5.4.2.2.4. RECOMMENDATIONS

From the environmental point of view, it is recommended to locate the line as much as possible in paddy areas, for minimizing forest clearing and subsequently long term maintenance of the ROW. The line must avoid passing too close from existing villages in order to reduce future conflicts when villages will expand.

5.4.3. IMPACTS ON LOCAL ECONOMY AND VILLAGERS INCOME

5.4.3.1. EMPLOYMENT OPPORTUNITIES

There will be numerous employment opportunities through contractors and sub-contractors carrying out the NNHP construction. Manual labor associated with such construction projects is keenly competed for by farmers and others in the Lao PDR as a way to earn the additional cash that subsistence rice farming does not provide. However, the rhythms of subsistence production and of village life make it difficult for farmers to compete with non-farmer laborers who are prepared to work for very low wages in poor conditions for long periods of time without breaks.

As a result, many large construction projects in the Lao PDR have attracted outsiders to work as unskilled laborers. These outsiders have been poorly paid, even by national standards, and have contributed little positive towards the local economy. Indeed in many cases they have ended up competing for firewood and 'wild' food resources with the local populations.

In the Nam Leuk Hydropower Project, a proposal was made in the Social Action Plan (SAP) to 'internalize' labor, to enable the developer to reserve work which local communities have a high aptitude to do, and which they also have the tools to carry out, for the families living in villages which could be affected by the Project. The biomass clearance program for the reservoir was set aside for this 'internalized' labor program under the SAP.

5.4.3.1.1. ON CONSTRUCTION SITES

There will also be numerous opportunities for local private business concerns to subcontract work and to provide services, such as shops, for the work force. These will be particularly required at the construction sites, which are in areas remote from human habitation.

5.4.3.1.2. FOR VEGETATION BIOMASS CLEARING

The Nam Leuk Hydropower Project provided opportunities for some 600 villagers from 13 villages to earn 'above market' rates and given their food to participate in the reservoir biomass clearance program undertaken to improve the water quality downstream after the reservoir impoundment. There was strong competition among villagers to work in the biomass clearance program cutting bamboo, shrubs, small trees and other biomass in the reservoir area, as well as larger trees. The villagers regarded the availability of lucrative work close to their homes, which the whole family could carry out following their own timetable, at a time when work demands of their cropping cycle were negligible as a windfall.

In addition, some of the villagers participating in the program requested to temporarily grow rice in the cleared and burnt firebreaks around the reservoir. Twenty-one (21) households were allowed to cultivate dry rice in the firebreak, which was good for local relations and but more importantly prevented re-growth of natural vegetation in the firebreaks.

5.4.3.2. LOCAL SUPPLY TO CONSTRUCTION SITES

It was also important in the Nam Leuk Hydropower Project to set up through the main contractor a Recruitment Center that regularized the process of attracting local and outside skilled labor. Such a Center assisted the process of monitoring the conditions under which laborers were hired and worked for the project. The Recruitment Center can be the focus of planning to attract local skilled labor. There will need to be an effort made some time in advance of the actual commencement of labor activities to procure a Manpower Plan from the Contractor(s) to make an assessment of needs and determination where and how these might be made locally.

5.4.3.3. RECOMMENDATIONS

Part of the RAP will be an assessment of skills among the affected population needed to participate in NNPP construction activities and to assist in upgrading these. This will be part of setting up a mechanism for Project Affected Persons (PAPs) to obtain employment with construction contractors and to participate in business opportunities created by the Project and in other Project-related employment sectors such as the biodiversity clearance program, where skills in removing forest cover are important, as will the ability to take advantage of opportunities to make and sell charcoal. Advanced planning, centering on the creation of a Recruitment Center, will be important to take maximum advantage of all such opportunities. These will be part of the SAP prepared along with the Environmental Management Plan (EMP).

5.5. FILLING PHASE : IMPACTS ON INUNDATION ZONE

5.5.1. FILLING EVENT

5.5.1.1. IMPORTANCE OF THE EVENT

The filling event is probably the most important and impacting stage of a hydropower project. Indeed, this is the short tine during which

- the hydrology of the downstream system will be abruptly modified,
- the water quality of the system will be strongly altered, and
- the population in the reservoir area must be resettled.

This event is the starting point for several activities which should not suffer delays in their implementation, as the situation from there will be highly dynamic.

5.5.1.2. DURATION

At this stage of the Feasibility, no study of the filling procedures is anticipated by the technical side. Because of the importance of this event from the environmental point of view, some simple simulations are presented below, in order to get a reasonable idea of the duration of the event under various objectives and conditions.

The simulation is based:

- on 3 hydrological years: a mean year, a wet year and a dry year, and
- on 3 riparian release conditions: (No RR, 20 m^3/s, 50 m^3/s)
- on 2 options for turbine operation: turbining starts when level reaches MOL, or when level reaches FSL.

It is assumed that filling starts on June 1. In the simulation, the first year is mean, wet or dry, but the second year is always considered as a mean year. The inflow considered for these years corresponds in the 30 years generated series to year 17 (mean year), 27 (dry year) and 29 (wet year). These 3 typical years have been used for any simulation in the other sections of this report.

The selection of the riparian release follows 2 principles:

- 20 m^3/s corresponds roughly to 10% of the yearly average flow, as it is the recommended practice in European countries.
- 50 m^3/s is close from the average discharge observed during the 3 driest months of the mean year.

Regarding the filling target, we consider two situations: start of turbine operation when the reservoir is full (mainly for reference) and start of the turbines when the reservoir reaches MOL.

We insist on the fact that these simulations are only indicative, to provide some idea of the filling duration under various conditions. Detailed simulation will be required in the next stage of the study.

Whatever the filling strategy selected is, the filling of the reservoir is reasonably fast. It is obvious that the most probable strategy will consider turbine operation the soonest, which is when water level reaches MOL.

Table 5.4 : Simulation of Filling Event Duration

Hydrological yearr	Riparian Release	Time to reach (months)			
		Alternative FSL360		Alternative FSL320	
		FSL (360m)	MOL (335m)	FSL (320m)	MOL (284m)
Mean Year	No Riparian Release	15	4	3	2
	RR= 20 m3/s	16	5	3	2
	RR= 50 m3/s	18	6	4	2
Wet Year	No Riparian Release	9	3	3	1
	RR= 20 m3/s	13	3	3	1
	RR= 50 m3/s	15	3	3	1
Dry Year	No Riparian Release	17	13	8	2
	RR= 20 m3/s	25	15	12	3
	RR= 50 m3/s	27	15	14	3

The incidence of the riparian release level on the duration of the filling event is quite limited, and even neglectable in case of a wet year conditions. Fast filling means also that the ratio between inflow and storage is high, and that the water level will fluctuate rapidly during operation. This situation is considered as very favorable for the natural control of aquatic weeds development, like water hyacinth. Observation of existing reservoirs in africa shows that the risk of invasion by floating vegetation is the highest for reservoirs with limited and slow variation of their water level.

5.5.2. EVOLUTION OF INUNDATION ZONE

The ecological impact of reservoir filling is concentrated in the first few months after closing, when the flooded area expands rapidly. A short simulation based on a normal year and without riparian release gives the results shown in following table.

The area expands very rapidly the first 5 to 7 months after closing. The reservoir is half its full size after only less than 3 months. The water level raises by 145m the first 3 months, or an average of 1.6m/day (and more than 2m/day the first month). This has evident implications on public safety and animal rescue.

However, these values are based on hydrological conditions at site, and do not consider engineering requirements, which, according to dam type, may slowdown the process.

Table 5.5 Evolution of Reservoir Level and Area during Filling

Month	Level (m)	Monthly variation of level (m)	Area (km^2)	Monthly variation of area (km^2)
May	180	0	0	0
June	250	70	15	15
July	290	40	38	23
August	325	35	85	47
September	335	10	104	19
October	339	4	115	11
November	341	2	116	1
December	343	1	124	8
January	344	1	125	1
February	345	1	126	1
March	346	1	127	1
April	346	1	127	0
May	348	1	129	2
June	351	3	133	4
July	354	4	140	7
August	360	6	148	8

Note: Values expressed end of month; Closing on 1st June.

5.5.3. IMPACTS ON VEGETATION AND FORESTRY

5.5.3.1. ESTIMATED LAND USE IN THE INUNDATION ZONE

As no aerial photographs of the area were made available during this stage of the study, land use has been estimated from satellite imagery (SPOT 1997) and processed by NOFIP. For that reason, the land use presented here is tentative, but probably reflects reasonably well the present land cover as it wasobserved during the field visits.

Figures 5.4 and 5.5 presents land use map of the reservoir respectively for alternatives FSL 360 and FSL 320. Areas concerned are detailed in the following table.

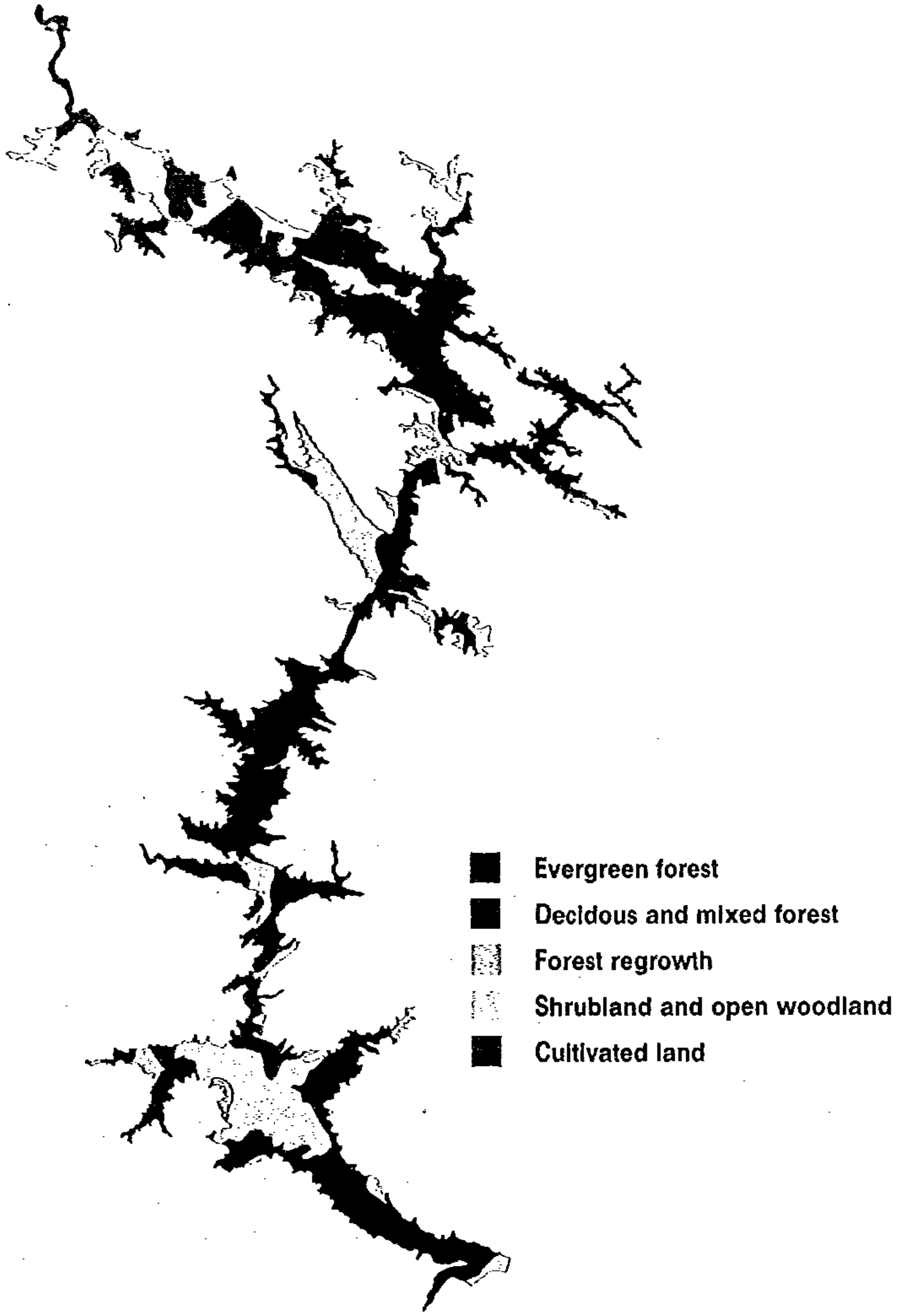
Table 5.6 Distribution of Land Cover in Inundation Zone

Items	Area (ha)	
	FSL360	FSL320
Evergreen forest	830	450
Deciduous forest	8,950	4,480
Forest regrowth	1,200	380
Shrubland	2,890	1,770
Cultivated land	950	310
Total area	14,820	7,390

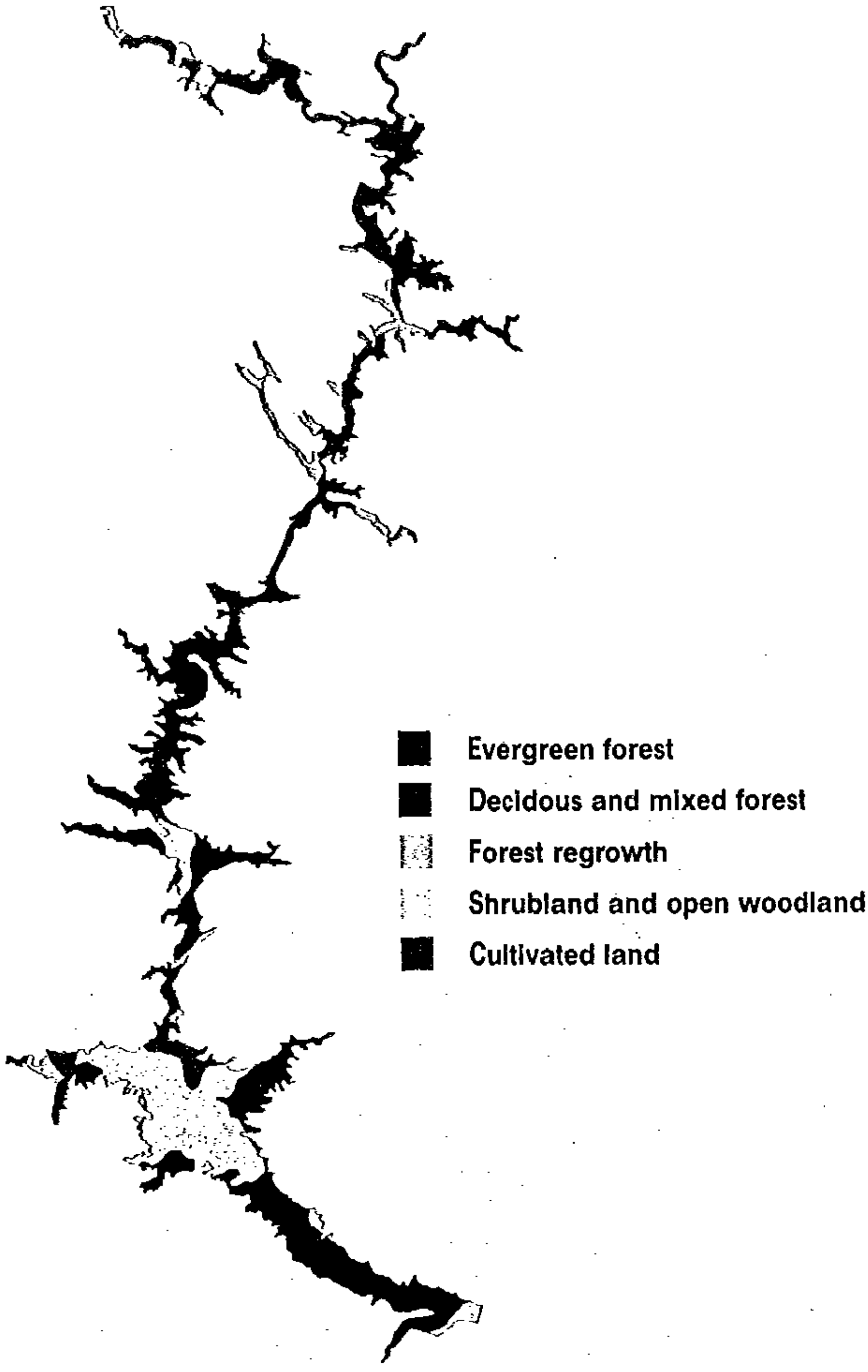
The alternative FSL360 affects almost twice land area as the alternative FSL320.

5.5.3.2. LOSS OF FOREST PRODUCTS

The flooding of the forest will affect habitats and wildlife, but also will represent an economic loss for all the products, which will be lost: timber, non timber forest products (medicinal plants, fruits, material, value for animals and conservation) and more globally, the forest as a carbon storage.



FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	First Environmental Impact Assessment	Figure 5.4
JAPAN INTERNATIONAL COOPERATION AGENCY	Land Cover in Reservoir Area (FSL 360)	



FEASIBILITY STUDY ON THE NAM NGIEP-I HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	First Environmental Impact Assessment	Figure 5.5
JAPAN INTERNATIONAL COOPERATION AGENCY	Land Cover in Reservoir Area (FSL 320)	

At FSL360, 9,780ha of forest represent a timber volume of 290,000m^3 based on the average of 30m^3/ha resulting from the field investigation. Only 148,000m^3 of commercial timber will be flooded by the alternative FSL320 (4,930ha of forest). Assuming a value of timber of US$ 50/m^3 (standing crop, excluding labor), and a potential commercial harvest of 20%, this represents a potential value of 2.9 and 1.5 millions US$ respectively for each alternative.

On the other side, the annual production of the forest will be lost, together with non-forest products. Based on an annual increment of 1.5m^3/ha of commercial wood (0.5% per year), and if valued at an economic cost of US$ 100/m^3 (including US$ 50/m^3 for labor, taxes), it represents for a 50 years period (the life duration of the Project) a net present value loss of 7.3 and 3.7 million US$ respectively for alternatives FSL360 and FSL320 (discounted at 10%/year).

Non timber forest products (NTP) will also be lost. Their valuation is more difficult as it includes products for consumption or for sell, but also the valuation of the forest in terms of biodiversity and tourism development. For NT2, the economic value for NTP has been established at US$ 100/ha/year using the same value, we have an additional economic loss of US$ 148,000 to 74,000 respectively for alternatives FSL360 and FSL320.

Loss for agricultural land and related compensation aspects are detailed and discussed in the Preliminary Resettlement Plan report.

5.5.3.3. RECOMMENDATIONS

It is recommended that additional field work be carried out to establish more precisely the commercial timber volume available in the inundation zone. The cost of a reservoir timber inventory and a logging plan, which integrates with the biomass clearance program is estimated about $150,000 for FSL360 and US$ 110,000 for FSL320.

Prior to or in coordination with the clearing activities, a collection program of NTP inside the reservoir should be organized with the local population in order to maximize their direct benefits from this operation. This should be a part of the elaboration of the Logging and Clearing Plan.

5.5.4. IMPACTS ON CONSERVATION AND WILDLIFE

5.5.4.1. VELOCITY OF FLOODING

As presented in Section 5.5.2, the water level will raise fast during the first few months of the filling (about 140m in 3 months, 2.3m/day the first month). The rapid expansion of the flooded area means that the move of the water line on the ground will be fast also. If considering the reservoir as a circle, the increase of area during the month of August for example, is equivalent to an average horizontal progression of the water line of 2.5m/hour. It is evident that in flatter areas, this move may easily be 5 to 10 times faster. It is probable that animals become trapped on temporary islands or stranded.

5.5.4.2. OUT-MIGRATION

The inundation event will have a number of complex impacts on the terrestrial fauna, which will react in a number of ways, mainly out-migration and drowning.

It is not yet certain what level of activity will occur in the inundation impact zone prior to flooding. If there is timber removal and/or biomass clearance this could disturb many of the large animals and cause them to move out of the area. Even if these activities do not occur most large animals, and highly mobile small animals, will successfully leave the area as the water rises. It must also be appreciated that the inundation event runs steadily through the 24-hour period, offering strictly nocturnal and strictly diurnal animals special problems. Flooding is however a natural phenomenon and most large and small mobile animals are well adapted to avoid being drowned.

This problem is in any event not ecologically speaking very significant. "Displaced" animals may escape drowning, but are usually so disadvantaged by displacement that they suffer accelerated mortality from other causes. Even those animals which successfully establish themselves after displacement will temporarily at least, until population pressures decline through natural regulation processes, be subject with all other members of the species and its competitors, to higher rates of mortality.

The ecological instability generated by the flooding of a large area and the consequent movement of large numbers of animals can have an impact on public health and on crop pests. If large numbers of rodents and carnivore are displaced there are possibilities that the human health environment will be temporarily disturbed. For similar reasons crops pests could become a more serious problem for a short period on fields close to the reservoir. This situation will require monitoring during, and immediately after, reservoir filling.

5.5.4.3. DROWNING OF ANIMALS

The more rapidly moving fauna will by and large have left the inundation area during logging and biomass destruction (if these measures are taken). Those which remain in the area or which return could become trapped on the numerous temporary islands which may form as inundation proceeds (due to the depth of the reservoir and the local topography, it is not anticipated permanent islands except the large one located near the Thaviang area in the Upper reservoir

Animals which become trapped on islands will be difficult to capture, and unless some exceptional species are involved the efficient solution to the problem is to allow the population of islands to stabilize to levels which can be sustained by the food supply, or; for large animals on small islands, to allow the animal to swim to the mainland.

Most of the animals which drown will be small flightless terrestrial animals, immature and injured animals incapable of moving, and soil fauna. Even at 5 tons per ha, a high biomass density for these animal, the bodies of animals drowning will make only a minor contribution to the total biomass decomposition pool. This is unlikely to have any significant effect on future water quality.

Very few floating carcasses are to be anticipated. Any which are found during the more rapid filling period will be towed to a landing place and dragged ashore to undergo decomposition on land.

Suffering and distress of animals: Some slower moving faunal components of the reservoir ecosystem will be drowned when the inundation occurs, and in any case most of those displaced by flooding will not successfully establish new home ranges.

Although the long term ecological affects of this will be inconsequential it is necessary to consider the prevailing attitudes of the developed world in respect of animals living in distant locations, perceived as "natural and unspoiled". It is suggested that some measures, limited to the actual periods of rapid inundation, should be taken to provide safe retreats for, and to collect the slow moving flood survivors.

5.5.4.4. RECOMMENDATIONS

Regular boat patrols should be made during rapid filling to capture these stranded specimens which will be processed in the same way as the slow-moving species.

Provision of safe retreat and collection of slow moving survivors could be achieved using tethered floating rafts (felled low-density timber trees of no commercial value lashed together and distributed as capture sampling points), and "flood survival" trees (i.e. one or a small clump of, tall but timber defective tree(s) every 1,000m² to be left standing after timber felling), which could be patrolled daily by a fast speedboat to capture stranded animals. Captured specimens will be identified. Some could be kept alive for scientific study and breeding, a few could be preserved as scientific specimens and most will be released. The data such an exercise will produce will give a unique picture of the slow moving and burrowing fauna (invertebrates, reptiles, small mammals) which persist in an area even after timber felling and destruction of above ground biomass.

The implementation of such a rescue program for animals during filling, (which has been already implemented four years ago in French Guyana, during the filling of the Petit Saut reservoir) is estimated at US$250,000 for FSL360 and US$170,000 for FSL320 for a 2 years period.

Additional studies to carry out during the next stage of the EIA on wildlife and on the preparation of the rescue plan area estimated at US$80,000.

5.5.5. IMPACTS ON GEOLOGY AND MINERALS

As mentioned in the baseline information section, there is no recognized source of minerals of economic importance in the inundation zone. The regional geology confirms this observation

No mineral extraction by villagers was reported during the surveys, except some collection of sand in the river bed for construction purposes. Concession provided to private companies for exploration are all located outside the inundation zone and even outside the catchment area. The impact of the inundation on mineral resource is considered as insignificant according to the information available at present.

5.5.6. IMPACTS ON INITIAL WATER QUALITY

5.5.6.1. FLOODED BIOMASS

5.5.6.1.1. GENERAL CONSIDERATIONS

As the terrestrial area becomes flooded with rising water immediately following dam closure, several processes occur which have a dramatic effect on the impounded water quality. Plants, starved of atmospheric oxygen die and start to decompose which, when combined with the decomposition of the organic matter from the top soil, depletes the dissolved oxygen of the reservoir water. If this deoxygenated water is not replaced quickly enough, then anoxic conditions will develop at the bottom of the reservoir.

Anoxic conditions create a reducing environment, which with the assistance of anaerobic bacteria will cause many previously insoluble compounds to change into soluble forms, with many undesirable consequences: release of ammonia, metals such as iron, manganese, sometimes mercury. Additionally, sulfate will be reduced to the highly acidic hydrogen sulfide by a bacteria which can corrode metal components of the turbines. The severity of these changes is highly detrimental to both the project electro-mechanical equipment and the aquatic life. The extent and severity of the anoxic region depends upon several parameters, the major being the quantity of organic matter flooded and the characteristics of the reservoir.

Another consequence of the vegetation flooding is the release of nutrients such as nitrogen and phosphorus, which participate in the eutrophication process of the reservoir, with dramatic consequences on water quality in the long term.

The aim of this section is to establish a first evaluation of alteration risk regarding water quality, by reviewing successively the vegetation biomass flooded, the natural inflow of nutrients and the possibilities to minimize the anticipated impacts, mainly by pre-impoundment clearing.

5.5.6.1.2. ESTIMATE OF FLOODED BIOMASS

Assessment of flooded biomass is generally based on approximate figures from various origins in the world, with high uncertainties on their representativity. For the present case, the situation is quite different as some measurements have been carried out during field investigations, but also because comprehensive studies have been carried out in the past few years for the Nam Leuk Hydro electric Project, located only some 40km west from Nam Ngiep HEPP. Based on these sources, the anticipated biomass in the future reservoir has been estimated. The following table summarizes the results on biomass volumes in the reservoir, based on data from field work and Nam Leuk experience, and on the land use distribution in the inundation zone as previously presented.

Table 5.7 Estimated Biomass in Reservoir Area

Items	Biomass (t/ha)		Area (ha)		Total biomass (in '000 t)			
					FSL360		FSL320	
	Soft	Hard	FSL360	FSL320	Soft	Hard	Soft	Hard
Evergreen forest	28.9	185.9	830	450	24.0	154.3	13.0	83.7
Deciduous forest	28.9	185.9	8,950	4,480	258.7	1,663.8	129.5	832.8
Forest regrowth	28.9	111.5	1,200	380	34.7	133.8	11.0	42.4
Shrubland	28.9	55.8	2,890	1,770	83.5	161.3	51.2	98.8
Cultivated land	23.1	0	950	310	21.9	0.0	7.2	0.0
Total area			14,820	7,390				
Total above ground					422.8	2,113.2	211.8	1,057.6
0-5 cm top soil	9.8	1.8	14,820	7,390	145.2	26.7	72.4	13.3
0-25 cm top soil	20.7	16.1	14,820	7,390	306.8	238.6	153.0	119.0
Total with 5 cm soil					568.0	2,139.8	284.2	1,070.9
Total with 25 cm soil					729.6	2,351.8	364.7	1,176.6

Note: Cultivated land soft biomass estimated 80% of forest soft biomass value
Forest regrowth hard biomass is 60% of forest hard biomass value
Shrubland hard biomass is 30% of forest hard biomass value

Vegetation biomass in the reservoir area at FSL320 is exactly 50% of the biomass flooded at FSL360. Almost 85% of the total biomass is represented by the hard biomass (slow decay biomass).

5.5.6.1.3. ESTIMATE OF INITIAL CARBON QUANTITIES

The carbon is the key component of the biomass, as it represents 80 to 90% of the dry biomass weight. The decay of the organic matter will release in the water either carbon dioxide (aerobic conditions) or methane gas if anaerobic conditions. Then methan gas is oxidized using dissolved oxygen or atmospheric oxygen. In the first case, the water is rapidly depleted of its oxygen, with the death of aquatic organisms. In the second case, it participates to the Global Warming process, as CO_2 and CH4 are the two most important gases involved in the warming of the Earth. This later aspect is discussed in further details in Section 5.7.9 "Impacts on Global Warming issues".

Table 5.8 Estimate of carbon content in the reservoir area

Items		Per ha (tons/ha)	Unit	FSL360			FSL320		
				Soft	Hard	Total	Soft	Hard	Total
Dry biomass*	Before clearing	183	'000 tons	568	2,140	2,708	284	1,071	1,355
	After clearing	89	'000 tons	230	1,083	1,313	115	542	657
Carbon	Before clearing	165	'000 tons	454	1,712	2,166	227	857	1,084
	After clearing	80	'000 tons	184	867	1,050	92	434	526

Note: * Dry biomass includes above ground plus 0-5 cm soil biomass

5.5.6.1.4. IMPACT ON DISSOLVED OXYGEN

According to investigations carried out during the filling period of the Petit Saut dam in French Guyana, which flooded almost 500km² of tropical forest (without pre-impoundment clearing), methane gas is mainly released during the first year of the decay process, until methano tolerant bacteria develop at the level of the thermocline and use CH4 and oxygen of the epilimnion to produce CO_2.

Only a limited part of the methane gas is released by diffusion through the water surface to the atmosphere (20%). The remaining gas is transformed using the dissolved oxygen of the water. This is the reason why water in a new reservoir is generally anoxic. Studies of Petit Saut reservoir show that the oxydation of 1mg CH4 requires almost 3mg Oxygen. Concentrations of CH4 in Petit Saut water during the filling phase reached 6.5mg/l after 250 days, 12mg/l after 330 days and 14mg/l after 450 days (or 15 months).

In October 1999, 60 days after impoundment, dissolved oxygen in Nam Leuk reservoir was nil below 5m. These observations applied to Nam Ngiep made unavoidable the fact that the reservoir will face anoxic conditions. The release downstream of up to 80% of the methane gas produced in the reservoir will have detrimental impacts on the lower reach of the Nam Ngiep, except if a re-aeration device is implemented at tail race level: Such a device implemented in Petit Saut (2 levels waterfall) shows an abatment of 80% of CH4 concentration in water.

As an example, if we assume 10mg CH4/l after 1 year reservoir filling, without riparian release, the total stock of dissolved methane will be about 50,000 tons, 20% or 10,000 tons being released to the atmosphere through the lake surface. To oxydize the remaining stock of 40,000 tons, about 120,000 tons of dissolved oxygen will be required, to compare with the annual oxygen inflow of 38,000 tons (based on a DO content of inflow of 7.5mg/l). The deficit is obviously high.

5.5.6.2. PRE-IMPOUNDMENT RESERVOIR MANAGEMENT

5.5.6.2.1. CLEARING OPTIONS

Four options for basin clearing may be considered:

1. Do nothing
2. Cut trees without removal
3. Cut trees and remove
4. Cut trees and burn.

Following table adapted from IMC, 1982) presents some advantages and disadvantages of each option.

Table 5.9 Reservoir Clearing Options

Strategy	Advantage	Disadvantage
Do Nothing	Long tern fish yield increased through increased nutrients. Standing trees provide : - protection for several fish species - environment for algal growth Very low cost.	Rapid de-oxygenation of bottom water results in fish kills and production of hydrogen sulfide. High nutrient load can cause rapid growth of large floating macrophytes which can provide habitats for vectors for various diseases and also clog turbines. Navigation and gill net fishing is hindered. Re-oxygenation by wind mixing is hindered. Loss of valuable timber. Methane generation results in large greenhouse gas emissions.
Cut trees without removal	Long tern fish yield increased through increased nutrients. Permits fishing and navigation.	Rapid de-oxygenation results in fish kills and production of hydrogen sulfide. High nutrient load can cause rapid growth of large floating macrophytes which can provide habitats for vectors for various diseases and also clog turbines. Labor intensive. Promotes shoreline erosion through soil instability. Loss of potential fish habitats. Loss of valuable timber. Methane generation results in large greenhouse gas emissions.
Cut Trees with removal	Reduces oxygen demand and associated hydrogen sulfide production. Sale of timber can increase economic viability of project. Permits fishing and navigation. Reduces total greenhouse gas emissions.	Very costly. Logistic problems in removing materials. Lower overall lake production. Promotes shoreline erosion through soil instability.
Cut Trees and burn	Reduced total greenhouse emissions. Easier than hauling trees. Permits fishing and navigation. Reduces hydrogen sulfide production.	Allows immediate solubilisation of inorganic nutrients. Potential for explosive algal and macrophyte growth. Promotes shoreline erosion through soil instability. Loss of valuable timber.

The best strategy for the Nam Ngiep is most likely a combination of the above options. The objectives of the pre-impoundment could be:

- To maximize income from commercially viable timber
- To minimize adverse impacts of high initial oxygen demand
- To control nutrient concentrations and risk of eutrophication during initial filling
- To create a suitable area for fish
- To allow reservoir navigation and commercial fisheries
- To create stable lake shorelines
- To minimize greenhouse gas emissions.

5.5.6.2.2. PRIORITY ZONES FOR CLEARING

It is too early to identify precisely the areas to be cleared, but it is assumed that dense forest areas have to be considered first as having higher biomass per hectare. The central part of the reservoir will probably be a priority. The development of roads close to the reservolr in the coming years will probably facilitate the commercial logging considered to day to be able to release only 20% of the standing crop of the area.

5.5.6.2.3. EFFECTS OF CLEARING ON RESERVOIR CARBON AND NUTRIENTS

Based on the recent clearing experience of the Nam Leuk reservoir, a rapid clearing and burning may reduce the soft vegetation biomass by 88% when burning is 100% efficient. Most of the time, (as measured for Nam Leuk) unburned biomass and regrowth reduce the efficiency of the process to a total reduction of about 77% to 80% in soft biomass. This is the best case with a short duration of clearing (few months). For longer duration, it may be expected a lower result as regrowth becomes more significant, measured at more than 3 tons/ha/year (dry weight).

Regarding the biomass from the soil, no practical solution exists to reduce it. The effect of clearing in terms of percent biomass reduction will be quite different according to the depth of soil concerned. The actual situation will probably be between this range of 5 to 25cm according to the local area (soil texture, slope, located in draw down zone or not).

For hard biomass, the clearing and logging operation can hardly remove more than 45 to 50% of the original volume.

Table 5.10 Potential Maximum Reduction of Biomass in Reservoir Area

Biomass in '000 tons		Total soft biomass		Total hard biomass	
		FSL 360	FSL 320	FSL 360	FSL 320
Before clearing	with soil 0-5 cm	568.0	284.2	2,139.8	1,070.9
	With soil 0-25 cm	729.6	364.7	2,351.8	1,176.6
After clearing	with soil 0-5 cm	229.8	114.8	1,083.3	542.1
	With soil 0-25 cm	391.3	195.3	1,295.2	647.8
Biomass reduction (as a % of initial situation)	with soil 0-5 cm	59.54	59.61	49.37	49.38
	With soil 0-25 cm	46.37	46.45	44.93	44.94

Further studies are obviously required in order to optimize the cost of clearing with the benefits expected. It is worth to mention that clearing operation is not only necessary for water quality aspects but also for the future management of the lake regarding tourism and fisheries development opportunities. Some areas may require to remain uncleared to provide habitats for fishes and some protection against fishing, as in spawning areas.

Based on the experience of Nam Leuk, where the reservoir (1,300ha) was totally cleared by hand by the local population (400 persons) in 5 months, the average cost for clearing comes to US$420/ha. This represents a clearing cost of about US$ 4 to 5 millions for the FSL360 and about US$ 2 to 3 millions for FSL320.

5.5.6.2.4. IMPACTS OF CLEARING ON GREENHOUSE GAS EMISSION

The destruction of forest to make way for the reservoir will result in the release of stored carbon in the vegetation to the atmosphere. The release of carbon either as CO_2 from burning or methane gas through submerged anaerobic decomposition contributes to the worldwide built up of greenhouse gas and resulting global warming.

This aspect is discussed in further details in Section 5.7.9 "Impacts on global warming issues".

5.5.6.2.5. RECOMMENDATIONS FOR CLEARING OPERATIONS

Based on the recent experience of Nam Leuk, some preliminary principles for clearing may be proposed at this early stage of the study. These will have to be detailed during the preparation of a logging and clearing plan during the next stage of the study. The main recommendations and objectives may be summarized below:

- Removal of maximum commercially viable timber except in some designated buffer zones. With an estimated conservative timber standing crop of 30 m^3/ha in average in the forested area, valued at US$50/$m^3$, this represents a potential gain of US$15-7 millions, respectively for FSL360 and FSL320. As evacuation of logs from reservoir area may be difficult, costly and impacting for surrounding forest areas (because of the creation of access roads), transformation on site with portable sawmill and removal of logs by flotation during the filling phase should be considered (see also next section).
- Cut, clear and burn a maximum of the remaining vegetation. Experience from Nam Leuk shows the possibility to rely on hand clearing in areas inaccessible by heavy equipment. The cost proved also much lower, with an average for Nam Leuk of US$420/ha for clearing and burning. This social approach is also in line with the request of major funding agencies to have these major project to generate benefits not only to the Government but also to local communities. For Nam Leuk, the clearing operation represented for the participating communities and income of US$ 350,000 over a 5 months period.
- Avoid removing stumps as soil disturbed may release faster more nutrients in water.
- Haul as much as possible of the burnt vegetation residual from the reservoir area (see next section)
- Maintain a 200m wide buffer zone along the major creek channels to control sediment movement down the reservoir and additionally to provide habitats for fish and to preserve them against commercial fisheries (nets can hardly be used because of the branches)
- Preserve at least a 100m wide vegetation strip around the perimeter of the reservoir so that the intact root structure of the trees will help bind the soil and reduce shoreline erosion and wave erosion. This will also provide a shelter for fish.

5.5.6.3. MANAGEMENT OF FLOATING DEBRIS

Large volumes of floating debris will be produced during the filling phase. Observation from Nam Leuk shows that after clearing and burning, large volumes of partly burnt material, mainly composed of soft wood branches and trunks were becoming a hazard for the equipment and the bottom outlet during the first floods which partly fill the reservoir. Estimated quantities ranged from 20-90 tons/ha. Special measures will be required to collect these debris and to haul them on appropriate landing grounds to collect and transform those which may be usable and to burn the others. This program has to be combined with activities of filling phase management which includes also the rescue of animals.

5.5.7. IMPACTS ON FISHERIES

The conversion of a fast flowing stream to a reservoir is a profound habitat modification. Most individuals, and many species, will be unable to find suitable new habitat in the reservoir, particularly during its unstable early evolution stages. Fortunately there are many kilometers of rivers and streams upstream of the reservoir which are virtually identical to those parts of the Nam Ngiep which are to be inundated.

5.5.8. RESETTLEMENT, ARCHEOLOGY AND CULTURE ISSUES

These issues are detailed in the Preliminary Resettlement Plan report.

5.6. THE FILLING PHASE : IMPACTS ON THE DOWNSTREAM ZONE

5.6.1. IMPACTS ON THE AQUATIC SYSTEM

5.6.1.1. ALTERATION OF RIVER FLOW

As soon as the dam is closed, the downstream area will face a drastic change in flow. The remaining catchment below the dam is by far too limited to provide a discharge in the river sufficient to preserve the aquatic ecosystem and human activities related to the river.

The following table provides results from simulation of various riparian releases.

Table 5.11 Change in Flow during Filling with Various Riparian Releases (Mean year)

	(in m^3/s)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Muangmai	Before	69	58	50	46	80	217	276	680	419	196	124	76
no RR	After	10	8	7	7	12	32	40	99	61	28	18	11
RR 20 m^3/s	After	30	28	27	27	32	52	60	119	81	48	38	31
	% of ini.	44	49	54	58	40	24	22	17	19	25	31	41
RR 50 m^3/s	After	60	58	57	57	62	82	90	149	111	78	68	61
	% of ini.	87	100	114	123	77	38	33	22	26	40	55	80
Mekong Conf.	Before	72	61	53	49	84	228	290	714	440	206	130	80
no RR	After	13	11	10	9	16	43	54	134	82	39	24	15
RR 20 m^3/s	After	33	31	30	29	36	63	74	154	102	59	44	35
	% of ini.	46	51	56	60	43	27	26	21	23	28	34	44
RR 50 m^3/s	After	63	61	60	59	66	93	104	184	132	89	74	65
	% of ini.	88	100	113	122	78	41	36	26	30	43	57	81

As shown in this table, change in the downstream river flow is particularly significant.

In addition to the option "no riparian release", two other options have been considered according to the following objectives

- to provide at least 50 to 60% of natural flow during the driest months of the year in Muangmai. This is the case for a RR of 20m^3/s, and
- to provide 80 to 100% of natural flow during the driest months of the year in Muangmai. This is the case for a RR of 50m^3/s.

This is a preliminary basis for further optimization during the next stage of the study. As explained previously, because of the relatively fast filling of this reservoir, increasing the riparian release has moderate effects on the filling duration. An important role of the riparian release will also be the elimination of a part of the nutrients quickly released in the reservoir by the rotting vegetation. The higher is the RR, the larger is the amount of nutrients released from the reservoir. This has also to be optimized with the level turbines will start. It may be better to have a lower RR during a shorter period in order to start turbining sooner with higher discharge. All these points will have to be clarified during the next stage of the study.

Regarding the "no riparian release option", it cannot be eliminated. Indeed, in case of the alternative FSL320, the filling of the reservoir to MOL+2 m is very fast, less than 4 months. If the closing of the dam is delayed by one month, the duration of filling is not really much longer, and it gives the opportunity to have more probability for secured rains (June is sometimes quite dry, with late rains). In this case, the inflow from the downstream catchment ranges from 40 to 100m^3/s at Muangmai, which may be sufficient to maintain in reasonable condition the downstream ecosystem, and avoid the heavy load of organic matter which will concentrate at the beginning of the closure. By the time turbine operation starts, there should be already some dilution of the organic matter, with lower and possibly less detrimental concentrations.

The opportunity to let the diversion open in the beginning of the wet season, may also allow run off to wash the reservoir bottom and to eliminate a probably significant part of the nutrients and carbon load. But this option may impact more seriously the downstream area.

A global optimization of the filling procedure is required in the next stage of the study.

5.6.1.2. ALTERATION OF WATER QUALITY

This aspect has already been discussed. As soon as the filling starts, heavy loads of organic matter will be transported by the water and released downstream. The water will probably be anoxic, and fish kills in the upstream and downstream aquatic zones are expected.

Over consumption of dissolved oxygen is the key factor of downstream impact. As the project will implement a re-regulation structure to regulate the flow downstream, various types of re-aerating equipment must be considered, to accelerate the capture of oxygen in water and thus to reduce impact on ecosystems.

Air injection systems, hollow jet valves are among classical systems. Increased turbulence through a metallic structure at the outlet of the tailrace channel has been experienced for the Petit Saut dam in French Guyana. But in case of flat slope downstream, the situation for Nam Ngiep, as for many hydro projects, this may require the loss of few meters head, which has a cost.

Also as discussed previously, it is anticipated that the re-aeration of water under natural condition will affect the whole downstream area, which is only 54 km up to the Mekong confluence.

It is also probable that a significant organic matter load will reach the Mekong during filling, but the dilution ration between a riparian release and the Mekong during the wet season is such that no significant impact is anticipated.

5.6.1.3. IMPACTS ON WATER USES

Water uses of the river in the downstream area will be directly impacted by the filling. As the problem of low water quality is not limited to the filling but covers a longer period of time, an alternative water supply system will be required for the downstream population.

As presented in Section 5.4.1, a system consisting of large hand pumps may provide the population with a reliable and safe water source for all domestic uses, and for watering animals. A ratio of one pump per 20 households (about 100 people) may be achieved at a cost estimated at US$ 250,000 (1,32 households).

Regarding river transportation, only the flow may be restrictive, if a too small RR has been selected.

For irrigation, the same remark apply. There is at present only limited areas irrigated from the Nam Ngiep (only 3 pumps, the most important being at the confluence with Mekong). In the last 10km before the confluence with the Mekong, the water level should not be too much affected as it is basically fixed by the Mekong level. As the pumps are all located in this reach of the river, no impact is anticipated on irrigation.

The rich nutrient water is not a constraint for irrigation, at least during the filling period. Later one, the release of anoxic but possibly colder and acidic water may become a problem.

5.6.1.4. IMPACTS ON FISHERIES

Fisheries will be probably severely affected by the filling of the reservoir. Fisheries in the downstream area are river dependent. As confirmed by the socio-economic survey, most of the fishing activity is located in the Nam Ngiep River. No doubt that the filling phase and the following years will see a drop in fish catches and subsequently in the animal protein diet of the population. The impact on the river fisheries may be possibly reduced in terms of intensity and duration, but will not be avoided.

It will be of utmost importance to implement all measures, which have already been mentioned to improve the water quality, and to implement during the construction stage a fishery intensification program with the objective to initiate a fish production more independent from the river.

A recent survey carried out in 1998 by RMR in the context of the Nam Leuk Project consisted in the identification of existing processes and trends in fishery intensification in the area of Thabok and in the Vientiane plain. Several practices have already been identified, namely: Rice field fish pond, Funnel trapping of surface drainage channel, Fish home fattening tanks, Opportunistic fish ponds, Village fish ponds, Field fish ponds, Floating net cages.

Various sources establish the potential yield of rivers in Laos at 10 to 15 kg/ha of river surface, based on a maximum sustainable production of 50% of the standing crop (fish stock). If we consider that the Project will alter the fisheries in the downstream river, which represents an area of 820ha, it means on these production basis that the loss may be estimated at 12,3 tons fish/year. However, this represents only about less than 10% of the total fish consumption in these downstream villages, estimated at about 150 tons per year.

5.6.1.5. RECOMMENDATIONS

Further study for the elaboration of a fishery development plan and intensification program is recommended during the next stage of the Feasibility study.

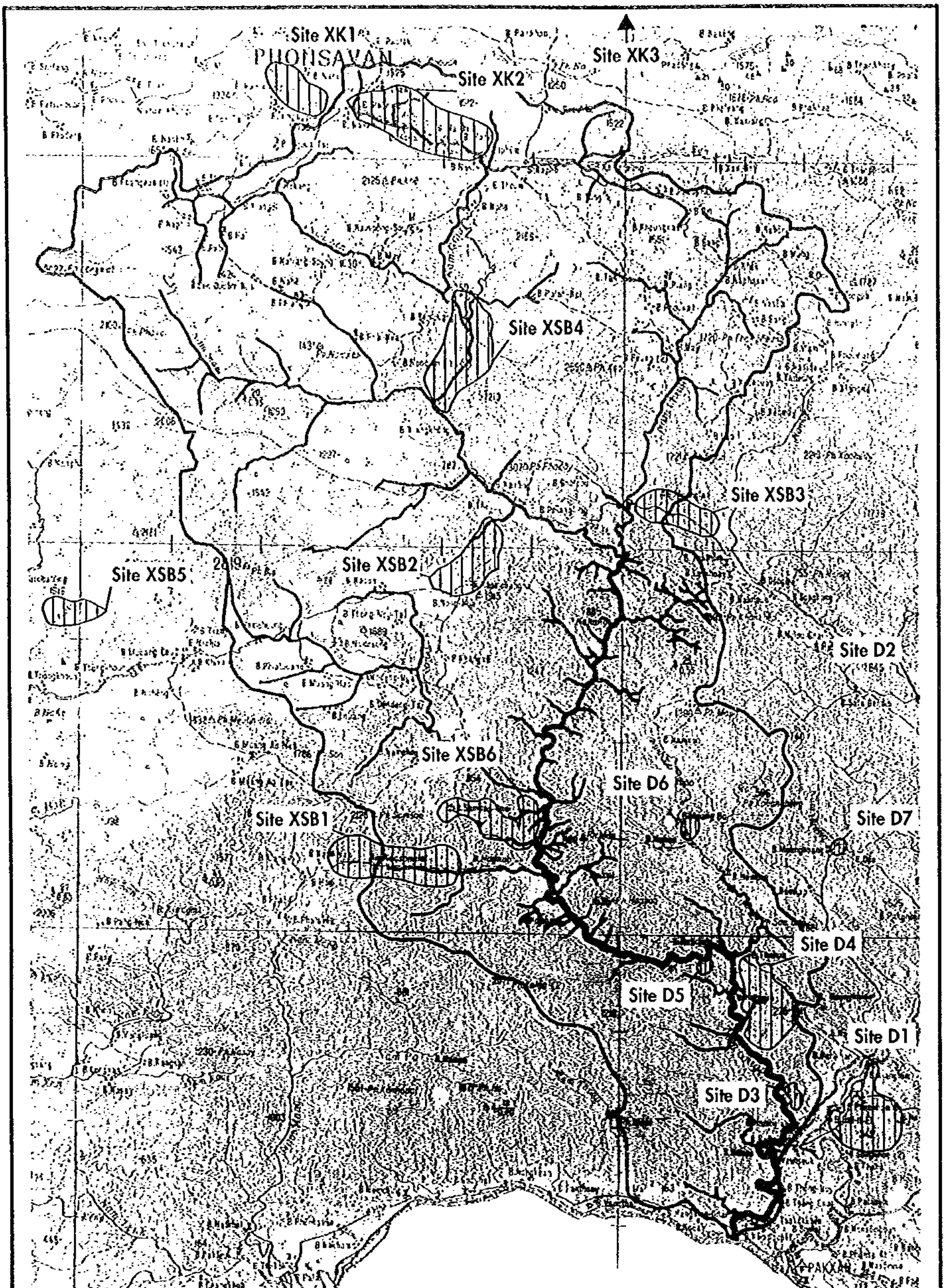
5.6.2. IMPACTS ON THE LAND SYSTEM

5.6.2.1. POTENTIAL FOR RESETTEMENT ALONG ACCESS ROAD

As shown on following figure, few sites have been identified in the downstream area as possibly suitable for resettlement. During the late construction period and during the filling period, if some of these sites are eventually used, there should be land development in the area, with additional requirements in terms of water and firewood. Additional pressure on wildlife and biodiversity may also be observed, particularly in areas considered as interesting for wildlife. These aspects will have to be fully considered in EIA studies for resettlement sites to be prepared during the next stage of the Feasibility. Figure 5.6 shows the potential resettlement sites.

5.6.2.2. REHABILITATION OF ALL CONSTRUCTION SITES

At the end of the construction, the Contractor will be required to carry out the rehabilitation of all construction sites, quarries, spoil disposal sites and borrow areas. Specifications related to these tasks will be clearly detailed in the contractual specifications of the Contractor(s).



FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	PRELIMINARY RESETTLEMENT PLAN	Figure 5.6
JAPAN INTERNATIONAL COOPERATION AGENCY	**POTENTIAL RESETTLEMENT SITES**	

5.6.2.3. IMPACTS ON CONSERVATION AND WILDLIFE

Nothing special to the filling phase will happen downstream, except perhaps the departure of the worker population, which may possibly reduce the pressure they may have induced during construction on the wildlife in the area. However, strict regulations regarding hunting and gathering in natural areas will be imposed by contract to the contractor's workers.

5.7. THE OPERATION PHASE IN THE INUNDATION ZONE

5.7.1. RESERVOIR BEHAVIOR AND MANAGEMENT

5.7.1.1. STORAGE SIMULATIONS

Storage simulations have been carried over a period of 30 years during the hydrological studies. These simulations have been used in the present study to assess impacts resulting from reservoir behavior.

When appropriate, the situations observed concern 3 typical years selected from the 30 years simulations: year 17 (mean year), year 27 (dry year) and year 29 (wet year).

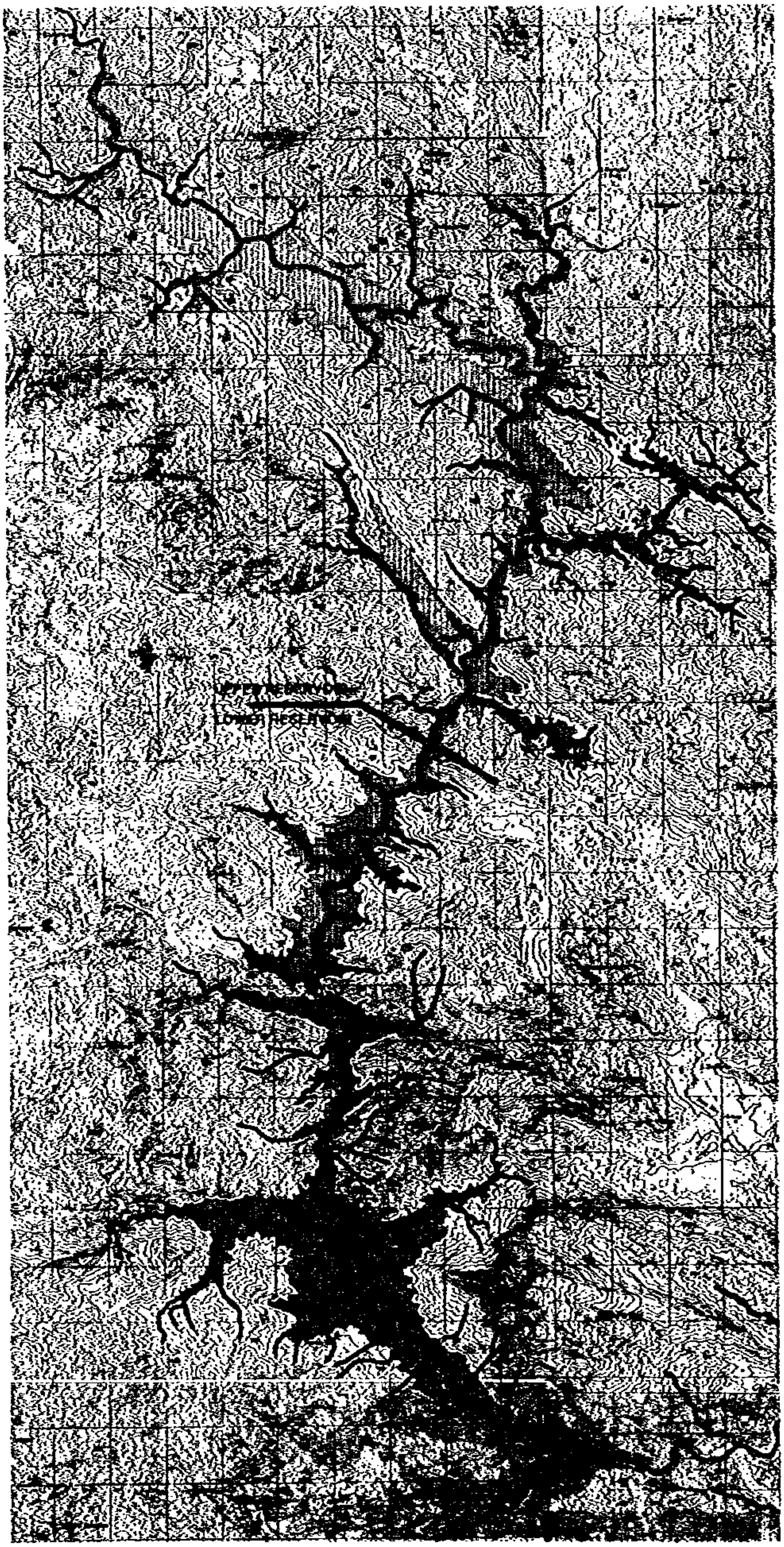
5.7.1.2. RESERVOIR LEVEL

The reservoir will be a highly dynamic system with permanent changes of level and area according to season, inflow conditions and power production.

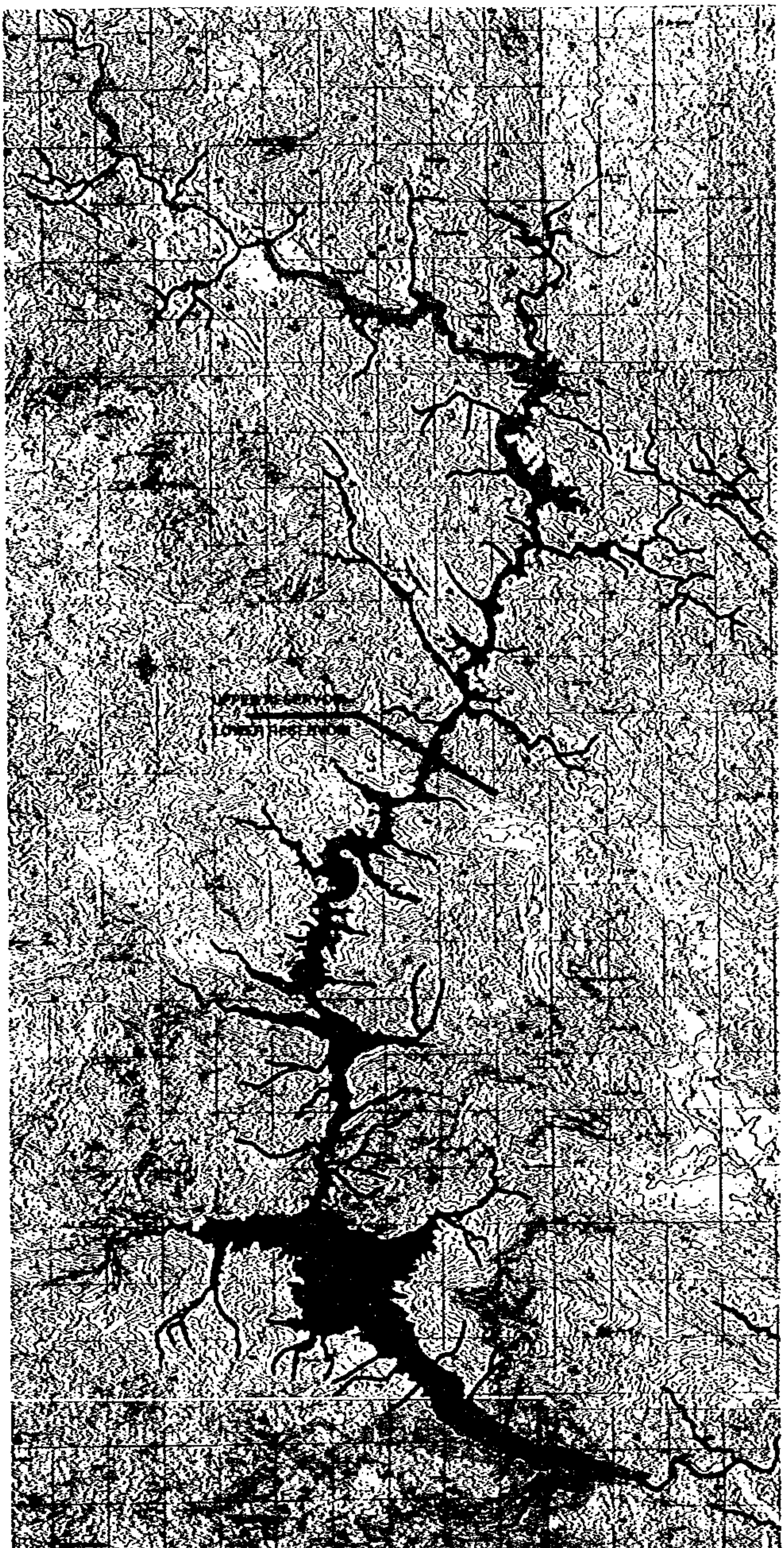
The reservoir level varies from EL.360m to EL.335m for the high dam alternative, and from EL.320m to EL.284m for the low dam alternative. Both alternatives are presented in Figures 5.7 and 5.8.

In a mean year, the draw down for FSL360 is very limited, to about 11m only. The management of the reservoir is based on keeping a maximum head rather as water volume is not a limiting factor. For FSL320, amplitude of drawdown is almost the double, 20m, as a result of a more intensive use of the active storage.

Data for each typical years are presented in the following table.



FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	FIRST ENVIRONMENTAL IMPACT ASSESSMENT	Figure 5.7
JAPAN INTERNATIONAL COOPERATION AGENCY	**PROJECT ALTERNATIVE FSL 360m**	



FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	FIRST ENVIRONMENTAL IMPACT ASSESSMENT	Figure 5.8
JAPAN INTERNATIONAL COOPERATION AGENCY	**PROJECT ALTERNATIVE FSL 320m**	

Table5.12 Variation of Reservoir Level according to Hydrological Year

Typical Year	Level of reservoir (FSL360)			Level of reservoir (FSL320)		
	Mean	Dry	Wet	Mean	Dry	Wet
Jan.	356.5	340.7	344.7	314	307	310
Feb.	354.7	337.9	342.5	311	303	305
Mar.	352.6	335	340	307	296	301
Apr.	350.5	335	337	302	286	293
May	349.1	335	335.5	299	284	289
Jun.	350.2	335	340.7	301	284	303
Jul.	352.4	337.3	347	306	291	317
Aug.	360	340	360	320	299	320
Sep.	360	340.4	360	320	301	320
Oct.	360	338.6	360	320	297	320
Nov.	359.2	335.7	359.5	319	290	320
Dec.	357.6	335	357.9	316	284	317

5.7.1.3. AREA OF SHALLOW WATER

Only one large island will be located near Thaviang area in the Upper reservoir. The topographical documents available at present do not indicate any other possibilities of islands even temporary, between FSL and MOL for both alternatives.

The area of shallow water, between 0 and 15m depth, is an important zone in a reservoir. It follows generally the shoreline of the lake and allows penetration of the lightover most of its depth. It is an area of high biological production. Fish is mainly located in this area, benefiting warmer conditions and the presence of food on the bottom. Spawning areas are also located in the shallowest areas, 0-5m deep. Shallow waters are preferential areas for fishing.

Variations of shallow areas for both alternatives are presented in the following table.

Table 5.13 Evolution of Shallow Areas

Level	Unit	Shallow area		
	ha	0-5m	0-10m	0-15m
Alternative FSL360				
360	14,800	400	1,300	2,200
355	14,400	900	1,800	2,500
350	13,500	900	1,600	3,100
345	12,600	700	2,200	3,200
340	11,900	1,500	2,500	3,400
335	10,400	1,000	1,900	3,000
Alternative FSL320				
320	7,400	500	1,000	1,700
315	6,900	500	1,200	2,000
310	6,400	700	1,500	2,900
305	5,700	800	2,200	2,600
300	4,900	1,400	1,800	2,200
295	3,500	400	800	1,200
290	3,100	400	800	1,100
285	2,700	400	700	1,100

Spawning areas may be more promising with the FSL360 alternative, as shallow water area is large when the lake level comes close to its lowest level (end of dry season).

For the 0-15 m deep area, which offers the potential for fishing, the difference between both alternatives is also significant. However, a more limited area for fishing may provide higher fish yield per hectare, with lower fishing effort.

For the alternative FSL360, the larger area with up to 10m depth is observed for reservoir levels EL.340-345m. This most probably corresponds to the Thaviang plain area in the upper reservoir.

5.7.2. THE DRAWDOWN AREAS

The temporary inundation zone (drawdown area) is an important zone, which is exposed to air a part of the year, and flooded the other part. If reasonably flat, this zone may provide opportunities for agricultural development, grazing land, or even wetland where the production of aquatic products may be high. It is also positive for water quality because a part of the organic bottom of the reservoir will continue to decay, but in air conditions, using atmospheric oxygen instead of dissolved oxygen for oxydation process. This is also an excellent way to control aquatic vegetation, which is seasonally left drying up in the sun.

Maximum draw-down areas are presented for each alternative in Figures 5.9 and 5.10.

5.7.2.1. LOCATION OF DRAW DOWN AREAS

The distribution of draw down areas in accordance with project alternative and reservoir area is presented in the following table.

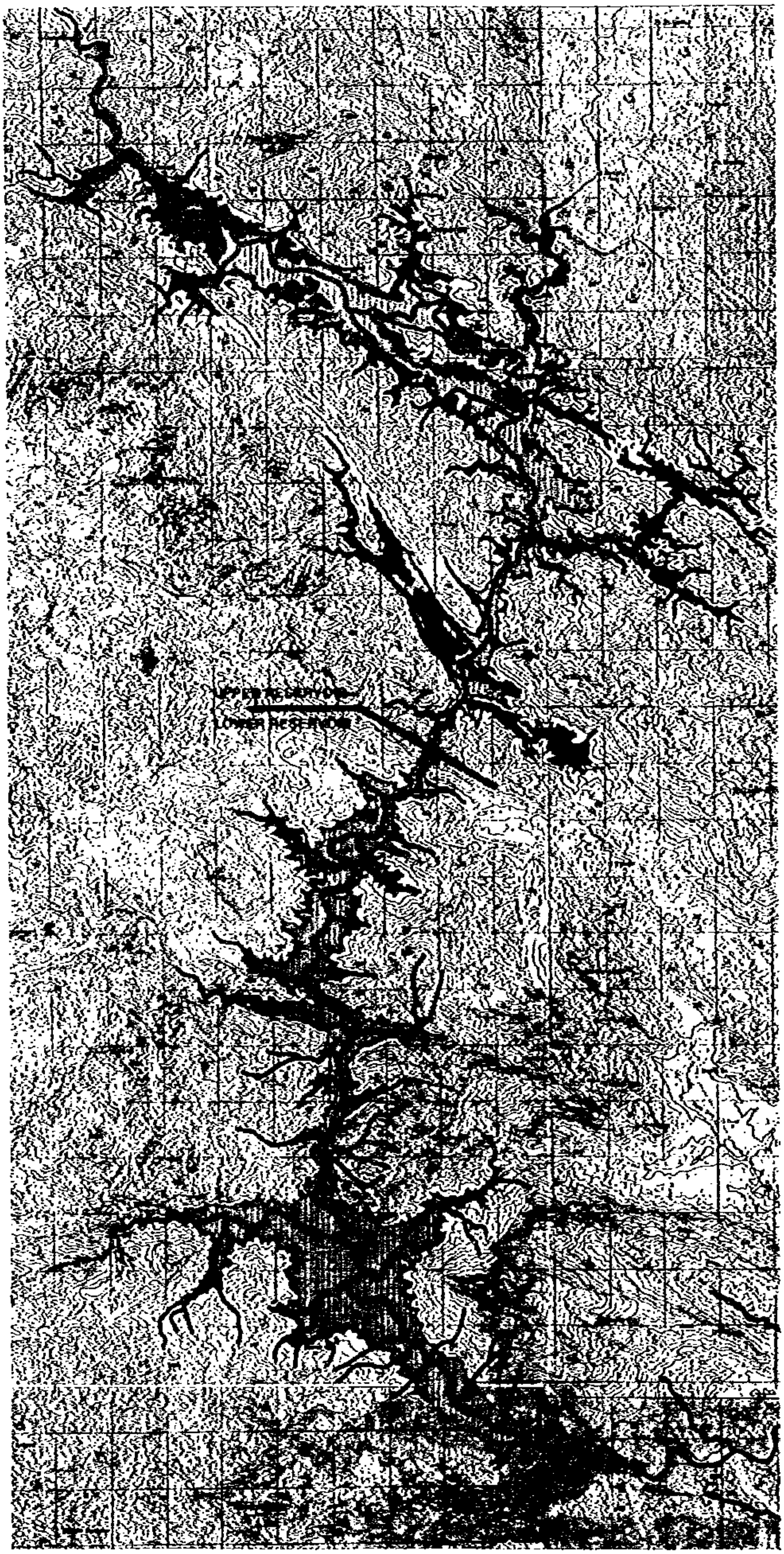
Table 5.14 Distribution of Maximum Draw-Down in Upper and Lower Reservoirs

Area	Areas in ha	FSL 360	FSL 320
Upper Reservoir	FSL Area	7,210	2,130
	MOL Area	3,960	440
	Maximum Draw down	3,250	1,690
Lower Reservoir	FSL Area	7,610	5,250
	MOL Area	6,440	2,830
	Maximum Draw down	1,170	1,690
Total Reservoir	FSL Area	14,820	7,380
	MOL Area	10,400	3,270
	Maximum Draw down	4,420	4,110

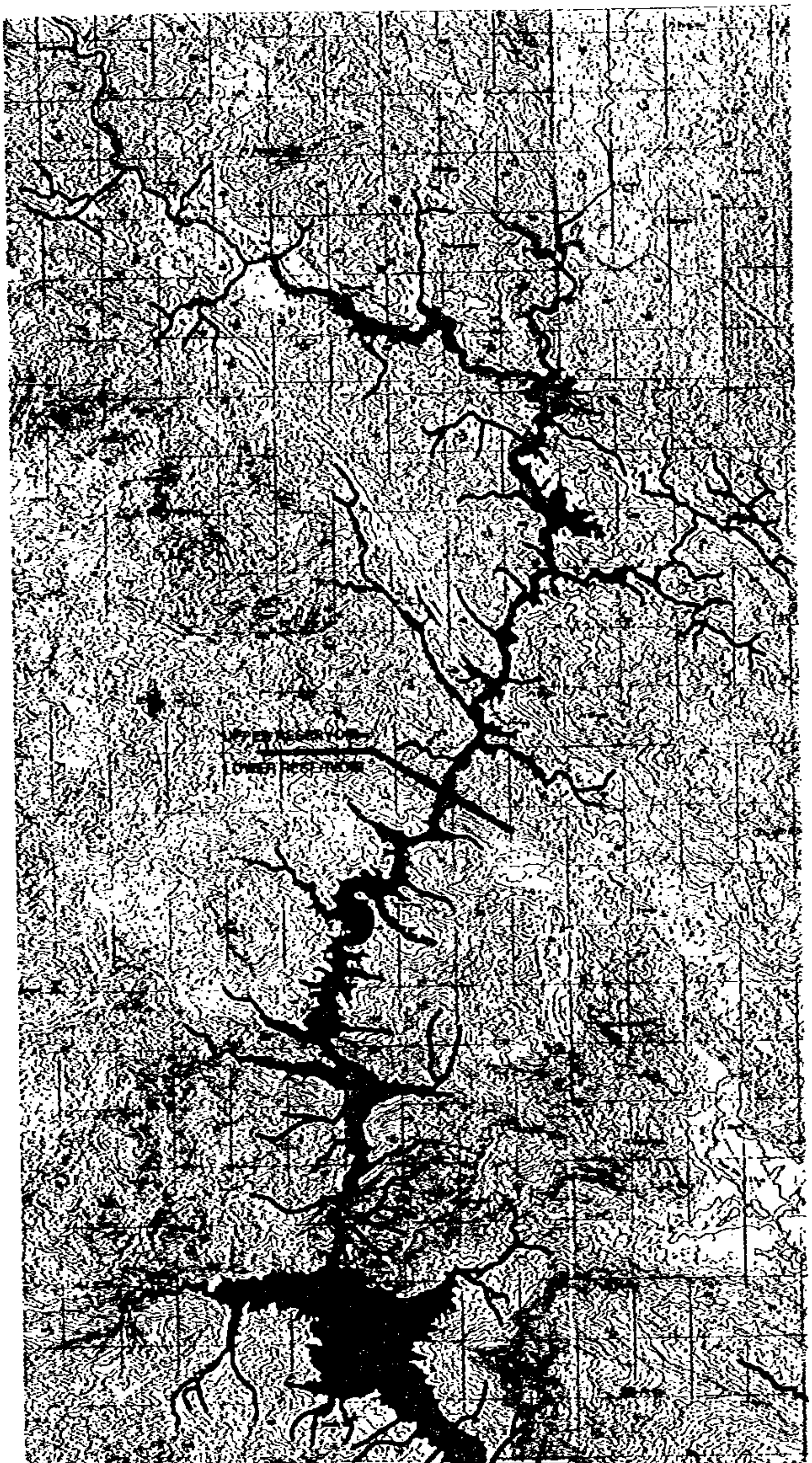
The result is quite surprising, but both alternatives offer almost the same draw down maximum area. This is explained by the higher draw down amplitude of the FSL320 alternative, with 36m (EL.320m to EL.284m), when compared with the FSL360 alternative which has only 25m draw-down amplitude.

However, the distribution of draw down areas is different according to the alternative considered. FSL360 develops mainly draw down area in the Upper reservoir, while FSL 320 presents equivalent areas in the upper and lower reservoirs.

This aspect will have to be considered in the resettlement strategy during the next stage of the study.



FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	FIRST ENVIRONMENTAL IMPACT ASSESSMENT	Figure 5.9
JAPAN INTERNATIONAL COOPERATION AGENCY	**DRAWDOWN AREAS FOR FSL 360m**	



FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	FIRST ENVIRONMENTAL IMPACT ASSESSMENT	Figure 5.10
JAPAN INTERNATIONAL COOPERATION AGENCY	**DRAWDOWN AREAS FOR FSL 320m**	

5.7.2.2. DRAW DOWN EVOLUTION DURING THE YEAR

Draw down areas may be interesting for agricultural development. However, this is a very dynamic system, which is exposed to air only a limited part of the year. Any evaluation of sustainable and reliable development of agriculture in these areas must take into consideration the duration of exposition of the land. In the following figure, the evolution of the draw down over a 5-year period (year 1 to 5 of the reservoir 30 years simulation) is presented.

A key observation is the much wider draw down area offered every year by the lower alternative FSL320. This is a direct consequence of the reservoir management. With a small reservoir, the whole active volume is used during the year, and the level fluctuates from FSL down to MOL every year. With alternative FSL360, the MOL is exceptionally reached. As a result, the draw down areas offered by the high dam alternatives are much more limited.

Draw-down variations over 5-year are shown in Figure 5.11.

5.7.2.3. DURATION OF EXPOSURE

The potential for agricultural development of these areas is directly dependent upon the duration of land exposure, which must be long enough to satisfy a crop cycle.

Some productions like vegetables require only short period of time for their cycle, from 2 to 3 months depending on the use of nursery or not. Areas which are exposed for 3 months may be suitable for this kind of activity. For paddy, the cycle is 120 days, or 4 months. With a security margin, development of paddy may be considered in areas exposed for 5 months. Of course, soil suitability and local topography are other parameters to consider before deciding on the suitability of an area for agricultural production

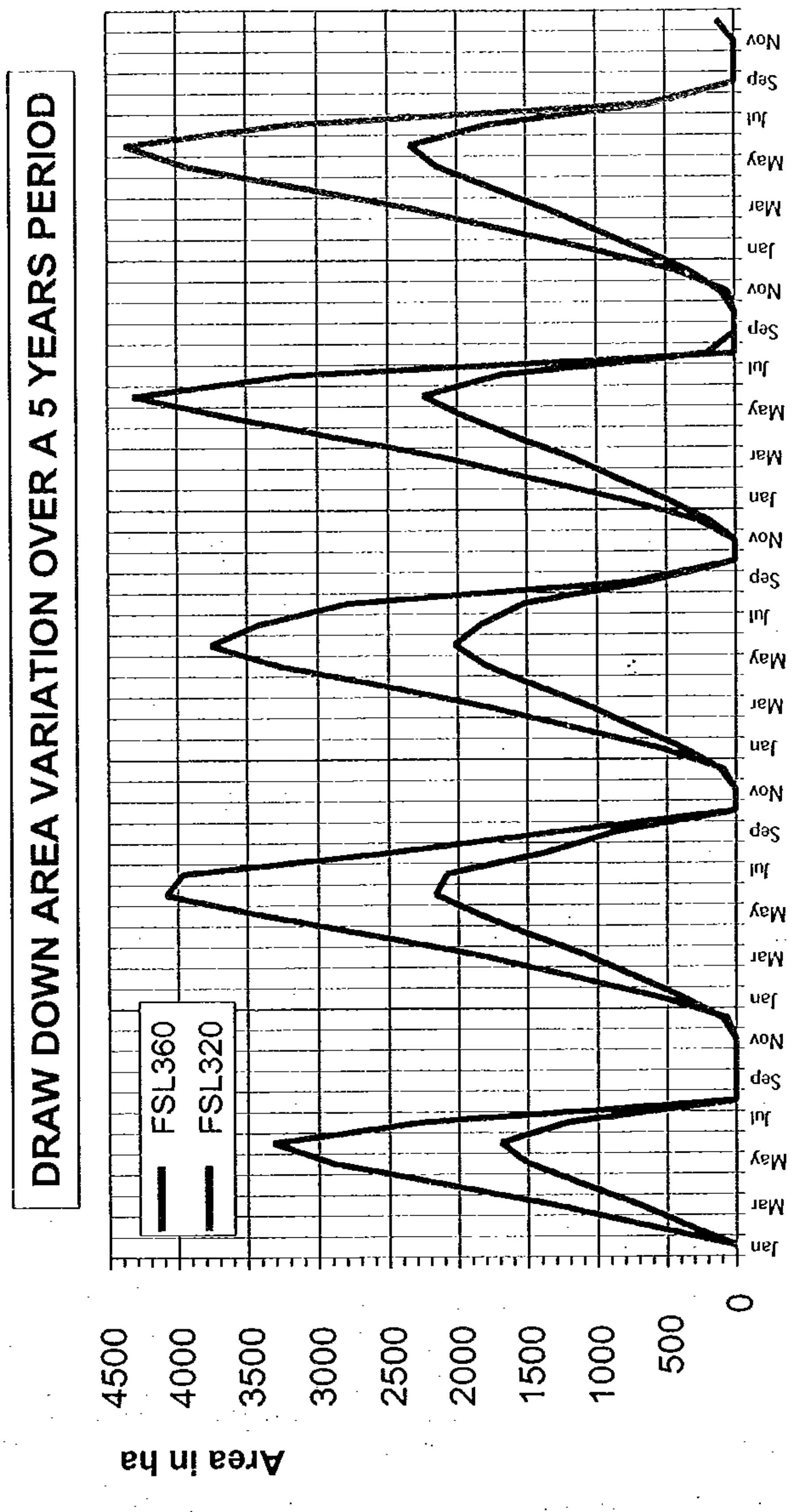
The following table is derived from the previous figure and presents the areas exposed every year for 3, 4 and 5 moths.

Table 5.15 Availability of Draw-Down Area

Alternative	Area available for	Year 1	Year 2	Year 3	Year 4	Year 5
FSL 360	3 months	1,200	1,600	1,600	1,500	1,700
	4 months	800	1,400	1,400	1,200	1,400
	5 months	500	1,100	1,200	900	1,200
FSL 320	3 months	2,000	3,000	2,900	3,000	3,100
	4 months	1,500	2,500	2,500	2,500	2,500
	5 months	1,000	2,000	2,000	1,800	2,000

As observed previously, the FSL320 alternative offers a more promising opportunity for agricultural development of the draw-down area than the high dam alternative does (only based on the exposed area criteria).

It is recommended that a study of these draw-down areas is carried out within the context of the detailed resettlement studies.



FEASIBILITY STUDY ON THE NAM NGIEP-I HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	First Environmental Impact Assessment	Figure 5.11
JAPAN INTERNATIONAL COOPERATION AGENCY	Draw Down Area Variation Over a 5 Years Period	

5.7.3. IMPACTS ON GEOLOGY

5.7.3.1. SEISMICITY

Preliminary conclusions from the Pre-F/S stated that there are very few seismic events in the region, and all those recorded during the last 20-30 years were all of low magnitude. Seismic activity is considered low in the region and the risk of induced seismic event is estimated almost nil.

5.7.3.2. SLOPES STABILITY

Observation of slopes along the future reservoir was performed during the aerial reconnaissance by helicopter. No severe traces of erosion or landslide were observed. Areas with significant slopes are covered by forest or bamboo vegetation. It may be concluded at this stage that slopes are stable and will probably remain stable if vegetation cover is not affected during clearing and logging operations.

5.7.4. RESERVOIR SEDIMENTATION

5.7.4.1. VOLUME OF SEDIMENTS

Preliminary assessment based on observation from recent projects has estimated the sediment inflow at 413.4 ton/km²/year, or about 1,450,000 tons/year trapped by the reservoir, equivalent to a volume of 550,000 m^3/year. Further studies on the sediment load will be a part of the technical studies to be carried out during next stage of Feasibility study.

In order to control further development in the catchment area and to avoid increasing sedimentation, it is recommended to carry out a watershed management study. A preliminary watershed management plan is to be prepared during the next stage of the Feasibility study, in order to provide the strategic basis for the resettlement plan and the regional development plan. When the Project goes ahead, a detailed watershed management plan has to be prepared during the construction phase.

5.7.4.2. SEDIMENTATION AND BACKWATER EFFECTS

It is anticipated that most of the solids solids will sediment in the upstream part of the reservoir and at the level of confluence of major tributaries with the reservoir.

This will probably raise a major issue concerning the conjunction of a higher reservoir bed level with unavoidable backwater effects for the upstream area. This issue is particularly critical for the FSL320, as a slight increase of water level in the Thaviang area may have significant impact on cultivated land and built up properties located close to the river.

It is recommended to carry out a detailed assessment study of this phenomenon before any decision is taken regarding the level below which people will be entitled for compensation or resettlement. A raise by 1m or 2m may significantly increase the numbers of displaced families and the lost agricultural land for the alternative FSL320.

5.7.5. RESERVOIR WATER QUALITY

5.7.5.1. RESERVOIR PARAMETERS

Forecasting of the most probable condition in the reservoir after several years is a perilous exercise. However, observation of phenomena in existing reservoirs all over the world has set up the basis for empirical modeling to assess mainly the nutrient and potential productivity in the future water body. Special criteria have thus been established to allow comparison and prevision, related mainly to the morphometry (shape) of the reservoir and to the water management. This section presents some of the most used criteria and prevision models.

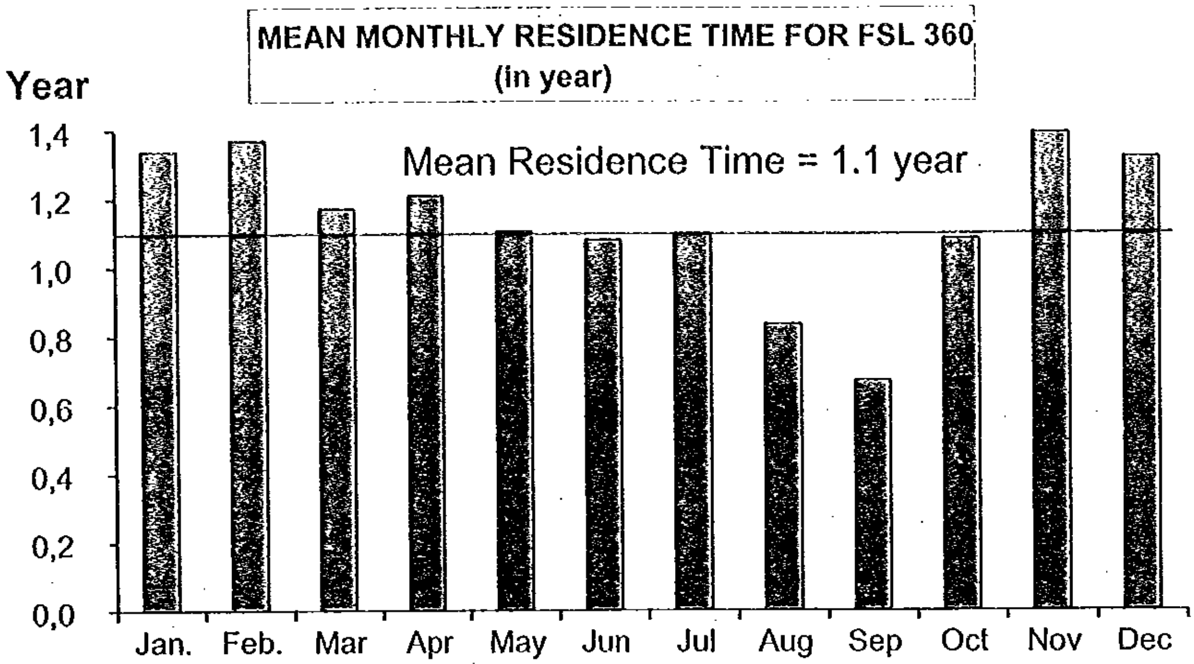
These parameters are presented in the following Table 5.16 for both options, in addition to a recapitulation of base data for the reservoir area.

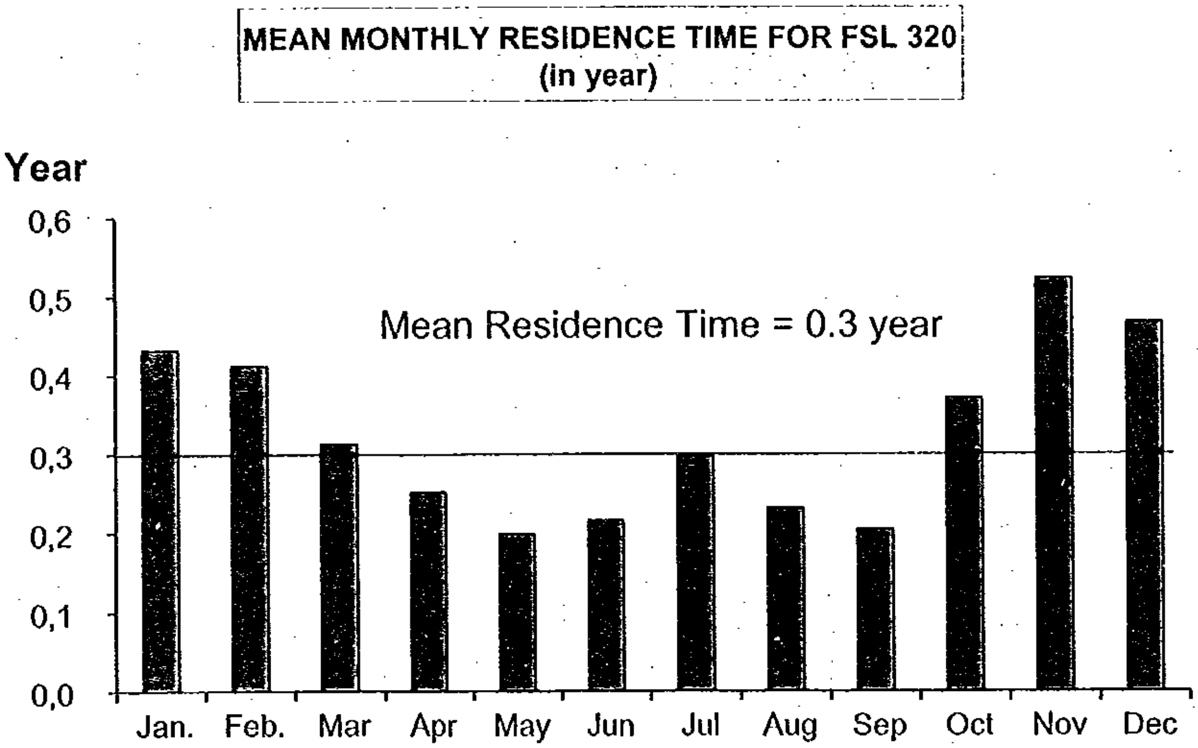
The hydraulic residence time is related to the duration water is expected to stay in the reservoir. Indeed, the longer the water stay, the higher is the nutrient concentration and the risk of reservoir eutrophication. The faster the water is renewed in the reservoir, the better is its quality. It is the ratio between the reservoir volume and the annual release (controlled and uncontrolled). It changes from month to month according to the management of the reservoir. Its monthly value is given on Figure 5.12.

The water stays in the reservoir in average 13 months for FSL360 and 3.6 months for the FSL320. These residence times are relatively short when compared with other Projects in the region: Nam Theun 2 (6.7 months), Nam Leuk (3.1 months) and Xe Kaman (3.3 years).

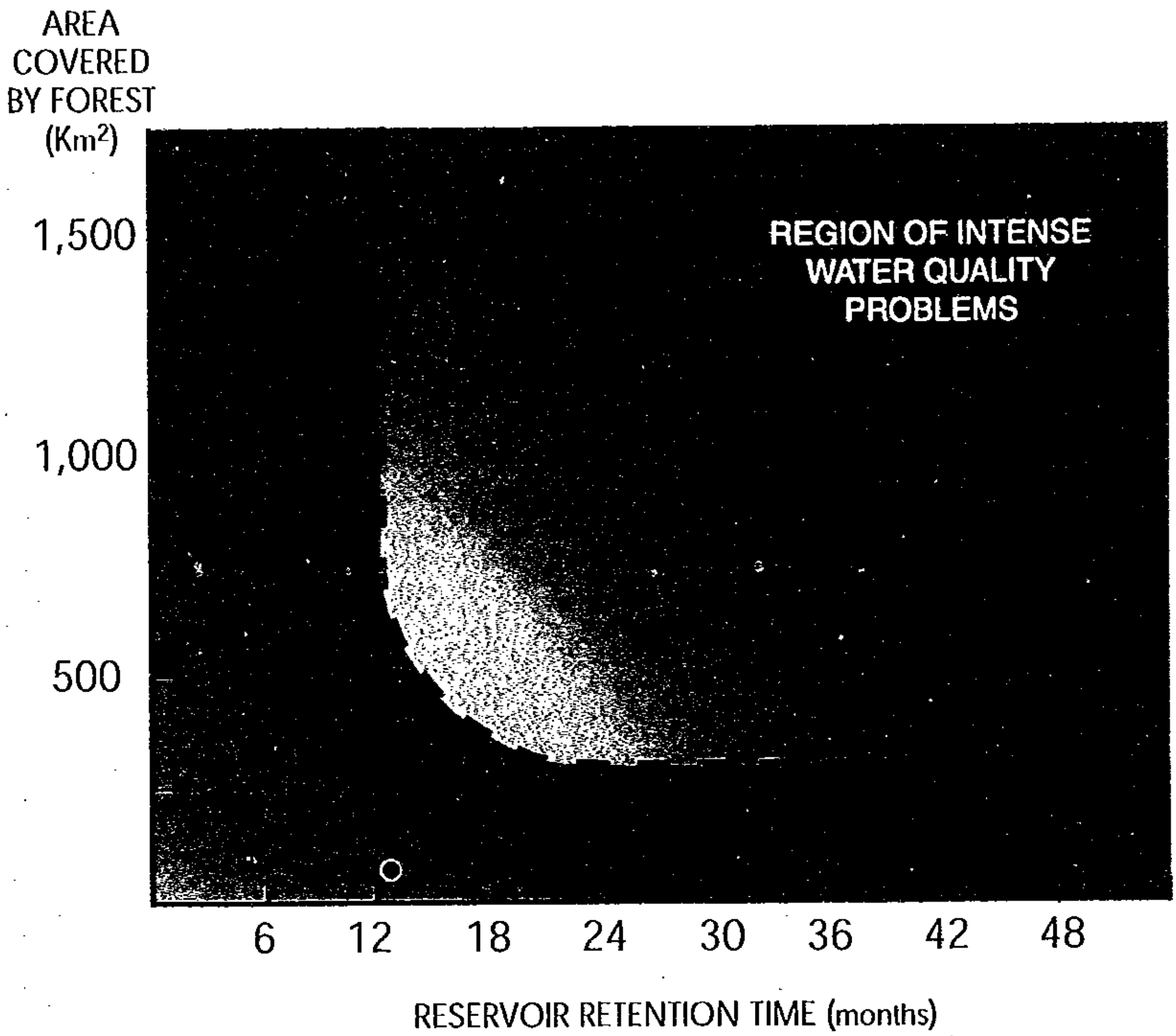
According to the diagram presented in Figure 5.13, the Project is not anticipating long term intense water quality problems. It must be stressed here that this assessment does not consider the special influence of reservoir stratification, which is a specificity of each project.

The catchment to reservoir ratio is the double (50.1) for the FSL320 alternative than for the high dam alternative (25). It means the low dam will be more sensitive to sedimentation or pollution than the high dam. In case of a low dam, a watershed control is even more important than for a high dam.

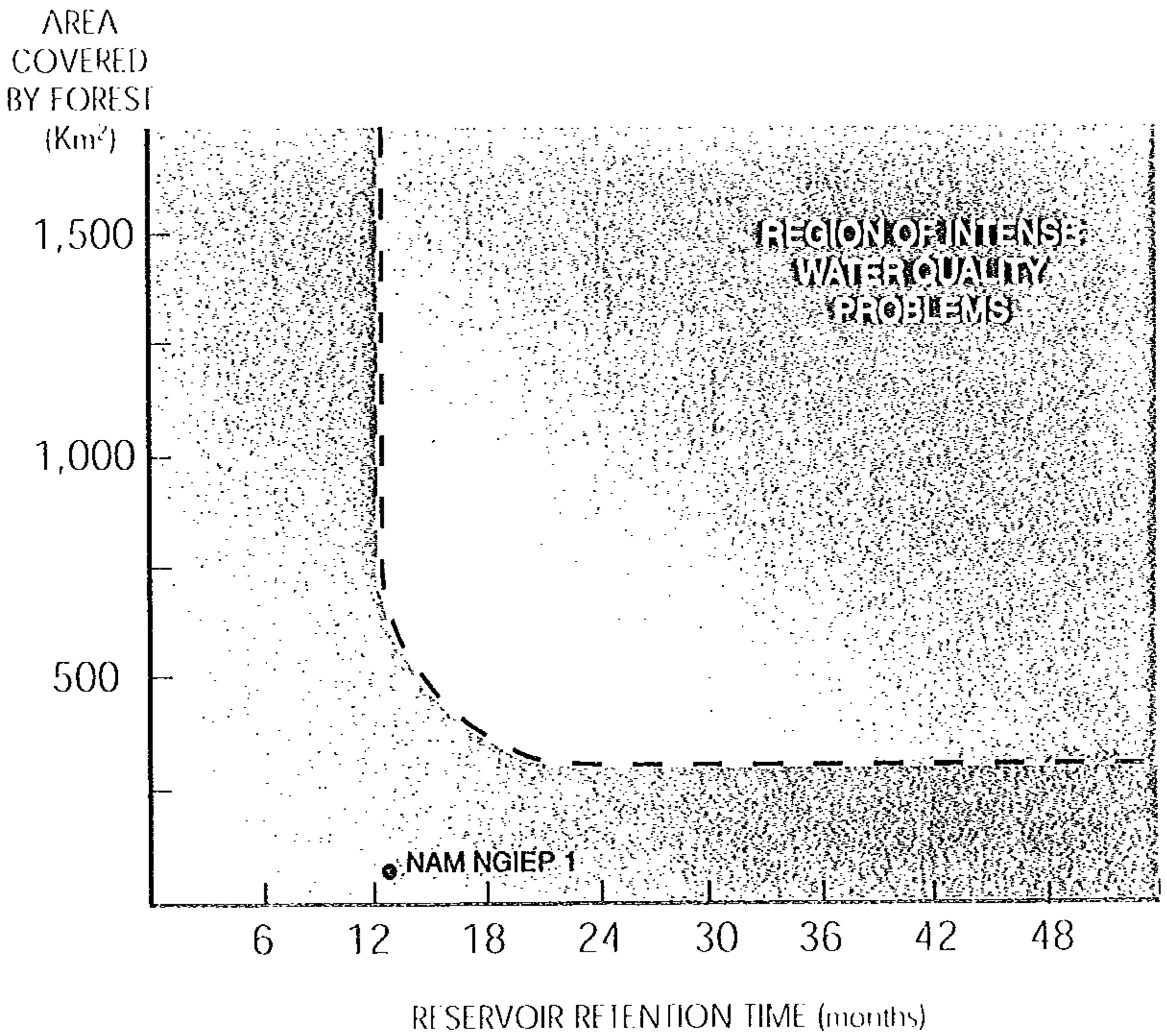




FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	First Environmental Impact Assessment	Figure 5.12
JAPAN INTERNATIONAL COOPERATION AGENCY	Mean Monthly Resident Time	



FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	First Environmental Impact Assessment	Figu 5.13
JAPAN INTERNATIONAL COOPERATION AGENCY	Water Quality as a Function of reservoir Retention Time	



FEASIBILITY STUDY ON THE NAM NGIEP 1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	First Environmental Impact Assessment	Figure 5.13
JAPAN INTERNATIONAL COOPERATION AGENCY	Water Quality as a Function of reservoir Retention Time	

Table 5.16 Base Data for Reservoir Characteristics and Forecasts

No	COMPONENTS AND INDICATORS	UNIT	ALTERNATIVE	
			FSL 360	FSL 320
	INNUNDATION AREA			
	FSL Level	m	360	320
	FSL Area	km²	148 2	73.8
	FSL Volume	Mm³	6,780	2,280
	MOL Level	m	335	284
	MOL Area	km²	104.0	32.7
	MOL Volume (Dead storage)	Mm³	3,689	627
	Mean Level	m	342	306
	Mean Area	km²	133	54
	Mean Volume	Mm³	5,471	1,548
	Mean Depth	m	41.4	28.7
	Reservoir shoreline at FSL	km	565	350
	Draw down (DD) magnitude	m	25	36
	DD area (maximum)	ha	7,500	4,100
	Length of Nam Ngiep river flooded	km	90	70
	Average river width in reservoir area	m	80	80
	River area flooded	ha	720	560
	River area above reservoir	ha	228	388
	Length of tributary system dammed	km	372	372
	Area of tributary system dammed	ha	2,100	2,100
	Average river bank width in reservoir	m	50	50
	Area of river bank flooded	ha	450	350
	Controlled catchment area	km²	3,700	3,700
	RESERVOIR FORECAST			
	Hydraulic Residence Time (months)	month	13.2	3.6
	Areal Hydraulic Loading (m/year)	m/year	41.6	68.8
	Catchment to Reservoir area ratio	-	25.0	50.1
	Filling Period (no riparian release)	month	15	3
	Filling Period with RR of 20 m3/s	month	16	3
	Filling Period with RR of 50 m3/s	month	18	4
	Mean annual evaporation	Mm³	204	83
	Reservoir shoreline development	-	13.1	11.5
	Maximum temperature	°c	29	29.7
	Minimum temperature	°c	21	21.4
	Phosphorus loading rate	gP/m²/y	0.449	0.902
	Electrical conductivity	µS/cm	46	62

The reservoir shoreline development express the dendritic level of the lake boundary. It is almost the same for both alternatives. When a reservoir is highly dendritic, there is a risk of bad circulation and renewal of water in some isolated parts with local risk of eutrophication. Values observed for Nam Ngiep are reasonably low.

5.7.5.2. NUTRIENT LOADING

Nutrient loading is related to the expected load of Phosphorus to be supplied to the reservoir every year by the inflowing water. As phosphorus is generally the limiting factor for algae development, it is considered alone for anticipating on the eutrophication risk.

Based on the observed concentrations of P during the water quality surveys, the results of the loading rate are as follows:

FSL360:	FSL320:
: 66.54 t P/year or	: 66.54 t P/year or
: 0.449 gP/m²/year or	: 0.902 gP/m²/year or
: 0.010 gP/m³/year	: 0.029 gP/m³/year.

This information has been used to fill the Vollenveider phosphorus model which results are presented on Figure 5.14. Both alternatives are in the oligotrophic to mesotrophic zone, indicating a probability that these reservoirs will not turn eutrophic in the long term, if present Phosphorus loading conditions are preserved in the future by an efficient watershed control.

5.7.5.3. STRATIFICATION OF THE RESERVOIR

The permanent inundation zone concerns the lake itself. Deep lakes are generally stratified. This means that a superficial layer of water (the epilimnion), about 20m thick will become quickly well oxygenated. This is the layer where algae development and fish development occurs. Below this layer, the rest of the water body of the reservoir will receive no oxygen and will be the place where organic decay happens. This is the hypolimnion, where no fish or other aquatic life develop, except anaerobic bacteria releasing methane gas and sulfur hydrogen. This water shows a lower temperature, and a lower pH, which may create corrosion problems for the equipment. Both layers area separated by a line which is called the thermocline.

In large lakes, this stratification may turn over once a year, when colder flow and colder air temperature affect the water body. There is a mixing, detrimental for the upper layer and which results often in serious fish kills, but positive for the bottom layer which liberates part of its gas and receive some oxygen, thus reducing the corrosiveness of the water.

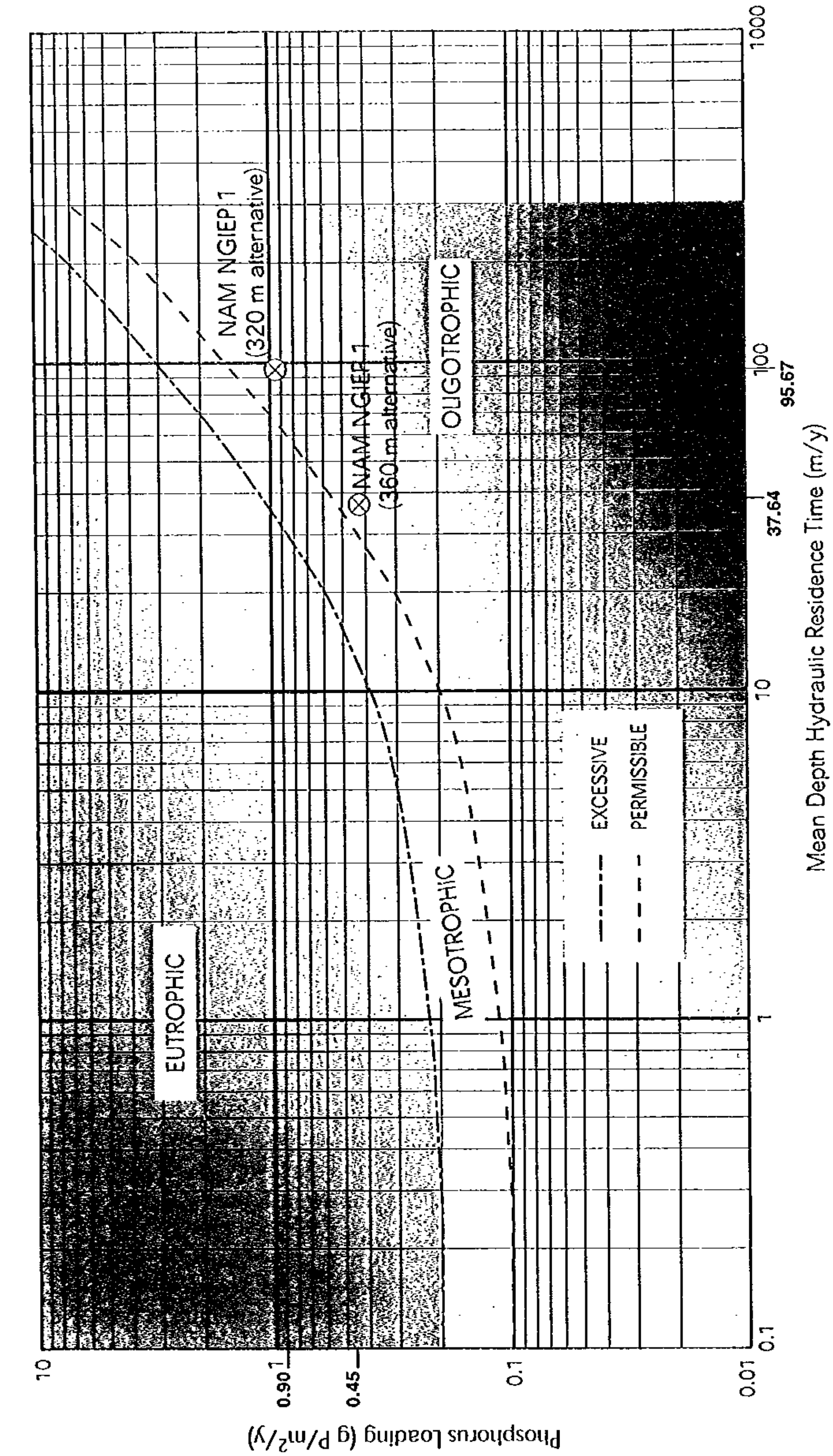
This is the case for the Nam Ngum reservoir. Each year during December and January (cold months), the reservoir destratifies or turns over. Dropping air temperature, increased inflow of colder water and increased wind action lead to the mixing of the epilimnion and of the hypolimnion. Because of the extent of the lake (about 450km^2), the volume of epilimnion is huge and increases dissolved oxygen in the whole water column. No fish kill is observed.

The main issues for the present project are summarized in these few questions:

1. Will the Nam Ngiep reservoir be stratified?
2. Will seasonal turn over happen?
3. What is the prospect regarding the risk of eutrophication in the long term?
4. Will the water intake be located in the good or bad water layer of the reservoir?

Due to its depth and for both alternatives, the Nam Ngiep reservoir will certainly be stratified.

Its very narrow and long shape is not appropriate for seasonal turnover. This may happen in the upstream part of the reservoir, but it is more uncertain for the lower part next to the dam (and the deepest) where the intake is.



FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	First Environmental Impact Assessment	Figure 5.14
JAPAN INTERNATIONAL COOPERATION AGENCY	Vollenweider Phosphorus	

5.7.5.4. EVOLUTION OF THE THERMOCLINE

A simulation has been done using the variation of reservoir water level for typical hydrological year, but combining to it the observation of 2mg/l DO level depth performed in Nam Ngum since 1985. This DO level is equivalent to the thermocline, and corresponds to the DO level below which most aquatic species will not survive.

Results are provided in Figures 5.15 and 5.16. The major conclusion is that except in a dry year situation, the water intake is located part of the year below the thermocline, and will thus release water of low quality in the downstream Nam Ngiep.

The possible mitigation to this situation concerns basically 3 options:

- A multi level water intake, but a very costly solution,
- A reduction of the draw down amplitude, but probably not viable economically at least for the FSL320 alternative,
- System for boosted re-aeration of water at the tailrace channel level, but probably with the resulting loss of few meters of head.

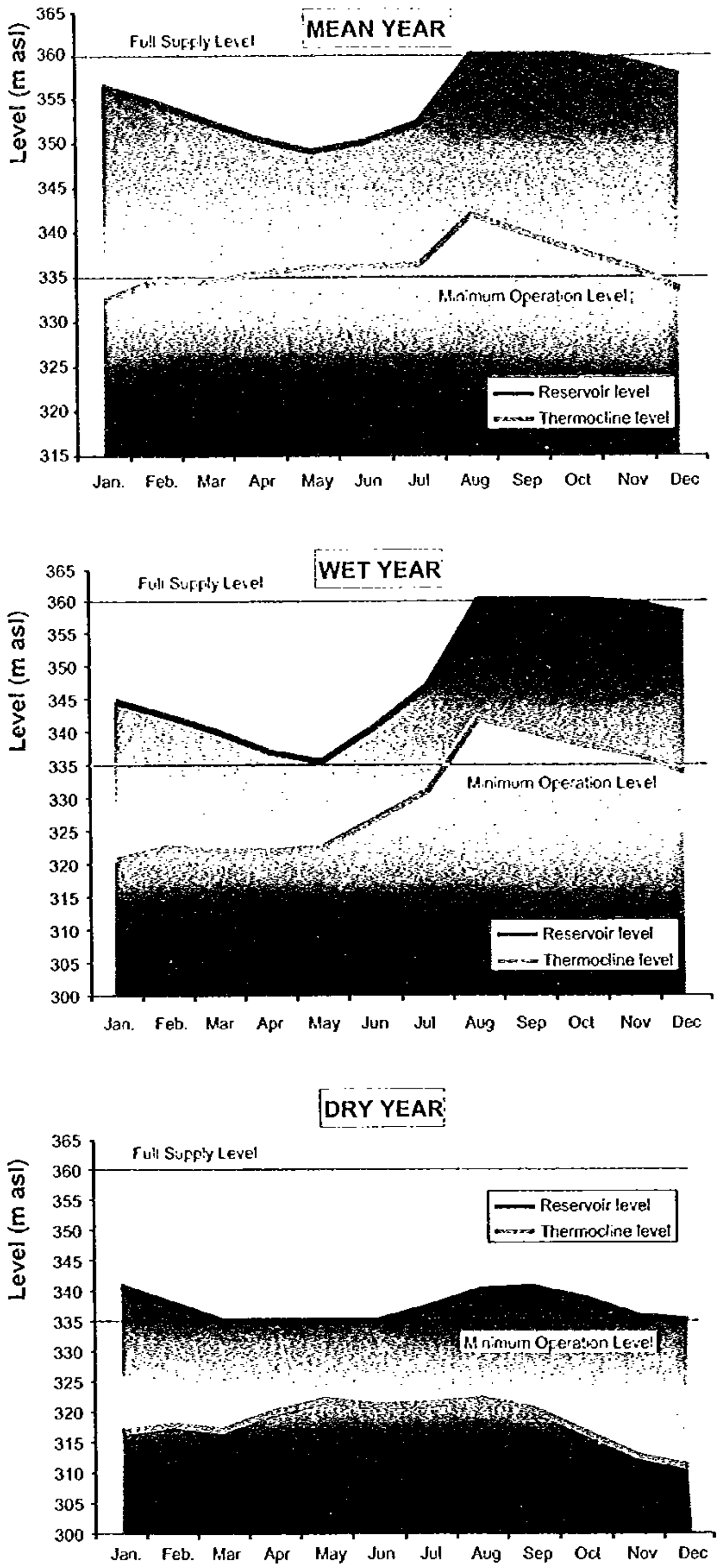
The last solution remains a financial compensation to the downstream area, but this may raise international concern and protest if water is not reasonably re-aerated when it reaches the Mekong River. This issue has to be studied during the next stage of the Feasibility.

5.7.5.5. EXPECTED DURATION OF WATER QUALITY PROBLEMS

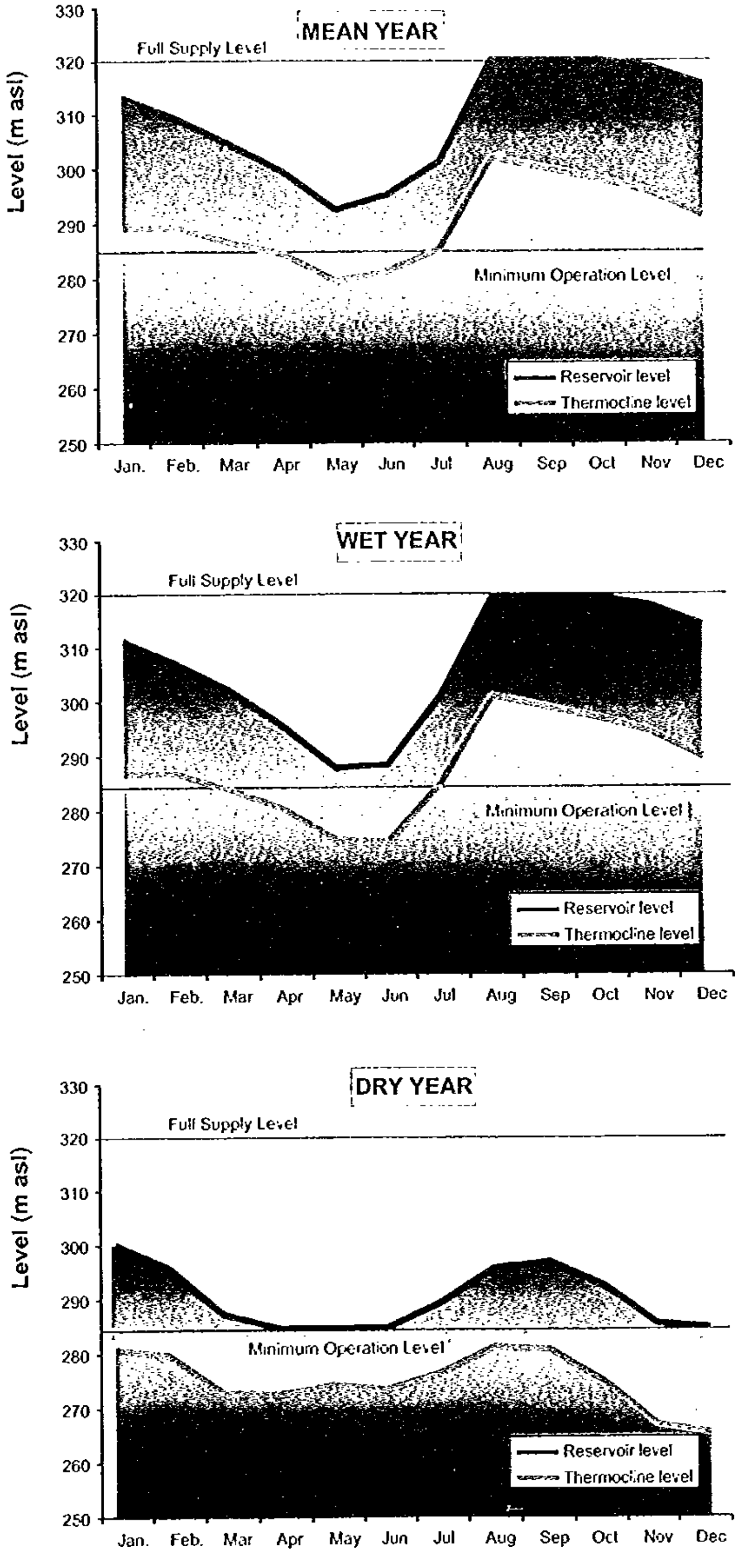
An empirical approach, based on the observation from several reservoirs in Thailand and in other parts of Asia, has been proposed by RMR in a study for Nam Theun 2 project. It links mean depth and mean residence time of water. According to this approach, the duration of water quality problems after impoundment should last no more than 5 to 6 years for alternative FSL360 and than 2 years for alternative FSL320. This expected duration does not consider, of course any possibility of stratification of the reservoir.

5.7.5.6. OTHER SPECIAL WATER QUALITY ISSUES

The strategic importance of Highway 4 during the Vietnam war in the Upper Reservoir area meant that it is a site of extensive UXO contamination. The strong likelihood that defoliants such as Agent Orange were used in the area will require a reconnaissance survey to determine the extent, if any, of contamination by such chemical substances, which some of the components may be released in the water after flooding. This may have a bearing on the potential for fisheries in the newly created reservoir.



FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	First Environmental Impact Assessment	Figure 5.15
JAPAN INTERNATIONAL COOPERATION AGENCY	Evolution of Thermocline FSL360	



FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	First Environmental Impact Assessment	Figure 5.16
JAPAN INTERNATIONAL COOPERATION AGENCY	Evolution Thermocline FSL320	

5.7.6. IMPACTS ON FISHERIES

5.7.6.1. INITIAL AND SHORT TERM SITUATION

After the reservoir has stabilized as a productive water body populations of aquatic animals from upstream waters, from downstream and from more distant waterways, will gradually explore, and if conditions are appropriate, colonize the reservoir and its draw down zone. It is impossible with the presently available data to forecast which of the species will become successfully established. Animals with a high dependence on the land/water interface (eg. otters, terrapins, turtles, crocodiles and frogs/toads) will find the draw down zone offers unusual problems and/or opportunities. Some of the fish species will adapt their feeding and migratory/breeding behavior to occupy the new riches offered by the reservoir. Other species will be unable to adapt, or find habitats sufficiently close to their requirements and will therefore never colonize the reservoir.

5.7.6.2. PROBABLE EVOLUTION OF FISH BIODIVERSITY

5.7.6.2.1. ADAPTATION OF SPECIES

As presented in the following table, several species observed in the Nam Ngiep river during the field work have already been reported from other water bodies, particularly the Nam Ngum reservoir and various ponds or small lakes. A total of 53 species observed are in this situation, or 40% of the Nam Ngiep fish biodiversity. We may at least consider that these species will have the capability to redevelop population in the future reservoir. However, due to probable low water quality conditions during the first few years, most of the species will take refuge in the upper tributaries and it may be reasonable to consider 5 to 10 years before fish population redevelop in the reservoir at a level acceptable for fisheries to be economically viable.

The closing of the dam will definitely prevent migrations of fish reaching the reservoir and upstream waterways from downstream or moving downstream after breeding in the upper tributaries. There is no sufficient information at present to draw a realistic view of this impact. This has to be examined in further detail during the next stage of the study.

Table 5.17 Distribution of Fish Species Observed in the Nam Ngiep River

SCIENTIFIC NAME	LOCAL NAME	COLLECTED IN NAM NGIEP			REPORTED FROM		
		Upper Reservoir	Lower Reservoir	Down stream	N. Ngum Reservoir	N.Theun2 .Hinboun	Fish Ponds
Notopterus notopterus	Pa Tong (Khao)		•	•	•	•	•
Xenentodon cancila	Pa Sathong			•	•	•	
Pangasius siamensis	Pa Yon			•	•		•
Pangasius pleurotaenia	Pa Yon Nou			•			•
Pritolepis fasciata	Pa Ka			•	•		
Bagarius yarrellii	Pa Khea	•	•	•	•	•	
Bagarius bagarius	Pa Khea Leuang	•	•				•
Channa striata	Pa Khor		•	•	•		•
Channa gachua	Pa Kang	•	•	•	•		
Oxyeleotris marmorata	Pa Bou gnai			•			•
Mystus singaringan	P.KaGneng(kho)		•		•	•	
Mystus nemurus	Pa Kot	•	•	•	•		•
Clarias batrachus	Pa Douk	•	•		•		•
Mastacembelus armatus	Pa Lat	•	•	•	•		•
Macrognathus siamensis	Pa Lot		•				•
Kreptopterus cryptopterus	Pa Nang		•		•	•	
Ompok bimaculatus	Pa Seuam		•		•		•
Wallago leeri	Pa Khoun			•	•		
Wallago attu	Pa Khao			•	•		•
Mystacoleucus greewayi	Pa Langnam	•	•	•	•	•	
Mystacoleucus marginatus	Pa Ket kheng	•			•	•	
Tor tambroides	Pa Thot		•		•		
Hampala dispar	Pa Soud 1	•	•	•	•	•	•
Hampala macrolepidota	Pa Soud 2	•	•		•	•	
Rasbora sp. (Holizontal red line)	Pa Siew		•		•		
Parachela maculicauda	Pa Siew 6		•	•	•	•	
Puntius brevis	Pa Khaomon	•	•	•	•		•
Dangila Sp.	Pa Khee lam		•	•	•		
Barbodes schwanefeldi	Pa Vienfai		•		•	•	
Barbodes gonionotus	Pa Pak		•		•	•	
Barbodes altus	Pa Leuanfai			•	•	•	
Cirrhinus molitorella	Pa Keng	•	•	•	•	•	•
Puntioplites falcifer	Pa Sakang		•	•		•	•
Systomus orphoides	Pa Pok	•	•		•		
Cyclocheilichthys sp	Pa Dok ngiew			•	•	•	•
Osteochilus sarawakensis	Pa..			•		•	
O. melanopleurus	Pa Nok khao			•	•	•	•
Barilius sp	Pa Vahao			•		•	
Scaphognathops sp	Pa Pien			•	•	•	
Morulius chrysophekadion	Pa Phia			•	•		•
Monopterus albus	Eel	•	•		•	•	
Anabus testudineus	Pa Kheng	•	•		•		•
Rasbora rubridosalis	Pa Siew		•	•		•	•
Rasbora trilineata	Pa Siew		•	•			•
Heterobagus sp.	Pa Kayeng		•	•			•
Mystus rhegma	Pa Kayeng		•	•		•	•
Cyprinus carpio	Pa nai	•			•		•
Osphronemus exodon	Pa Menh			•	•	•	
Belodontichthys dinema	Pa Khop		•	•		•	•
Trichopsis vittata	Pa Matt	•	•	•		•	•
Trichopsis pumila	Pa Matt	•	•	•		•	•
Betta smaragdina	Pa Katt		•	•		•	•
Oreochromis niloticus	Pa nin	•			•		•

5.7.6.2.2. EVOLUTION OF BIODIVERSITY

It is widely observed that diversity of fish species in a reservoir is always lower than