[A]: Upstream of the Xe Bangfai and Nam Phit Confluence
- Zone 10[B]: Upper Xe Bangfai
- Zone 11: Middle Xe Bangfai
- Zone 12: Lower Xe Bangfai
- Zone 13: 500 kV Transmission Line Route South of Road 13 Bridge
- Zone 14: Road 8 / 12 Road from Thakhek to Mahaxai and 115 kV Transmission Line Route West of Mahaxai
- Zone 15: Mekong River

Zone 1: Inundation Zone (Nakai Reservoir)

Zone 1 is defined as the area below elevation El 538 on the Nakai Plateau that will be inundated by the Nakai Reservoir. Since the tributaries of the Nam Theun follow in relatively flat gradients out of the catchment area, this zone includes the channels of streams and rivers that will be affected by the rising water. Zone 1 has an area of approximately 640 km², which includes the reservoir with an area of 450 km² at FSL as well as the islands which will be formed by the reservoir at El 538.

Approximately 1,030 households and 5,684 people are encompassed by this zone. Much of the RAP is dedicated to planning their resettlement. The people will also be affected to some degree by the construction activities on the Nakai Plateau, which include activities related to the construction of the Nakai Dam, intake structure, saddle dams, and the headrace channel.

Figure 2-3: Project Zones Map



Zone 2: NT2 Catchment/NNT-NBCA and Corridor Areas

This area contains a portion of the Nakai dam site, the Nakai dam access road and a portion of Road 8b from the northern edge of the Nakai Reservoir. Some 5,500 people inhabit the NNT-NBCA in enclaves of human populations located along the main river valleys. Within this zone there will be areas set aside for the customary use for these inhabitants. These people are not directly affected by the Project, but have the potential to affect the performance of the Project. A significant increase in erosion from the catchment area would increase sedimentation in the Nakai Reservoir and ultimately shorten its life and efficiency. This sedimentation can be avoided if logging is prevented and shifting cultivation on the slopes of the NNT-NBCA is ceased or restricted. In addition, this zone includes two corridor areas, which cover an area of 770 km².

Zone 3: Proposed NT2 Resettlement Area

The proposed resettlement zone of 208 km² is situated on the rim of the Nakai Plateau escarpment on the southern edge of the Nakai Reservoir. At its northern end, the resettlement area abuts the Nakai Nam Theun Phou Hin Poon (NNT-PHP) Corridor, which links with the NNT-NBCA and the Phou Hin Poon NBCA. This zone currently consists of a mix of primary and secondary forest. Currently, this area contains the current villages of Talang, Nongbouakham, Nakai Tai, Nakai Neua and the District centre of Ban Oudomsouk. In October 1998 the entire zone contained 520 households Of these 520 households, 283 households were in Ban Oudomsouk (of which 94 are below elevation El 540 and therefore are classified as inundation zone households and will be included in the resettlement). This area is also affected by some construction activities such as construction of the intake structure, some of the underground works, the portion of Road 8B which is to be relocated on the southern edge of the Nakai Reservoir and some construction camp activities.

Zone 4: Nam Theun Downstream to Theun-Hinboun Headpond

Zone 4 encompasses the riparian land of the Nam Theun from the Nakai Dam site to a point where the river meets the backwaters of the Theun Hinboun Reservoir, 32 km downstream of the Nakai Dam. Much of this zone is included in the NNT-PHP Corridor area and is largely bordered by Zone 2. One major tributary, the Nam Phao, joins the Nam Theun approximately 12km below the Nakai Dam site. The riparian strip ranges from approximately three to five km wide, giving a land area of about 130 km². There are no established villages or settlements along this reach of the river, principally because of the topography features and difficult access.

Zone 5: Theun Hinboun Dam to the Mekong

Zone 5 includes the Theun Hinboun Reservoir and a riparian strip along the Nam Kading to the Mekong River over which issues are relevant.

Flows in the river below the Theun Hinboun dam are limited to the minimum release from the Theun Hinboun Reservoir as well as the significant spillage that occurs during the wet season.

Zone 6: Road 8B "Lak Sao Road" and Phou Phako Quarry

Zone 6 includes Road 8B from Ban Lak Sao south to approximately the intersection between Road 8B and the border of the Zone 2. Human incursion along Road 8B is likely to be the main form of impact. This is predominately attributed to the numbers of people entering the area as a result of construction. The northern aggregate quarry, located at Phou Phako and to be used in the Nakai dam construction, is also included in this zone.

Zone 7: Power Station, Regulating Dam and Operators Village

Zone 7 is the area immediately surrounding the power station and extends to the regulating dam and the operators village, also known as Residence Nam Theun. Factors associated with construction and operation of the power station are critical issues to be considered from the inundation area of the regulating pond to the Xe Bangfai. The factors include water quality and quantity, diversion of flow into natural watercourses and re-routing of the natural stream drainage around the regulating dam.

While there are no permanent houses in these zone, there are many vegetable and banana gardens and some fields huts in the area of the regulating pond. The regulating dam and residence Nam Theun is directly next to the Village of Ban Keovilay and its agricultural fields, situated in an area of degraded forest or swiddens of this village.

Zone 8: Downstream Channel from Regulating Dam to Nam Phit / Xe Bangfai Confluence

Zone 8 includes the downstream channel from the regulating dam to the XBF confluence. The majority of the discharge from the power station will be transferred to the XBF via the downstream channel. This zone encompasses some of the most productive agricultural land which will be directly affected by the Project. The downstream channel will traverse rice paddy land for approximately 8km of its 27km length and will then flow in the modified Nam Phit. The zone encompasses any adjacent areas which are modified in conjunction with the NT2 Project, including spoil areas, embankments, existing irrigation schemes and other physical modifications.

Besides physical land requirements of the NT2 Project, other social issues stem from the flow introduced to the downstream channel and the water quality profile as it changes in the channel prior to release into the XBF. The interaction of water released through the power station with background wet and dry season flows from catchment areas adjacent to the downstream channel and their related water quality profiles are determinants for actual impacts on the associated human component.

Approximately 60 households, who either use or occupy the land on the channel alignment in this Zone, could be adversely affected by the Project, however, households along the channel may benefit from increased potential irrigation.

Zone 9: Nam Kathang / Nam Gnom

Zone 9 consists of the Nam Kathang / Nam Gnom and riparian land to its confluence with the XBF. The zone consists of approximately 1,632 households within 23 villages, and a population of approximately 12,722. The zone is important because of the potential for diverting additional water for support of various beneficial uses for the villages along the river, especially in dry season when water in the Nam Kathang is limited.

Zone 10A: Upstream of the Xe Bangfai and Nam Phit Confluence

This zone is located upstream of the confluence of the NT2 downstream channel, the mouth of the Nam Phit and the XBF. The zone contains five (5) villages, from Ban Na Phong to Ban Na Kio. Impacts in this zone will be limited to affects associated with the backwater effect created by the additional discharge entering the XBFat what is now the Nam Phit.

Zone 10B: Upper Xe Bangfai

This zone extends from the confluence of the downstream channel and the XBF to the Sayphou Xoy Ridge about 25 km downstream of district center of Mahaxai. Thirteen (13) villages are located in this zone from Ban Keng Savang down to Ban Tha Hat. The impacts of the NT2 project waters will be greatest in this zone, being the first stretch of river receiving the additional discharge. Issues are mainly related to increases in flows and river levels, changes in discharge regime, erosion of the river banks, effects on land use (river bank gardens) and effects on fisheries.

Zone 11: Middle Xe Bangfai Zone

The Middle XBF zone extends from the Sayphou Xoy Ridge to the Road 13 crossing. There are thirteen (13) villages in this stretch, from Ban Keng Kheng, just downstream of the ridge, to Ban Pa Lai, many of which have already started to practice dry season irrigation. Issues relating to this zone will be similar to those outlined for the Upper XBF Zone, although the severity of some of the impacts is expected to be less due to the larger size of the XBF and large natural discharge in this stretch of the XBF.

Zone 12: Lower Xe Bangfai Zone

The Lower XBF, or XBF flood plain, covers an area of about 50,000 ha ranging from Ban Khua Xe at the Road 13 bridge crossing and to Ban Pakxe Pak XBF at the confluence with the Mekong River 70 river kilometers downstream of the bridge. This zone encompasses the main flood plain of the XBF. The area is relatively densely populated, compared with other Project zones, with some fifty two (52) villages. The

zone contains approximately 40,000 ha of rice paddy fields on some of the better agricultural land in the Lao PDR.

The main social issues in this stretch relate to the beneficial reduction of flood levels in the Mekong resulting from the storage of Nam Theun flood waters in the Nakai Reservoir and the diversion of the Nam Theun to the XBF, and some flooding of lower riverbank gardens and possible changes in fisheries catches. The Lower XBF already experiences natural flooding almost every year. The Lower XBF will experience some special hydraulic conditions as a result of the NT2 Project, possibly resulting in a decrease of overall flood levels due to the reduction of flood levels in the Mekong River as a result of the diversion of flows from the Nam Theun to the XBF. As a result, the timing and duration of flooding is the main issue for this zone and the results are expected to be beneficial.

Zone 13: 500 kV Transmission Line South of Road 13 Bridge

Zone 13 extends from the bridge over the XBF on Road 13 to Savannakhet along the route of the 500 kV transmission line. Upstream of Road 13 bridge the 500 kV transmission line is included in zones 7, 8, and 10B.

The social factors relevant to this zone are mostly related to land use and human occupation. The 500kV transmission line route has been selected to avoid permanent settlements as much as possible.

Zone 14: Road 8 / 12 from Thakhek to Mahaxai, and 115kV Transmission Line West of Mahaxai

This zone consists of the area surrounding Road 8/12 which leads from the outskirts of Thakhek to Mahaxai, which will be upgraded as part of the NT2 Project. Other parts of the road are included in other zones.

Zone 15: Mekong River

Zone 15 consists of the reach of the Mekong River from the confluence of the Nam Kading to the confluence of the XBF and downstream to a point near Savannakhet. Flood stage elevation is the only concern. The entire Mekong Basin is a huge area, approximately 795,000 km² in extent, and of this the Nam Theun-Nam Kading catchment only represents about 1.8 percent of the total.

2.4 **PROJECT COMPONENTS**

The Project will divert discharge stored on the Nakai Plateau from the Nam Theun to the XBF, in doing so producing electricity for delivery to EGAT and EDL, utilising the difference in elevations between the Plateau and the Plain. To accomplish this certain infrastructure will be constructed and will include:

- A dam on the Nam Theun and necessary saddle dams to create the reservoir;
- Structures to divert flow from the reservoir to the power station;
- A power station with the necessary facilities for converting the energy to electricity;
- Downstream hydraulic control and conveyance structures to direct the diverted flows to the main channel of the XBF;
- Transmission lines to interconnect the power station switchyards with the EGAT and EDL power transmission systems; and
- Ancillary works to enable construction, operation and maintenance of the Project and to meet other obligations of NTPC.

This infrastructure is described in more detail below and location indicated in Figure 2-6.

2.4.1 Nakai Dam & Reservoir

<u>Nakai Dam</u>

The Nakai Reservoir will be formed by the construction of a gravity dam located at a sandstone outcrop in a horseshoe-shaped bend of the Nam Theun at Keng None. The dam will have a crest length of approximately 325 m and an approximate height of 48 m from the deepest foundation to its crest, which will not exceed El 541.5 m. The foundation will be grouted for seepage control. The dam will be constructed with a drainage curtain and a drainage gallery.

Spillway

The spillway will have at least four radial gates that will be constructed within the dam section. A flap gate will be added to the top of at least two of the gates to allow for discharge of small floods without operating one of the large radial gates. The spillway chute will terminate in a hydraulic jump-stilling basin with a concrete floor and retaining walls to reduce riverbed scour. The Project has been designed to handle the 24 hour inflow of 15,985m3/s and the 15 day inflows of 8,720 MCM without overtopping or endangering the safety of the Nakai Dam or the saddle dams. The spillway and reservoir will accommodate the passage of the 5,000 year average return period flood inflow, estimated to be 8,360 m³/s. Through the reservoir, the flood peak is attenuated so the peak passing over the spillway is less than the inflow peak. The spillway is also sized to work efficiently for any lesser flood and hydraulic model tests have shown that it will not experience damage with the passage of the PMF. An acoustic warning system will be installed on the dam crest and at the downstream end of the stilling basin to warn people when the Nakai Dam spillway will be opened.

To prevent problems from floating debris, a continuous floating trash/log boom will be attached to the reservoir banks upstream from the dam. The boom will be positioned diagonally across the reservoir to promote movement of logs and debris to the right bank. A concrete ramp will be provided to enable clearing of the logs and debris. The boom will be located to prevent floating debris from fouling the spillway and will include brightly coloured, visually prominent markers and appropriate warning signs to warn small boats and other lake craft not to approach the structure.

Outlet Conduit for Riparian Release

An outlet conduit will be provided next to the spillway to meet the downstream riparian release obligations. The riparian water will be drawn from the reservoir through a variable-level intake structure equipped with stoplogs. A trash-rack will be located upstream of the stoplogs. The outlet conduit will be equipped with a cone valve permitting discharge of riparian flows without scour or damage to the channel of the Nam Theun, and enabling aeration of the riparian flows. The outlet conduit will have the capacity to release a discharge equal to 2 m³/s continuously during the entire year. In addition, it will be able to accommodate up to 10 m³/s on a continuous basis for short periods of time.

Ancillary Structures at the Nakai Dam

Additional facilities at the Nakai Dam site will include:

- A spillway control building to house all necessary controls and equipment, direct current and uninterrupted power supply systems, stores, workshops, control room and office facilities, and employee amenities for short term accommodation;
- Communications systems to the power station, intake structure and hydrometric measuring stations;
- A building for the diesel generators and fuel storage facilities; and
- A 1.8 m high security fence, chain wire or equivalent to enclose the right and left abutments areas and the riparian release discharge channel area.

Nakai Reservoir

The full supply level for the Nakai Reservoir will be at El 538.0 m. At full supply level, the reservoir will have an area of approximately 450 km² and will hold 3,910 million m³ of water. The minimum operating level is designed to be at El 525.5 m. At this level the reservoir will have a surface area of approximately 82 km². The reservoir volume between full supply level and minimum operating level is approximately 3,530 million m³.

Saddle Dams

Thirteen earth embankment saddle dams will be constructed along the escarpment side of the reservoir rim to enable storage to the full supply level. The crest levels of these saddle dams will be set at El 542.25 m. Where the lowest point of a saddle dam foundation is below El 539 m, the saddle dams will be earth fill or earth and rock fill structures with an impervious core. A foundation cut-off of not less than 3 m depth will be used and the embankment shoulders will be constructed with materials from excavations and borrow areas.

Where the lowest point of a saddle dam foundation is at El 539 m or higher, the saddle dam will be designed as a homogeneous embankment with cross section geometry adjusted to the materials selected for construction. The materials will be selected to achieve the required stability and permeability characteristics. The upstream slope will be protected against erosion either by rip rap or suitable vegetation and a flat gradient designed to limit erosion and ensure the integrity of the water retaining structure. Grass or other suitable native vegetation will protect the downstream slope. Each of the saddle dams will be equipped with instrumentation consistent with modern international dam safety practice.



Figure 2-4: Nakai Reservoir Water Level (period of simulation 1953 – 2000)





2.4.2 Flow Diversion

Headrace Channel

A 4.25 km long headrace channel will be excavated in the reservoir floor, approximately 35 km southeast of the Nakai Dam, to convey water to the intake structures. Materials excavated from the headrace channel will be placed in approved spoil areas in the reservoir or used as landfill for roads, in saddle dam construction, or in the resettlement areas. Also, a rock trap will be constructed in front of the intake structure to retain loose material that might be carried into the intake and tunnels. Between the end of the headrace channel and the Nam Theun riverbed, a 5.1 km long corridor will be levelled and cleared. The levelling and clearing of this area will minimise head loss between the water at the minimum operating level and the start of the headrace channel.

A continuous floating trash/log boom will be constructed as close as possible to the entrance of the headrace channel to prevent floating debris from fouling the power conduit intake. The trash/log boom will also act as a floating marker and barrier to prevent small boats and other lake craft entering the headrace channel and the power conduit intake.

Intake Structures

The power conduit intake will be a concrete structure with four openings. Each opening will be equipped with trash racks and mechanised trash-cleaning rakes. The intake structure will be supplied with power from the power station. Additional back-up for operating the intake structure will be provided by a diesel generator. Initially, the water passage will be horizontal and lead to a rectangular section where two gates will be placed to control flow into the tunnels. The gates will consist of a fixed-wheel downstream service gate and an upstream guard gate, to be used for maintenance work and emergency access. The service gate will be used in conjunction with the guard gate to isolate the headrace tunnel from the reservoir, allowing for de-watering and inspection of the tunnel and surge shaft.

Underground Works

The headrace tunnel, pressure shaft and power tunnel will convey water from the intake structure at El 525.5 m to the power station at El 170 m, providing a net head of 348 meters. The underground works will include a sub-horizontal headrace tunnel connected to a pressure shaft and then to a horizontal pressure tunnel. In sections of the tunnels where the surrounding rock cannot contain internal water pressure within the required margin of safety, or to prevent seepage losses, the conduits will be steel-lined. Otherwise, the remainder of the tunnels will be concrete lined.

A series of surge shafts will be constructed to reduce pressure transients created in the tunnels during start-up and load-rejection operations. The surge shafts will be concrete lined and will be of varying diameters, increasing with height. The upper ends of the shafts will be at the ground surface. All parts of the headrace tunnel, surge shaft, pressure shaft and pressure tunnel will be accessible for inspection and maintenance.

Figure 2-6: Nakai Reservoir Plan



2.4.3 Power Station

Power Station & Generation Units

The power station will be located approximately 10 km north of the village of Ban Gnommalat, at the foot of the escarpment of the Nakai Plateau. The power station consists of a single, surface building to house six generating units, the administrative and operating offices, the control room and facilities for the management and control of the Project. Auxiliary infrastructure will include a workshop, garage, standby diesel generating facilities and water treatment and storage facilities. A minimum of 0.5 m freeboard above the level of the 10,000-year flood will be provided for each of the structures.

The main portion of the power station will be approximately 130 m long and 35 m wide. The location of the power station relative to the underground works is shown in Figure 2-7 with a cross-section through the power station presented in Figure 2-8. The turbines will include four Francis Turbine units, which will generate energy for delivery to EGAT and two Pelton Units, which will generate energy for delivery to EDL, the power station, and the operator's village.

Figure 2-7: Underground Works



SCADA System

A Supervisory Control and Data Acquisition (SCADA) system will interface with a water management system to monitor, supervise and control the elements of the power station and switchyard. This system will enable analysis of the reservoir, power station, generator, transformer and tailrace conditions. The system will enable checking against predefined limits and, if necessary, cause changes to the operation of the Project. All relevant information will be transmitted to EGAT's national and regional control centres and to NTPC's Vientiane office. The SCADA system will enable automatic operation of the Project. Information provided to EGAT will enable them to integrate the energy into their power network, but not to control operations.

Figure 2-8: Power Station Cross-Section



2.4.4 Downstream Hydraulic Control & Conveyance

Tailrace Channel, Regulating Pond & Regulating Dam

Water discharged from the turbines will be conveyed through a concrete transition stilling structure into an excavated tailrace channel. The tailrace channel will convey the water to a regulating pond downstream from the power station and downstream from the confluence of the Nam Kathang Noi and Nam Kathang Gnai rivers. The maximum discharge from the power station into the regulating pond will be 330 m³/s. The regulating pond enables the Project to be operated as an intermediate peaking facility by regulating, for environmental and social reasons, the downstream flows.

The purpose of the regulating pond is to limit water level fluctuation in the XBF, in particular during start-up, shut-down and load changing operations. It will be created by the construction of an additional dam consisting of two contiguous concrete structures, one spilling into the Nam Kathang and the other into a downstream channel. An earth and rock-fill embankment will be constructed to complete the downstream closure of the regulating pond. The regulating pond will have an active storage volume of 8 million m³.

The regulating dam will be equipped with gates for irrigation intakes and outlet channels. The capacity of the irrigation channel will be approximately 5 m³/s when the regulating pond is at minimum operating level. A trash/log boom across the regulating dam's discharge intake area will be provided to trap floating debris, to provide signs to warn people not to approach the dam, and to stop small boats from approaching the discharge gates. An acoustic warning system will be installed on the dam crest and at the downstream end of the stilling basin, as well as along a portion of the Nam Kathang downstream of the regulating dam to warn people, upstream or downstream of the spillway, of the imminent opening of the spillway gates.

Nam Kathang Release

Water will be released from the regulating pond into the Nam Kathang River below the regulating dam at a rate equivalent to the natural inflows of the Nam Kathang Gnai and Nam Kathang Noi plus up to 15 m^3/s of additional water during power station operation and 10 m3/s when the power station is shut down. The arrangement of the Nam Kathang River riparian release structure and the spillway stilling basin and end-sill will be designed to provide aeration of the discharge. To prevent problems from floating debris, a continuous floating trash/log boom will be attached to the reservoir banks upstream from the dam. The boom will be positioned diagonally across the reservoir to promote movement of logs and debris to the right bank. A concrete ramp will be provided to enable clearing of the logs and debris. The boom will be located to prevent floating debris from fouling the spillway and will include brightly coloured, visually prominent markers and appropriate warning signs to warn small boats and other lake craft not to approach the structure.

Downstream Channel

A 27 km long, excavated channel will direct flow from the regulating pond to the Xe Bangfai near the town of Mahaxai. The maximum capacity of the channel will be 315 m³/s, plus the discharge from the surrounding drainage, equivalent to a two-year flood event. The downstream channel will accommodate discharges from the power station, flow variations, local drainage and flood inflows without damage to the channel invert, banks or ancillary structures. The first 8.5 km of the channel will be lined with concrete, rock gabions or rock, with a bottom width of approximately 20 m. This section of the channel will be sufficiently above natural ground to permit the installation of gravity fed irrigation release points along the course of the channel. At Ban Gnommalat an inverted siphon will take the downstream channel under the Nam Gnom. The first section of the downstream channel ends at the aeration weir.

Downstream of the aeration weir, the channel will be lined with concrete, rock gabions or rock, with an invert width of approximately 21.5 m. The maximum regulating pond discharges in this section of the channel will be contained either below natural surface level or within levee banks, as required by the local terrain. It will allow surface run-off and floodwaters from local adjacent catchments to drain into the channel. The downstream channel will then pass through a karst outcrop, via a tunnel. Upstream of this tunnel, an emergency spillway will be constructed with a capacity of not less than 100 m³/s. This spillway

will protect the channel when discharge exceeds the design discharge, inclusive of flood inflow from the local drainage area. Discharge from the emergency spillway will flow into the Nam Phit, facilitating the discharge of water in the downstream channel. Downstream from the tunnel, the downstream channel will be designed as an erodible channel. Its geometry is made of a pilot channel of 20 m width and will extend on both sides, with a flat minor bed demarcated by levee banks, situated at 150 m from the axis of the pilot channel. Average speeds in the total unlined section will reach approximately 2.3 m/s and levee banks will have a height of approximately 2 m. This channel will deliver the water to the XBF. The gradient of the downstream channel will vary according to the different sections. The downstream channel starts at El 166.97 m and ends at El 142.06 m. Runoff from local adjacent catchments will be managed or regulated to ensure that the nominal release of 315 m³/s can continue for all events up to and including the 10-year average flood. The downstream channel will be designed for withstanding overtopping and/or inundation from local catchment flood flows up to the 1000-year average flood event. The unlined channel will be designed to enable runoff to enter the channel, or drain to natural channels.

As noted above, the downstream channel alignment crosses through irrigated paddy land in the Gnommalat region and crosses several existing irrigation canals. The irrigation system is a gravity fed system, utilizing water from the Nam Gnom, located to the east of the proposed downstream channel alignment. During construction NTPC will provide temporary irrigation facilities where irrigation canals or channels are affected by the downstream channel and associated construction activities. Any land adjacent to the downstream channel which was used for agricultural activity prior the the project and is required to be used or is impacted during the construction period will be restored by NTPC to allow for the same agricultural activity to continue after the downstream channel is constructed. This includes providing for a permanent solution to the problem of the downstream channel crossing the existing irrigation canals, as well as restoration of land which may be used as working areas during the construction period. Regarding the restoration of the irrigation canals, the exact design of the works required to restore the system is not currently available and will be completed during the detailed design stage of the project. However, at this time two concepts are currently seen as being potentially feasible. One concept is re-establish irrigation on the eastern side of the downstream channel by providing facilities to irrigate using water directly from the Downstream Channel. The second concept is to restore the system by connecting the irrigation canals on the eastern and western sides of the Downstream Channel, through construction of siphons which would pass under the downstream channel. In either case, the existing irrigated area to to east of the downstream channel will not be lost.

In addition to maintaining the current irrigation system, NTPC will provide additional irrigation potential. Where the normal flow levels are above ground level the actual design and construction of the downstream channel NTPC will provide for 16 locations where irrigation pumps or gravity fed irrigation facilities can be installed. (Note: such irrigation equipment will not be provided by NTPC). The exact design and location of these irrigation access points is not currently known and will be determined during the detailed design stage of the project. To improve the concentration of dissolved oxygen and to reduce the concentration of methane and hydrogen sulphide in the water released through the power station, a U-shaped aeration weir will be installed in the downstream channel. It will allow water to spill over the structure



Figure 2-9: Downstream Channel

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Figure 2-10: Relative Location of Power Station, Regulating Pond and Dam, and Downstream Channel Tunnel





2.4.5 Transmission

Substations

The Project will include a 500/115 kV substation as well as a 115/22 kV substation, both of which will be constructed adjacent to the power station. Through these substations, it will be possible to supply energy to EGAT (500kV) and EDL (115kV to Thakhek and 22kV locally). Power supply for the substation auxiliaries will be tapped from two redundant auxiliary transformers located in the Project substation. Back-up electricity will be derived from the power station's stand-by diesel generating units.

Transmission Lines

Electricity generated for EGAT will be delivered at the Lao PDR – Thailand border north of the town ofSavannakhet, the capital of Savannakhet Province, via a 138 km long, double circuit, 500 kV transmission line. To feed the electricity into the EGAT system an additional double circuit, 500 kV transmission line, approximately 160 km in length, will be constructed from the Lao PDR – Thailand border to a new substation at Roi Et, Thailand. The 500 kV transmission line within Lao PDR will be designed so that any future link to a switching station near Savannakhet can be constructed without interrupting the delivery of electricity to EGAT. The normal operating configuration of the 500 kV transmission line shall be two circuits in service, irrespective of the number of generating units synchronised to the EGAT system.

Energy for EDL will be transferred from the Project substation via a 70 km, 115 kV transmission line to a 115/22 kV substation transformer in Thakhek, the capital of Khammouane Province. EDL will also be able to off take approximately 20 MW of energy at the power station substation via existing and project built 22 kV transmission lines.

The transmission line towers will be constructed as self-supporting steel lattice structures. The normal spacing between consecutive towers will be approximately 450 m. The footprint of the towers will be approximately 10 m by 10 m. The precise route of the transmission line is still being defined, but will avoid houses or settlements and, where practical, agricultural areas. Minor compensation may be required as a result of the construction of access roads and the towers themselves.

Mekong crossing

Two towers will be placed in the Mekong River channel, one near the Lao PDR side and the other near the Thailand side of the river. Construction of the foundations is expected to occur during the dry season, when the Mekong River is at its lowest, to limit potential adverse impacts to the river.

2.4.6 Ancillary Works

Roads and Bridges

As part of the Project, NTPC will construct and/or improve a number of roads. These roads are shown in Figure 2-11.

Between Thakhek and Ban Gnommalat, the existing Roads 12 and 8B will be upgraded to provide a safe two-lane road. Existing bridges will be improved or rebuilt as needed to ensure they are in a safe and serviceable condition. Two additional bridges will be constructed where Road 12 and Road 8B cross the downstream channel, near the intersection of Roads 12 and 8B, and at the Ban Itak crossing, respectively. Another new bridge will be constructed where the road to Ban Thathot Ban and Ban Lao Saeng, both located on the western side of the downstream channel in the Gnommalat plain, crosses the downstream channel. The upgrading of these roads will facilitate the construction and operation of the Project.

Between Ban Gnommalat and Ban Oudomsouk, the existing road will be significantly upgraded. In the section leading from Ban Gnommalat to the Nam Kathang, the road will be raised above flood levels and drainage works will be installed. From the Nam Kathang to Ban Oudomsouk, earthworks and drainage improvements will be constructed to ensure a stable and safe all-season road. In addition, an access road will be built from Ban Oudomsouk to the resettlement community south-east of Ban Oudomsouk, partly through the rehabilitation of an existing road and partly through new construction.

A new road will be constructed to replace the section of Road 8B northwest of Ban Oudomsouk as this part of the road will be inundated by the reservoir. The new road will follow the southern rim of the Nakai Plateau from Ban Oudomsouk to Ban Thalang and cross the Nam Theun via a new bridge. The new road will join the existing Road 8B at Ban Nam Nian.

A new access road will be constructed to enable travel to the Nakai Dam on the Nam Theun. The road will be constructed from Road 8B, near Ban Phonkeo.

Existing roads will be upgraded and new roads will be constructed as necessary to enable access to the resettlement villages. New tracks to the resettlement houses and farm lots will also be constructed. These roads will have a maximum width of 3 m, within an 8 m wide right of way. Forest roads will also be constructed to assist with the management of the community forest areas.

In addition to the three road bridges, eight local community bridges will be constructed across the downstream channel to maintain existing access tracks. Determination of the exact locations of the bridges will be based on consultations with local residents. The bridges will be of two types:

- Five pathway bridges will be constructed. Each of these bridges will support two-tonne loads and will be dimensioned to accommodate small farm tractors up to 1.75 m wide.
- Three bridges will be constructed where the downstream channel crosses existing local public roads. Each of these bridges will be able to support four-tonne loads and will be dimensioned to accommodate vehicles up to 2.5 m wide.

The bridges will also incorporate two pedestrian refuges at each column location.

Location	Route	Distance (km)	Width (m)	Pavement Type
From Thakhek Route 12/13 junction to the junction of Route 8 & 12	8	55	9	Gravel
Route 8 & 12 Junction to Ban Gnommalat	8	5	9	Gravel
Ban Gnommalat to regulating dam	8	5	9	Gravel
Regulating dam to the crossroads with the power station access road	8	4	7	Gravel
From the crossroads with the power station access road to Oudomsouk (Nakai)	8	7	7	Concrete/ Gravel
Resettlement roads south of Oudomsouk (Nakai)	Other	30	7	Gravel
Total		106		

Table 2-1: Upgrade of Existing Roads

Table 2-2: New Road Construction

		Distance		Pavement
Location	Route	(km)	Width (m)	Туре
Oudomsouk (Nakai) to Ban Nam Nian	8	41.3	7	Gravel
(including Ban Signo Bridge)				
Dam site access road (a side road from Route 8b	Other	15.4	5	Gravel
Ban Phonkeo to the Nakai Dam site)				
Total		56.7		



Figure 2-11: Planned Road Improvements and New Constructions

2.4.7 Residence Nam Theun

The Project will require an operator's village, Residence Nam Theun, to be established for the permanent employees. Approximately 150 permanent employees will be housed at Residence Nam Theun to enable the ongoing operation and maintenance of the facility. The new village will be constructed near the regulating dam. Apart from housing, the village will include shops, a post office, a telecommunications centre, water and sewerage treatment plants, fire fighting units, an emergency power supply, a helipad, recreational and leisure facilities, a health dispensary and a school. The village will be accessible by a two-way, paved road.

Materials Sources

There are two main limestone quarries for aggregate production for concrete and other construction needs. The first is located at Phou Phako. It will provide materials for civil works largely on the Plateau. The second source is located at Pha Thung, near the downstream channel, and will supply material for the power station and downstream civil works. Laboratory results from both sites indicate acceptable mechanical properties and the materials are classified as non-alkali reactive. In addition to these two major sources, several smaller sources have been identified, including an area just downstream from the dam site from where sandstone can be quarried, and several borrow sites along Road 12. Potential sand sources are located near the construction areas.

Spoil Disposal Areas

A number of potential spoil disposal sites have been identified for placing excavated materials not utilised in the construction of the Project. Spoil materials will be generated mainly from the excavation of the downstream channel, and to a lesser extend by the headrace channel and other construction activities. Spoil, whenever possible, will be used to construct roads, saddle dams, for landscaping, and for fill in the resettlement areas. All spoil disposal areas and other areas disturbed during the construction period will be landscaped to restore drainage, encourage the re-establishment of vegetation, stabilise slopes and minimise visual impact once construction is complete.

Potential Location	Description of Anticipated Spoil Disposal	Estimated Volumes (m ³)
Nakai Dam	Spoil disposed upstream of dam, in dead storage of reservoir	500,000
Headrace Channel	Spoil used for construction of saddle dams, sediment traps, and the remaining would be placed in spoil deposit zones within reservoir or as backfill to create a platform at 540 El for Oudomsouk town	3,100,000
Headrace tunnel, surge shaft & access addit	Spoil to be deposited in spoil location across from access addit on road 8B, in location with total capacity for 230,000 m ³	155,000
Pressure shaft and tunnel, power station foundations, tailrace channel	Deposit in switchyard platform (~500,000 m ³), platforms for power station (60,000 m ³), and other areas around regulating pond, which have an approximate total capacity of 2,400,000 m ³	1,300,000
Regulating pond	Spoil is to be used in construction of the regulating dam and deposited along edge of regulating pond	1,500,000
Downstream channel	Over 5,200,000 m ³ is estimated to be needed in construction of channel (banks as needed, access road parallel to channel as required). Preliminary sites have been identified along the downstream channel and further studies will determine their suitability for disposal of the 3,500,000 m ³	8,700,000
	Total	15,225,000

Table 2-3:Potential Spoil Disposal Sites

Construction Work Camps

Four zones have been identified for the development of construction work camps within the Project area. They will accommodate a maximum construction worker population of approximately 4,000. These zones, from north to south, are:

- i Dam area construction camp;
- ii Nakai work camp zone;
- iii Power station work camp zone; and
- iv Downstream work camp zone.

Additional zones have been identified in the vicinity of each major work site, outside and separate from the formal construction camps. These zones have been selected to accommodate the businesses, as well as their families, that will likely become established in the neighbourhood of the construction camps. To accommodate these businesses, it was assumed that land for four times the number of workers will be required at each of the work sites. Figure 2-13 indicates the locations of the construction work camps in relation to significant construction areas.

Work Camp Zone	Peak Workforce Expected	Potential Followers
Dam Site	800	about 1,600 to 3,200
Power Station Site	2,200	about 4,400 to 8,800
Nakai	600	about 1,200 to 2,400
Xe Bangfai	400	about 800 to 1,600
Total	4,000	

 Table 2-4:
 Construction Work Camp Zones and Estimated Workforce Numbers



Figure 2-12: Potential Locations of Spoil Zones (indicative only, pending detailed planning)



Figure 2-13: Potential Location of Work Camps and Number of Workers and Possible Followers.

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