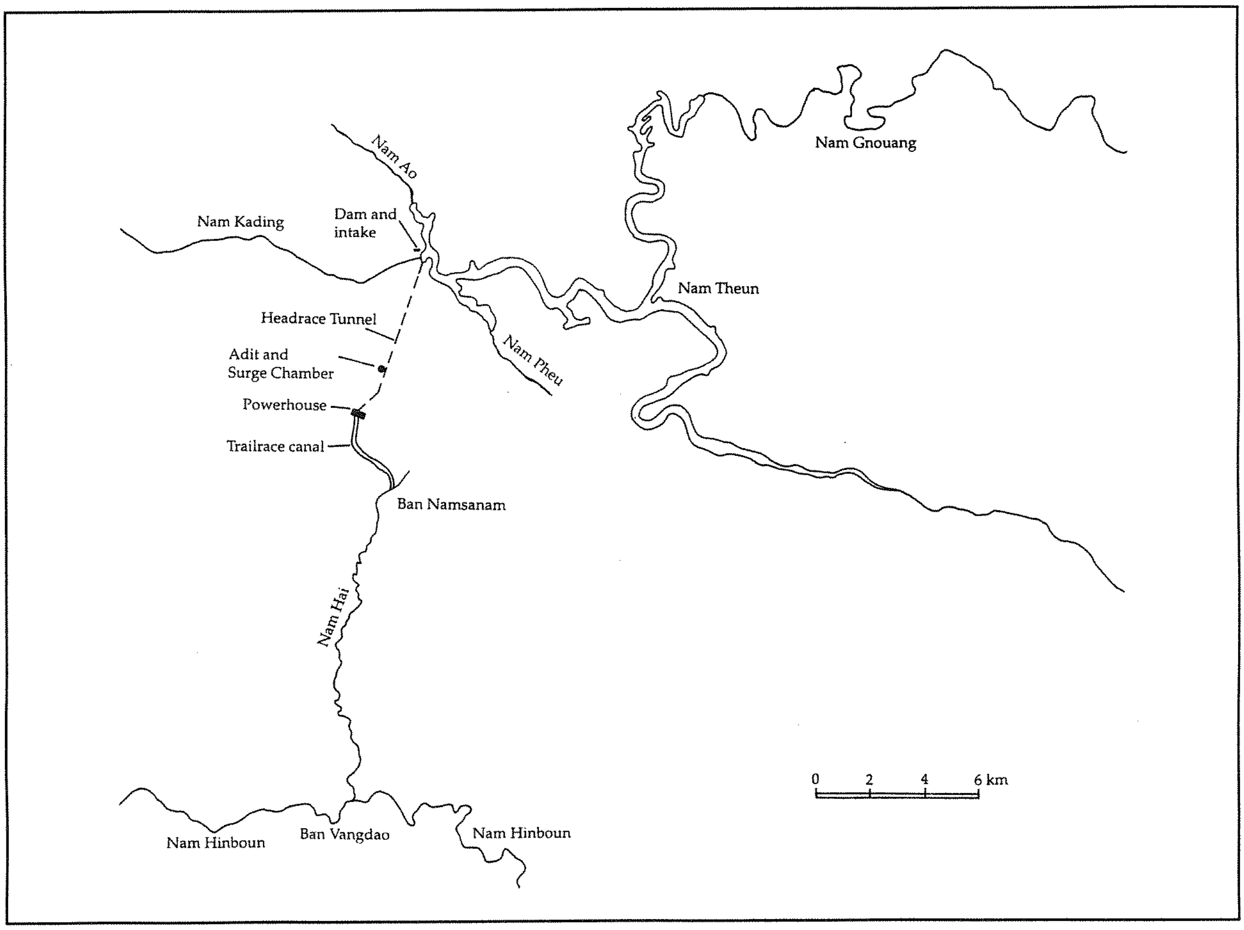
Theun - Hinboun Impact Studies
LAO PDR

Final Report

WATER QUALITY AND AQUATIC LIFE STUDY

October 1995



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Abstract: The present report summarises the results from the environmental impact assessment study on water quality and aquatic life in connection with the Theun Hinboun Hydropower Development Project, Lao PDR. The river Nam Theun, which is going to be dammed and partly diverted to Nam Hai/ Nam Hinboun, is a nutrient poor softwater river with low content of sediments. The proposed hydropower development will have considerable negative effects on the productivity of the Nam Theun and Nam Kading river, particularly the production of large edible fish species will decline. To avoid catastrophy in the downstream river fisheries a minimum release from the dam of 6-15 m^3/s is neccessary. Likewise it is recommended to build a fish bypass through the dam to allow for fish migration. It is not recommended to establish a stocking programme introducing new fish species. In Nam Hai considerable erosion is expected to occur in the first period after the regulation. This may impose some smaller negative effects on the productivity of the receiving Nam Hinboun, which however, will be of transitional character. The new hydrological regime in Nam Hai can be positive to the aquatic life and fish production if the river is not allowed to be dry at any time after the regulation. A power house bypass should be built to allow for at least some flow during periods of power station maintenance. Some basins, or weirs should also be built in the tailrace system to reduce the fast water flow fluctuation in Nam Hai. This to prevent stranding of juvinile fishes.

4 keywords, Norwegian

1. Vannkraftsutbygging
2. Miljøkonsekvensanalyse
3. Vannkvalitet - Fisk
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For the Administration

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Preface

This report presents the results from The Water Quality and Aquatic Life Study, a part project under the Theun Hinboun Hydropower Impact Studies. The study is supplementary to the previous Environmental Impact Assessment Study reported in 1992. The field work was performed in the period Dec 1994-Aug 1995.

Dag Berge, NIVA, is project leader for the Aquatic Life Study and has compiled the report from the different participants. The Water quality part is performed by NIVA, whereas the fish study is performed by NINA-NIKU, both in cooperation with Burapha Development Consultants Ltd, Vientiane, LAO PDR. At NIVA Leif Lien has performed the field work together with Phoutalom Vongsay, Burapha. Pål Brettum (NIVA) has analysed the phytoplankton, Bjørn Rørslett (NIVA) has treated the material on aquatic macrophytes, and Torleif Bækken have performed the analysis of bottom animals. The material on dioxin pollution of fish is treated by Jon Knutzen.

NINA-NIKU is responsible for the fish study in cooperation with Burapha. NINA's project leader is research scientist Nils Arne Hvidsten, with participation from senior research scientist Tor G. Heggberget. Dr. Tyson R. Roberts, Kasetsart University, Bangkok, Thailand, have assisted NINA with species identification of the fish and descriptions of their ecology. The field work is carried out by Nils Arne Hvidsten, Phoutalom Vongsay and Thyson Roberts.

Ministry of Industry and Handicraft, Hydropower Office, Vientiane, has been responsible for transportation and practical questions during the planning of the study and field work. We wish to thank our contractors, NORPLAN A/S and our collaborators for their contributions and participation in the project. Special thanks goes to Phoutalom Vongsay for assisance during field work and Dr Tyson R. Roberts is also acknowledged for his valuable contributions to this report.

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1. CONCLUSIONS

1.1 Present situation

1.1.1 Water chemistry

The water in Nam Theun and Nam Gnouang are relatively soft with low content of nutrients (oligotrophic levels) and low content of suspended sediments.

No remnants of war time pollutants could be found. The content of heavy metals are low.It could not be found any clear indications that remnants of dioxins from the use of Agent Orange up to 1970 in the Vietnam war is the source of a moderate degree of dioxin contamination in the catfish. The content are comparable to background levels that arise from atmospheric fallout and does not represent any danger with respect to human consumption of fish.

The water of Nam Gnouang are clean and does not show any noticable signs of pollution from human activities.

The Nam Hai and Nam Hinboun are more hardwater rivers in that they have a much higher content of calsium reflecting limestone geology in the catchment area. They are also much more sediment loaded. i.e. particlarily during the wet season. The nutrient content are higher (mesotrophic levels) than in Nam Theun and Nam Gnouang.

The content of heavy metals are low also in Nam Hinboun and does not indicate such pollution from human activities. The iron content of Nam Hinboun were high in the dry season, which may indicate intrusion of iron rich low oxygenated ground water. It may also indicate iron rich deposits in the catchment.

1.1.2 Hygienic pollution

Nam Theun upstream reservoir showed low values of coliform bacteria at all 4 samplings, as did Nam Gnouang except for the July observation. Nam Kading at Damsite, Nam Hai at Ban Namsanam and Nam Hinboun showed all higher values, a natural result of higher human activity.

During long dry periods lots of animals seek down to the river both for drinking and cooling. The buffalo is a typical example. Considerable amounts of animal faeces will accumulate in the near shore area in these periods. When water levels are rising, these pollutants are washed into the water. Thus relatively unaffected rivers may seem rather polluted in such periods from a water quality point of view. This effect is most likely the reason for the peak values in Nam Gnouang, Nam Hai and Nam Hinboun in the wet season.

1.1.3 Biology other than fish

Phytoplanton

The phytoplankton production in Nam Theun and Nam Gnouang were low. Typical concentrations of Chlorophyll was from 0.5 - 1.8 ug/l which reflect the low nutrient status of these rivers. Algal species composition were diverse with slightly dominance of *Chrysophyceae*, *Cryptophyceae*, and *Bacillariophycea*, which are typical for oligotrophic (nutrient poor) water bodies.

Nam Hai and Nam Hinboun had higher algal productivity, particularily Nam Hinboun which had peak values of chlorophyll of nearly 6 ug/l, which is a relatively high level in rivers. The high algal productivity in Nam Hinboun was also seen as algal growth on the fish nets during the test fishing.

Bottom dwelling animals

The relative density of bottom dwelling animals did also reflect the differences between the rivers with respect to productivity. In Nam Theun upstream the reservoir the density was 100 individuals per sample while it was recorded approximately 600 animals per sample in Nam Hinboun. The fauna was diverse with most freshwater groups represented. The insect groups *Chironomidae* and *Ephemeroptera* dominated at all stations. High densities of snails, mussels, and shrimps were also observed.

Zooplankton

Net hauls of zooplankton are collected to serve as baseline material for the future monitoring programme. The samples are not analysed at this stage. It is expected that zooplankton will be a more important ecological component of the reservoir area than it is to day after the damming.

Aquatic macrophytes

Only minor stands of aquatic macrophytes were observed in the rivers. This is because nutrients are low, the physical flow regime are variable and rather rough in the wet season, and the hydrosoil is sandy and unstable.

Nutrient enrichment may cause mass development of aquatic plants. However, excessive growth sometimes results after hydropower development even under quite oligotrophic conditions. Such changes are mediated by alteration of the flow hydrograph to enable aquatic macrophytes to persist in an actively growing state for a prolonged time.

Excessive growth of macrophytes can hamper generation of hydroelectricity by impeding flow and by blocking intake screens. Whether the hydroelectric impacts on the Nam Theun would give rise to mass development of macrophytes is unclear, however, existing evidence suggests this is unlikely to occur.

1.2 Fish fauna

The Nam Theun, Nam Kading and Nam Gnouang have a rich and diverse fish fauna that are still scientifically poorly known. Several not previously described fish species have been found. In the fish survey 72 fish species were recorded, which is obviously an underestimate. The fish serve as the most important protein source for the people in the area, and all species are heavily exploited for this purpose.

Catfish and carps are the most important fishtypes for human consumption. Catfish individuals bigger than 20 kg are commonly caught in the wet season. Even though fish migration has not been properly studied, there are indications that big catfish and several other fish species are long distance migrators, and perform annual migrations from Nam Theun to the mainstream Mekong. Several of the important species for human consumption seems susceptible to river damming and flow reductions.

Limited collecting in the lower Nam Hinboun (including the part into which water from the Nam Theun will be diverted by the Nam Theun Hinboun project) indicates that this river is inhabited by fishes characteristic of the Mekong mainstem and its large , muddy, lowland tributaries. The fishes of the upper Nam Hinboun (not sampled) may be very different from those in the lower reaches.

1.3 Impacts

1.3.1 Water chemistry

In the first phase after the damming it is expected to take place some shoreline erosion in the reservoir area. The water will be more turbid than to day and the river bottom will be subjected to siltification. It is not expected that the sediment content of the water will reach extreme values that are acute lethal to aquatic organisms, but all experience indicate that siltification impose stress on river organisms and reduces river productivity. The increase in turbidity and other parameters confined with erosion will make the water less suitable for drinking water purposes. The erosion is believed to decline after some years.

The often observed initial seepage of reactive nutrients, resulting from decomposition of organic terrestrial material in the inundated areas, which often is taking place in the first years after damming, will be negligible in the Theun Hinboun project. This because the reservoir will mainly be confined within the borders of the natural high flow river bank brims. Thus very little previously terrestrial areas will be inundated.

It is not likely that there will be any oxygen problems in the reservoir due to thermal stratification and decomposition of organic material. High degree of water renewal and low levels of organic material in the reservoir water are the reason for this conclusion.

Downstream the dam in Nam Kading, low water flow in dry season will give rise to high temperature development in the pools, which will physically give reduced oxygen content of the water. This may be critical to large fish speciments.

It is expected that in Nam Hai there will be a considerable erosion in the first years after the regulation. This will affect not only Nam Hai, but also Nam Hinboun. Also this erosion will decline after some years.

1.3.2 Biology other than fish

Rapids are the most productive areas in rivers with respect to fish food items, particularly bottom animals. The creation of the reservoir will reduce these areas and concequently reduce the biological productivity of the reservoir stretch.

In the first years after the regulation, there will be increased erosion of the river banks. This erosion will give rise to siltification of the river bottom by inorganic silt and sand which is not a favourable substrate for most organisms. This effect will also act negatively on the aquatic life in the downstream reaches of Nam Kading.

Increased turbidity in the water will decrease the light available for photosynthesis by river flora, which will result in lower production on all the other trophic levels in the river ecosystem.

As the reservoir will mainly be confined within the borders of the natural high flow river bank brims, we do not expect an initial increase in biological production due to nutrient leakage from the very restricted inundated terrestrial areas.

In Nam Hai permanent water flow will in the long run act positively with respect to aquatic life and fish production. It is , however, important that the river then are not allowed to dry out, for example in case of turbine maintenance. Only a short dry up will destroy fish fauna and other aquatic life.

Several problem species of aquatic macrphytes are present in the rivers. Taken into account the unstable physical conditions in the rivers combined with relatively low levels of plant nutrient it is not likely that there will be any problems confined with aquatic weeds due to the regulation. In irrigation canals on the Nam Hai plain, excessive growth of macrophytes can be a problem, as these canals in periods will have stagnant water rich in nutrients from the agricultural fields.

1.3.3 Fish fauna

Generally, the people living along the rivers in the area affected by the Theun Hinboun hydropower project, are extremely dependent on the fish fauna as the main source for protein. The existence of a very special, and partly endemic fish fauna in the reservoir area was found. This include several new fish species, that are not previously described in the literature. Indications of fish migrations between the reservoir area and the Mekong have been found. Resident people harvest the fish fauna effectively, and virtually all species are important as human food sources.

The hydropower project will have strongly negative impacts on Nam Theun fish ecology and riverine fisheries.

Downstream drifting of eggs and early life stages of fish through the turbines and over the dam will probably reduce fish production and hence harvest of fish in the reservoir, because there will be no, or very limited possibilities for reentry of adult fish to the reservoir area. Species diversity in the reservoir is expected to be significantly reduced due to loss of riverine habitats. It seems unlikely that the reservoirs resulting from this hydropower project can sustain highly productive fishing over time.

In Nam Hai permanent water flow will in the long run act positively with respect to fish production. It is , however, important that the river is not allowed to dry out at any time, for example in case of turbine maintenance. Only a short dry period will destroy fish fauna and other aquatic life.

In Nam Hinboun the fish production will be little affected. It may be some decline in production in the first years of the regulation due to siltification.

1.4 Mitigation measures

Based on the available knowledge, mitigation measures are not expected to change the negative ecological aspects significantly. The general lack of basic biological information, especially on timing of fish migrations, spawning areas and feeding areas do not allow us to suggest detailed mitigating measures.

However, some general measures are suggested. Among these are minimum water release of 6 - 15 m^3/s of water over the Nam Theun dam at all time and construction of an artificial fish passage through the Nam Theun dam. Release of introduced fish species should not be permitted. Further detailed mitigating measures cannot be suggested until additional knowledge about some basic elements is gained. A monitoring programme initiated immediately after the completion of the hydropower plant will probably create a basis to reduce some of the negative ecological impacts.

To take advantage of the increased waterflow in Nam Hai it should be built some device that ensures the river not to dry up at any time of the year. Some power station bypass should be considered to allow for water flow in periods of turbine maintenance. It should also be considered to build some dams and weirs that will dampen the rapid diurnal flow fluctuations that are likely to occur in Nam Hai.

It is expected that there will be an increase in the human activity in the reservoir region and in the Nam Hai/Hinboun region. This will leed to an increase in the bacteriological pollution rendering the river water less suitable for drinking water purposes. At least in the villages drinking water should be supplied from deep wells along the river (infiltrated water), and not directly from the river.

2. INTRODUCTION

The purpose of this study is to assess the impact of the Theun - Hinboun Hydropower Project on the aquatic ecosystems in the affected water bodies, and to propose mitigating measures to reduce possible negative environmental impacts. This includes assessing the effects on water quality and aquatic life with particular emphasis on fish.

There has been carried out an Environmental Impact Assessment by Norconsult International A/S prior to this, which however, showed up to lack some important data particularly from the wet season concerning water quality and fish migration. Thus, this is a supplementary study which shall make use of both new and previous collected data to verify or otherwise the main conclusions from the Norconsult EIA-study.

Norwegian Institute for Water Research (NIVA) and Norwegian Institute for Nature Research (NINA), which has been the leading institutions on Hydropower EIA's in Norway, have decided to cooperate for the Water Quality and Aquatic Life Study. This to ensure the quality and reduce the costs in relation to the comprehensive Terms of Reference for the study.
The study focus's on assessing the impacts of Stage 1 - diversion of 100 m^3/s from the Nam Theun to the Nam Hai and Nam Hinboun. In addition we will give comments on what is likely to happen if stage 2 - diversion of 200 m^3/s, is going to be realized.

The Terms of Reference are very ambitious, particularly concerning the baseline study of aquatic biota and migratory behaviour of important fish species. To be able to provide undisputable data on Keng Vangfong falls as a barrier for fish migration as well as data on the necessity of minimum release from the dam in the dry season, radio - telemetry (radio tagging) studies are necessary. These studies are, however, rather expencive and was not possible to perform within the budget available.

The studies are carried out in close cooperation with the local institutions:

- Hydro Power Office (HPO)
- Burapha Development Consultant Co. LTD
- Ministry of Agriculture and Forestry - Dept. of Irrigation - Lab of Water Quality Analysis
- Norplan A/S
- Norconsult A/S

The field work has been carried out in the period Dec 1994 - Aug 1995. Based on information gained from the present survey, earlier studies, and general information on ecology of the important fish species, this report describes the impacts and proposes mitigation measures to reduce negative effects on water qaulity, aquatic life and fish in Nam Theun / Nam Kading and Nam Hai / Nam Hinboun. Minimum release of water over the Nam Theun dam and the necessity of establishing artificial fish ways will be addressed. Possible enhancement of fish stocks in the reservoir as compensation for reduced natural production are also discussed. Technical measures to reduce/prevent loss of fish through the turbines will also be an important future goal.

The work is performed in good coordination with the other ongoing speciality studies.

3. SHORT DESCRIPTION OF THE RIVER REGULATION

The river Nam Theun is one of Laos' largest tributaries to Mekong with a total catchment area of 14650 km^2 . The proposed Theun Hinboun Hydropower Project is located about 100 km upstream the confluence with Mekong. In this area a narrow mountain ridge separate the Nam Theun basin from the lower Nam Hinboun basin which offers the opportunity to exploit the difference in elevation of about 240 m for power generation through a trans-basin diversion. About 10 km of waterways are planned to divert the Nam Theun flow into Nam Hai, a tributary to Nam Hinboun, and eventually back to Mekong. Figure 1 gives an overview of the situation.

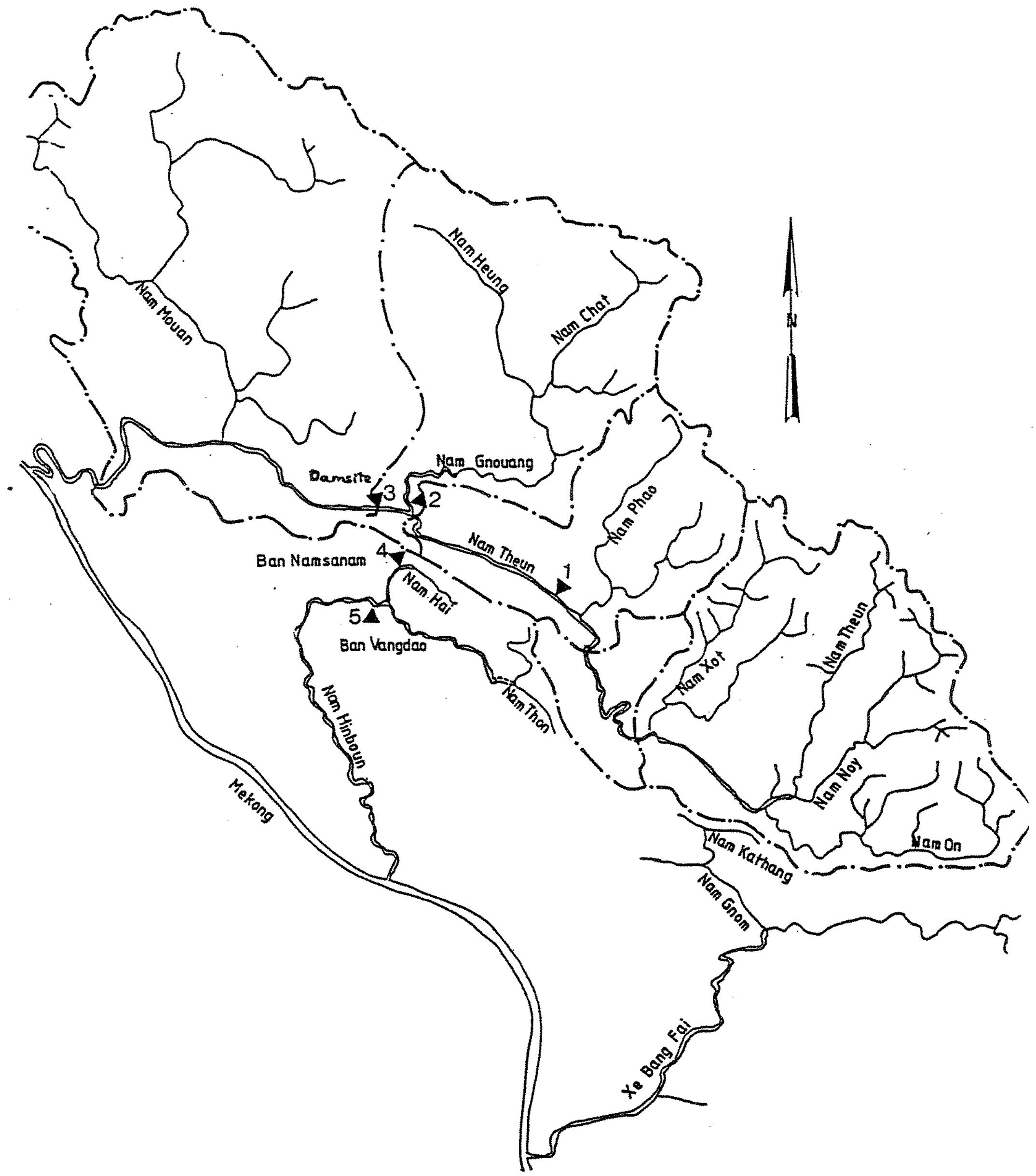

Figure 1. Overview of the area for the Nam Theun Hinboun Hydropower Project. 100 m3/s is going to be diverted from Nam Theun to Nam Hai.

At the dam site the catchment of Nam Theun is 8937 km2 and the mean annual flow is about 460 m3/s. 100 m3/s is going to be diverted from Nam Theun to Nam Hai via a low, gated intake dam throug a 5.2 km long low-pressure headrace tunnel followed by a 300 m long inclined pressure shaft and a 650 m long pressure tunnel to a surface power station with an installed generating capacity of 210 MW at 233 m net head. The water will be discharged to Nam Hai through a 4 km long tailrace canal.

Theun Hinboun hydropower project is a run-of-river development with only a small headpond to be used for diurnal regulation. The headpond area at normal headwater level is 6.3 km2 and will be confined within the existing river banks of Nam Theun, Nam Gnouang and somewhat into the minor tributaries Nam Ao and Nam Pheu. The normal headwater level will not exceed natural annual flood levels and the dam has been designed to pass maximum floods with minimum increase in natural flood levels. In fact the dam will be drowned during extreme high flow events due to natural constraints in the river channel downstream the dam. This concern has been the main design criterion for selecting the headpond elevation and consequently the height of the intake dam. Fig. 2 gives an overview of the reservoir area.

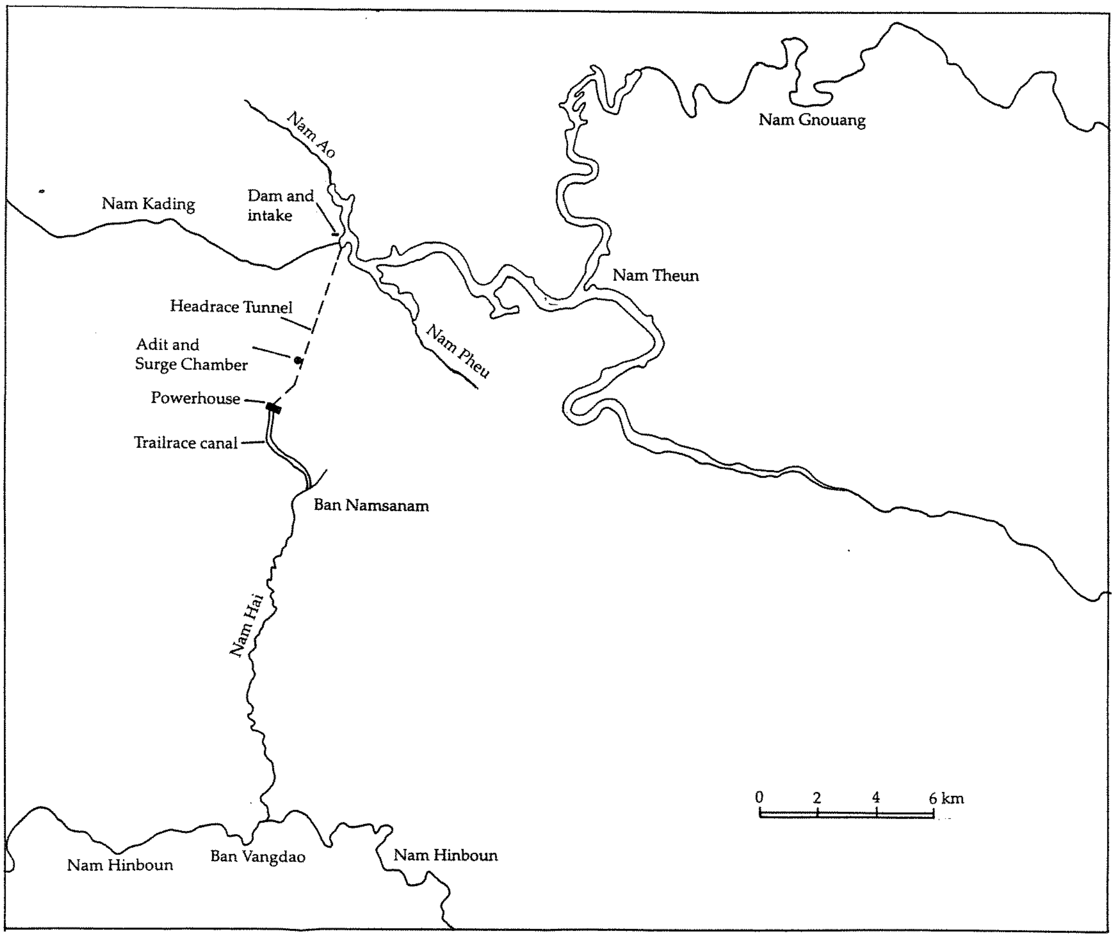

Figure 2. Overview of the reservoir area.

The concrete intake dam has a total length of approximately 300 m and a 25 m maximum height above foundation. A 2x12m long gated section and a 185 m long rubber gate section will allow passage of floods with little influence on present flood levels upstream the dam. During flooding the 5 rubber gates will be deflated (5x250 m^3/s). With increasing flood the two segment gates will be opened (2x1000 m^3/s), which will, in addition to passage of floods, enable flushing of sediments.

During the wet season the Theun Hinboun (TH) will normally operate at full capacity 24 hours a day and discharge a constant flow 100 m3/s to Nam Hai at Ban Namsanam. During the dry season when the river flow in Nam Theun is below 100 m^3/s, TH will reduce or stop generation during night time which is the off-peak period in Thailand.

Nam Hai is a small river with a catchment area of 85 km2 at the entrance of the tailrace canal. The villagers have informed that overbank flooding occurs most years but lasts each time only from a few hours to a couple of days. The maximum water level reported at Ban Namsanam during a large flood in 1991 was 160.3 m. This is approximately 8 m above the river bed, and 1.2-1.8 m above the brim of the river bank, i.e. above ground level in the village of Ban Namsanam. The river channel is here about 5.5 m deep.

No flow records exists from Nam Hai, but Norconsult (1993) has estimated a duration curve based on measurements in a neighbouring catchment. According to this maximum flow is approximately 250 m3/s whereas the river has more or less no flow for 4 months each year. At the end of the dry season the river is completely dry, and the local recidents dig wells in the river bed for water supply. Mean annual flow is approximately 4 m^3/s. The 100 m^3/s diversion from Nam Theun will only cause overbank flooding a few days during natural peak flow in Nam Hai. If step 2, diversion of 200 m3/s, some river brim enforcement and channel excavation is necessary to prevent to much flooding.

Nam Hinboun at the confluence with Nam Hai (Ban Vangdao) has a catchment area of 944 km2. The river bed bottom is here at elevation 144 m whereas the brim of riverbank is approximately at 154 m which gives a river channel depth of 10 m. Highest recorded flood was in 1991 which reached 157 m, i.e. 3 m above the brim of the river bank. Several floods in 1991 resulted in paddy rice failure. The highest recorded level in 1992 was 154 m, i.e. at the level of riverbank. Only during very short periods, and not each year, will diversion of 100 m3/s from Nam Theun cause any flooding problems in Nam Hinboun.

Study area

The Nam Theun flows into the Mekong mainstream about 180 km downstream from Vientiane. About 20-30 km upstream of the confluence with Mekong there is a section of rapids called the Keng Vang Fong, characterized by big boulders and rapids for several kilometers. Many fish species characteristic of the Mekong mainstream and its large lowland tributaries inhabit the mouth of the Nam Theun (Nam Kading) and the lowermost Nam Theun up to the Keng Vang Fong waterfalls.

Nam Theun upstream of the dam site is characterized by relatively steep banks consisting of fine silt and sand. In the head pond area, the river varies between rapids and pools. The length of the pools ranges from a few hundred meters to more than one km. In the rapids, there is old eroded limestone bedrock, providing a high variety of different habitats for hiding and feeding for fishes. The Nam Gnouang is steeper than the Nam Theun and the shift between rapids and pools is more frequent.

In the Nam Kading upstream of Keng Vang Fong to the dam site, the river banks consist of bedrock and huge stones. The river is generally narrower and faster than in upstream and downstream areas. Three locations were electrofished in mainstream, two downstream from the dam site and one upstream of the first two falls of the downstream section of Keng Vang Fong. These falls were low, less than 2 meters, with back eddies and probably provide passage for fishes having strength to ascend rapid water. In total there are about ten rapids in Nam Kading, and none of these are bigger than the two lowest ones. Upstream migrating fish from the Mekong are therefore assumed to be able to pass the Keng Vang Fong.

In the Nam Hai and the Nam Hinboun there are no waterfalls downstream of the confluence of the two rivers and the outlet to the Mekong. Nam Hai dries up in the dry season and pools with stagnant water were observed in February 1995. The river banks and bed consisted of silty materials. About 1 km downstream of the confluence with the Nam Hinboun there is bedrock on southern side of the river bank and deep pools.

The Nam Theun between Keng Vang Fong and the confluence with the Mekong has silty banks, except for an area just downstream of the falls where rapids with bedrock and large stones are present.

The Theun Hinboun project is designed to divert 100 m^3/s to the neighbouring Nam Hai/ Nam Hinboun. There are also plans for other hydro-power projects in Nam Theun and Nam Gnouang upstream of Theun Hinboun. The Nam Theun 2 project will divert water from river upstream of Theun Hinboun. A minimum release of water giving minimum flows of 6 m^3/s downstream of the Nam Theun 2 dam is proposed. The Nam Theun 3 project (situated in the upstream part of Nam Gnouang) will provide a large reservoir and give increased water discharge in the dry season in Nam Theun. Downstream of Theun Hinboun the Nam Theun 1 will block the Nam Theun with a dam 80-120 m high at a point situated 36 km from the confluence with Mekong.

In the present report, we primarily discuss the effects from the hydro-power project Theun Hinboun.

4. MATERIAL AND METHODS

4.1 Water quality study

The sampling stations are shown in Figure 1, whereas the station visit schedule is shown in Table 2. Table 3 shows the parameters to be sampled and analysed.

Table 1. Sampling stations

No.	Location
1	Nam Theun in the upper part of the reservoir
2	Nam Gnouang at the first rapid upstream the confluence with Nam Theun
3	Nam Kading downstream the damsite (and diversion tunnels)
4	Nam Hai just downstream the entrance of the tailrace canal
5	Nam Hinboun Downstream the entrance of Nam Hai

Table 2. Sampling periods and stations

Period No	Period	Access by	Participants	Localities
1	December 1994	Car, long tail canoe	HPO, NIVA, Burapha	All 5 stations
2	March 1995	Car, long tail canoe	HPO, NIVA, Burapha	"
3	May 1995	Car, long tail canoe	HPO, Burapha	"
4	July 1995	Car, long tail canoe	HPO, NIVA	"

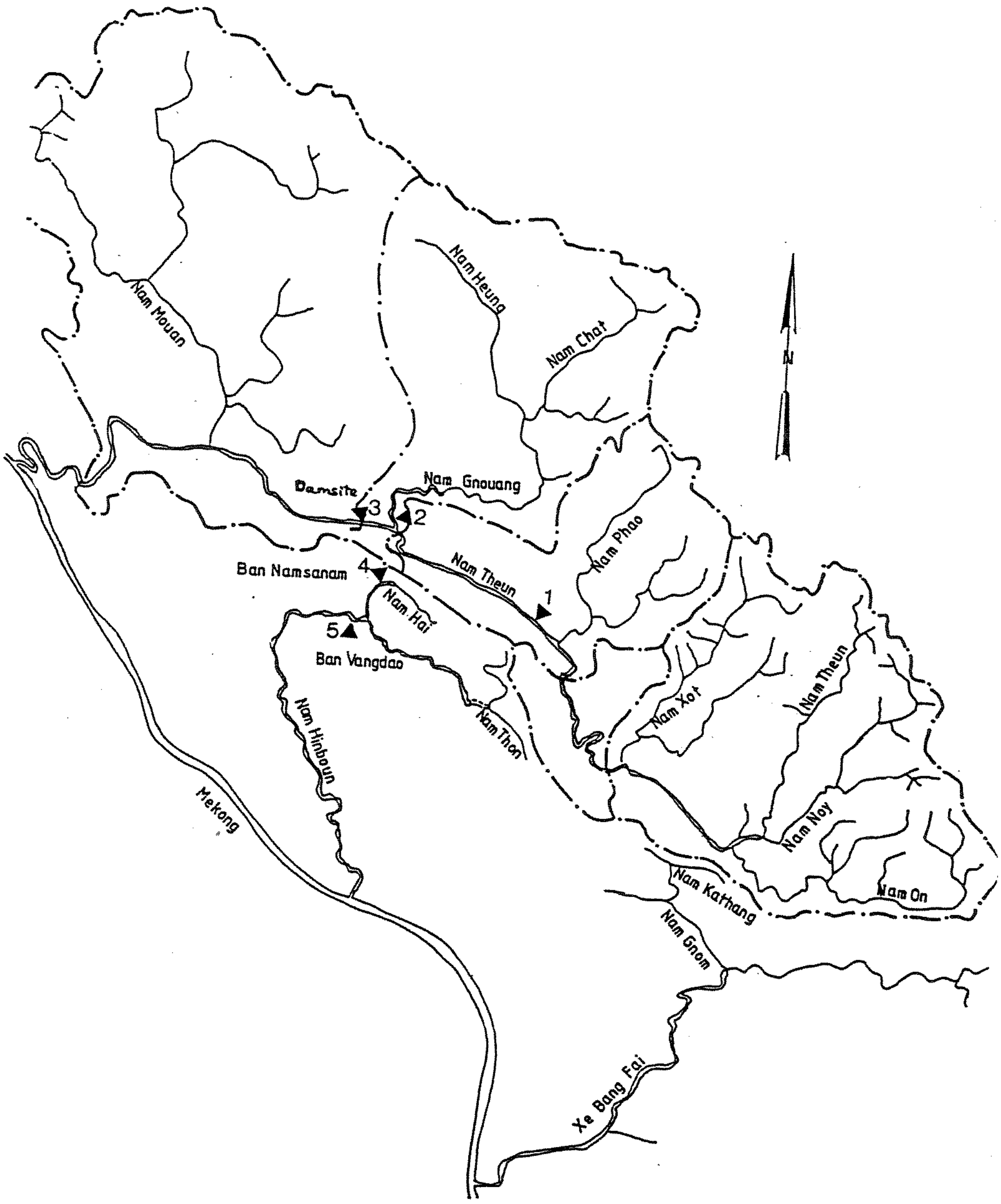

Figure 3. Sampling stations for water quality study

Table 3. Parameters to be sampled/analyzed

Parameter	Station	Dec. 94	March 95	May 95	July 95
Basic Characteristics					
pH	1,2,3,4,5	x	x	x	x
Konductivity	1,2,3,4,5	x	x	x	x
Turbidity	1,2,3,4,5	x	x	x	x
Total organic carbon	1,2,3,4,5	x	x	x	x
Suspended Sediments					
Total Suspended Solids	1,2,3,4,5	x	x	x	x
Suspended ignition Rest	1,2,3,4,5	x	x	x	x
Nutrients					
Total Phosphorus	1,2,3,4,5	x	x	x	x
PO4-P	1,2,3,4,5	x	x		
Total Nitrogen	1,2,3,4,5	x	x	x	x
Nitrat	1,2,3,4,5	x	x		
Major constituents					
Ca	1,2,3,4,5	x	x		x
Mg	1,2,3,4,5	x	x		x
Na	1,2,3,4,5	x	x		x
K	1,2,3,4,5	x	x		x
Cl	1,2,3,4,5	x	x		x
Alcalinity	1,2,3,4,5	x	x		x
SO4	1,2,3,4,5	x	x		x
Trace elements					
Cu	1,5	x			
Pb	1,5	x			
Al	1,5	x			
Zn	1,5	x			
Ni	1,5	x			
Cr	1,5	x			
Sn	1,5	x			
Cd	1,5	x			
Fe	1,5	x			
As	1,5	x			
Mn	1,5	x			
Phytoplankton					
Chlorofyll a	1,2,3,4,5	x	x		
Species composition	1,2,3,4,5	x	x		
Bacteria					
Fecal coliforme bacteria (44 °)	1,2,3,4,5	x	x	x	x
Zooplankton					
Collection of baseline material	1,2,3,4,5	x	x		
Zoobenthos					
Collection of baseline material	1,2,3,4,5		x		
War time pollutants					
Dioxine in fish liver	3	x			

X = Planned sampling

During the field work for water quality, the sampling also included phytoplankton, zooplankton and bottom animals. The samples are fixed and stored as baseline data for the future monitoring programme. Only a simple analysis can be undertaken here.The aquatic weed study was restricted to supplement already established species list from the existing

Norconsult/Burapha prefeasibilty study and other litterature, by simple observation during field work otherwise carried out. From the planned alterations in the hydrological regime, and the effects on water chemistry, the possible problems connected to these biological components are described.

4.2 Fish study

Fish sampling was performed using electrofishing gear (Paulsen Type) and nets with multi-mesh sizes 5- 50 mm, 30 m long and 1.5 m deep, as well as 100 m long and 0.6 m deep nets with a mesh size of 24 mm. Fishing by rod and lures, and by long line with fish bait were also used. In addition, fish were bought from fishermen who had used different methods of harvest. The most efficient means of fishing was by electric fishing gear which allowed the opportunity to catch fish in rapids (sites in Figure 1). In the Nam Hinboun, high conductivity prevented normal range efficiency of the fishing gear. Fishing with nets was difficult in the Nam Hinboun due to drifting alga, restricting their use to only a few hours each time.

Most sampling areas in the Nam Theun were visited by boat, except for two sites (at dam site and Nam Gnouang wading area). These sites and the sites in the Nam Hai and the Nam Hinboun were reached by car. The main field work was carried out in February 1995, while additional sampling was performed in June, July and August 1995.

Information on breeding time of important fish species were gathered by questioning local fishermen. The fish samples are stored at the Ministry of Industry and Handicrafts, Hydropower office (HPO), Vientiane.

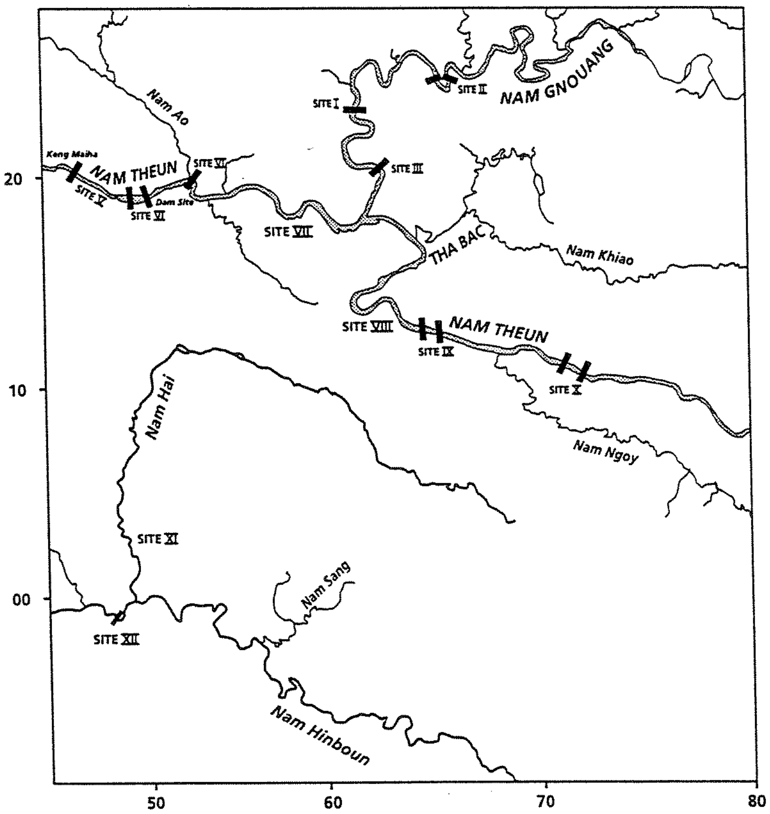

Figure 4. Locations for fish sampling in the affected rivers.

5. RESULTS

5.1 Water discharge in the sampling period

Hydrology, discharges, etc. is taken care of in a separate study by AB Hydroconsult, and should not be treated here. However, water flow impacts the concentration of many water quality parameters, and it is therefore instructive to have overview of the discharge during the sampling period for explanation purposes. We have not been able to get this data for more than one gauging station from Nam Theun just downstream the damsite (see Fig.5).

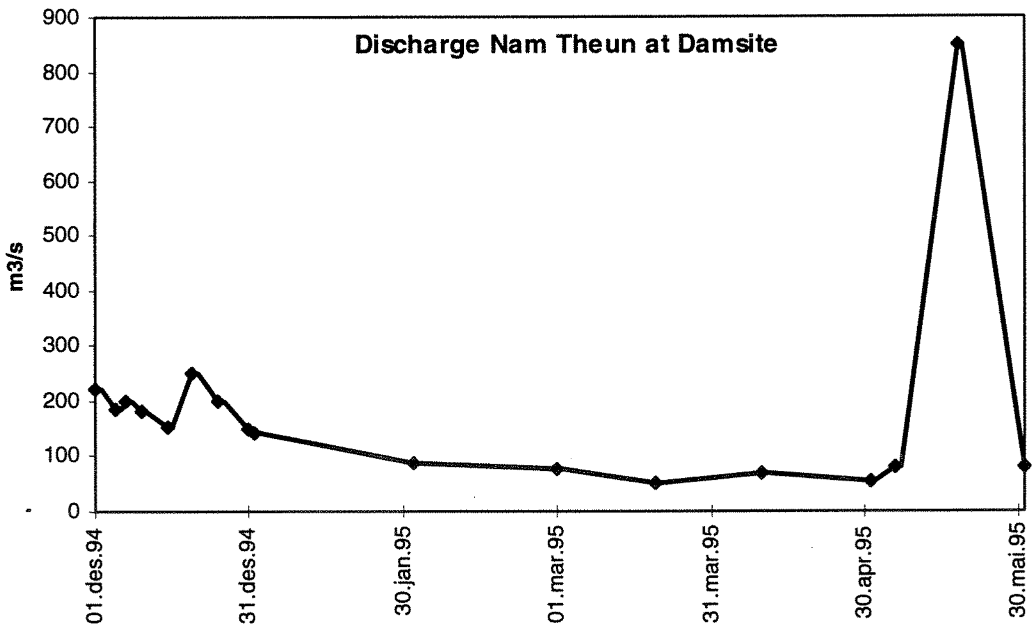

Figure 5. Water discharge in Nam Theun from December 1994 to May 1995 at the gauging station at Keng Maiha, just downstream the damsite (Data provided by Norplan).

Despite having no discharge data from the other rivers, we believe that the pattern is somewhat similar to the Nam Theun curve.

The prefeasibility report from Norconsult (Chapter 4 Hydrology) indicates that peak flows at Keng Maiha can be as high as 3000 m3/s in July - September. It is quite clear that we do not have any such conditions in our sampling period.

Our sampling period lasted to the end of July 1995, and the flooding intensity during the wet season this year must be characterised as low compared to other years. Some of the parameters susceptible to erosion are therefore most likely lower that would have been found in more normal years.

5.2 Temperature in river water

Temperature is one of the most important factors to take into consideration when a high altitude river is diverted to a low altitude river. Several species are adapted to narrow temperature ranges, specific temperatures may be the switch on of breeding season etc. Our temperature records are given in Fig.6 below.

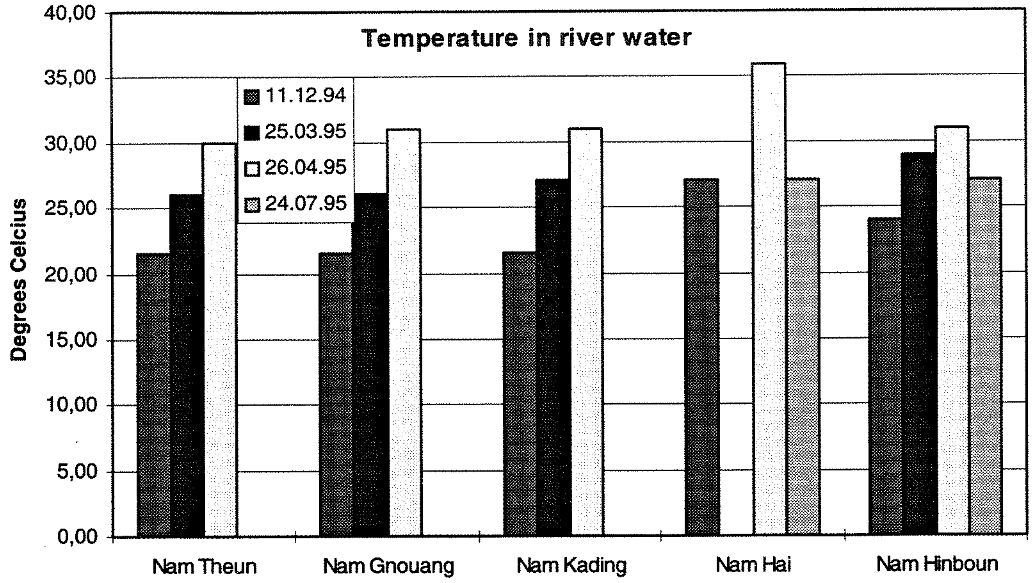

Figure 6. Temperature records in the rivers at different times of the year.

Being situated in the subtropical region the annual variation in river temperature is not very great in any of the rivers, i.e. from 21-31 °C. One exception is a 35 °C record in Nam Hai which in effect was in a stagnant river pool. The river was dry between the pools. All rivers had a temperature of more than 30 degrees in the first part of the summer.

At this high temperatures the physical solubility of oxygen is low whereas the consumption of oxygen from decomposition of organic material is very high. Another moment confined with high temperature is that the density of water changes very much per unit temperature change. These three facts implicate that stagnant situations with low oxygen and fish kills during night time (no oxygen production via photosynthesis) will happen more easily in tropical and subtropical regions as compared to temperate and northern regions.

The nutrient poor water of Nam Theun, its low organic content combined with a high degree of water renewal, will secure that no such situation is likely to occur in the Theun Hinboun reservoir. In the Nam Theun 2 reservoir, however, this should be a matter of concern.

There are only moderate temperature differences between and Nam Theun and Nam Hai / Nam Hinboun, and it is not likely that these differences will bring about any severe ecological damage. The most pronounced effect will be that Nam Hai will have a permanent water flow after the diversion.

5.3 Transparency and turbidity

Erosion products, i.e. suspended sediments as well as phytoplankton will make the water turbid and the transparency will decrease. Increased erosion due to the regulation will give a more turbid water. Aquatic plants will experience reduced light. Increased turbidity will reduce the applicability of the water for several human use categories.

Secchi depth transparency and turbidity records from the rivers are given in Fig.7 below.

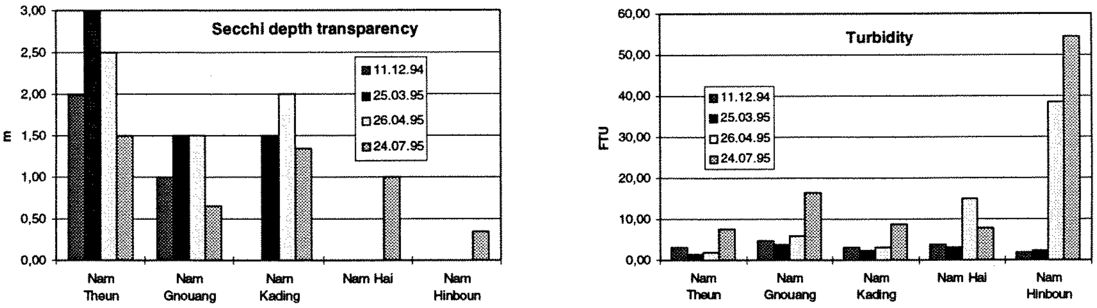

Figure 7. Secchi depth transparency and turbidity measurements in the rivers at different times of the year.

At the end of the dry season the secchi depth transparency in Nam Theun was 3 m and the turbidity as low as 1.4 FTU. In this respect the water complied almost with drinking water standards which most frequently require less than 1 FTU. In Norway the requirement for good drinking water quality is <0.5 FTU. Nam Gnouang is somewhat more turbid, whereas the Nam Hinboun is very turbid in the wet season.

Inspecting the 2 parameters will show that there is an inverse relationship between them. This is shown more in detail in Fig.8 with an degree of explanation of 91% (R-squarred). In the same figure is shown the correlation between suspended sediments which is even better. In fact it is the concentration of suspended sthat steers both the turbidity and secchi depth.

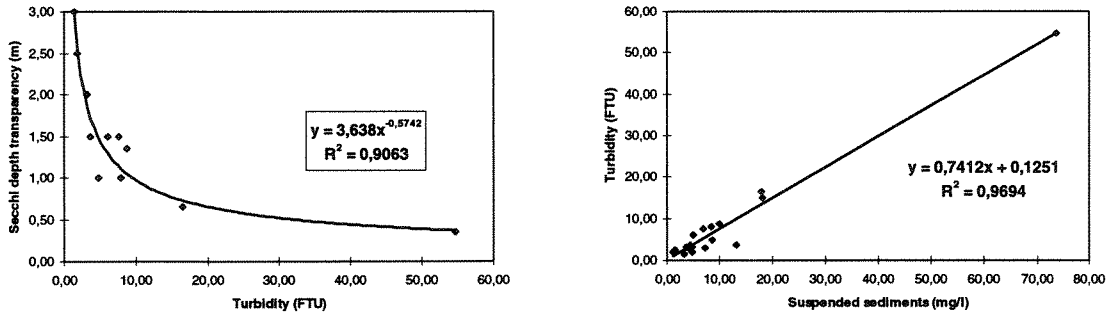

Figure 8. The relationship between turbidity and secchi depth transparency and between suspended sediments and turbidity.

5.4 Basic water chemistry

The basic water chemistry which often comprise the major ions and pH and conductivity (see Primary Table in Appendix) is determined mainly by the geology in the catchment area. In Fig.9 we have shown some of these constituents.

All rivers have pH values well above the neutral point of 7. The alkalinity are high, particularly in Nam Hai and Nam Hinboun. No acidification problems due to acid rain will ever take place in these watercourses.

Nam Theun and also Nam Gnouang are soft water rivers with relatively low conductivities. Nam Hai and Nam Hinboun have high conductivities and must be classified as rather hard water rivers.

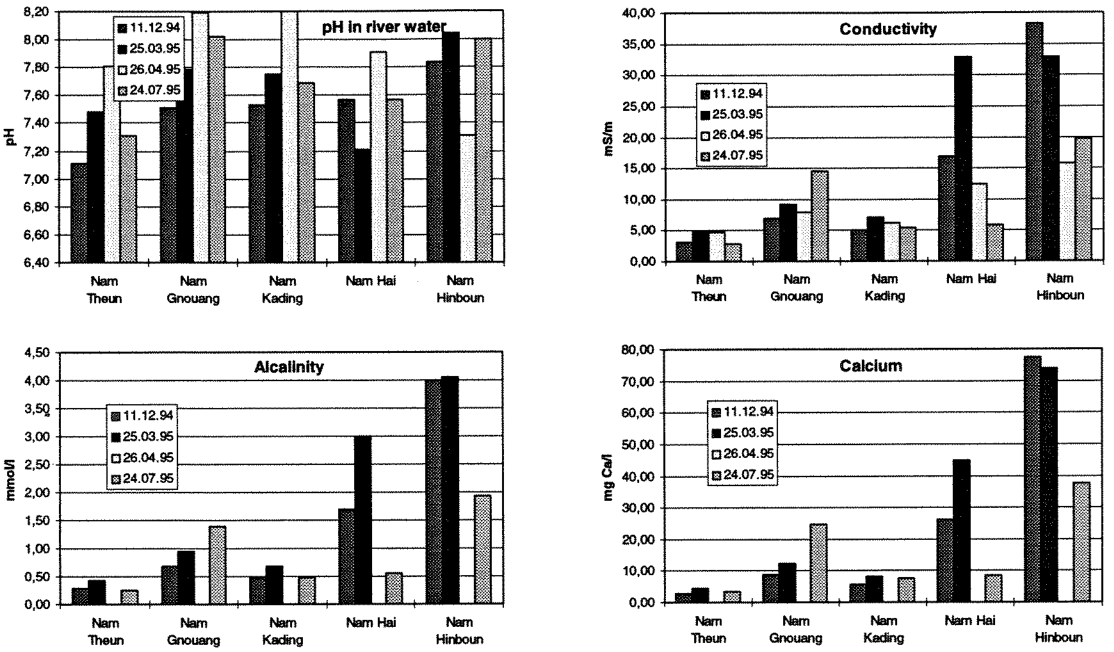

Figure 9. Some basic water chemistry parameters from the rivers at different times of the year.

The calcium content of Nam Theun is relatively low and this river is classified as lime poor according to international standards. Nam Gnouang is moderately lime rich, whereas Nam Hai and Nam Hinboun are definitely lime rich rivers. These findings is in good agreements with the high content of lime stone in the catchments.

5.5 Nutrients

Phosphorus and nitrogen concentration are the most important factors regulating freshwater primary production, particularly phosphorus. The results are given in Fig.10 below.

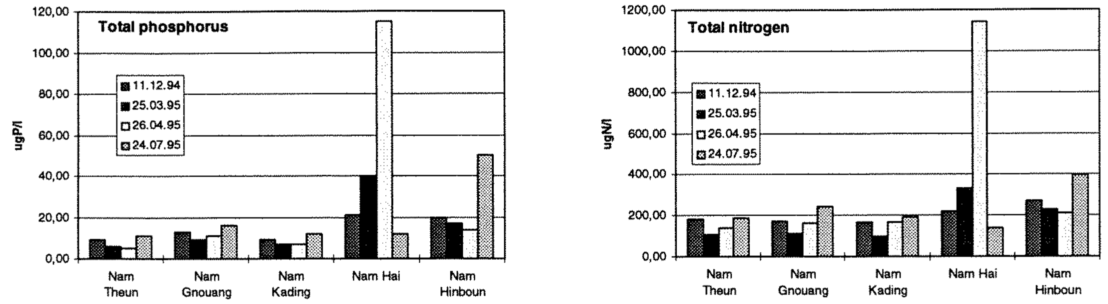

Figure 10. Concentrations of total phosphorus and total nitrogen in the rivers at different times of the year.

Nam Theun and Nam Gnouang are both nutrient poor rivers with low concentrations of phosphorus and nitrogen. Nam Gnouang have slightly higher values than Nam Theun. No sign of man made eutrophication can be detected in these two rivers.

Nam Hai and Nam Hinboun are more rich in nutrient salts. Of particular interest is the high value of both phosphorus and nitrogen in the beginning of the wet season in Nam Hai. This is very parallel to what was found for bacteria (see this section). During long dry periods lots of animals seek down to the river both for drinking and cooling. The buffalo is a typical example. Considerable amounts of animal faeces will accumulate in the near shore area in these periods. When water levels are rising, these pollutants are washed into the water. Thus relatively unaffected rivers may seem rather polluted in such periods from a water quality point of view.

Nam Theun, being a nutrient poor river periphyton production in rapids will be the most effective primary producer, as periphyton are able of utilising low nutrient concentrations much more efficient than planktonic algae (Lindstrøm and Johansen 1993, Berge and Källqvist 1995). The reservoir area will therefore be of lower productivity after the damming than to day. Increased plankton productivity will not compensate for this loss. The residents of the area will experience this as decline in the fisheries.

The nutrient content of the diverted water will not give rise to any problems in the receiving rivers Nam Hai and Nam Hinboun.

5.6 Suspended sediments

Suspended sediments, or particulate material, may reduce the applicability of water for several human purposes, as e.g. drinking water, raw water for most industrial purposes, particularly food processing activities. Siltification of a watercourse that are not adapted to turbid water, will also often give damage to the biological species originally present.

The results from the analysis are given in Fig.11. The results are divided into particulate organic (POM) and particulate inorganic material (PIM). In rivers PIM is made up of erosion material, whereas POM most often are confined with algae, either planktonic or detached periphyton. Terrestrial detritus, often called allochtonous matter, may also constitute parts of the POM in rivers.

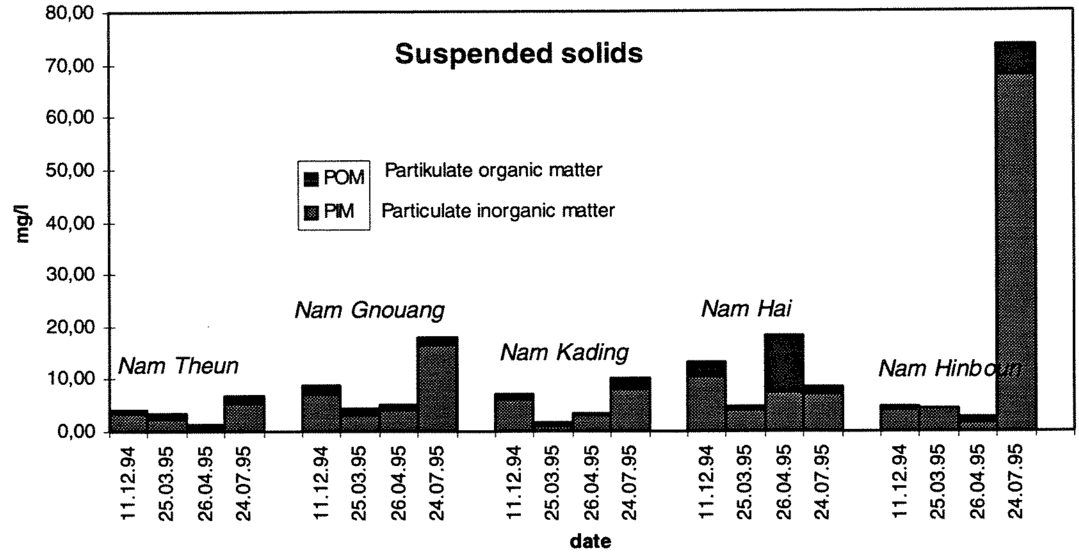

Figure 11. Concentrations of suspended sediments (Watmans GFC-filter 1.2 um pore size)

None of the rivers comply with the international standards for untreated drinking water. However Nam Theun must be classified as a clear water river, Nam Gnouang a little more affected but still low content of particles. Nam Hai and Nam Gnouang have higher sediment content. Most of the particulate matter is inorganic, which indicate erosion material rather than algae and detritus. Nam Hai and Nam Hinboun show however some algal material.

It should be noted that much more comprehensive data on suspended sediments are given in the hydrology study (AB Hydroconsult). 120 Measurements over three years (from 1988-1990) in Nam Theun at Ban Signo gives peak values of more than 90 mg/l. Most values are however below 40 mg/l. Their values seem to be a little higher than shown by our rather few measurements which do not seem to have hit peak values. However as they represent both dry and wet season, they should be of indicative value with respect to water quality.

No direct damage to fish is likely to occur below 35 mg/l (Alabaster and Lloyd 1983). In extreme clear water rivers and lakes in Norway, ecological damage due to siltification is showed several times in connection with hydropower development schemes (Aas 1979).

What happens to the erosion of river banks in the reservoir area will be an important factor in how the diversion will affect Nam Hai and Nam Hinboun. If the water quality of the diverted water will be as it is to day, or close to it, the water itself will dilute Nam Hai and Nam Hinboun. Nam Hai will have permanent flow, which will be an advantage with respect to most aquatic life, fish included. For Nam Hinboun the erosion that will take place in Nam Hai itself will most likely be of greater importance with respect to siltification damage than the water diverted from Nam Theun.

It is reasonable to believe that some ecological stress may be imposed on the aquatic life in Nam Hinboun after the regulation, at least in a transition phase the first years after the diversion. Recovery is likely to occur after the initial erosion in the river channel in Nam Hai and the reservoir area in Nam Theun is decreasing. Reduced fish catch over a period of about 10 years is the way the local residents will experience this ecological stress.

5.7 Heavy metals and trace metals

Leakage of heavy metals are often confined with leakage from War time dumps and mining activity or from natural ores in the catchments. In the Nam Hinboun catchment there are reported some tin mining activity, whereas in the Nam Theun catchment there may be some war time pollutants. Several heavy metals are environmental toxicants and tend to accumulate in biota. Heavy metal polluted water can thus also be a threat to human health. When transferring water from one basin to another, the content of heavy metals should be checked in both the diverted river as in the recipient.

The results are given in Table 4 below. In both rivers the concentrations of heavy metals are low and indicate no significant pollution from human activity. One exception is the high iron content in Nam Hinboun. This is most likely of natural origin and may indicate iron rich areas in the catchment. It can also be a result from intrusion of iron rich, poor oxygenated, ground water in the dry season as the river drain areas with mighty loose deposits.

If this high iron content comes from ground water, it may be a problem for water supply from ground water wells.

Table 4. Some heavy metals and trace metals in Nam Theun (Damsite) and Nam Hinboun (Ban Vangdao) Dec. 1994.

Name	Notation	Units	Nam Theun	Nam Hinboun
Copper	Cu	ug/l	<0.1	<0.1
Lead	Pb	ug/l	0.06	0.05
Zink	Zn	ug/l	<0.5	<0.5
Nickel	Ni	ug/l	<0.5	1
Chromium	Cr	ug/l	<0.5	0.9
Tin	Sn	ug/l	<0.5	<0.5
Cadmium	Cd	ug/l	<0.01	<0.01
Iron	Fe	ug/l	94.4	640
Arsen	As	ug/l	0.3	0.4
Manganese	Mn	ug/l	1.9	7.2

5.8 Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/PCDF) in fish

Liver of a 3 kg big catfish (*Mystus micropthalmus*) from Nam Theun caught at Tabac Dec 11 1994 was analysed for PCDD/PCDF at the Norwegian institute for air research. The results are shown in table 5, recalculated to toxicity equivalents (TEQ) according to TEFs (toxicity equivalency factors) in the Nordic model (Ahlborg, 1989).

Table 5. *PCDD/PCDFs in liver of catfish from (locality, date) given as TEQs (cf. text) ng/kg wet weight.*

Congeners	Concentration
2378-TCDD	0.07
12378-PeCDD	0.15
123678-HxCDD	0.04
123789-HxCDD	0.05
1234678-HpCDD	0.02
OCDD	0.01
Sum PCDDs	**0.34**
2378-TCDF	0.01
23478-PeCDF	0.09
123478/9-HxCDF	0.03
123678-HxCDF	0.02
234678-HxCDF	0.01
Sum PCDFs	**0.16**
Sum PCDD/PCDFs	**0.50**[1)]

[1)] 0.51 according to the proposed international model (cf. Ahlborg et al., 1992).

With 2.9 % fat in the liver the sum corresponds to 17.2 ng TEQ/kg lipid.

This is a moderate or low concentration. We have no reference values for catfish or other species from south east Asia, but "normal" values in for instance liver of Atlantic cod from areas far from point sources are 10-20 ng/kg wet weight (Knutzen, 1995), corresponding to about 20-40 ng/kg lipid. Levels in the same order of magnitude are found in other marine fish and shellfish from coastal reference localities (Knutzen, 1995).

The concentration is also moderate in relation to consume. A Nordic expert group has proposed 35 pg/kg body weight as the upper limit of tolerable weekly intake as a life-long exposure (Ahlborg, 1989). For an adult of 60 kg this corresponds to maximum 2.1 ng per week. Consequently, one may eat 4 kg catfish liver per week and still be within the limit (not taking into account other sources).

It should be added, however, that the liver also contained non-ortho PCBs amounting to 0.08 ng TEQ/kg w.w. (according to the model proposed by Ahlborg et al., 1994). Nevertheless, the observed dioxin/PCB content represents a negligible risk to consumers.

The PCDD/PCDF pattern gave no clear indications that remnants of dioxins from the use of Agent Orange up to 1970 in the Vietnam war is the source of the moderate degree of contamination in the catfish. From table 1 it is seen that 2378-TCDD, which was the all dominant PCDD/PCDF in Agent Orange (Rappe et al., 1978), represents less than 15 % of the total TEQ content.

5.9 Bacteria

The river water serve as drinking water for both humans and household animals. Water samples are therefore analysed for faecal coliforme bacteria, i.e. bacteria that lives in the colon of warm blooded animals. Sanitation runoff from humans and manure seepage are often the sources of such pollution.

The results are given in Fig.12.

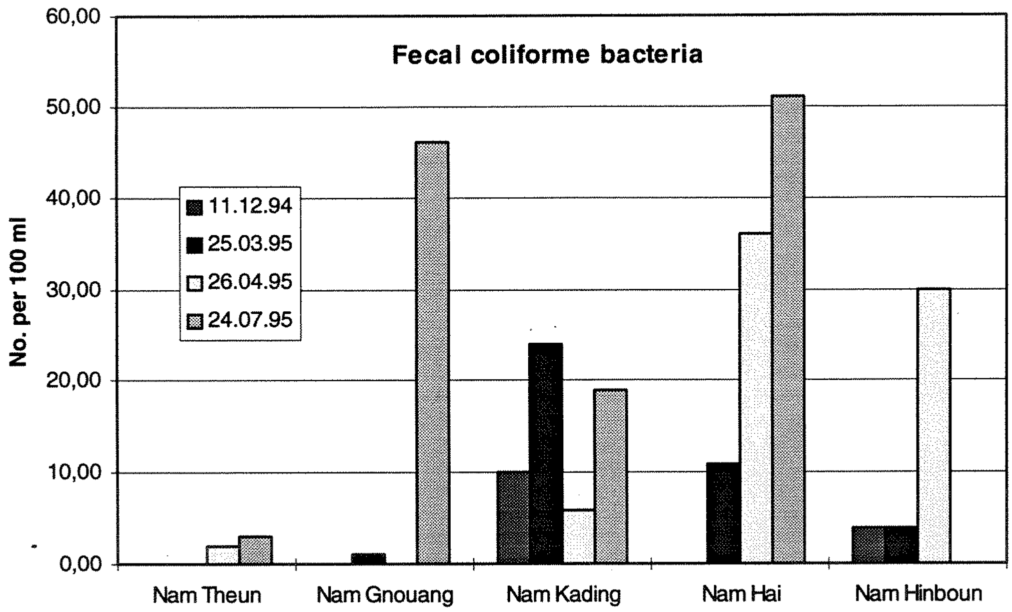

Figure 12. Faecal coliforme bacteria from the rivers at different times of the year.

Nam Theun upstream reservoir showed low values at all 4 samplings, as did Nam Gnouang except for the July observation. Nam Kading at Damsite, Nam Hai at Ban Namsanam and Nam Hinboun showed all higher values, a natural result of higher human activity.

During long dry periods lots of animals seek down to the river both for drinking and cooling. The buffalo is a typical example. Considerable amounts of animal faeces will accumulate in the near shore area in these periods. When water levels are rising, these pollutants are washed into the water. Thus relatively unaffected rivers may seem rather polluted in such periods from a water quality point of view. This effect is most likely the reason for the peak value in Nam Gnouang, Nam Hai and Nam Hinboun in the wet season.

Anyhow such high values of intestinal bacteria indicate that human diseases may spread via consumption of untreated river water. River water should not be used for drinking without boiling. The best solution would have been to supply water from ground water wells close to the river. The water would then have been infiltrated through the sandy soils which effectively removes bacteria and other infectious agents.

5.10 Phytoplankton

Phytoplankton is the primary respondent upon alterations in nutrient input to water bodies from human activities in the catchment area. This applies particularly to lakes, but slow flowing tropical rivers may also develop considerable phytoplankton biomass, especially during the dry season. During the flood season it is not likely to be conditions for plankton development due to high flow velocity and turbid water.

On this basis phytoplankton samples have been collected during the dry season. The samples from the last part of the dry season (25-26th of March), when maximum impact from human nutrient runoff are expected, are analysed with respect to quantity and quality of the phytoplankton community. Nam Hai was, however, dry at this time so no representative plankton sample could be obtained. The results are given in Fig.13.

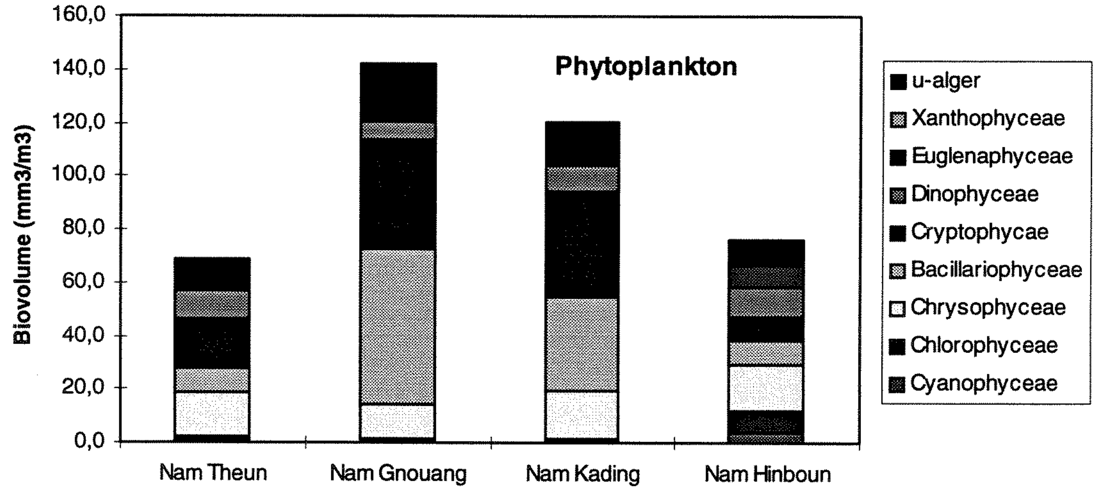

Figure 13. Results of quantitative phytoplankton analysis (dry season 25-26th March) from Nam Theun at inlet of planned reservoir, Nam Gnouang at the inlet of planned reservoir, Nam Kading at Damsite, and Nam Hinboun just downstream the confluence with Nam Hai. Nam Hai itself was dry at the time of sampling.

The biovolume of phytoplankton in the rivers varies from 68 - 142 mm^3/m^3 (= mg/m^3 fresh weight), which are low values that indicates low productive waters (oligotrophic waters). This was also the conclusion from the water chemistry surveillance. It is therefore not likely that any phytoplankton bloom problems will arise in the reservoir, not even during periods of low flow.

Species of diatoms (Bacillariophycea) and chrysomonads (Chrysophyceae) were most common in the poor Phytoplankton community.

The green algae (Chlorophyceae) contributed with most species, but each species occurred only in a very small number of individuals. The species list are given in Table 6.

5.11 Chlorophyll a

The content of chlorophyll a in the free water masses is a relative measurement of the total algal biomass. Analysis is taken from the dry season, 11th of December 1994 and 25th March 1995. In the wet season with flooding rivers chlorophyll consists for a large part of terrestrial debris, and gives no relevant information on river productivity. Samples from the wet season is therefore omitted.

Algal biomass given as chlorophyll a from the rivers are shown in Fig.14.

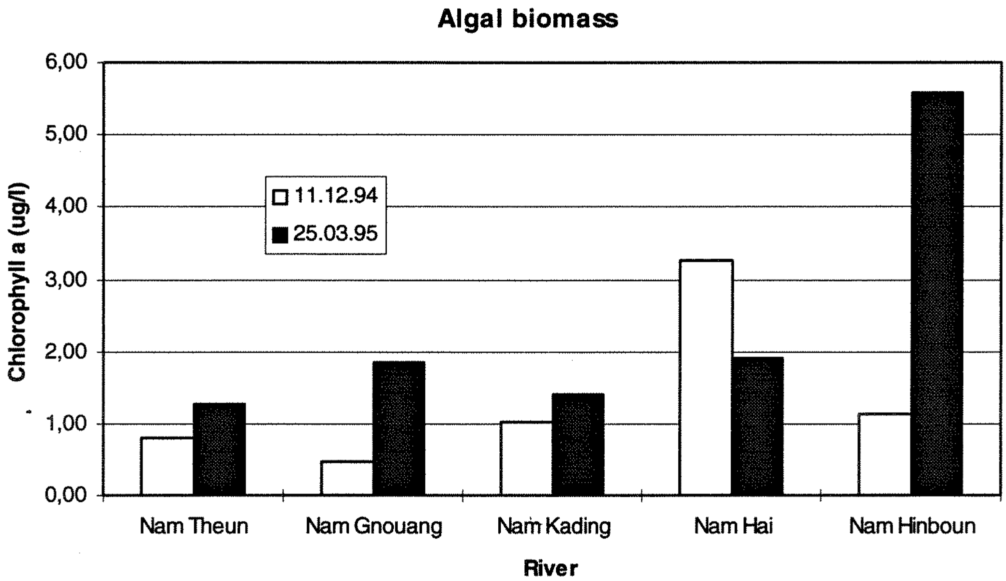

Figure 14. Algal biomass given as chlorophyll a in the dry season from Nam Theun at inlet of planned reservoir, Nam Gnouang at the inlet of planned reservoir, Nam Kading at Damsite, and Nam Hinboun just downstream the confluence with Nam Hai.

The values from Nam Theun, Nam Gnouang and Nam Kading are rather low and indicates low productive waters (oligotrophic waters). Nam Hai and Nam Hinboun are more productive. Particularly Nam Hinboun seems to support a higher algal productivity than is expected as natural background. This is likely a result of nutrient runoff from a much larger human population than in the other rivers. A chlorophyll content of 5-6 ug/l is higher than recommended by international drinking water standards. However, the chlorophyll content is not so high that it will produce any problems for the river ecosystem in Nam Hinboun.

Addition of nutrient poor water from Nam Theun will dilute the algal content of Nam Hinboun.

Table 6. Results of quantitative phytoplankton analysis from Nam Theun at inlet of planned reservoir, Nam Gnouang at the inlet of planned reservoir, Nam Kading at Damsite, and Nam Hinboun just downstream the confluence with Nam Hai.

Analyses of phytoplankton

Group/Species	1 NamTheun	2 Nam Gnouang	3 Damsite	5 Nam Hinbon
Cyanophyceae				
Oscillatoria cf.splendida				3.8
Volume Cyanophyceae				3.8
Chlorophyceae				
Ankistrodesmus falcatus		0.2	0.3	
Chlamydomonas sp.	0.5		0.3	4.5
Chlorella sp.	0.4			
Cosmarium pygmaeum (v.perornatum ?)	0.2		0.2	
Cosmarium subcostatum		0.5		
Golenkiniopsis cf.viridis	0.6			
Koliella sp.	0.1		0.1	
Monoraphidium contortum	0.1	0.5	0.2	
Pandorina morum				2.5
Pediastrum tetras		0.7		
Scenedesmus quadricauda	0.4			1.1
Schroderia setigera			0.2	
Volume Chlorophyceae	2.3	1.8	1.4	8.0
Chrysophyceae				
Chromulina sp.	1.7	0.1	0.7	0.5
Craspedomonads			0.1	0.5
Dinobryon korsikovii	0.6		0.8	
Kephyrion rubri-claustri	0.8			
Large chrysomonads (>7)	5.2	2.2	6.0	4.3
Mallomonas spp.		2.7		
Ochromonas sp. (d=3.5-4)	3.6	2.8	4.4	4.5
Small chrysomonads (<7)	4.7	4.7	5.9	7.9
Volume Chrysophyceae	16.4	12.4	18.1	17.7
Bacillariophyceae				
Achnanthes minutissima v.cryptocephala		8.9	6.6	0.4
Aulacoseira granulata	2.0			
Cyclotella stelligera			0.9	
Fragilaria sp. (l=40-70)		0.4		
Fragilaria ulna		4.2	4.2	4.2
Gyrosigma acuminatum				2.0
Navicula sp.			1.5	0.5
Nitzschia sp. (l=40-50)	6.5	42.7	22.3	1.4
Stephanodiscus hantzschii	0.4	2.3		
Volume Bacillariophyceae	8.9	58.5	35.4	8.5
Cryptophyceae				
Chroomonas sp.	10.6	33.4	25.0	2.8
Cryptomonas erosa	0.8	1.5	6.3	4.2
Cryptomonas erosa v.reflexa (Cr.refl.?)	7.2	4.9	7.9	1.8
Cryptomonas marssonii		1.2		
Volume Cryptophyceae	18.6	41.1	39.3	8.8
Dinophyceae				
Gymnodinium cf.lacustre	1.6	1.9	1.6	
Gymnodinium sp.				9.0
Indet.dinoflagellate	2.4	1.3	3.2	0.3
Peridinium umbonatum	6.8	3.6	5.2	2.0
Volume Dinophyceae	10.8	6.8	10.0	11.3
Euglenophyceae				
Euglena sp.	0.6			
Euglena sp. (l=40)				2.7
Phacus curvicauda				6.0
Volume Euglenophyceae	0.6			8.7
Xanthophyceae				
Ophiocytium sp.	0.3		0.3	
Volume Xanthophyceae	0.3		0.3	
μ-algae				
My-alger	10.8	21.6	15.9	9.8
Volume μ-algae	10.8	21.6	15.9	9.8
Total volume (mm³/m³ = mg fresh weight)	68.7	142.2	120.3	76.5

5.12 Aquatic macrophytes

No new survey on aquatic macrophytes has been carried out during this supplementary environmental impact assessment study. Comments on anticipated development of macrophyte growth after regulation is given with basis in the species composition list that are provided from the previous EIA reports (Dept. livestock and Vet., Burapha LTD. 1992) see Table 7, and the hydrological and water quality regime that is likely to prevail after regulation.

Table 7. Aquatic vegetation found in the rivers (after Dept. livestock and Vet., Burapha LTD. 1992).

Aquatic Vegetation	Nam Kading	Nam Theun	Nam Hinboun
Submerged plants			
Hydrilla	+	+	+
Najas	+	+	+
Ceratophyllum	+	+	+
Potamogeton	+	0	+
Ottelia	+	+	+
Utricularia	+	0	+
Vallisneria	+	0	+
Chera	+	+	+
Filamentous algae	+	+	+
Floating plants			
Wolffia	+	0	+
Lemña	+	0	+
Spirodella	+	0	+
Azolla	+	0	+
Salvinia	+	0	+
Pistia	+	0	+
Eichornia	+	+	+
Emergent plants			
Nelumbo	+	0	+
Nymphaea	+	0	+
Nymphoides	+	+	+
Spread marginal species			
Ipomea	+	0	+
Marsilea	+	0	+
Jussiaea	+	+	+
Stand marginal species			
Sagittaria	+	+	+
Colocacia	+	+	+
Typha	+	0	+

Aquatic macrophytes comprise vascular plants, mosses and macroalgae. They are commonly classified into life forms, according to their growth form and habitat use. Under conducive conditions, aquatic macrophytes can develop into nuisance proportions and only then should they be designated aquatic weeds. Floating-leafed or submerged macrophytes prevail among candidate weedy species. Nutrient enrichment may cause mass development of aquatic plants. However, excessive growth sometimes results after hydropower development even under quite oligotrophic conditions. Such changes are mediated by alteration of the flow hydrograph to enable aquatic macrophytes to persist in an actively growing state for a prolonged time.

The available information relating to aquatic macrophytes within areas affected by the hydropower scheme is scanty. Therefore, only an outline of potential vegetation problems can be given.

Possible candidates to become weeds within the headpond area on Nam Theun are free-floating species such as *Azolla*, *Wolfia*, *Lemna*, *Salvinia*, *Pistia stratiotes* and *Eichhornia [crassipes?]*. Excepting *Eichhornia*, none of these species are previously recorded from the Nam Theun watercourse upstream the dam site. However, this does not preclude their presence here in the future. Judged from the oligotrophic water quality prevailing in that river segment, *Azolla*, *Lemna* or *Salvinia* are the only species of these floating plants which might develop into nuisance quantities. Other potential weeds are submerged macrophytes, for example, *Hydrilla [verticillata?]* or *Ceratophyllum*, both of which are present on the Nam Theun. These genera are known to have caused growth problems within a number of waterway development schemes in the subtropical region.

Excessive growth of macrophytes can hamper generation of hydroelectricity by impeding flow and by blocking intake screens. Whether the hydroelectric impacts on the Nam Theun would give rise to mass development of macrophytes is unclear, however, existing evidence suggests this is unlikely to occur. This is because nutrients are low, the hydrosoil is sandy and there are low levels of suspended solids on the Nam Theun. <u>All these features suggest the developed river is not likely to support noxious quantities of aquatic species</u>. It is possible that mass development of some of these macrophyte species may occur in irrigation canals on the Nam Hai Plain where the water flow will be low and nutrient content high.

Following hydropower development and diversion to the Nam Hai and Nam Hinboun, changes in vegetation community structure, species composition and biomass quantities are likely to result below the tailrace channel outlet. Given that the affected reaches of Nam Hai and Nam Hinbun are enriched in nutrients, excessive growth of submerged and marginal macrophytes is a possible outcome of the diversion from the Nam Theun watercourse. Future macrophyte development should be monitored on Nam Hinboun downstream its confluence with Nam Hai.

On the minimum-flow reaches of the Nam Kading, upstream of the confluence with the Nam Mouan, enhanced growth of semi-aquatic and terrestrial species is likely to occur. Using intermittent flushing flows is a mitigative means to reduced unwanted vegetation. However, the efficiency of this measure is likely quite low. Compensating flows need to be substantial to abate macrophyte growth and encroachment of shrubs on the Nam Kading below the dam site.

5.13 Benthic Invertebrates

Benthic macroinvertebrates were collected at the end of the dry season (March 25th 1995) from rapids in Nam Theun, Nam Gnouang and Nam Kading (Damsite), as well as from a slow flowing site at Nam Hinboun. No fast flowing stretch could be found here. Nam Hai was dry and no sample was collected. The sample was performed using the kick method (Frost et al. 1971). The bottom substrate are stirred up by the boots for three minutes and collected downstream with a handnet with mesh size 0.25 mm.

The macroinvertebrate material is so far analysed to main groups, see Fig.15. All samples are stored as reference material for future monitoring.

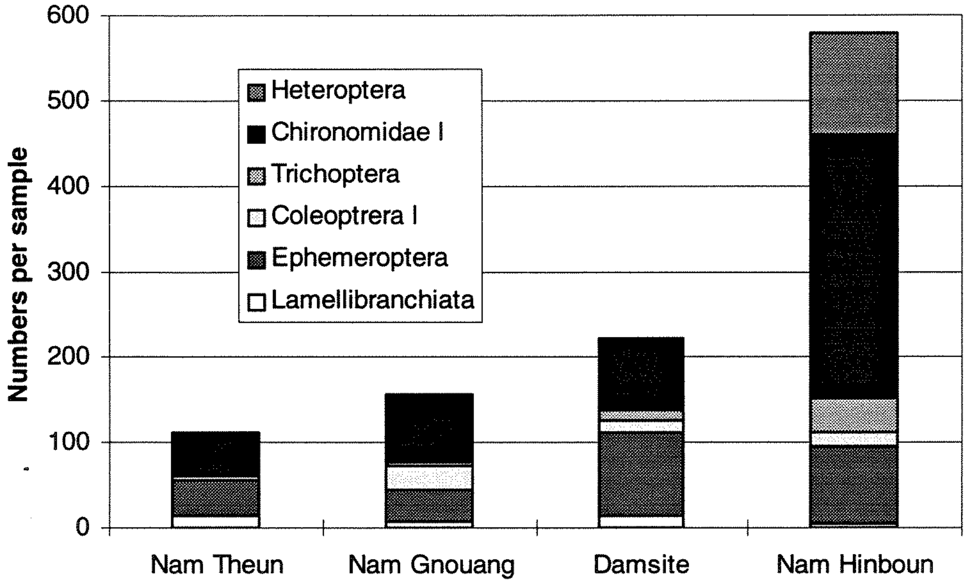

Figure 15. Main groups of benthic macroinvertebrates collected in rapids and still water (Nam Hinboun) March 25th 1995. Semi-quantitative numbers provided by three minutes sampling by the kick method.

The number of animals and groups reflect the different productivity reported in previous chapters, with Nam Theun upstream the reservoir as the least productive locality and Nam Hinboun as the most productive. The total number of animals found in each sample ranged from about 125 to 650. As usually observed in freshwater localities chironomides were the most common macroinvertebrate group. The number of individuals in each sample ranged from about 50 at Nam Theun to more than 300 at Nam Hinboun. The second most common group was the mayflies which even outnumbered the chironomides at the dam site. A large proportion of these were species from the families *Caenidae* and *Baetidae*. Larvae of water beetles (Coleoptera) from the family Elmidae also were quite common at all sites. Other taxa frequently encountered were caddisflies (Trichoptera), bivalves (Lamellibranchiata), unidentified diptera and Heteroptera. The caddisflies were dominated by species of the Hydroptilidae- and Polycentropidae- families, and were most common at Nam Hinboun. The bivalves were dominated by small sphaeridae, but empty shells with size about 2-3 cm were observed as well. The heteroperans were numerous at Nam Hinboun, and were dominated by long legged "water striders". "Water boatmen" of the family Corixidae were common as well. Both these invertebrate groups typically is found along the shore of slow flowing waters and lacustrine environments.

In addition to the invertebrates captured in the kick samples, shrimps (Macrobrahcium sp.) were abundant at slow flowing reaches. Crabs were also observed.

5.14 Zooplankton

Zooplankton are sampled but not analysed at this stage. The samples are stored as reference material for future monitoring.

5.15 Fish and fisheries

5.15.1 Fish species identified in Nam Theun

Only those fish known to occur in the Nam Theun including the Nam Kading upstream of Keng Vang Fong are included. Lao names (Thai Men and Thai Meui) in use in the general area of the Theun Hinboun hydro-power project are included in our fish list, Table 8.

The Nam Theun fish fauna must be regarded as highly interesting, quite distinct from other parts of Mekong basin surveyed so far, and still very poorly known. Several of the species found are not described in the present literature. *Anabarilius* sp. is an not described species; the genus *Anabarilius*, with numerous species in highland streams and lakes in China, has not been reported previously from the Mekong basin. At least one of the nemacheilin loaches (genus *Nemacheilus* or *Schistura*) is not described. The unidentified gobiid and eleotrid are undescribed. The cyprinids cf. *Luciocyprinus* sp., *Poropuntius* sp. and *Scaphiodontichtys* sp. probably are new species.

Nam Theun in the vicinity of the Theun Hinboun project site and the Nam Gnouang below the Nam Theun 3 site appear to be inhabited mainly by fishes characteristic of large, clearwater mountain streams. The collections reported from here represent perhaps 80-90 % of the fish species present in the middle and upper Nam Theun. The full complement of species present will not be known until the entire system has been surveyed using a variety of collecting gear throughout the year and over all habitats.

The Nam Gnouang up to Ban Sensi (site of Nam Theun 3 hydropower project) appears to be inhabited by the same fish species as the mainstream Nam Theun. This was confirmed by villagers interviewed in Ban Sop Gnouang, Ban Sop Pong and Ban Sensi, as well as our direct observation of fish in the Nam Gnouang. From these and other interviews we learned of several Nam Theun/Nam Gnouang fish species that remain to be scientifically identified: pba laht meao (possibly *Anguilla marmorata*) pba wa kam (*Bangana behri*), and pba dam and pba jaht nooat (cyprinids). Pba laht meao was reported by villagers of Ban Sop Gnouang and Ban Geng Bit. A fish of 10 kg was caught at Ban Geng Bit (dam site Theun Hinboun) in April

1995. *Bangana behri* was identified by villagers from photographs, but we have not yet obtained specimens from the Nam Theun. It is a very important migratory species.

The most important species in the catches of Lao Loom fishermen working in Nam Theun just below Keng Vang Fong are large catfishes, *Mystus microphthalmus* and *Bagarius yarrelli*, and the carp *Labeo pierrei.* These people fish mainly with hooks and gillnets. *Labeo pierrei* also was reported as one of the more important large fishes caught at Tha Bac (ferry site). However we did not observe any individuals of this species during numerous visits to Tha Bac in June - August 1995.

By far the most important species being sold at Tha Bac in June 1995 were *Mystus microphthalmus* and *Poropuntius* cf. *deauratus,* followed by *Hypselobarbus* sp. and *Bagarius yarrelli.* According to the dealers, most of the fish brought to Tha Bac were caught in the Nam Gnouang (rather than in the Nam Theun itself). The most aboundant forage fishes (i.e. species fed upon by other fish species) in the Nam Theun would appear to be *Anabarilius* sp. and *Barilius pulchellus.*

A particularly interesting discovery is the presence of *Misgurnus laosensis* in the Nam Theun watershed. We observed this large airbreathing loach in the Laksao market on several occasions, and were told that it was caught in the swamps of the Nam Phao, a slow flowing smaller tributary of the Nam Theun near Laksao. As far as we know, this is the only record of the species since a single specimen from Laos (no other locality data) was originally described over 100 years ago. It may be the same as *Misgurnus anguillicaudatus*, an important aquaculture species in Japan.

Limited collecting in the lower Nam Hinboun (including the part into which water from the Nam Theun will be diverted by the Theun Hinboun project) indicates that it is inhabited by fishes characteristic of the Mekong mainstream and its large, muddy, lowland tributaries. The fishes of the upper Nam Hinboun (not sampled) may be very different from those in the lower reaches.

a) Nam Theun/ Nam Gnouang/ Nam Kading upstream Keng Vang Fong

Table 8. Fish species identified upstream of Keng Vang Fong in the Nam Theun, Lao PDR. Species known or thought to be strongly migratory are marked with an asterisk.

Cyprinidae (carps)	
cf. *Acanthorhodeus* sp.	beh
Anabarilius sp.	seth
Bangana cf. *sinkleri**	
Barilius guttatus	sam sohp
Barilius pulchellus	
*Cirrhinus molitorella**	gaeng
Cyclocheilichthys cf. mekongiensis	doc mai; oop
Danio sp.	siu
*Folitor brevifilis**	chawn
Garra fasciacauda	chi ko
Garra cf. *pingi*	pi
Garra taeniata	gaw

Garra sp.	pi
*Hampala macrolepidota**	soot
Hemibarbus labeo	goom/gohm
*Hypsilobarbus sp.**	pak gai
*Labeo pierrei**	wa kai
Luciocyprinus sp.	kang
*Mekongina erythrospila**	ee
Mystacoleucus cf. *marginatus*	ka chai
Mystacoleucus cf. *greenwayi*	kae dahm
Onychostoma sp.	king
Neolissocheilus sp.*	*sawng*
Poropuntius cf. *deauratus**	jaht leuang
Poropuntius sp.*	jaht dahm
*Puntioplites proctozystron**	sagang
Puntius leiacanthus	
Puntius sp. or spp. undet.	
Rasbora cf. *lateristriata*	siu
Scaphiodontichtys sp.*	mom
*Scaphognathops stejnegeri**	dawk tong
Tor cf. *tambra** (yellow fins)	tohn
*Tor sp.** (red fins).	daeng
Gyrinocheilidae (spiracled suckers)	
*Gyrinocheilus aymonieri**	gaw
*Gyrinocheilus pennocki**	hua koowan
Balitoridae (loaches)	
Balitora/Homaloptera, ca 4 spp.	tit hin
Cobitidae (loaches)	
*Botia helodes**	kaew gai
Lepidocepthalichthys sp.	eet
Misgurnus laosensis	
Misgurnus anguillicaudatus	lai
Nemacheilus/Schistura, ca. 6 spp.	lai, pahn lai
Bagridae (catfishes)	
Leiocassis siamensis	nyang bohn
Mystus microphthalmus	keung
Schilbeidae	
Laides siamensis	nyawn
Siluridae (catfishes)	
Silurus sp.	gin
Sisoridae (catfishes)	
Bagarius bagarius	kae
Bagarius yarrelli	kae
Glyptothorax trilinieatus	gniaw hia; kae ngeng
Glyptothorax sp.	kae ngeng
Glyptothorax sp.	kae ngeng
gen. sp. undet.	pbeh
Clariidae (catfishes)	
Clarias sp. *or* spp.	dook
Oryziatidae (ricefishes)	
Oryzias sp.	
Ambassidae	
Parambassis siamensis	kahp kawng
Eleotridae (sleepers)	
cf. *Oxyeleotris* sp.	boo

gen. sp. undet.	
Gobiidae (gobies)	
Rhinogobius sp.	boo
Rhinogobius sp.	boo
gen. sp. undet.	
Anabantidae	
Anabas testudineus	keng
Channidae (snakeheads)	
Channa gachua	gahng
Channa cf. *marulius*	goowan
Channa striata	kaw
Mastacembelidae (spiny eels)	
Mastacembelus armatus	lat
Symbranchidae (swamp eels)	
Symbranchus bengalensis	ien

Nam Theun in the vicinity of the Theun Hinboun project site appears to be inhabited mainly by fishes characteristic of clearwater foothill streams. The collections of reported fishes here come from surveys conducted in February, June through August 1995. The numbers of fish species we have found thus far in Nam Theun (above Keng Vangfong) and Nam Gnouang (just over 70) are remarkably few for such large tributaries of the Mekong basin. Evidently the fish fauna of the Nam Theun is much less than that of the Mekong mainstream and some of its large lowland tributaries, such as the Se Kong (southern Lao PDR) and Menam Mun (Thailand). Further field work should result in discovery of numerous additional species, but we expect this basic conclusion will remain unchanged.

On the other hand, the Nam Theun has a number of species, some of considerable ecological importance, that have not yet been found elsewhere and that may be endemic to the Nam Theun watershed. We expect that further survey work in the Theun Hinboun hydro-scheme stretch of the Nam Theun, Nam Gnouang and other parts of the Nam Theun watershed (especially highland areas) will result in many more undescribed species.

High densities of shrimps, *Macrobrachium sp.* were found at all sites and especially in the Nam Theun upstream of Keng Vang Fong. Crabs, snails and mussels were also recorded.

b) Nam Kading downstream Keng Vang Fong

Table 9. Fish species identified downstream of Keng Vang Fong in the Nam Kading (Nam Theun), Lao PDR

Channa marulius
Mastacembelus favus
Sikukia stejnegeri
Mystus cf. *atrifasciatus*

The densities of shrimps in the downstream area were less than in upstream areas.

c) Nam Hai/ Nam Hinboun

Table 10. Fish species identified in Nam Hai and Nam Hinboun, Lao PDR.

Macrognathus siamensis
Botia helodes
Acanthopsis sp.
Xenentodon cancilia
Epalzeorhynchus siamensis
Pristolepis fasciatus
Puntius orphoides
Osteochilus hasselti
Mystacoleucus spp.
Mystus nemurus
Mystus atrifasciatus
Microphis decatoides

Limited collecting in the Nam Theun (Nam Kading), downstream of Keng Vang Fong and Nam Hinboun indicate that these areas are inhabited by the fishes characteristic of the Mekong mainstream and its large muddy, lowlands tributaries.

5.15.2 Migratory species

Species known or thought to be strongly migratory are marked with an asterisk in Table 8. Among the most important of these are the cyprinoides *Labeo pierrei, Puntioplites proctozysron, Mekongina erythrospila, Scaphognathops stejnegeri, Gyrinocheilus aymonieri, G. pennocki and two catfishes, Mystus microphthalmus and Bagarius yarelli.* These species may possibly migrate to and from the Mekong mainstream, and their continued existence in Nam Theun may depend upon this migration.

Other species (e. g. *Bangana* cf. *sinkleri, Folitor brevifilis, Hampala macrolepidota, Neolissochilus* sp. *Tor* spp.) may migrate mainly between the middle and upper reaches and tributaries of Nam Theun. These may or may not inhabit reservoirs, but will probably continue to exist in large headwater streams above the reservoirs.

It should be noted that other species may be weakly migratory, exhibiting regular seasonal movements for shorter distances up- and downstream, and that virtually all riverine fish species (not just in the Nam Theun) need to move up and down the river continuum (a linearly organized habitat) in order to survive and thrive.

Of particular concern are the migratory species from the Mekong mainstream which are most important to the Mekong basin fisheries, such as the strongly migratory members of the catfish families *Pangasiidae* and *Siluridae* and many of the larger carps, family *Cyprinidae*. These species, as far as we can determine, are almost entirely absent from the Nam Theun. Some of them do occur in the lowermost Nam Theun below Keng Wang Fong and in Nam Hinboun.

Large catfishes (> 20 kg), *Mystus microphthalmus* and *Bagarius yarrelli,* were reported to occur at Tha Bac, mid Nam Theun during the monsoon season. A fish trader (Mr Yan) buys about 500 catfishes (> 1kg) annually, 50 of which are *Mystus microphthalmus* with weights greater than 20 kg each. The most frequent catches of this big catfish occur during the rainy season and first part of the dry season. All these large fishes are pba keung, *Mystus microphthalmus. Mystus microphthalmus* is a predator (piscivore) and the largest species of the family *Bagridae* in the Mekong basin, attaining 100 kg (Roberts 1993). It might also be a strongly migratory species, and migrate regularly to and from the Nam Theun and the Mekong mainstream but definitive information on this is lacking.

5.15.3 Reproduction

The survey conducted in February 1995 was carried out at a time of year when water levels are lowest and most fish species are reproductively inactive. The main reproductive season in the Nam Theun, as elsewhere in the Mekong basin, is presumably during the period of rising and high water levels, May-August. Nevertheless, a number of Mekong species (most notably the large carp *Probarbus jullieni*, probably absent from the Nam Theun above Keng Vang Fong) spawn mainly or only during falling or low water levels, November-January. Some species (notably *Barilius*, perhaps *Tor* spp., *Scaphiodontichthys*) spawn throughout all or most of the year.

Nam Theun fish species with large numbers of small juveniles present in February 1995, and which may reproduce during the dry season or throughout the year, include *Barilius pulchellus, Scaphiodontichthys acanthopterus*, and *Tor* spp.

From June to August 1995 we observed three species with females in reproductively ripe condition: *Cirrhinus molitorella* and *Hypsilobarbus* sp. in June, and *Masta cembelus armatus* in August.

Interviews with village fishermen resulted in information on reproductive activity for additional species we were unable to observe in reproductive condition (Table 11).

Reproduction of individual fish species occur during only one or two months, all of the months of the year are utilized for reproduction by some of the species. This information is based mainly upon larger fish species and some of the smaller fish species might have more extended reproductive periods.

One interesting finding on fish reproduction in Nam Theun is that the large predatory cyprinid pba kang (*Luciocyprinus* sp.) reproduces in December-February, i. e. at the coldest time of the year. This has been reported by fishermen from several villages on the Nam Gnouang and at Ban Sop Gnouang on the Nam Theun. Much more work is needed to determine time of spawning and spawning sites. Almost no work has been done on naturally occurring fish larvae and fry in the Mekong basin.

Table 11. Monthly occurence of Nam Theun fish species with females in reproductively ripe condition (based mainly on interviews with fishermen of Ban Sop Chat and Ban Sensi on the Nam Gnouang and Ban Sop Gnouang on the Nam Theun).

	J	F	M	A	M	J	J	A	S	O	N	D
Cyprinidae												
Anabarilius sp.	+											+
Cirrhinus molitorella							+	+				
Garra cf. *pingi*										+	+	
Garra taeniata										+	+	
Garra sp.										+	+	
Hampala macrolepidota			+	+								
Hypselobarbus sp.			+	+	+	+						
Labeo pierrei							+					
Luciocyprinus sp.	+	+										
Mekongina erythrospila							+					
Mystacoleucus sp.			+	+								
Neolissochilus sp.					+	+						
Onychostoma sp.				+	+							
Poropuntius cf. *dearatus*		+										
Schaphiodontichys sp.		+	+									
Tor cf. *tambra*						+	+					
Tor sp.						+	+					
Bagaridae												
Mystus microphthalmus	+											
Channidae												
Channa gachua	+											
Channa cf. *marulius*			+	+	+							
Channa striata			+	+	+							

5.16 Regulation impacts on fish fauna

5.16.1 Local effects

a) Reservoir, head pond area

In the Nam Theun a total of about 72 fish species upstream Keng Vang Fong were identified (Table 1). The total number of fish species in the area probably does not exceed 100.

The reservoirs that will result from hydro-power schemes such as Nam Theun 1, Theun Hinboun, and Nam Theun 3 will be limnologically and biologically quite different from any previous reservoirs in the Mekong basin, and entirely unlike the Nam Ngum reservoir. Based on what is known about fish in Nam Ngum and other reservoirs, we would predict that some species presently found in the Nam Gnouang and the Nam Theun will disappear rather quickly. This may include such abundant species as *Poropuntius, Scaphognathops* and *Tor.* Species that may become established and contribute to the reservoir fish fauna include *Hampala macrolepidota, Puntioplites proctozystron, Mystus microphthalmus,* and *Channa* cf.

marulius and *Channa striata* (all important in Ngum reservoir). An important question is whether the forage species *Anabarilius* sp. (extremely abundant in Nam Theun, but not known from the Nam Ngum or other previously dammed rivers in Mekong basin) will become established in reservoirs. Endemic species of *Anabarilius* occur in several lakes in China.

Total productive wetted area after regulation is expected to increase. Small change in submerged area will occur during the monsoon period in the lower area near damsite e. g. Nam Ao. Daily changes in water level between HRWL and LRWL will be less than 0.5 meters, except in April when LWL will be lowered to 395 and maximum daily variation in water level may reach 1 m (Anon 1994). This will probably not result in washouts or drowning of the river bank vegetation. The dammed area is within the previous river banks and is therefore not a traditional reservoir. In periods of high water flow during the monsoon season, water levels as well as the current speeds will probably remain nearly unchanged. Assuming peaking production during winter current speeds will vary considerably through the day. Slow current will occur when water is stored in the reservoir. Current speed will increase from the dam site to the two river inlets (Nam Gnouang and Nam Theun). In the uppermost parts of the reservoir, the water current will be considerable, being close to natural current speed. During the last month of the winter period (HRWL at 395) the riverine character will be prolonged downstream of the rivers Nam Theun and Nam Gnouang. Low water levels in April will probably flush sediments from the upstream reaches of the reservoir, providing good habitats for fish. Sedimentation within the reservoir is believed to be greater in the downstream part of the reservoir than in the riverine upstream part. Effects of daily regulations of one meter in April and a half meter the rest of the year on turbidity are uncertain. The Nam Theun is principally a clear water river during the winter. Increased turbidity will reduce algae production, and in turn, reduce food available for invertebrates and fishes. Decreases in riverine vegetation will occur at least in the downstream reaches of the reservoir. The extent of this reduction is dependent on the importance of the algae in the food chain and the extent of changes in turbidity and sedimentation. Sedimentation of hard bottom habitats due to reductions in current speed combined with high water levels will negatively affect herbivorous fishes closely linked to the river bottom.

Total wetted area through the year will increase. Fish production over time as a total will be reduced because riverine production is typically greater than that of reservoirs. There will also be fewer types of habitat within the reservoir, which will probably result in reduced species diversity after regulation. However, a small bloom in fish production after impondment is expected to occur as the reservior will be fertilized form the wetted areas.

The tropical rain forest surrounding the river will not be altered by regulation and will provide the same amount of allochthonous material important for detritus eating invertebrates and fishes. There is a possibility that the reservoir area will trap more allochthonic material than previously and thereby increase production of detritus feeders. The reservoir is expected to proceed beeing an aerobic area due to the riverine character.

In the rainy season the possibility for fish migration into swamps for feeding and spawning will be increased as the water level will increase somewhat in the tributaries near the dam. This will increase fish production.

The difference between HRWL and LRWL is expected to be too small to eliminate invertebrates, such as river shrimps and crabs. Dense populations of shrimps were found at all sites electrofished in the Nam Gnouang, the Nam Kading and the Nam Theun. Design of the dam will be especially important in ensuring that maximum water levels during the monsoon period do not increase. The narrow valley downstream of the dam will determine the flood water level and thus the dam will be drowned under extreme peak flow conditions (at water discharges above 3000-4000 m^3s^{-1}).

Fish populations upstream of the dam site seem to be heavily exploited by local residents. During the fish survey it was difficult to catch fish bigger than 15 cm. Fish are caught using all kinds of equipment and methods, including dynamite and poisonious plants. Fishing should be regulated in order to ensure fish diversity and sustain fish production.

Diversion of 100 $m^3s^{-1}$with a head of 233 meters will result in fish loss through the turbines. The life history of most fish species is unknown and we can only pinpoint some general effects of water diversion from the Nam Theun to the Nam Hai. The probability for adult and juvenile fish, and eggs to drift through the turbines will be highest during the dry season. When fish go through turbines survival is dependent on the type of turbine, specifically the probability of hitting the turbine blades. Large fish thus have higher mortality rates than small fish (Monten 1985). In high pressure Francis turbines, the probability of survival is low (Hvidsten 1990). Drifting fish eggs and larvae are reported to survive turbine passage. Passage of fish and eggs through the turbines and also over the dam will result in a loss of recruitment to the reservoir and the lower Nam Theun.

If the Nam Theun 2 project is realized, the catchment area of Theun Hinboun will be reduced by 50 %. This means that the amount of water and water velocity at the reservoir at Theun Hinboun will be reduced, further exaggerating the change from riverine character to a reservoir. The realization of Nam Theun 3 will result in higher water discharges in the dry season and lower water discharges in the rainy season than natural.

Fish passing through the turbines represent a loss of fish production to the reservoir. Loss of drifting eggs and juveniles may possibly reduce recruitment in the Nam Theun reservoir and also for the river upstream of the dam. Fish passing over the dam may face significant problems when returning to the headpond area with low current. An artificial fishway combined with a minimum water release at the dam can mitigate some of the negative impacts. Without a fish passage there will be very few possibilities for fish to reenter to the reservoir area. Without a fish passage, upstream fish migration can occur only during extreme flood conditions, when water discharge exceeds 4000 m^3s^{-1} (dam is drowned). It should, however, be emphasized that very little experience with artificial fishways exists for the fish species in question. Thus construction of an artificial fishway that will operate successfully can not be guaranteed.

Flushing of sediments through the dam should be performed in the rainy season and at day time as flushing during night also will flush important food items for fish (Hunter 1992). Peaking artificial water discharges should be omitted.

b) Downstream from the dam site in Nam Kading

Without a compensation flow, all water will be diverted from this river section, resulting in a dry river bed outside the monsoon season in the area below the dam site. Also the river downstream of Nam Mouan and in the area downstream of Keng Vang Fong will be affected, especially during the dry season. In the area between the dam site and Keng Vang Fong, electrofishing showed high densities of different catfish species. Few specimens of juvenile *Bagarius yarrelli* and none of *Mystus microphthalmus* were found during our survey. These are species that probably migrate to the upstream reaches of the Nam Theun and Nam Gnouang.

All riverine fish species migrate to some extent, and some species perform very long spawning and/or feeding journeys while others perform more local displacements. Both upstream, downstream and lateral migrations take place. *Mystus microphthalmus* and *Bagarius yarrelli* are the two important species that local people believe migrate from Mekong to Nam Theun/ Nam Gnouang through the Keng Vang Fong area.

After diversion, without any minimum releases, very low water flow in the lower Nam Kading will result in stagnant pools with poorly oxygenated water with high water temperature. Fish production will suffer in this area and many species will disappear during the winter.

There are no reports of any species of catfish having ascended a fish ladder. The dam will therefore prevent catfish and probably most fishes from ascending back to the Nam Theun. This may affect fish species diversity and total fish production in the reservoir and the Nam Gnouang and the Nam Theun upstream of the reservoir. The duration and frequency with which the dam is drowned (or in other ways passable for upstream migrating fish) might reduce negative impacts on fish migration.

Water quality is important for fish migration. The water from the Nam Kading will change after Theun Hinboun is established, because the tributaries below the dam site will become its dominant sources without a minimum release. Fish migrating early in the season from the Mekong to the Nam Mouan, Nam Gnouang and Nam Theun will experience water of different quality after regulation, and straying to other tributaries might occur.

Fishing in Nam Kading downstream of Keng Vang Fong is important for food supply and sale for villages in the area. This fishery is important throughout the year and significant reduction in water flow will result in corresponding reduction in fish production, particularly during the dry season. During the monsoon period, the fishery is probably dependent on the number of fish returning to the home waters from the areas upstream Keng Vang Fong. If recruitment of juveniles in Nam Theun and Nam Kading is negatively affected, a reduction of fish available for the important fisheries in Nam Kading will occur.

c) Tailrace, Nam Hai and Nam Hinboun

The Nam Hai and the Nam Hinboun will have increased water flow after regulation. In the rainy season, water flow in the Nam Hai will increase by 100 m^3s^{-1}. During the dry season, the Nam Hai dries out naturally, except for some pools. In the Nam Hinboun, water discharge will increase considerably (In February 1995 the natural discharge is about 10-20 m^3s^{-1}). The increase in water discharge during the dry season will vary. The water diverted will vary from 0 to 100 m^3s^{-1} through the day in the dry season. The outlet of the tailraise canal is designed to delay water entering the Nam Hai, such that it will take 1-2 hours before reaching a discharge of 100 m^3s^{-1} from zero. The Nam Hinboun is a clearwater stream in the dry season. After regulation, turbidity will increase due to erosion of banks in Nam Hai. The fish populations present are not adapted to turbid water during the winter. For example, some fish larvae can be vulnerable to suspended matter during the period after hatching, which might result in reduced recruitment downstream of the confluence of the Nam Hai and the Nam Hinboun. High turbidity is expected to decrease downstream of the confluence with the Nam Hinboun.

A number of different fishing methods are used in Nam Hinboun (Claidge 1995). Probably, several of these methods will not be efficient after regulation.

5.16.2 Effects on mainstream Mekong

Fish species spending their entire life cycle in the mainstream Mekong will be little affected by the Theun Hinboun hydropower development. However, fish species that are dependent on the tributaries for spawning and/or feeding areas, will be negatively affected. Lack of basic knowledge about fish migrations in this river system restrict possibilities of assessing impacts on fish production and harvest.

6. MITIGATION MEASURES

6.1 General effects of minimum release on fish production and aquatic life

Fish and other aquatic life are dependent of the presence of water. Only the shortest incident of dry river will have catastrophic effects. In this respect the periods of minimum release is the critical period for a majority of the aquatic life in a river, and for fish production in particular.

No predictive quantifiable model of general validity is available to calculate the reduction in fish yield, however, a generalised conceptual model is given in Fig.16 below. With no water the fish production is zero, with unaltered discharge fish production is 100%. The simplest impact model is to assume proportionality between minimum release and fish production, which is described by the 1:1-line in the figure. There is however, some adaptations to year-to-year variations in minimum discharge, i.e. fish production is little affected by small reductions in minimum release. Rapids are the most productive areas with regard to fish food item production, and these areas are most heavily affected by water diversion. Beyond a certain reduction in minimum discharge larger fish, particularly migrating species will suffer due to high temperature, low oxygen, too little water between pools, and we experience a dramatic decline in fish yield.

The curve levels out at a low fish production mainly made up by small pool living species as minimum release approaches zero.

It should be noted again that this model is a generalised sketch based on experience from Norwegian river regulations, i.e. it is not specifically adapted to the minimum release stretch in Nam Kading. However, the causality lying behind the sigmoid curve should be the same all over the world, so it should not be very different. Some deviations can be expected. For example the reduction in wetted area in Nam Kading per unit reduction in flow is low due to steep river sides. This should imply that the sigmoid curve should be moved somewhat to the left.

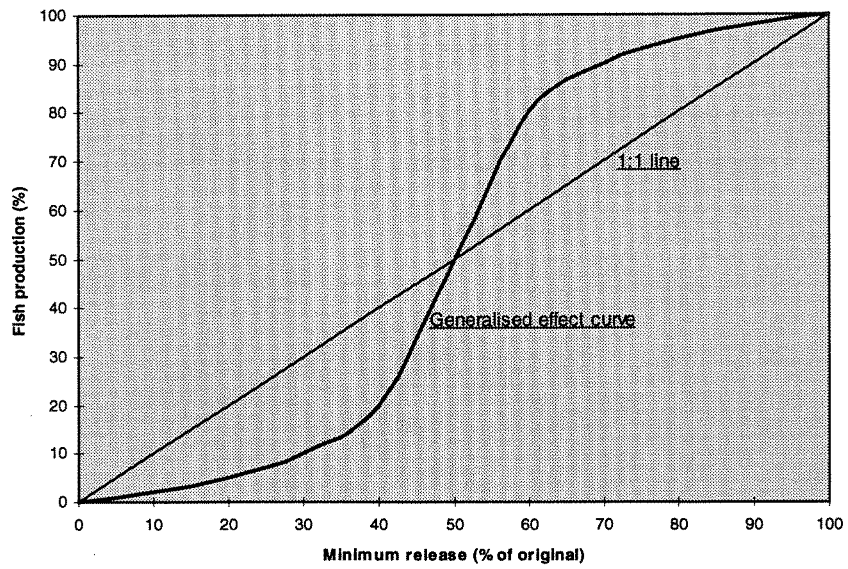

Figure 16. Generalised model describing effect of minimum release on fish production. NB! The model is only a conceptual sketch and cannot be used in any quantitative calculation. See text for explanation.

6.2 Mitigating measures in the reservoir area

Water level will rise close to the top of the river bank brim and will be kept relatively stable in this level. Water speed will be reduced. Most rapids will disappear. Fish may be lost over the dam, whereas possibilities for returning will be restricted.

Natural production and diversity of bottom animals will decline due to siltification from river bank erosion and the reduction of productive area of rapids. This will inevitably also reduce fish production. The effects of siltification might be partly self repaired after some years when the river banks are adapted to the new hydrological situation. Active plantation of amphibious plant species in riverbanks susceptible for erosion should be considered.

One way to compensate for reduced productivity is to introduce a controlled fertilisation programme which have been tried many places in USA and Canada (Hyatt and Stockner 1985). The measure is, however, disputed as it may bring about eutrophication problems. It cannot be recommended here without a thorough evaluation.

The biological and hydrological effects of daily regulations of water level in the reservoir are uncertain. The total wetted area, and hence the productive area for aquatic organisms, will be increased when considered on a yearly basis. Total fish production, comparing reservoir to riverine habitat, will be reduced because running waters generally have higher production than lakes. There will also be fewer habitat types within the reservoir, and hence reduced species diversity is expected after regulation. River bank vegetation is expected to remain unchanged after the regulation. Allochthonic material (terrestrial debris) available for detritus-eating invertebrates and fish will be unchanged. There is a possibility that the reservoir will trap more allochthonic material than previously and thereby increase production of detritus feeders.

Sedimentation of the hard bottom habitats caused by slowing of currents combined with high water levels will reduce herbivorous fishes closely linked to the river bottom.

Introduction of cultured fish is frequently used to compensate for negative impacts of fish production caused by hydropower regulation. Because several significant negative effects from introductions of new fish species have been shown during the last years, we do not recommend release of fish species into the reservoir that are not already present (Reid 1990). As a principle, efforts should be directed towards taking care of the existing species, recognizing their original habitats.

Passage of fish and eggs through the turbines should be avoided. The problem is most severe in the dry season, as the majority of the water discharge will pass through the turbines. Screens with narrow openings in front of the tubine intake will prevent larger fishes to pass the intake. In the rainy season the ducts through the dam for flushing sediments might also be manouevered in parallell with periods of drifting eggs and juveniles, flushing the juveniles downstream of the dam. This will most likely take place in the wet season.

Reduction in important fish species due to lack of, or insufficient reproduction, can be (at least partly) mitigated by releasing hatchery reared fish.

6.3 Mitigating measures in Nam Kading

The lowest discharge in the Nam Kading just downstream the dam averages 30-35 m^3s^{-1} . We propose a minimum release of 6 -15 m^3s^{-1}. This will provide fresh water downstream the dam and maintain some of the fish habitats. A minimum release less than 6 m^3/s will more or less completely destroy the fisheries on the river stretch between the dam and Nam Moan, whereas a minimum release of 15 m^3/s is anticipateded to give relatively small reductions in the fish production. It is difficult to propose a distinct number for the minmum release.

An artificial fishway will reduce the negative effects of the dam as a physical barrier for fish migration. A fish sluice passage is proposed, with the objective to pass fish through the dam at water discharges from 6 to 1000 m^3s^{-1} . This will hopefully permit fish to pass the dam at most water discharges occuring through the year. The pass is designed to guide both pelagic and bottom fishes through the dam by two enterances. One opening of the ladder is at the river bottom and will be kept open for fishes migrating along the river bottom. The other enterance is at the upper surface layers manouevered according to the water level (downstream of the dam). The discharge through the two sluices are held constant at 0.5 m^3/s (sum 1 m^3/s). Flushing of sediments from the reservoir should occur during the monsoon season. If water discharge is increased during this procedure, flushing should be conducted during day time to avoid flushing of drifting insects.

Much attention have to be given to the fish bypass canal. It is crucial that it will be built in such a way that the migrating fish will find the entrance and ascend through the channel to the reservoir.

Construction of threshold weirs in order to keep a high wet surface area during low flow periods is another measure that is commonly used, and the feasibility of such weirs should be looked upon. The weirs should not be built too high, otherwise they can act as migration barriers. The need for weirs is depending upon the minimum release of water over the dam that will finally be chosen.

The only way to reduce negative effects in the Nam Kading and the areas further downstream, is to release a sufficient amount of water through the Theun Hinbuon dam in the dry season.

A fish sluice should be established to maintain at least some of the fish migrations. This is important for both the areas downstream and upstream of the dam. On the basis of existing knowledge, it is impossible to argue for an exact minimum water release. 6 m^3/s is considered an absolute minimum water releas, i.e. a release less than that will more or less completely destroy the fisheries on the river stretch between the dam and Nam Moan. A release of 10 m^3s^{-1} would increase the chances of maintaining minimum fish production and fish migrations in the Nam Theun significantly, whereas a minimum release of 15 m^3/s is anticipateded to give relatively small reductions in the fish production. A more exact minimum release could be decided after a monitoring period where fish migrations and fish production are analyzed in relation to water flow.

6.4 Nam Hai and Nam Hinboun

The aquatic life in Nam Hai may benefit from the diversion and the population in the catchment will experience an improved fishery. However, as fish die only once, the increased fishery is depending on that the river will have water all year round. If the water is held back only one single time during the dry season the fish population will be spoiled.

To allow for power station maintenance in the dry season, a turbine bypass should be built. For short maintenance periods, the establishment of threshold weirs in Nam Hai will also reduce the damage on aquatic life due to stop in water flow.

Some river brim enforcement should be considered to prevent overbank flooding in wrong season, and to reduce erosion.

Increased human activity is anticipated along Nam Hai and this will result in increased pollution loading to the river. Health problems may arise from using the river for drinking water. Drinking water supply in the villages should be provided from deep wells situated near the river which will be fed by infiltrated river water.

The effects on fish fauna in the Nam Hai will be decided by the stability of water flow. A high, but fluctuating water flow in Nam Hai will not increase fish production. Water flow should not fluctuate rapidly as decrease in water flow (ramping) will result in stranding of fish (Hvidsten 1985). A future goal should be to stabilize the water flow by establishing weirs in the upper parts of Nam Hai. Weirs create permanently wetted areas and will increase fish production.

To stabilize water discharges in Nam Hai/ Nam Hinboun different turbine sizes or turbines with a wide scale of high effiency at different water discharges should be installed.

The increased water flow in Nam Hinboun during the dry season will most likely not accomplish serious problems. The water will be more turbid for some years, which may result in a small decline in fish production. The problems are not so big that any mitigating measures should be needed.

7. MONITORING PROGRAMME

7.1 Water quality

7.1.1 Monitoring stations

The stations used in this study should also be used in a future monitoring programme. Some more stations should be included according to the following reasoning:

As erosion and water quality parameters influenced by this process will be the most pronounced effect of the regulation, a station at the lowermost part of Nam Hai should also be included, i.e. at the confluence with Nam Hinboun. Nam Hinboun should also be monitored just upstream the confluence with Nam Hai as well as downstream at the existing Ban Vangdao station.

The development with respect to thermal stratification in the reservoir will be of particular interest.

The proposed monitoring stations will then be:

New st.no	*Old st. no*	Approximately description of the location of the proposed monitoring stations
1	*1*	Nam Theun at the entrance of the reservoir
2	*2*	Nam Gnouang at the entrance of the reservoir
3	*3*	Nam Theun / Nam Kading at damsite
4	*New*	*Reservoir just upstream the dam*
5	*4*	Nam Hai at entrance of the tailrace channel
6	*New*	*Nam Hai at the entrance of Nam Hinboun*
7	*New*	*Nam Hinboun upstream Nam Hai entrance*
8	*5*	Nam Hinboun at Ban Vangdao

7.1.2 Parameters at the river stations (St. 1,2,3,5,7,8):

In the reservoir area and the Nam Hai area it will most likely be increased human activity in the future. This will create pollutants, mostly as nutrients and bacteria. On the other hand the increased activity will also increase the demand for water, e.g. potable water, irrigation water, etc. Erosion will also increase as a result of the regulation, at least for some years. Parameters which give information on the erosion impact in the rivers will be interesting to follow.

The following parameters can therefore be proposed at the river stations:

Temperature
ph
Conductivity
Turbidity
Total phosphorus
Total Nitrogen
Nitrat
Suspended sediments (organic and inorganic)
Chlorophyll a
Secchi depth transparency
Fecal Coliforme bacteria (44 °C)

7.1.3 Reservoir station (St.4):

The reservoir station will be sampled according to procedures for lake monitoring. Of particular interest will be to follow the development in vertical temperature and oxygen to clarify any thermal stratification and the possibilities for oxygen depletion in deepwaters. The other parameters which characterise the reservoir can be described by the data collected at the outlet station as the water in the reservoir has rather short recidense time.The additional reservoir parameters are:

Secchi depth transparency
Oxygen profile
Temperature profile

7.1.4 Sampling frequency

The water quality parameters should be sampled 4 times a year, in December, in March, in May and in September.

7.2 Biology other than fish

This should include the following parameters:

Bottom animals
Phytoplankton and drifting algae
Zooplankton
Aquatic vegetation

The first 3 parameter groups should be sampled once a year at the end of the dry season at station 1,2,4,5,7,and 8. Aquatic vegetation should be surveyed each 5th year by a trained botanist.

7.3 Fish monitoring programme

Because of the general lack of biological knowledge, especially about spawning/feeding areas, timing of migrations and waterflow requirements for fish migrations, a monitoring programme should be established.

Future guidelines for sustainable fishing efforts and methods should be established, based on fish density/production analysis. The fish density analysis should be performed through standard fishing methods in a five years period.

The monitoring programme should establish detailed recommendations for minimum water release through the dam in Nam Theun.

Operation procedures of the fish sluice to optimize fish migrations through the dam should be established as a part of the monitoring programme. This will include the frequency of opening and closing the enterances and the exit of the sluice. Also, the surface enterance of the fishway downstream of the dam need analysis for proper fish migration and how to maintain/increase harvest of fish in the reservoir area.

Screening procedures of the diverted turbine water at the dam site to reduce emigration of fish eggs, juveniles and adult fish should be analysed by actual methods.

The flushing ducts for sediments should be operated to optimise upstream fish migration in the fishway, and to deflect fish, juveniles, eggs and insects in front of the turbine intake.

Ramping rates to prevent stranding of fish below the tailrace of the Theun Hinboun hydropower station should be analysed.

In the headpond, oxygen contents of the water should be examined to prevent possible development of anaerobic conditions.

8. FISHERIES MANAGEMENT

A fisheries management plan for the Theun Hinboun hydro-power area is nesseccary, as earlier proposed by Norconsult. The management plan should be modifed on different subjects. Our report conclude that the total fish production will decrease after regulation. Fishing efforts after regulation should be based on the changes in fish production after regulation.

Education in sustainable fishing methods and efforts should be stressed in the management programme (Midas, report 1995).

We do not recommend introduction of new fish species. Hatchery operations and release of hatchery reared juveniles should not be performed before reduction in recruitment of important fish species are documented.

Operation procedures resulting from the monitoring programme should be supervised by the fisheries management plan.

9. LITERATURE

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10. PRIMARY DATA

Table 5. Results fra Nam Theun upstream reservoir area

Parameter	Units	Dec. 94	March 95	April 95	July 95
Basic Characteristics					
Temperature	°C	21.5	26	30	
pH	pH-value	7.11	7.48	7.81	7.31
Conductivity	uS/cm	3.23	4.85	4.78	2.77
Turbidity	FTU	3.1	1.4	1.9	7.6
Total organic carbon	mg C/l	0.83	3.7	1.3	1.1
Secchi depth	m	2	3	2.5	1.5
Suspended Sediments					
Total Suspended Solids	mg/l	3.94	3.22	1.21	6.82
Suspended ignition Rest	mg/l	3.39	2.42	0.57	5.45
Nutrients					
Total Phosphorus	ugP/l	9	6	5	11
PO4-P	ugP/l	3	<1	-	
Total Nitrogen	ugN/l	180	107	138	185
Nitrat	ugN/l	114	<1	-	
Major constituents					
Ca	mg/l	2.74	4.55	-	3.44
Mg	mg/l	0.81	1.15	-	0.65
Na	mg/l	2.11	3.86	-	1.18
K	mg/l	0.67	0.79	-	0.41
Cl	mg/l	1.9	2.0	-	0.8
Alcalinity	mmol/l	0.279	0.437	-	0.253
SO4	mg/l	1.5	1.3	-	0.5
Tracè elements					
Cu	ug/l	<0.1	-	-	-
Pb	ug/l	0.06	-	-	-
Al	ug/l				-
Zn	ug/l	<0.5	-	-	-
Ni	ug/l	<0.5	-	-	-
Cr	ug/l	<0.5	-	-	-
Sn	ug/l	<0.5	-	-	-
Cd	ug/l	<0.01	-	-	-
Fe	ug/l	94.4	-	-	-
As	ug/l	0.3	-	-	-
Mn	ug/l	1.9	-	-	-
Phytoplankton					
Chlorofyll a	ug/l	0.79	1.28	-	
Algal volume	mm^3/m^3				
Bacteria					
Fecal coliforme bacteria (44 °)	No./100ml	0	0	2	3
Zooplankton					
Collection of baseline material					
Zoobenthos					
Collection of baseline material					
War time pollutants					
Dioxine in fish liver	pg TE/g fat	16.6	-	-	-

Table 6. Results from the Nam Gnouang

Parameter	Units	Dec. 94	March 95	April 95	July 95
Basic Characteristics					
Temperature	°C	21.5	26	31	
pH	pH-value	7.51	7.79	8.19	8.02
Conductivity	uS/cm	6.99	9.24	7.87	14.5
Alcalinity	mmol/l	0.687	0.948		1.39
Turbidity	FTU	4.8	3.7	6.0	16.5
Total organic carbon	mg C/l	0.59	0.98		1.1
Secchi depth	m	1	1.5	1.5	0.65
Suspended Sediments					
Total Suspended Solids	mg/l	8.01	4.47	5.0	18.0
Suspended ignition Rest	mg/l	6.98	3.06	4.15	16.5
Nutrients					
Total Phosphorus	ugP/l	13	9	11	16
PO4-P	ugP/l	7	1		
Total Nitrogen	ugN/l	175	110	165	245
Nitrat	ugN/l	114	<1		245
Major constituents					
Ca	mg/l	8.85	12.3	-	24.8
Mg	mg/l	1.80	2.48	-	3.0
Na	mg/l	2.02	2.84	-	1.19
K	mg/l	0.72	0.86	-	0.71
Cl	mg/l	0.5	0.5	-	0.5
Alcalinity	mmol/l	0.687	0.948	-	
SO4	mg/l	1.5	1.7	-	2.4
Trace elements					
Cu	ug/l	-	-	-	
Pb	ug/l	-	-	-	
Al	ug/l	-	-	-	
Zn	ug/l	-	-	-	
Ni	ug/l	-	-	-	
Cr	ug/l	-	-	-	
Sn	ug/l	-	-	-	
Cd	ug/l	-	-	-	
Fe	ug/l	-	-	-	
As	ug/l	-	-	-	
Mn	ug/l	-	-	-	
Phytoplankton					
Chlorofyll a	ug/l	0.48	1.84	-	
Algal volume	mm^3/m^3				
Bacteria					
Fecal coliforme bacteria (44 °)	No./100ml	0	1	0	46
Zooplankton					
Species composition				-	
Zoobenthos					
Collection of baseline material				-	
War time pollutants					
Dioxine in fish liver		-	-	-	-

Table 7. Results from Nam Kading (Damsite).

Parameter	Units	Dec. 94	March 95	April 95	July 95
Basic Characteristics					
Temperature	°C	21.5	27	31	
pH	pH-value	7.53	7.75	8.2	7.69
Konductivity	uS/cm	5.04	7.07	6.24	5.37
Alcalinity	mmol/l	0.476	0.676		0.491
Turbidity	FTU	3.0	2.4	3.2	8.7
Total organic carbon	mg C/l	0.52	1.0	1.2	1.0
Secchi depth	m		1.5	2	1.35
Suspended Sediments					
Total Suspended Solids	mg/l	7.17	1.60	3.54	10
Suspended ignition Rest	mg/l	6.21	1.10	3.20	8
Nutrients					
Total Phosphorus	ugP/l	9	7	7	12
PO4-P	ugP/l	4	<1	-	-
Total Nitrogen	ugN/l	170	98	170	190
Nitrat	ugN/l	98	<1	-	-
Major constituents					
Ca	mg/l	5.81	8.25	-	7.58
Mg	mg/l	1.19	1.69	-	1.08
Na	mg/l	2.06	3.29	-	1.15
K	mg/l	0.69	0.88	-	0.47
Cl	mg/l	1.0	1.4	-	0.8
Alcalinity	mmol/l	0.476	0.676	-	
SO4	mg/l	1.2	1.5	-	0.9
Trace elements					
Cu	ug/l	-	-	-	-
Pb	ug/l	-	-	-	-
Al	ug/l	-	-	-	-
Zn	ug/l	-	-	-	-
Ni	ug/l	-	-	-	-
Cr	ug/l	-	-	-	-
Sn	ug/l	-	-	-	-
Cd	ug/l	-	-	-	-
Fe	ug/l	-	-	-	-
As	ug/l	-	-	-	-
Mn	ug/l	-	-	-	-
Phytoplankton					
Chlorofyll a	ug/l	1.03	1.42		
Algal volume	mm^3/m^3				
Bacteria					
Fecal coliforme bacteria (44 °)	No./100ml	10	24	6	19
Zooplankton					
Collection of baseline material		+	+	-	-
Zoobenthos					
Collection of baseline material		-	+	-	-
War time pollutants					
Dioxine in fish liver		-	-	-	-

Table 8. Results from Nam Hai (Tailrace entry, Ban Namsanam)

Parameter	**Units**	**Dec. 94**	**March 95**	**April 95**	**July 95**
Basic Characteristics			river almost dry	river almost dry	
Temperature	°C	27	-	36	27
pH	pH-value	7.57	7.21	7.91	7.57
Conductivity	uS/cm	16.9	32.9	12.5	5.78
Alcalinity	mmol/l	1.695	3.00		0.547
Turbidity	FTU	3.7	3.1	15.1	7.9
Total organic carbon	mg C/l	1.2	2.5	8.3	2.1
Secchi depth	m				1.0
Suspended Sediments					
Total Suspended Solids	mg/l	13.1	4.83	18.1	8.33
Suspended ignition Rest	mg/l	10.3	4.08	7.50	7.13
Nutrients					
Total Phosphorus	ugP/l	211	40	115	12
PO4-P	ugP/l	7	34		
Total Nitrogen	ugN/l	220	330	1145	138
Nitrat	ugN/l	6	210		
Major constituents					
Ca	mg/l	26.3	45	-	8.55
Mg	mg/l	2.90	7.46	-	1.11
Na	mg/l	4.69	11.5	-	1.44
K	mg/l	0.89	0.40	-	0.28
Cl	mg/l	0.4	11.2	-	0.3
Alcalinity	mmol/l	1.695	3.00	-	
SO4	mg/l	3.4	6.7	-	0.7
Trace elements					
Cu	ug/l	-	-	-	-
Pb	ug/l	-	-	-	-
Al	ug/l	-	-	-	-
Zn	ug/l	-	-	-	-
Ni	ug/l	-	-	-	-
Cr	ug/l	-	-	-	-
Sn	ug/l	-	-	-	-
Cd	ug/l	-	-	-	-
Fe	ug/l	-	-	-	-
As	ug/l	-	-	-	-
Mn	ug/l	-	-	-	-
Phytoplankton					
Chlorofyll a	ug/l	3.26	1.90		
Algal volume	mm^3/m^3				
Bacteria					
Fecal coliforme bacteria (44 °)	No./100ml	-	11	36	51
Zooplankton					
Collection of baseline material		+	-	-	-
Zoobenthos					
Collection of baseline material		-	-	-	-
War time pollutants					
Dioxine in fish liver		-	-	-	-

Table 9. Results from Nam Hinboun (Ban Vangdao)

Parameter	Units	Dec. 94	March 95	April 95	July 95
Basic Characteristics					
Temperature	°C	24	29	31	27
pH	pH-value	7.84	8.04	7.31	8.0
Konductivity	uS/cm	38.3	32.9	15.8	19.8
Alcalinity	mmol/l	3.992	4.05		1.934
Turbidity	FTU	2.0	2.5	38.6	54.6
Total organic carbon	mg C/l	0.51	1.4	1.0	1.0
Secchi depth	m				0.35
Suspended Sediments					
Total Suspended Solids	mg/l	4.82	4.35	2.64	73.2
Suspended ignition Rest	mg/l	4.09	4.29	1.64	68.0
Nutrients					
Total Phosphorus	ugP/l	20	17	14	50
PO4-P	ugP/l	12	4		
Total Nitrogen	ugN/l	270	230	210	395
Nitrat	ugN/l	175	20		
Major constituents					
Ca	mg/l	77.4	74	-	37.5
Mg	mg/l	2.90	3.27	-	2.17
Na	mg/l	1.34	1.09	-	1.24
K	mg/l	0.43	0.49	-	0.30
Cl	mg/l	0.5	0.9	-	0.7
Alcalinity	mmol/l	3.992	4.05	-	
SO4	mg/l	1.4	1.3	-	1.1
Trace elements					
Cu	ug/l	<0.1	-	-	-
Pb	ug/l	0.05	-	-	-
Al	ug/l		-	-	-
Zn	ug/l	<0.5	-	-	-
Ni	ug/l	1	-	-	-
Cr	ug/l	0.9	-	-	-
Sn	ug/l	<0.5	-	-	-
Cd	ug/l	<0.01	-	-	-
Fe	ug/l	640	-	-	-
As	ug/l	0.4	-	-	-
Mn	ug/l	7.2	-	-	-
Phytoplankton					
Chlorofyll a	ug/l	1.13	5.59		
Algal volume	mm^3/m^3				
Bacteria					
Fecal coliforme bacteria (44 °)	No./100ml	4	4	30	0
Zooplankton					
Collection of baseline material		+	+	-	-
Zoobenthos					
Collection of baseline material		-	+	-	-
War time pollutants					
Dioxine in fish liver		-	-	-	-

Table 10. Results from Nam Pao (Lac Sao)

Parameter	**Units**	Dec. 94	**March 95**	April 95	July 95
Basic Characteristics					
Temperature	°C	-	26	-	-
pH	pH-value	-	7.42	-	-
Konductivity	uS/cm	-	4.19	-	-
Alcalinity	mmol/l	-	-	-	-
Turbidity	FTU	-	15	-	-
Total organic carbon	mg C/l	-	1.0	-	-
Suspended Sediments					
Total Suspended Solids	mg/l	-	-	-	-
Suspended ignition Rest	mg/l	-	-	-	-
Nutrients					
Total Phosphorus	ugP/l	-	33	-	-
PO4-P	ugP/l	-	16	-	-
Total Nitrogen	ugN/l	-	280	-	-
Nitrat	ugN/l	-	98	-	-
Major constituents					
Ca	mg/l	-	-	-	-
Mg	mg/l	-	-	-	-
Na	mg/l	-	-	-	-
K	mg/l	-	-	-	-
Cl	mg/l	-	-	-	-
Alcalinity	mmol/l	-	-	-	-
SO4	mg/l	-	-	-	-
Trace elements					
Cu	ug/l	-	-	-	-
Pb	ug/l	-	-	-	-
Al	ug/l	-	-	-	-
Zn	ug/l	-	-	-	-
Ni	ug/l	-	-	-	-
Cr	ug/l	-	-	-	-
Sn	ug/l	-	-	-	-
Cd	ug/l	-	-	-	-
Fe	ug/l	-	-	-	-
As	ug/l	-	-	-	-
Mn	ug/l	-	-	-	-
Phytoplankton					
Chlorofyll a	ug/l	-	1.90	-	-
Algal volume	mm^3/m^3	-	-	-	-
Bacteria					
Fecal coliforme bacteria (44 °)	No./100ml	-	54	-	-
Zooplankton					
Species composition		-	-	-	-
Zoobenthos					
Collection of baseline material		-	-	-	-
War time pollutants					
Dioxine in fish liver		-	-	-	-

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