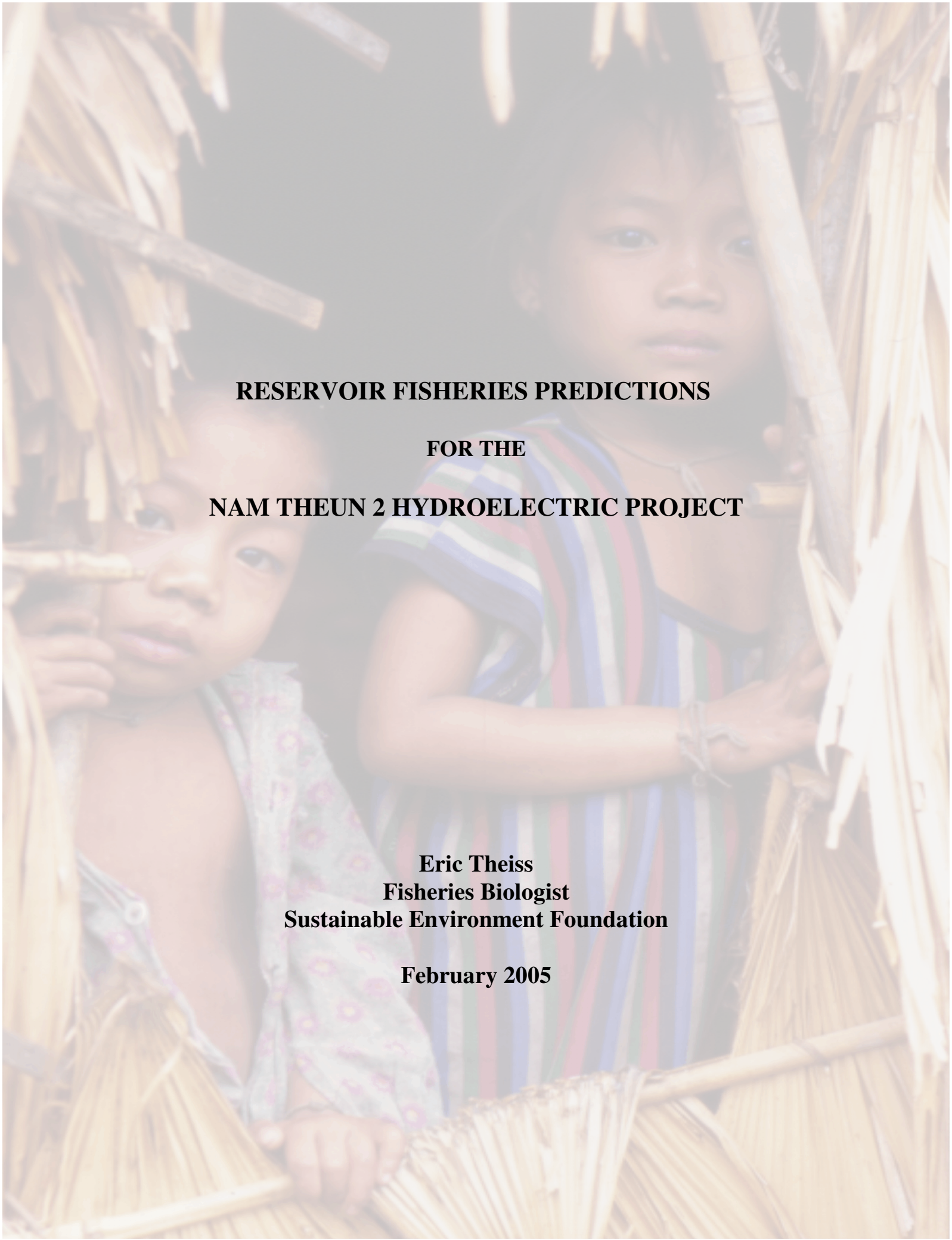

RESERVOIR FISHERIES PREDICTIONS

FOR THE

NAM THEUN 2 HYDROELECTRIC PROJECT

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February 2005

Executive Summary

A reservoir fishery is the primary mitigation feature for approximately 6,200 people which currently utilize the area to be flooded by the Nam Theun 2 reservoir. However the years immediately after filling are not modeled, and the reservoir will likely be predominantly anoxic during this period. The fishery is intended to be developed from fish trapped by the dam, however many of these fish will die, and it will be difficult to build a substantial population in the foreseeable future. Operations will draw down the reservoir nearly to the river bed (538 to 525.5 m above mean sea level), which eliminates most of the underwater habitat. The water quality report predicts that only the lowest 6-8 m will be anoxic when the reservoir is filled, but does not adequately consider the potential for anoxia problems as a result of aquatic macrophytes or increased turbidity. At low pool during early and late phases, increased turbidity caused by reservoir fluctuations and by siting the headrace structure in the middle of the reservoir will negatively affect fisheries in the reservoir, and in the Xe Bang Fai and Nam Theun Rivers. Approximately 126,000 people may be affected by the project in total.

Introduction

The Nam Theun 2 Hydroelectric Project (Project) proposes to flood the Nakai Plateau in Laos, diverting water from the Nam Theun watershed to the Xe Bang Fai watershed. The reservoir fishery is intended to partially mitigate for the lost livelihoods of approximately 6,200 people, although other small-scale mitigations are also proposed.

This report was prompted by a request from International Rivers Network to perform an independent analysis of Chapter 24 of the Project's Social Development Plan entitled "Nakai Reservoir Fisheries Development and Management" (NRFDM), and Annex G of the Project's Environmental Assessment and Management Plan entitled "Water Quality Modeling Assumptions and Results" (WQM).[1] The Sustainable Environment Foundation[2] produced this report as a free gift to the people of Laos and Thailand.

Water Quality

Although a substantial amount of documentation is presented regarding other reservoir impacts, the Environmental Assessment and Management Plan (EAMP) provides only a short synopsis of the critical issue of water quality. The sensitivity of the model to turbidity appears to be inadequately addressed, and the sedimentation rate underestimated, as described in a review by Wegner:[3]

> *7. Sedimentation Impacts*
> *The predicted reservoir sedimentation rate for the Nam Theun 2 reservoir would be 13 million cubic meters in 50 years or 260,000 cubic meters per year.*
>
> Comments
>
> It is unclear from the EAMP where this sedimentation figure came from. No supporting documents on the range of numbers is provided. It is stated in the document that the total capacity of the reservoir below the minimum operating level is calculated to be 490 million cubic meters. The report states that this should provide for well over 1,850 years

[1] As of the writing of this report, these documents can be located at www.namtheun2.com/gallery/library.htm

[2] The Sustainable Environment Foundation is comprised of natural resource professionals and other dedicated individuals which volunteer their time and talents in the service of those in need. SEF recognizes the need for development, but rejects the necessity for development at great environmental and human cost.

[3] "Review Comments on Nam Theun 2 Hydroelectric Project Environmental Assessment and Management Plan (EAMP)." David L. Wegner, Ecosystem Management International, Inc. Flagstaff, Arizona. http://www.irn.org/programs/mekong/wegner.html

> of sediment accumulation if the current watershed, sediment and hydrology remain "normal". The potential for change in the watershed is very high with the relocation of people and potential for additional logging. It is quite likely that the sedimentation rates will increase substantially over the 260,000 cubic meters per year predicted.

A common side-effect of dam projects is that they increase access to harvestable timber, which increases soil erosion far above the baseline condition. The project website[4] makes sedimentation predictions based on this effect:

> At these very high levels of erosion there is a small but measurable reduction in available energy for sale, by the end of 50 years, of about 11% per year. The reduction after 25 years is about 6.6%.

These "small but measurable" reductions add up to 100% reduction in available energy for sale in just a few decades. A turbidity level higher than that modeled in WQM could also have significant, negative effects for the reservoir fishery. High turbidity in the Pak Mun reservoir regularly coincides with fish kills (Tyson R. Roberts, personal communication). Increases in turbidity reduce light penetration and generally decreases the depth of the thermocline. The ability of phytoplankton to produce oxygen in the epilimnion is also reduced. The WQM confirms that turbidity could cause a reduction in oxygen level by stating:

> The simulated water quality results were found to be sensitive to ascribed sediment release rates. Increased sediment nutrient release rates of an order of magnitude greater than that estimated to be present in the impoundment significantly lowered the dissolved oxygen concentrations in the reservoir.

The WQM predicts that the lower 6-8 meters will be anoxic, which will be below the level of withdrawal (506 - 525.5 m). However, at the full supply level (FSL) of 538 m, most of the reservoir area will be less than 10 m deep. The WQM apparently takes a one-dimensional view of the reservoir, and does not address these more shallow waters.

Although the NRFDM asserts that "Anoxic conditions affecting the entire basin are ruled out due to strong periodic re-oxygenation during circulation events", it is difficult to conclude other than that project documents are optimistic about reservoir water quality. Section 24.3.2.5 of the NRFDM is entitled "*Increase of nutrients and development of a long-lasting anoxic epilimnion*", however there is only tangential discussion of this dramatic statement in the text. A "long-lasting anoxic epilimnion" undermines the foundational premise of the EAMP and Social Development Plan, that the epilimnion will support a sustainable fishery.

As the reservoir matures, the current river bottom and lowest parts of the reservoir will become filled with sediment. As the reservoir is drawn down, the South-Eastern arm of the reservoir will

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[4] http://www.namtheun2.com/faq/faq_env.htm#predicted

once again become flowing water. The layer of sediment collected here throughout the year will be flushed downstream (into the headrace channel), and turbidity will increase as the velocity of water increases. For several years the former river channel will once again become exposed, until a sufficient amount of armoring occurs to cause it to meander. Meandering will cut into new and old sediments in the reservoir bottom, causing additional turbidity problems.

Depending upon the consistency of the underlying soil on the Nakai Plateau, this process may also occur over much of the reservoir bottom as it is drained. Water-laden soil will drain from the shallow reservoir bottom toward the former river and the 4.25 km-long headrace channel, potentially causing down-cuts into the substrate as these coalesce into larger channels. This effect may cause further increases in turbidity as the reservoir is drawn down. Wind-driven waves and seiches may further exacerbate this problem.

Logging has also been done above the future reservoir site.[5] Instead of improving water quality, exposing the drainage to erosion will have the opposite effect by increasing sediment- and nutrient-laden runoff into the reservoir. Although the nutrient load was assumed to be the same in the future as it is now, it is clear that this parameter has been underestimated.

An increase in nutrients can lead to problems with aquatic plants such as *Eichornia*, which the WQM does not address. The WQM was derived from two reports, one of which was reviewed by Dr. Guy R. Lanza:[6]

> The new excess biomass will add to the oxygen deficit produced by the decay of existing biomass during the filling of the reservoir. A cascade of environmental degradation could result including lowered dissolved oxygen levels with fish kills, population explosions (= nuisance blooms) of extremely toxic microorganisms in the cyanobacteria group, increased growth of aquatic weeds, the expansion of habitat for vectors of major waterborne diseases (e.g. Malaria, Dengue Fever, Schistosomiasis, Fasciolopsiasis) oxygen depletion at the deep water sediment-water interface (i.e. the oxidized microzone) causing releases of sediment-bound toxic chemicals, nutrients, toxic gases (e.g. hydrogen sulfide, methane) and serious taste and odor problems from volatile organic compounds produced by nuisance organisms.

The NRFDM states:

> Thus, in an effort to ensure reasonably good water quality in the first few years after

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[5] Fluvicide: an Independent Environmental Assessment of Nam Theun 2 Hydropower Project in Laos, with Particular Reference to Aquatic Biology and Fishes. Tyson R. Roberts, September 2004.

[6] Letter from Dr. Guy R. Lanza to the International Rivers Network. August 9, 1997.

> impoundment, residual biomass (above and under ground) must be removed as much as possible...

The biomass must be removed, but there are no clear plans for removal according to that assumed in the WQM. A memorandum of understanding was signed by the Lao government which gave permission to Borisat Phatana Khet Phudoi (BPKP) to clear the inundation zone, although only the profitable timber has been removed so far. The WQM states:

> Assuming the oxygen demand is spread over 15 years, gives a daily demand of 0.5 g/m^2/day. This estimate is consistent with reported values for lake sediments that are relatively low in organic and nutrient content

It is clear that removing the biomass in the inundation zone has not been considered profitable by BPKP, therefore it is reasonable to assume that the biomass will not be removed and the oxygen demand will not be relatively low. The BPKP is no longer operating on the Project, but their contract has not been fulfilled. Because the profitable timber was intended to pay for the unprofitable biomass removal, the Project now may no have budget to remove the biomass. As opposed to the WQM assumption above that the oxygen demand will be spread over 15 years, it is more reasonable to predict that oxygen demand will be high during the initial years after filling. The NRFDM is consistent with this conclusion by stating:

> ... the Centre's predictions are valid only for a matured Nakai Reservoir... There does not exist any reservoir water quality model that is able to predict water quality during filling and during the first years after impoundment.

In conclusion, the WQM states:

> During the initial several years after dam construction, high decomposition rates of inundated biomass is likely to lead to low dissolved oxygen concentrations of approximately 2-3 mg/l. However, seasonal minimum dissolved oxygen concentrations less that [sic] 5 mg/l may occur occasionally after the initial several years period of high decomposition rates.

Although the WQM also states “Anoxic conditions will likely occur only in the lower 6-8 m of the reservoir”, it is unclear whether this applies to the initial years after dam construction or not. With a total depth of 48 m, it seems unlikely that up to 42 m of epilimnion would remain oxygenated in ambient temperatures as high as 30ºC.

Reservoir Fishery Predictions

Although an aeration weir is being constructed to mitigate for low dissolved oxygen (DO) below the project, the WQM predicts that only aerated water will be drawn into the intake. Because a weir would not be proposed if there were no possibility of a DO problem, it seems clear that there is also a significant risk of damage to both the upstream and downstream fisheries. Chapter 31 of the Social Development Plan states:

> The aeration weir in the re-regulating pond does provide some solution to improve low DO concentrations, but cannot improve DO from 0 mg/l to 5mg/l, and cannot improve critical water quality parameters for aquatic life as BOD and ammonia.

Also:

> The aeration weir will increase DO levels and decrease to some extent possible methane and hydrogen sulfide concentrations, but the aeration weir will have little impact on reductions of ammonia concentrations, turbidity, and BOD.

Partial mitigation for DO problems below the reservoir may be possible, but mitigations within the reservoir (such as aeration systems) have been ruled out as too costly. Because anoxia is presumed to be a problem, and the magnitude of the problem is unknown, it must be assumed that conditions unfavorable for a reservoir fishery are possible. Because the founder populations of fish are expected to be those trapped during the initial filling of the reservoir, there is the potential the vast majority of these fish will be exterminated during the initial years after dam construction. Most fish can survive without oxygen for only a minute or two, not years.

The NRFDM compares other reservoir fisheries in Laos and Thailand to the Project, using a figure of 100 km^2 as its surface area at minimum operating level (MOL). This contradicts Table 24-2 and the EAMP in Chapter 2:

> The minimum operating level will be at El 525.5 m. At this level, the reservoir will have a surface area of approximately 82 km^2.

The justification for rounding up the reservoir surface area is not given. The difference between these two figures is substantial however, and undermines the conclusion that the Project can be compared to other reservoirs which have a reservoir fishery. The NRFDM states:

> An important feature of the future Nam Theun 2 is the small water surface area (approx. 100 km^2) at Minimum Operation Level. The Nakai Reservoir area fluctuates from 450km^2 at Minimum Operation Level (MOL) (see Table 24-2). Thus, the water surface area at MOL is 22% of water surface as FSL. The maximum annual fluctuation in water surface area will influence fish production in the reservoir and consequently influence annual reservoir fish yields

This important feature is understated. The water surface area at MOL is not 22% but 18% (or

less: see below) of water surface at FSL. Comparison of Figures 24-2 and 24-5 demonstrates that the reservoir (i.e. fish habitat) virtually disappears at low pool. Annex F of the EAMP confirms that in Week 22 (late May, or the end of the dry season), the maximum predicted water level in the reservoir will be 527.62 m (min. 525.65 m, avg. 526.63 m), which is about 2 m above the lowest point that the Project can be operated. It should also be noted that the rate of draw down may be just as rapid in dry years as in wet years, therefore the reservoir may be left at low pool for far longer than one week as portrayed in Figure F1.

Although a recalculation of surface area at low pool was not attempted, it is unlikely that a reservoir of even 82 km^2 (equal to a square of approximately 9 km on a side) is represented in Figure 24-5. A portion of this surface area is apparently not reservoir but the extremely modified tributaries, however this still does not appear to make up the discrepancy. Surface area calculations do not normally include tributaries above the given reservoir level. Several wetlands depicted in Map 15:4 of the Social and Environmental Management Framework and Operational Plan (SEMFOP) may be classified as reservoir, but it is difficult to imagine that these could be considered for fisheries or power production since they will apparently be isolated from the main water body and will disappear as they become filled with sediment.

Tables 24-4 and 24-5 compare the Project reservoir to selected reservoirs in Laos and Thailand. A process for selecting these reservoirs in an unbiased manner is not provided. With a minimum surface level of 125 km^2, Ubolratana is selected as the reservoir most similar to the Project. If we replace the more accurate MOL of 82 km^2,the Project appears to be qualitatively different from other large reservoirs which have substantive fisheries productivity.

As opposed to comparisons of reservoir productivity at FSL, a better comparison may be at MOL where very shallow reservoirs with dramatic surface area fluctuations are concerned. Assuming that a surface area of 82 km^2 of oxygenated water will be present at MOL, and using 15 kg/ha/year (asserted to be the minimum that the project will produce), fish production of the reservoir at low pool would be 123,000 kg/year. Given that each 5.5 person household will require 330 kg/year (NRFDM) and using the above assumptions, the productivity of the reservoir would sustain a maximum of 2,050 persons. Assuming that there will be 6,500 persons severely affected by the project, 4,450 will be without means of support.

If the reservoir at maximum pool is used with the NRFDM's highest predicted productivity (2,025,000 kg/year: Table 24-4), then the reservoir could support 33,750 persons. This appears to be extremely optimistic. Because of impacts on the heavily-populated Xe Bang Fai, the reservoir could be required to mitigate for many more additional people due to the failure of other planned mitigations. Therefore, if 126,000 lose their livelihoods because of the project, roughly 94,000 to 124,000 people could suffer from malnutrition.

As the reservoir recedes, fish will be carried generally downstream into the reservoir arm nearest the dam, along with a portion of the anoxic water that was generated in the rest of the reservoir. Floating aquatic plants will also be concentrated here, and as these plants die and decompose on

the bottom the oxygen demand will increase. In combination with the decomposition of the biomass and the concentration of fertilizers, pesticides and domesticated animal dung from agricultural production, deoxygenated water will greatly decrease the amount of habitat which will not be lethal to fish.

Few details are given of the headrace channel. There could be substantial problems maintaining adequate water depth due to sedimentation. In this case, the sediment will need to be excavated and hauled off-site so that water can continue to flow. Excavations could eventually be necessary in the former Nam Theun riverbed as well due to bank slumping. These operations will be expensive and reduce power production if not undertaken proactively, but will certainly have an ongoing effect on the lower river by raising the turbidity levels in the Xe Bang Fai river intensively as the channel begins to flow once more.

Turbidity will inhibit the ability to maintain position (reotaxis) in the reservoir/river, and many fish will be drawn involuntarily into the headrace. This will cause a constant waste of fish as they are killed by the turbines.

The NRFDM estimates that "at least" 31 fish species resident in the Nam Theun river will be able to adapt to reservoir conditions. Annex 24-2 however claims that only 14 species are adaptable, but the remainder "May adapt".

Assumptions that riverine fish will be just as productive or more productive in the reservoir environment do not consider that many riverine fish are migratory. Any riverine fish caught upstream of the dam or stocked above the dam may attempt to migrate downstream to fulfill their normal life cycle. If they are able to find the exit to the reservoir (the turbine intakes), the vast majority will not survive the trip through the penstocks and turbines: they will be lost to the reservoir fishery, but not added to the fishery of the lower river. Of the few fish species that may be able to survive the conditions of the reservoir, the potential for these fish to thrive becomes a function of their ability to complete their natural life cycle, which is based upon a riverine environment.

Because adaptability is a very difficult parameter to test without the reservoir in operation, this will not likely ever be investigated, although the success of the fishery may depend on these ephemeral variables. The only indication of this occurrence might come in the form of anecdotal reports of a few dead fish on the river bank below the turbines at certain times of the year. This would likely end in a few years as all of the fish of these particular species are killed off.

To fish in the reservoir, outboard motors will likely be a necessity, and because of their value they will likely need to be carried to and from the water's edge. There appears to be three likely access points to the reservoir at low pool; one at the dam, a second at an irrigation intake and the third at the bridge. Despite the NRFDM's assertions, these are a significant distance from most of the villages, therefore the remote villages would need to be supplied with transportation services in perpetuity. If these are not made available, the shallowness of the reservoir and the

muddy draw-down zone will likely make access from the reservoir to the markets extremely difficult.

The NRFDM is not sure what fishing access will be like at draw-down:

> The fish landing places may be at the proposed inlet channels of the village irrigation schemes to overcome the problem of draw-down, which still needs to be considered in relation to site selection and design of the landings.
>
> The landing place facilities will probably consist of wooden poles for boat mooring, concrete steps up (in the order of 12m vertical height)...

Although the vertical distance will be 12 m, the horizontal distance could be a kilometer. It is unlikely that concrete steps will extend that far. Villagers may be unable to anticipate the draw-down, with their boats grounded on the muddy lake bottom, and re-launching the boats might mean carrying them considerable distances through the mud. The NRFDM assumes that the Resettlement Management Unit and District Resettlement Working Groups should be trusted to design and construct these fish landing places. Any maintenance problems of the landing places and roads, such as excavating the mud off of steps or roads, will thereafter be the responsibility of those affected by the dam.

In the end, a fisherman's only option may be to bring equipment to-and-from the lake shore via ox cart. If they become bogged down in the mud, then the outboard and fishing gear will have to be carried down to the lake by hand, and all of this plus any fish caught would have to be carried back up to the nearest road or market-accessible village. Essentially this will limit the amount of fishing that is practical.

If there are live fish to be caught, and access is available, the reservoir at MOL may be the only practical time to fish: what fish are available will then be concentrated in one area. Despite the best intentions however, fishing interests with sufficient capital may be able to procure otherwise restricted rights, and out-compete those local fishermen which formerly subsisted on the river fishery. Because additional equipment buys the opportunity to maximize the exploitation of a fishery, the reservoir at MOL may be over-fished. This would depress the ability of fish populations to reproduce sufficiently to make use of the full 450 km^2 of habitat.

Conclusion

Annually, the reservoir will be drawn down into a small portion of the North-Western arm, which will likely be anoxic because of *Eichornia* infestation, decomposition of biomass, nutrients from logging and agriculture in the watershed, and the withdrawal of the most oxygenated water into the penstock. Of the fish which are not drawn into the dead storage zone, many will be trapped

in shallow, anoxic embayments and killed,[7] or drawn into the headrace as they attempt to find oxygenated water. These factors will depress the fishery for the foreseeable future.

At best, a relatively simple ecosystem will develop where with a small number of species present. At worst, the reservoir will become largely devoid of life, except for invasive aquatic weeds and small islands of survivor fish species near the tributary mouths. Biodiversity in the Xe Bang Fai and Nam Theun watersheds will also almost certainly be substantially reduced, even when the damage already caused by Theun Hinboun is taken into account.

This review found many inaccuracies and contradictions in the NRFDM, making it difficult to provide a thorough review. The WQM only contains a short overview of factors critical to a productive reservoir, and for adequate mitigation for those affected by the project. Although it might be assumed that these critical parameters are well understood by project engineers, that is not necessarily the case. When the goal is to build the project, the amount of oxygen in the water and the number of years it will take for the reservoir to fill with sediment become less important considerations.

The World Commission on Dams provides this assessment in the overview of its reports:

> ... failures to account adequately for these impacts and to fulfill commitments that were made have led to the impoverishment and suffering of millions, giving rise to growing opposition to dams by affected communities worldwide. Innovative examples of processes for making reparations and sharing project benefits are emerging that provide hope that past injustices can be remedied and future ones avoided.

The processes proposed for the Project are not innovative: reservoir fisheries, agricultural allotments and the like are the same as what has been proposed from the early days of developing-world dam construction. It will be impossible to fully mitigate for the effects of this project, and those that have the least political power will be affected the most, along with the environment that sustains them. This review found no guarantees: if the project's optimistic predictions fail, these villagers will be left with nothing.

It should be clear that the consultants that performed the environmental studies for the project have a financial interest in making optimistic predictions, because the failure to do so risks future contracts. Financial incentives also garner substantial influence upon other decision-makers. In Laos, as in many countries where construction companies partner with governments and international development agencies, the safety net for those affected by dams is almost non-existent. Those that protest often "disappear."[8] A villager affected by the Houay Ho project

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[7] See SEMFOP II Annex 6, Map 15.4

[8] "Whose Nation? The Displaced as Victims of Development", Smitu Kothari, report to the World Commission on Dams.

made this statement:

> My relatives and I don't want to live in the resettlement village but we were forced to and we could not protest. We miss our native lands where we used to live for hundreds of years, our crops, vegetables and our happy lives.[9]

Presuming that a reservoir fishery will adequately provide for the livelihoods of thousands of people is a precarious gamble at best. The failure of the reservoir to produce sufficiently, or even the failure of the economic system to fairly compensate those engaged in the proposed fishing economy would not simply undermine already affluent lifestyles. For many, it is the difference between life and death.

[9] "Hydroelectric Dams and the Forgotten People of the Boloven Plateau." Phetsavanh Saybouala ven. 2004