

**VIETNAM ELECTRICITY GROUP  
TRUNG SON HYDROELECTRIC PROJECT MANAGEMENT UNIT (PMU)**

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# **Impact assessment of Trung Son Hydropower project to Fish- biodiversity and Fisheries – Mitigation Measures Suggest**



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# **I. Impact assessment of Trung Son Hydropower project to Fish-biodiversity and Fisheries Mitigation Measures Suggest**

## **Summary Survey Results and Analysis Data of Fish Biodiversity and Fisheries Report:**

From 1 May 2008 to 5 June 2008, the domestic consultants under instruction of an international specialist, have investigated fish biodiversity and fishery of area influenced by Trung Son Hydropower Project in Ma River. The result of investigation shows that:

Based on collection of available works along with result of this investigation, the fish diversity in Ma River basin in general and in area influenced by Trung Son Hydropower Project is high. Species assemblages change from highland to lowland areas. There is mixture of specialist upstream and downstream species in the middle region of the basin. The total area projected to be influenced by the project has 198 species of fish, including 9 species listed in Vietnam Red data book in 2007, Part I: Animal, of which 1 species is of CR class (highly endangered), 1 species of EN class (endangered) and 7 species of VU class (vulnerable). The area upstream of the dam has 4 VU species, and all 9 species occur in lowland area of barrage. None of these species appeared in Red List of IUCN 2006. All species are widely distributed in rivers of North and Northern Central Vietnam, some species found in rivers of the middle central of Vietnam. Though species richness is high, fish resources in general and aquatic resource in particularly are not in good condition and even in strong decline, with fish catches only about 80% compared to the last 10 years. Nine species that have produced large catches in the past are now caught in much lower numbers. One species originally present no appears to be absent.

There are 45 economic species of fish in the impact area, among them only 4 species occur over the entire area, 11 species for highland, 17 species for midland and 29 species for lowland.

The species living on the bottom are most common in upper, middle and lowlands. In lowland, most species prefer mud bottom, but in the upper and midland stone bottoms are usually most preferred. More species are found along banks than in the middle of the river. Almost all juvenile and mature species appear in the beginning of rainy season.

There are 54 species in brackish water and salty water that penetrates into river but not past the dam's limit.

Food fish with restricted distributions occur in the lowland, but their numbers are reduced in the midland and highland. Likewise, widely distributed food fish are common. Fish that require fast water and food fish with restricted distributions will be seriously harmed if habitats are changed.

Based on the results of interviews of 927 fishermen in Ma River it is apparent that total fish output and average fish output is different among areas; highest concentrated in lowlands and lowest in the midland.

Daily income, rate of protein consumption and income from fish as proportions of total protein consumed and total income increase from highland to midland and then again to be highest in the lowland.

Protein from fish plays an important role for local people, it accounts from 50% to 59% total consumed protein source. However, the nutrient from river fish accounts for a very small percentage of total nutrient portions. The yield of river fish only accounts for 3.9% of annual fish yield (in 2002 and 2003) and the highest percentage is only 4.7% (in 2004 and 2005). Therefore, although the ratio of protein in the portion made from fish is generally high, the main source of protein in the downstream area is from sea fish and bred fish while river fish only accounts for less than 2% of total protein quantity consumed. On contrary, in the upstream area, river fish accounts for a relatively high ratio, It is 14.96%.

The amount of breeding fish that can be sourced naturally in the river reduces gradually from the upstream to middle-stream and particularly to downstream. The output of breeding fish exploitation by households, which are located above the dam, is higher than the for households, which are located below the dam.

Annual average fishing days per person over the entire project is 171 days per year. In the highlands it is 110 days, while in the midlands and lowlands it is 203 and 202 days respectively.

In 6 years, from 2001 to 2006, the number of people catching fish in Ma river increase rapidly. All criteria regarding human resources, output and catching capacity per person per year increased from highland to midland and lowland.

Fisheries products play an important role of export turnover of Thanh Hoa province, occupying 30% - 36% in total for period 2001 – 2006, however all this is sea product.

Area, output and capacity of aquaculture changes irregularly in Thanh Hoa province. Number of cages is small, and is the highest in midland and the lowest in highland.

Area, output and productivity for cultivation of aqua-products in the whole province increases and decreases inconstantly. Number of fish cages in the river is low and is highest in the middle region and lowest in the upper river; output and productivity of cage fish culture is not stable.

Fishing families are generally poor and have low levels of education. Aquatic resource export turn-over is large and increased from 2001 to 2006. In generally, role of aquatic resource in export turnover of Thanh Hoa province is quite high. It increased gradually from 2001 to 2006, but it is almost all from sea production.

Output of natural fish catching in the river of fishermen of localities along Ma river in project area of Thanh Hoa province makes up the lowest rate, fluctuating from 3.9% to 4.7% in comparison with total fish output of fishermen participating.

There were 52 species recorded in the market survey, but the catch of valuable wild species is smaller than the harvest from aquaculture. Ratio between cultured fish and nature fish sold in surveyed area is 5.6 times. The productivity of cultured fish stocks is also higher than that of natural fish stocks.

There is not currently any hydropower development (or the construction of major dams for other purposes) but pressures of overexploitation, pollution and habitat destruction are likely to continue, so freshwater, estuarine and coastal marine aquatic biodiversity is likely to continue to decline.

Summary of past and future trends without Hydropower project plant in Ma River as follow:

- Freshwater, Estuarine and Marine Biodiversity and Fisheries have been declining and are likely to continue declining due to overexploitation, habitat loss and modification and pollution.
- Migration along river, and between rivers and coastal waters is likely to undergo little change.
- Habitats integrity is likely to remain good in upstream areas, but continue to be modified in downstream freshwater, estuarine and coastal areas.
- Nutrient levels are likely to continue to increase in downstream areas due to pollution, leading to increasingly eutrophic conditions.

Biodiversity includes the abundance and variety of organisms, as well as the ecosystems to which they belong and the ecological processes that support them (Houston 1994, Kottelat and Whitten 1996). Viet Nam has extensive natural resources exemplified by extremely high aquatic biodiversity, including many of national and international importance (Moste 1995). The survey has shown that there are 1027 inland species of fish in Vietnam, divided into 127 genera, 98 families and 22 orders (Nguyen Van Hao, 2005), of which 36 species appeared in Red Book of Vietnam 2007 (Ministry of Science and Technology 2007).

Though knowledge of biodiversity (extending to the ecosystem structure and function as well as fish species richness) are still inadequate (Moste 1995), investigations to date describe the fish biodiversity of Vietnam in general and of Ma River in particular as high. However, these investigations are incomplete, with detailed information lacking on many aspects of biology and ecology.

There have been three research studies into the biodiversity of the Ma River basin. Until now 269 species of fish are discovered in Ma river basin; in the project zone, there are 198 species of fish. It's a high fish biodiversity zone.

The fisheries product play important role of export turnover of Thanh Hoa province, occupy 30% - 36% in total for period 2001 – 2006, however all is sea product.

The construction and operations of hydropower dams will directly or indirectly affect ecological processes in five spatial regions of river systems; reaches upstream from the reservoir, flooded reaches, reaches between the dam and power station, reaches between the power station and the confluence with the first major downstream tributary and reaches downstream from the confluence with the first major tributary. Within those reaches the extent and nature of impacts depends on the development stage of the project; construction phase, reservoir filling phase, first five years operation and beyond five years. The following sections provide details of key issues and their likely effects on environmental processes. Issues are discussed by reach for each of the four key time periods:

## The locations impacted:

### 1. Upstream from Reservoir:

The reservoir will have negligible direct effects on habitats upstream from the impounded area, however if construction roads and the reservoir become open access areas it will provide greater human access to upstream habitats (Trombulak & Frissell 2000). Despite this, the structural nature and distribution of habitats should remain intact. Similarly, the reservoir should not affect water quality in these habitats; therefore, fish regional fauna here is really not impacted.

Da river basin and Ma river basin have a great deal of similar characteristics: Da River in Vietnam is located in the North of Ma River. The two rivers run parallel and flow in the Northwest – Southeast direction and they have similar terrain, locating in the area of freshwater fish distribution of the Northwest of Vietnam (Mai Dinh Yen, 1973) (see Map No 1). Upstreams of Ma river have 87 species of fish (Duong Quang Ngoc 2007) of which 74 species are available in the upstreams of Hoa Binh Hydroelectric reservoir, a hydroelectric project, which has been come in to operation for 20 years, was built in Da river,.There are only 13 species of fish available in the upstream of Ma river but not in Da river, of which 12 species are for Ma river only; there had been (*Paraspinibarbus macracanthus*) before the Da dam was built, we have not found them again (Nguyen Thi Hoa 2008).

Mitigation: One major measure to mitigating the effects of this and other impacts is to ensure that at least one branch of the Trung Son system remains unaltered. This is termed an intact river approach (ICEM 2007, Sheaves et al in press), and has recently been adopted as policy for the Vu Gia – Thu Bon Basin (W.W.F 2008). This approach would consist of ensuring there was a complete sequence from the estuary to headwaters with no barriers and a high level of protection from other impacts, such as mining-related pollution and destructive fishing practices. Having a completely unaltered system would preserve connectivity within one branch of the system and provide species requiring inter-habitat migration a complete system in which they could perform necessary life functions. It would be important to ensure that all habitat types were well represented within the protected sequence (Sheaves M. & all., 2007).

### 2. Within the reservoir:

#### 2.1 The construction phase:

Possible impacts of the project on the aquatic biodiversity during construction include:

2.1.1 *Work in the river bed*. Work in the river bed will result in increasing the sediment load in the river. This affects fish downstream directly and indirectly. Fish living in clear water habitats are directly affected by increased suspended sediments which may damage their gills or accumulate in their gill chamber, leading to death. Indirect effects include: modification of the natural habitat by silt deposition (e.g. fish living over a rocky substrate cannot survive if rocks are covered by mud or sediments); destruction of spawning sites (some fish species may migrate to very precise spawning grounds and may not breed if these areas become silted) (Kottelat M, 1996); At the lower section where the dam is going to be built (it is 20°36'45" - 104°51'04") is a place where carp breed. This place may be affected by digging to build dam or due to sediment. However, there are many other spawning places along the Ma river. The most likely impacts would be from silt deposition over freshly laid eggs or newly hatched larvae; and reduced primary production as a result of reduced light

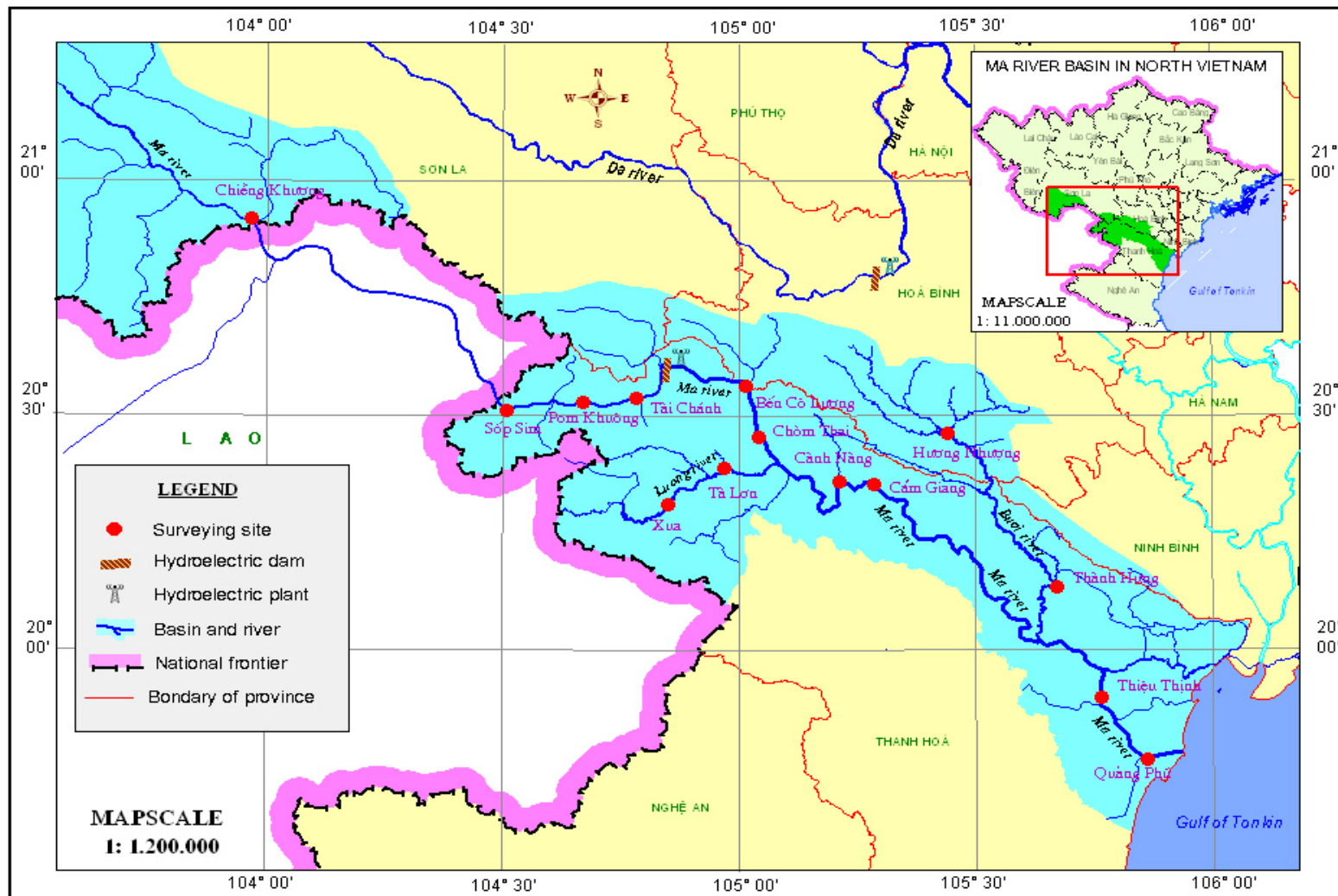
penetration (affecting herbivorous fishes as well as fish preying on invertebrates hiding in algae) (Kottelat M, 1996).

Mitigation: To reduce impacts, diversion works should be carefully planned for early completion so the riverbed is cleared before dam construction commences and should be designed to minimize relocation of sediments and disruption to natural flow patterns. Construction materials from diversion works and dam construction should not be disposed of or washed in the river or drainage systems. Washing of materials should be done in an appropriate off-site location designed to retain unwanted sediment for appropriate disposal. Under no circumstances should material washing facilities feed unwanted material back into a stream system, either directly or indirectly (Kottelat 1996).

*2.1.2 Road construction.* Road construction mainly affects the freshwater ecology when poor construction practices result in an increased sediment load (see above for effects). Beside work in the river bed, this happens when: 1) construction material is washed in the water course; 2) unstabilised roads are washed away in the rainy season; 3) small streams are dammed instead of bridged (this also often results in the creation of a reservoir of biologically dead water upstream of the dam and a dry stream bed downstream; and 4) inappropriate bridges are constructed (leading to partial restriction of the stream flow, extensive modification of the stream bed and banks). 2 - 3 are especially likely to happen when temporary roads are constructed (Kottelat M, 1996).

Mitigation: All roads, including temporary ones, should be stabilized and bridges should be built carefully, respecting the existing stream/river bed and bank morphology. Construction material should never be washed in the stream but transported to disposals areas. During construction roads should be stabilized to prevent construction material and all streams (even small or ephemeral) should be crossed with bridges rather than alternate forms of causeway. (Kottelat, 1996).

## Ma and Da Rivers are in the same zone



Map No 1: Upstream of *Ma and Da rivers* located in the same ecological zone of Northern Vietnam

*2.1.3 Water pollution:* Spills of fuel and chemicals may have direct and indirect impacts on the aquatic fauna, as well as on humans and animals feeding on it. Pollution's most often occur where pollutants are stored, but also where they are used. Improper and careless manipulations are a serious concern (M. Kottelat, 1996).

Mitigation: The use and storage of pollutants such as fuel and chemicals may directly or indirectly affect aquatic fauna. Secure handling and storage facilities surrounded by retention barriers should be constructed well clear of natural drainage systems. Handling of pollutants should be kept to an absolute minimum outside secure holding facilities. Staff should be adequately trained in safe handling and use procedures as well as emergency spill procedures. Packaging material should be disposed of in an appropriate off site facility. Where possible the use of products with recyclable packaging material should be encouraged. Appropriate measures (legal and common sense) should be monitored and enforced to safeguard both humans and the environment (Kottelat 1996).

*2.1.4 Use of explosives.* Use of explosives in the water is highly damaging for fishes (and probably other aquatic organisms). If they are not killed instantly, their internal organs may be severely injured leading to death within a few minutes to a few days, even if they were at a considerable distance of the explosion site. In theory, little or no explosives should be used underwater in the present project. But explosives will be used and experience shows that at most construction sites large quantities of explosives are stolen or diverted from their proper goal and used for fishing. Besides being illegal, fishing with explosives is a very inefficient method as most fishes killed cannot be recovered. Additionally, the explosives damage the fish habitats and occasionally kill fishermen. As these occasional 'fishermen' usually are project workers, this issue is also of concern for the project security.

It may not always be possible to distinguish between industrial explosives and the military and home-made ones. (In the surveyed area, 'home made' local explosives are reportedly made of recycled, unexploded bombs).

Mitigation: Staff should have appropriate training before allowing them access to explosives and it is recommended that no explosives be used in the water. Further, reports indicate that workers often acquire explosives from dam construction sites and use them to catch fish. Apart from being a hazardous practice it is extremely damaging to the environment. Consequently, explosives should be stored in a secure location and their use strictly monitored. In addition, workers should be banned from the practice of fishing with explosives and that ban must be strictly enforced (Kottelat 1996).

*2.1.5 Vegetation clearing:* One major problem that must be faced at the construction

phase is how to deal with vegetation in the area to be flooded. Vegetation left to flood and decay will negatively impact water quality in the reservoir by creating anoxic conditions (Rosa et al. 1996). Consequently the reservoir may be incapable of supporting aquatic life (Kottelat 1996). Moreover, the decaying vegetation will promote the release of greenhouse gasses to the atmosphere (Christensen et al. 2004a, Rosa et al. 2004, Abril et al. 2005) and may leave the project in carbon debt for many decades. On the other hand, removal of the vegetation has a potential to greatly increase sedimentation downstream of the construction site (Kottelat 1996).

Mitigation: the removal of vegetation destined to be flooded should be undertaken if possible. Failure to remove this vegetation may lead to poor water quality in the reservoir



with subsequent loss of potential for fisheries enhancement. During vegetation removal all possible measures to reduce movement of sediments (proper road construction, sediment traps) should be put in place and maintained rigorously. It would also be advantageous to delay vegetation clearing to the last possible moment to further reduce potential for transport of sediment. When possible cleared material should be utilized or disposed of appropriately. (Kottelat, 1996).

*2.1.6 Construction workers villages:* The environmental impacts from construction and habitation of a village essentially mirror those of a road. However, the impacts are likely to be more concentrated. Additionally, villages provide a site with a high potential for extensive and concentrated pollution, with the potential for both large pollution pulses during major environmental events, such as floods, and substantial chronic pollution inputs (Sheaves M. 2008).

Mitigation: Construction and placement of workers villages needs to be carefully considered to safeguard against additional impacts on waterways. As a guideline for minimizing impacts the mitigation measures for road construction can be used. In addition, appropriate methods for disposal of waste, particularly sewage and garbage, in an environmentally friendly manner should be followed (Sheaves M. 2008).

## **2.2 The dam creation**

### *2.2.1 Filling phase:*

Impoundments offer an opportunity to enhance fisheries values through stocking (Zhong & Power 1996) provided appropriate species and technology exist, or by providing additional areas for aquaculture. However those mitigation measures can only succeed if environmental conditions in the impoundment are appropriate.

The filling phase will result in the replacement of many kilometers of riverine habitat with a potentially inhospitable habitat. If vegetation is not cleared prior to flooding the decay process will almost certainly reduce water quality (Rosa et al. 2004, Abril et al. 2005), probably to a level unable to support aquatic life. Alternatively, if vegetation is cleared the best case scenario is a standing water habitat, with a relatively barren underwater landscape (Kottelat 1996); Imposition of dams will back-up water converting fast-flowing mountain streams to upland lakes, an effect seen throughout monsoon Asia (Dudgeon 2005). Natural habitats are lost (Dudgeon 2005, Silva et al. 2006) river ecosystem and the extreme habitat conversion means that conditions will be unfavorable for most species occurring naturally in the area (Sheaves M, 2007). A large river with rapids, riffles, runs and pools will be transformed into a large body of standing water. Species which need fast running waters will be negatively impacted or eliminated.

Mitigation: Little can be done to reverse the permanent change to habitat types. The most useful measure would be to ensure that any fish stocked in the reservoirs are native to the system so that possibly undesirable species are not introduced (Sheaves M, 2007). Here, most emphasis switches from mitigation measures to focus on compensatory measures such as fish stocking. Stream habitats (shallow, fast flowing, high ratio of edge to open water) are altered to lake-type habitats (deepwater, slow flowing, low ratio of edge to open water). Consequently, the new habitats will be hostile to stream species but beneficial to lake type species (Zhong & Power 1996). This means a trade-off between maintaining possibly unique biodiversity and the potential for increased fisheries production in the impoundments (Fleischer 2004, So et al. 2006).

*2.2.2 First five years:* Few tropical reservoirs have more than a lens of oxygenated water at the surface (Mtada 1988, Townsend 1999, Aughenbaugh et al. 2005). That introduces another problem for dams with large draw-down or large seasonal fluctuations in water level because pelagic and benthic aquatic productivity are both confined to that oxygenated layer. Draw-down produces a benthic “dead zone” that extends from high water levels down to the extent of draw-down levels. In the draw-down zone benthic productivity is essentially non-existent (Grimas 1962, Kaster & Jacobi 1978, Blinn et al. 1995, Okland & Okland 1996). Rapid draw-down results in the death of most benthic organisms (Blinn et al. 1995) with only highly mobile species potentially capable of retreating with the water. In turn, the loss of benthic productivity impacts on trophic function of the reservoir. Benthic organisms are important for the removal and processing of nutrients and for making them available to higher trophic levels. Without mechanisms for removal of nutrients there is an elevated risk of the system becoming eutrophic (Jones et al. 2001). Fish are also confined to oxygenated surface waters resulting in higher biomasses of fish around the shallow edges, the only accessible habitats with structure. Consequently, during draw-down there is a potential for stranding and subsequent loss of fisheries biomass unless submerged areas are landscaped to eliminate formation of pools.

Water quality outcomes for tropical reservoirs are difficult to predict because they depend on the combinations and interactions between a large number of factors including: the nature and type of sediments and nutrients entering the system and the way they are delivered (Faithful & Griffiths 2000, Jones et al. 2001), rainfall and water supply patterns (Mtada 1988), depth and mixing patterns (Sahoo & Luketina 2006), water extraction regimes and volumes (Boland 1995) and many more. If vegetation is not cleared from areas that will be flooded during construction then water quality will be degraded as bacteria break down sunken vegetation. This process releases carbon dioxide and methane gas (Rosa et al. 2004, Soumis et al. 2004, Abril et al. 2005) both of which are ultimately released to the atmosphere (Rosa et al. 2004, Abril et al. 2005). In turn, this lowers pH and promotes development of anoxic conditions, however, some degree of anoxia is expected in deeper areas even if vegetation is cleared before flooding. Nutrient input interacts across chemical and biological process to influence water column primary productivity (Fonseca & Bicudo 2008). In turn, the nature of that relationship (eutrophic, oligotrophic, etc) strongly influences the ability to maintain aquatic biodiversity and subsequent fisheries potential.

Typically, decaying organic matter in the reservoirs initially leads to enhanced nutrient flow from dams, but in the medium to long term (eg. 2-5 years) trapping increases leading to extremely low nutrient export. The effect is expected to be irreversible during the active life of the reservoir. The rate at which reservoirs accumulate nutrient depends on many factors but it is likely that regular draw-down of reservoirs has a potential to accelerate the deterioration of water quality parameters that are directly impacted by accumulation of nutrients. Rapid draw-down of a tropical reservoir in Australia resulted in substantial increases in chlorophyll-a and total phosphorus concentrations when levels were at their lowest and although values reduced considerably after a complete recharge of the reservoir they remained higher than pre-drawdown values (Boland 1995). This would indicate that repeated filling and draw-down is

likely to exacerbate the potential for water quality problems. Rapid draw-down and development of a dead zone can only exacerbate the accumulation of nutrient because of the loss of benthic organisms capable of incorporating nutrient into aquatic food webs. Draw-down also promotes the release of greenhouse gasses to the atmosphere (Fearnside 2005).

In initial years being flooded, the aquatic ecosystem of Trung Son hydroelectric power plant reservoir is basically of reservoir type. Flowing-water fish is lessened both in number of species and production, in the contrary, species eating organic matters and plankton boost due to fertile food source. In 5-6 initial years, the natural production is very high, decreases in the stage of nutrition deduction. Stays stable in stage of stability and increases in stage of development. When the sedimentary deposit reaches dead water level, the reservoir comes to stage of bogginess and the production will be lessened. Ms Bui Thi Lien, a fisher in Bai San, reservoir of Hoa Binh hydropower told us that some years ago, her family could catch 200 kg of fish/day, now with the same fishing tackle, catches only 10 kg/ day.

Mitigation: Here, most emphasis switches from mitigation measures to focus on compensatory measures such as fish stocking. Stream habitats (shallow, fast flowing, high ratio of edge to open water) are altered to lake-type habitats (deepwater, slow flowing, low ratio of edge to open water). Consequently, the new habitats will be hostile to stream species but beneficial to lake type species (Zhong & Power 1996). This means a trade-off between maintaining possibly unique biodiversity and the potential for increased fisheries production in the impoundments (Fleischer 2004, So et al. 2006). In the first years, it is likely to execute in-site spawning of *Spinibarbus denticulatus* and *Cyprinus carpio*, species currently available in the river. At the same time, we have carried out a method of catching fish appropriately for the local fishermen in the lake bed area.

*2.2.3 Beyond five years:* It is difficult to predict the longer term problems that may arise in a tropical reservoir. Most of the predictable problems are simply temporal extensions of the short-term issues already discussed. That said, it is highly probably that the reservoir will continue to output greenhouse gasses for many years beyond the initial five if vegetation is flooded rather than cleared (Soumis et al. 2004, Abril et al. 2005).

**Issue: Fisheries production will be changed**

Five years after full storage of the reservoir, the yield of fish in the reservoir will increase in comparison to the previous time. In the following years, the yield of fish in the reservoir will gradually reduce if there is no supplementation of artificial breeds. There are also some great changes in the fishing sector because people living in the reservoir catchment are all farmers who go fishing only to supplement a source of nutrient from fish to their daily mean and this source of nutrient is very important to them. They have been familiar with fishing in the rivers and streams and with the fishing facilities suitable for such condition. Therefore, the formation of reservoir and thus the great changes in the hydrological features of the catchment lead to the fact that fishing methods and facilities must be changed and cost is required for this change.

Mitigation: In some reservoirs there is a natural shift towards a greater biomass of lotic species if they are present in the system (Zhong & Power 1996) however in most cases fisheries production is not sustainable in the long term without extensive artificial propagation and stocking (Zhong & Power 1996). Additionally, change in habitats (fast flowing to still waters) and water quality (eg. temperature) may mean that species will need to be introduced from elsewhere to ensure productive fisheries. Such is the case in the Ea Kao reservoir in southern Viet Nam where almost 80% of fisheries productivity in the reservoir is provided by populations of introduced species which are maintained by extensive artificial stocking (Phan & De Silva 2000).

Compensatory approaches such as introduction of non-native species need to be assessed carefully on a case by case basis. One almost certain outcome of species introductions will be a loss of biodiversity (Fleischer 2004, So et al. 2006) even when exotics are carefully chosen to fit into apparently unexploited niches (Dudgeon & Smith 2006). The potential loss of biodiversity alone should prompt strong consideration for the development of fisheries based around native species. Whether fisheries are based on native or exotic species it is likely that the fisheries will only be sustainable with extensive artificial support (Phan & De Silva 2000) and then only if appropriate species are introduced (Dudgeon & Smith 2006). Success of exotic species will depend on physical conditions in the reservoir and their ability to survive alongside or to outcompete native species. Consequently there is sound reason for delaying decisions to introduce exotics to a new reservoir for at least ten years post-construction to allow establishment of stable physical conditions and provide native species time to establish viable populations (Kottelat 1996). Introduction of exotics should not be undertaken without prior comprehensive cost-benefit and risk analyses (Fenichel et al 2006).

Fisheries production in the reservoir and upstream reaches should be managed to safeguard biodiversity and productivity. Consequently, management strategies should aim to control and monitor exploitation and practices used in aquaculture as well as wild fisheries. Aquaculture ventures should be subject to the same levels of scrutiny as exotic species before being established in the reservoir. To safeguard biodiversity and productivity destructive fishing practices, such as electro-fishing, explosive fishing and monofilament gill nets, should not be permitted .

#### **Issue: Conversion of riverine habitats to lake-type habitats**

Imposition of dams will back-up water converting fast-flowing mountain streams to upland lakes, an effect seen throughout monsoon Asia (Dudgeon 2005). Natural habitats are lost (Dudgeon 2005, Silva et al. 2006) river ecosystem and the extreme habitat conversion means that conditions will be unfavorable for most species occurring naturally in the area (Sheaves M, 2007). A large river with rapids, riffles, runs and pools will be transformed into a large body of standing water. Species which need fast running waters will be negatively impacted or eliminated.

Because of sediment deposition, most of the stones, rocky outcrops and other elements of the underwater landscape will soon disappear; these are the main habitat of the species *Senilabeo lemassoni*, *S. dorsoarcus*, *S. xanthogeny*, *Garra pingi*, *G. orientalis*, which are likely to also disappear. Algae living on the stones will disappear, as well as the varied invertebrate fauna associated with them; fish feeding on these algae and fauna are very unlikely to switch to other food sources and will disappear. Spawning grounds will be covered by sediments (Kottelat M, 1996); Species of fish within the area will be greatly influenced and disappear. In particular species such as: *Varicorhinus (O.) gerlachi*, *V. (O.) laticeps*, *Scaphiodonichthys microcorpus*, *Senilabeo lemassoni*, *S. dorsoarcus*, *S. xanthogenys*, *Garra pingi*, *G. orientalis*, all species of Balitoridae family found as of *Schistura incerta*, *S. fasciolata*, *S. hingi* and *Balitora Brucei*; *Hemibagrus vietnamicus* and *Glyptothorax hainanensis* are very likely to disappear. Some high productivity species which are able to adaptable to the change from fast running water in the river into slow running water in pond and lake such as carp (*Cyprinus carpio*), *Spinibarbus denticulatus*, *Hemiculter leucisculus*, *Culter recurvirostris*, *Cranoglanis sinensis* should still exist and develop.

Due to sedimentation and destruction of vegetable blanket, the reservoir bed is generally a monotonous terrain. It is difficult for fish to find shelters in such conditions (Kottelat, 1996).

Although some algae will still exist micophytobentos, the main food of fish such as *Varicorhinus (O.) gerlachi*, *V. (O.) laticeps*, *Scaphiodonichthys microcorpus* is likely to disappear leading to disappearance of the fish that depend on it.

In the reservoir, there are 4 species of VU level in Vietnam Red Data Book that need protecting. 1) *Senilabeo lemassoni* live in bed and sub-bed layers with main food of micophytobentos. When water is stored living condition will not be suitable for this species any more, and it will disappear. However the reservoir is not very long, so this may move to live in upstream areas. This species can also be found in upper stream areas and may find suitable places for spawning there or move to Luong branch, a river branch intended to stay unchanged. 2) *Elopichthys bambusa* live in middle and surface layers. They are carnivorous, spawn egg-masses in middle stream, are distributed throughout the middle and upstream areas, and have a spawning season between April and July. Because of this they may disappear after water is stored. However, this species seems very suited to reservoir environments. Fishers say this grow well in Hoa Binh reservoir. It is possible to preserve this species in the post-dam area as long as spawning areas are protected. 3) *Bagarius rutilus* is fierce, living on the bed layer, spawn in middle and upper stream so it is possible to be preserved in upper area (pre-reservoir) and post-dam area. 4) *Hemibagrus guttatus* is fierce, living in bed layer, carnivorous, only spawns in upper stream; so likely to be preserved only in pre-reservoir area. It is not certain whether small fish of this species can come to lower area through bed discharging gates and sand discharging gates but this seems an unreliable possibility.

In addition, there are 10 other species without high conservation value but certain economic value including: *Spinibarbus denticulatus*, *S. hollandi*, *Cirrhina molitorella*, *Cyprinus carpio*, *Cranoglanis sinensis* and *Hemiculter leucisculus*. They should be able exist and develop in the reservoir and are likely to show high production. Species of *Varicorhinus (O.) gerlachi*, *Garra orientalis* will probably not be able to exist in the dam. There is no evidence about the ability of *Clarias fuscus* and *Mastacembelus armatus* to exist in dam conditions. *Spinibarbus denticulatus* has the greatest production of breeding fish in the area and the place of greatest production is in the pre-dam area.

**Mitigation:** Here, most emphasis switches from mitigation measures to focus on compensatory measures such as fish stocking. Stream habitats (shallow, fast flowing, high ratio of edge to open water) are altered to lake-type habitats (deepwater, slow flowing, low ratio of edge to open water). Consequently, the new habitats will be hostile to stream species but beneficial to lake type species (Zhong & Power 1996). This means a trade-off between maintaining possibly unique biodiversity and the potential for increased fisheries production in the impoundments (Fleischer 2004, So et al. 2006). In the first years, it is likely to execute in site multiplication for *Spinibarbus denticulatus* and *Cyprinus carpio*, species available in the river bed area.

### **Issue: Impaired Longitudinal Connectivity Leading to Migration Barriers**

**Character of Impact:** Imposition of dams will act as impassable barriers to longitudinal migration along the river, a consequence recorded throughout the world (eg. Borges Barthem et al. 1991, Fearnside 2001, Katano et al. 2006, Sheer & Steel 2006). Longitudinal connectivity is crucial because fish and mobile invertebrates use longitudinal migration to access spawning and nursery grounds, to move to deep water refuge areas when river levels fall, and as part of life-history migrations that are integral to the life cycles of many species (Jensen 2001, Poulsen et al. 2002). Impacts on longitudinal migration are expected to be particularly severe because Asian rivers contain large numbers of migrating species (Kottelat

& Whitten 1996). Particularly severe on fish with requirements for long distance migration within the river or between the sea and upstream areas, and on fish needing to make specific short distance migrations between areas separated by the dam. This is likely to be a particular problem for species like *Clupanodon thrissa* an important fisheries species that migrates from the sea to upstream freshwater areas for spawning (Berge et al. 2006) and is recorded as Endangered in Vietnam's Data Red Book 2007 (Vietnam Data Red Book, Part I. Animal, 2007). The spawning site of this species on the Ma river is Huoi Tram, Ba Thuoc district (Duc NH, Ngoc DQ, Thuy TT & Hao NV, 2003). The water flow pattern is also an important aspect with regard to fish migration. For many species it is the first flow increase in the beginning of the rainy season that triggers the migration. These triggering flows are often delayed, or have disappeared in a regulated river with reservoirs. The first part of the rainy season is used for filling the reservoir (Dag Berge, Hai HT & Son NK 2006). Some migratory fish species may travel very long distances between precisely delimited feeding and breeding grounds, sometime stretching over hundreds or thousand of km (like the giant Mekong catfish *Pangasianodon gigas*). Others may migrate for a few km only between different places within the main river, or between the main river and tributaries (Kottelat M 1996). It is objectively impossible to assign the above indicated species to any of these categories, but it seems that *Bagarius rutilus*, *Hemibagrus guttatus* and *Garra orientalis* may migrate over relatively long distances in the Ma basin. The presence at many localities in the lower, middle and upstream of Ma river with both juveniles and large adults of the *Hemiculter leucisculus* species indicate that they probably have several spawning grounds and possibly do not undertake extensive migrations. To exacerbate this problem, altered flows may not occur at times appropriate for migration needs (Sheaves M, 2007). Fifty six species of fish that live in brackish and salty waters migrate up Ma River (Duong Quang Ngoc, 2007). None of these is hampered by the dam because the longest species migration is that of *Lates calcarifer* which has a migration limit still 70km downstream from the dam. As far as we had known that 4 species of fish, which are living in the river, have migrated to the sea such as: (*Anguilla marmorata*), (*Lates calcarifer*), (*Mugil cephalus*) and (*Therapon jarbua*). These 4 species have been allocated in lowlands of the dam, therefore, dam is not a barrier of their migration and generation.

#### Mitigation:

i) One major measure to mitigating the effects of this and other impacts is to ensure that at least one branch of the Ma river system remains unaltered. This would need to consist of a complete sequence from the estuary to headwaters with no barriers and a high level of protection from other impacts such as mining-related pollution and destructive fishing practices. Having a completely unaltered system would preserve connectivity within one branch of the system and provide species requiring inter-habitat migration one part of the system in which they could perform necessary life functions. It would be important to ensure that all habitat types were well represented within the protected system. A potential candidate is the Ma – Buoi in the north-east system and Luong river in the north-west (see the map). Wild systems should be protected against future development, have no obstruction to migratory pathways and have all habitat types well represented (Sheaves M. 2007).

ii) Another solution is not to store water in the reservoir at the beginning of rainy season. An amount of water has to be discharged as the “stimulus” for migrating fishes. This is an area that requires extensive study to determine the extent, cues and timing of migrations, as well as the true likelihood of success (Sheaves M. 2007).

iii) Fish ladders have been constructed at many dams, in theory for allowing fish to migrate. The concept has been developed in northern and temperate countries of Europe and America and has sometimes worked. It has worked mainly where the fish fauna is very species poor, sometime consisting of only one or two species for which the ladders were specifically constructed. These were mostly trout and salmons, fish which are known to be good jumpers, and the ladders (a succession of closely set weirs with resting pools) were not obstacles to them.

Fish ladders for fish ways have rarely been constructed in tropical countries. There is no report of instances were they have been efficient. But there are accounts of their inefficiency (e.g. Roberts, 1994). These failures can be accounted by poor constructions (ladders leading from a dry place of the river to a place in the reservoir dry at the time of migrations), poor or lack of maintenance (ladder filled by sediments in a few days) and poor design (lack of

biological considerations). Important biological considerations are: 1) tropical fish communities usually include numerous species (sometimes more than hundred) and each species may have different requirements in terms of season, hydro dynamism, position in the water column, and swimming behavior; 2) fish must find the entrance of the ladder; 3) after ascending a ladder, the fish (or their offspring) will have to come back down through the barrier structure (i.e. the dam) (Kottelat M, 1996).

#### **Issue: Nutrient Trapping**

*Character of Impact:* Water entering dams slows down allowing nutrients to settle out (Rausch & Schreiber 1981). Water released from dams is depleted in nutrients leading to reduction in nutrient supplies to naturally nutrient limited freshwater areas downstream of dams (Domenech et al. 2006, Roelke et al. 2006). Reduced nutrient flows to offshore areas may benefit coral reefs that are damaged by high nutrient and sediment loads (Devlin & Brodie 2005, McKergow et al. 2005, Wooldridge et al. 2006). In the reservoirs with stratification as Ban Uon (Trung Son), chemical ingredients and their density variety in accordance with depth. During the stratification, the separating layer between surface and bed layers prevents nutrition from coming to surface layer and solutes from coming to lower layers. The dissociation of microbes and flooded plants into organic sedimentation leads to the lack of oxygen in bed layer. (Electronic Consultant No 4, 2004 (PECC 4, 2004)).

Mitigation: Discharging water from deep parts of the reservoir (Martin & Arneson 1978) could alleviate this problem, however this could lead to increased discharge of Greenhouse gases (see below). Attempts to add additional nutrients to downstream areas are unlikely to be practical because there is insufficient understanding of the processes operating, or how they would change following hydro development, to be able to determine appropriate addition levels.

The lack of oxygen in bed layer will last 3 to 4 years if the living mass in the reservoir is not removed. If the reservoir bed is cleared up, this period only lasts 1-2 years (PECC 4, 2004). To minimize this, the living mass in reservoir bed should be cleared before flooding.

### **3. Reservoir to power station**

**Issus:** *Environmental losses of post-dam and post-power plant river:* because the distance between the dam and discharging channel is relatively short (456m only) together with dam

penetration, the negative impact of dry river is not remarkable (PECC 2004). So this is a good design because the power plant does not make the dead river.

**3.1 Construction phase:** Potential impacts are similar to those at the construction site with translocation of contaminants and sediment into the waterway of primary concern. Consequently problems associated with work undertaken in the riverbed, construction of access roads, water pollution, use of explosives and vegetation clearing become directly relevant to this reach. Of greatest concern are increased sediment loads and increased turbidity. Both problems have been discussed above as part of the reservoir construction phase. In identifying the problems for this reach/time there is an assumption that natural flows will be maintained during construction.

Mitigation: For mitigation options see reservoir construction phase above.

**3.2 Filling phase:** This phase marks the first major impact on reaches downstream from the dam wall. During filling of the dam natural freshwater flows will be reduced as some proportion of the water is retained to fill the reservoir. In an ideal scenario this phase would have in place

a managed flow regime that favoured maintenance of the ecosystem. However the balance between regulating rivers and maintaining existing resource use is a complex challenge that has not yet been successfully achieved in industrialized nations (Hirji & Panella 2003) although it has long been acknowledged that declines in inland fisheries productivity are the result of degradation of fish habitat resulting from changes to land and water resource use (Swales 1993, Halls & Welcomme 2004). Moreover it is accepted that dams have pervasive effects on the entire length of rivers, even extending into associated estuaries (Zhong & Power 1996) and adjacent coastlines (Paskoff 1992) as a direct result of alterations to the timing and volumes of flows.

Many freshwater stream habitats are at risk if flow patterns are modified. Deep pools play a crucial role in the Viet Nam's river ecosystems because they are important habitats for many fish during the dry season and floodplains provide productive feeding habitats during the wet season (Poulsen et al. 2002). Change in the volume and timing of flows has the potential to significantly impair the availability of both habitat types, as well as the ability of fish to move between them (Eikaas & McIntosh 2006). Habitat effects go beyond depth of water or connection. Reduced flow following dam construction can lead to siltation of deep pool habitats (Poulsen et al. 2002) severely affecting the fish fauna they sustain. Although highly dependent on the relative inputs of the impacted stream and its tributaries, at this point it is worth noting the potential for impact further down stream. Altered flows can impact the location of the turbidity maximum zone (TMZ) (Pontee et al. 2004), an area crucial for larval fish (North et al. 2002), alter the transport of eggs and larvae to the TMZ (North et al. 2005), influence the retention of larvae in the TMZ (Chicharo et al. 2001), and modify productivity at the TMZ that supports high densities of larvae (North et al. 2005). Reductions in freshwater flow can reduce sediment delivery with subsequent reductions in diversity of river morphology and biota (Pohl 2000). Even beyond such specific problems, freshwater flows are necessary to provide the salinity gradient characteristic of estuaries (Bate & Adams 2000) that is the basis for supporting their function and biodiversity.

Water supply (excessive or insufficient flooding) and poor water quality, both of which are likely to be extensively impacted by changes in flow regimes, are ranked among the most pressing environmental problems faced by Viet Nam's aquaculture farmers (Jeney et al.



2002). Poor water quality goes beyond the question of anthropogenic pollutants to levels of salinity, water temperature and flow volume; all of which may be affected by hydro development.

Changes in stream flow volumes and variability can also lead to reduced natural cleansing and flushing, increasing the risk of pollution. This has obvious potential flow-on effects for environmental and public health. The residence time of contaminants is largely determined by flow regimes (Davide et al. 2003), however flushing times vary substantially depending on the nature of the system (geomorphology, length, etc) and the volume and duration of flows (Asselin & Spaulding 1993). In general, natural flooding tends to flush systems effectively whereas controlled release of water at non-flood levels greatly increases the time taken to remove contaminants (Davide et al. 2003).

Nutrient supply downstream is also likely to alter as a result of dam construction and altered flow patterns. Waters of upstream freshwater reaches of Vietnamese rivers are oligotrophic (low in nutrients) (Berge et al. 2006), a typical situation for similar systems around the world (eg. Leira & Sabater 2005, Alexander & Smith 2006, Domenech et al. 2006, Roelke et al. 2006) indicating systems in which productivity, and population sizes, are limited by nutrient supply. Over the long term nutrients settle out in the still waters of reservoirs, leading to the trapping of nutrients (Rausch & Schreiber 1981). This leads to a reduction in nutrient supplies to areas downstream of reservoirs (Childers et al. 2006). This is likely to lead to severe nutrient limitation directly below dams because upland streams like those in the Trung Son

basin are usually already low nutrient systems (eg. Leira & Sabater 2005, Alexander & Smith 2006, Domenech et al. 2006, Roelke et al. 2006). Impacts of altered flows can cascade downstream to produce effects throughout the whole river system. Perhaps the most crucial are likely to occur in estuarine areas, because the timing of seasonal low and high flows are crucial to productivity, recruitment of larvae and the location and nature of the Estuarine Turbidity Maximum (ETM) zone, an area vital to environmental processes.

There is a paucity of literature documenting how changes to water quality influence fish assemblages in tropical regions (Sheaves et al 2007b). Clearly, assemblages in highly degraded systems differ substantially from those in less impacted areas however the problem is the lack of information about the level of environmental change required to trigger biological changes, i.e. the point where species resilience is exceeded. In general, habitat generalists could be expected to demonstrate greater resilience to change than habitat specialists simply because generalists have alternative habitat options should one habitat be removed or become inhospitable. Given the high species diversity of freshwater fish in Viet Nam (Kottelat 2001), and evidence of low habitat overlap producing high levels of habitat specialisation in some streams (Herder & Freyhof 2006), there is a high probability that changes in water quality resulting from modified flow regimes would have negative impacts on at least the freshwater fish assemblages (Sheaves M., 2008).

**3.3 First five years and beyond:** Once the reservoir is filled the reservoir to power station reach will continue to suffer reduced flow as long as water is diverted to the hydro station. Environmental change will have commenced during filling and may continue to drift for several years. The extent of change is difficult to assess because detailed information on many of Viet Nam's stream habitats is sparse. Consequently, for habitat both upstream and downstream of impoundments, a lack of detailed knowledge of habitat types and ecological relationships means there is considerable danger that unique or special habitats (that often occupy only a small proportion of total area) will not be recognised and so lost or

substantially compromised. Catchment geomorphology and climate interact to form the hydrogeomorphic habitat composition of rivers, with each river having a unique composition (Thorp et al. 2006). The longitudinal distribution of particular hydrogeomorphic habitats in a river may see some habitats repeated multiple times while others occur infrequently. The habitats that occur least frequently have a potential to have high ecological value because of their unique physiochemical nature (Thorp et al. 2006) and are most likely to be lost under an altered flow regime.

Existing literature indicates that hydrogeomorphic habitat properties influence distributions of Vietnamese freshwater fauna. The spatial distribution of freshwater prawns in the Vietnamese highlands is strongly influenced by substratum properties and patterns of water flow (Binh 2004). Further, Herder & Freyhof (2006) reported both intra- and inter-specific differences in habitat use in a central Vietnamese freshwater fish assemblage. Differences in habitat use related specifically to differences in current velocity and type of substratum. Among the assemblage studied, habitat partitioning with little overlap had led to extreme specialization (Herder & Freyhof 2006), thereby producing obligate habitat associations. One danger is that failure to identify and conserve those obligate habitats could result in loss of habitat specialists (Sheaves M., 2008).

Reduced water quality is a particular problem immediately below outlets from dams and power stations. Large bodies of water in impoundments usually have quite different temperature and oxygen profiles to streams, while the volume and timing of flows act to raise or lower temperature and oxygen levels downstream of dams (Hayes et al. 1998, Viana 2002). The extent to which this becomes a problem in the reach below the dam will depend on whether warmer oxygenated surface or colder anoxic deep water is released from the dam, and whether structures that re-oxygenate effectively water are installed below outlets. Dissolved

oxygen levels can remain low for considerable distances below outlets (Viana 2002) resulting in impairment to ecological functioning. Issues arising from the timing and volume of flows are common to dam and power station outlets and are discussed below in relation to the reach below the power station.

#### **Issue: *Impaired Longitudinal Connectivity Leading to Migration Barriers***

*Character of Impact:* waterway off-take water to power stations diverts water that would normally pass through river channels immediately downstream of dams. This has the potential to severely impair flows downstream of dams during dry seasons when flows are naturally low, potentially creating additional impediments to migration, and increasing the impact noted in 1 above (Sheaves M, 2007).

Mitigation: Alleviation could take the form of compensatory flow releases at the dam wall. Success would depend on the extent to which compensatory flows matched the volumes and timing of natural flows. Measures to address water quality downstream from the dam need to be put in place. At the least, re-oxygenation of the water will be necessary unless oxygenated surface waters are released (Sheaves M, 2007).

## **4. Power station to Luong estuary**

### **4.1 Construction phase:**

Issues: for this reach during the construction phase will be the same as those for the reservoir construction phase.

Mitigation: For mitigation options see reservoir construction phase above.

#### **4.2 Filling phase**

Issue: This reach will have the same problems during the filling stage as the reservoir to power station reach.

Mitigation: For mitigation options see reservoir to power station reach above.

**4.3 First five years and beyond:** Once the reservoir is filled and the power station is operational annual flow volumes should return to normal but with an altered pattern of flows unless water is diverted away from the system. Problems of an altered flow scenario are detailed in the filling phase for this reach. Although annual flow volume may return to normal it cannot be stressed how important both timing and volume of flow are to maintenance of productive river fisheries (King et al. 2003).

For many freshwater species the nature of the managed flow is crucial. Excessively high flows from hydropower peaking result in a substantially lower biomass of fish and benthos downstream from outlets (Parasiewicz et al. 1998), a situation that may extend for many kilometers downstream. In addition to current velocities, the rate at which velocities are increased and decreased, or ramping, is also crucial. For example, rapid ramping back from peak flow can result in stranding of fish that are using shallow edges (Halleraker et al. 2007).

#### **4.4 Impact to aquatic ecosystem in downstream:**

*Character of impact:* Once the reservoir is created, river flow will be modified making lower stream banks scour (Trung Son Construction Project Management Unit 2008). Therefore, it will have influence on many species of fish because the most species occur along the river banks and are found close to the bed of the river (Duc NH & al. 2008). If the Trung Son power plant is constructed there will be no Hoi Xuan power plant (lower on the same river) because the distance between high level and low level at Hoi Xuan is only 3.2m. The flow from Trung Son dam to the joining point with Luong River will be modified and the water level difference will negatively affect the ecosystem. The long regulating plan is to be applied and peak load generation is only planned to be used during rush hours meaning great differences in levels are likely to occur during the course of a day. Additionally, 80% of sand and silt will be trapped in the reservoir increasing sand-containment in the post-dam area leading to greater erosion, great change of Ma lower river bank and bed morphology due to water level differences and great lack of sediment (Trung Son Construction Project Management Unit, 2008). Because of nutrition accumulation as mentioned in 2.3, post-dam water will be less fertile leading to lower production in estuarine region, water discharged to the downstream area will be less fertile and the reproduction place is gradually narrowed down. Consequently, the fisheries productivity of the downstream area will be reduced, which directly affects the life of fishermen and the rate of river fish being sold in the area.

Mitigation: To minimize negative impact to the downstream ecosystem, it is recommended to construct coordinated hydroelectric system with a proper regulation regime to harmonize the aims of producing and supplying electricity with that of protecting ecosystems downstream of the dam. The effects of altered flows are highly pervasive, impacting on all areas downstream of dams. As far as possible flow management should attempt to mimic natural flow patterns in timing, extent and volume of flow. Rapid ramping of flows should not be permitted (Sheaves M., 2008)

**Issue: Impact to fish with value of preservation:** there are 9 species of fish to be impacted by the project and 5 of them are found in down stream from Power station to Luong estuary. They are:

- *Anguilla marmorata* is a migrating species to sea for spawning; distributing in post-dam area so the dam does not block their spawning migration routes. As reported by the fishers, this species is available but vary rare in the area of the Project. For a period of about 5 to 10 years, the local people may catch a few fish of this species, sometimes in Cam Thuy, or Quan Hoa, or Ba Thuoc. These reports are through-photo survey result only, so it is not necessarily correct. If the appearance of this species if true, the Ma River is a northernmost river having this species in Vietnam. Being a species, which migrate to the sea for spawning and distributed below the dam, its migration and reproduction will not be obstructed.
- *Elopichthys bambusa* is distributed in upstream (pre-dam and post-dam) and midstream areas. Its spawning floodplain is in midstream (Vietnam Data Red Book 2007), the dam should not impact its spawning.
- *Senilabeo lemassoni*: Is distributed in upstream, both pre-dam and post-dam areas (Nguyen Huu Duc & Duong Quang Ngoc, 2003). They seem to find spawn in the post-dam area (see discussion above).
- *Hemibarbus guttatus*: Is distributed largely in upstream, midstream and downstream of Ma River (Nguyen Huu Duc & Duong Quang Ngoc, 2003). Spawning position is in midstream and upstream (Vietnam data Red Book, 2007) so they will spawn in post-dam area
- *Bagarius rutilus*: Is distributed throughout upstream, midstream and downstream of Ma River (Nguyen Huu Duc & Duong Quang Ngoc, 2003). Spawning position is in midstream and upstream (Vietnam Data Red Book, 2007) so they will spawn in post-dam area.

Mitigation: keep the intact river as recommended in 2.1 for migrating species to find new spawning positions in upstream area.

**Issue: Impact to species of economic value:** 12 economic species. Two species of *Hemibarbus guttatus*, *Bagarius rutilus* are considered local economic fish with relatively good production even those have been mentioned in Vietnam Data Red Book 2007. These are mentioned in 5.3 already.

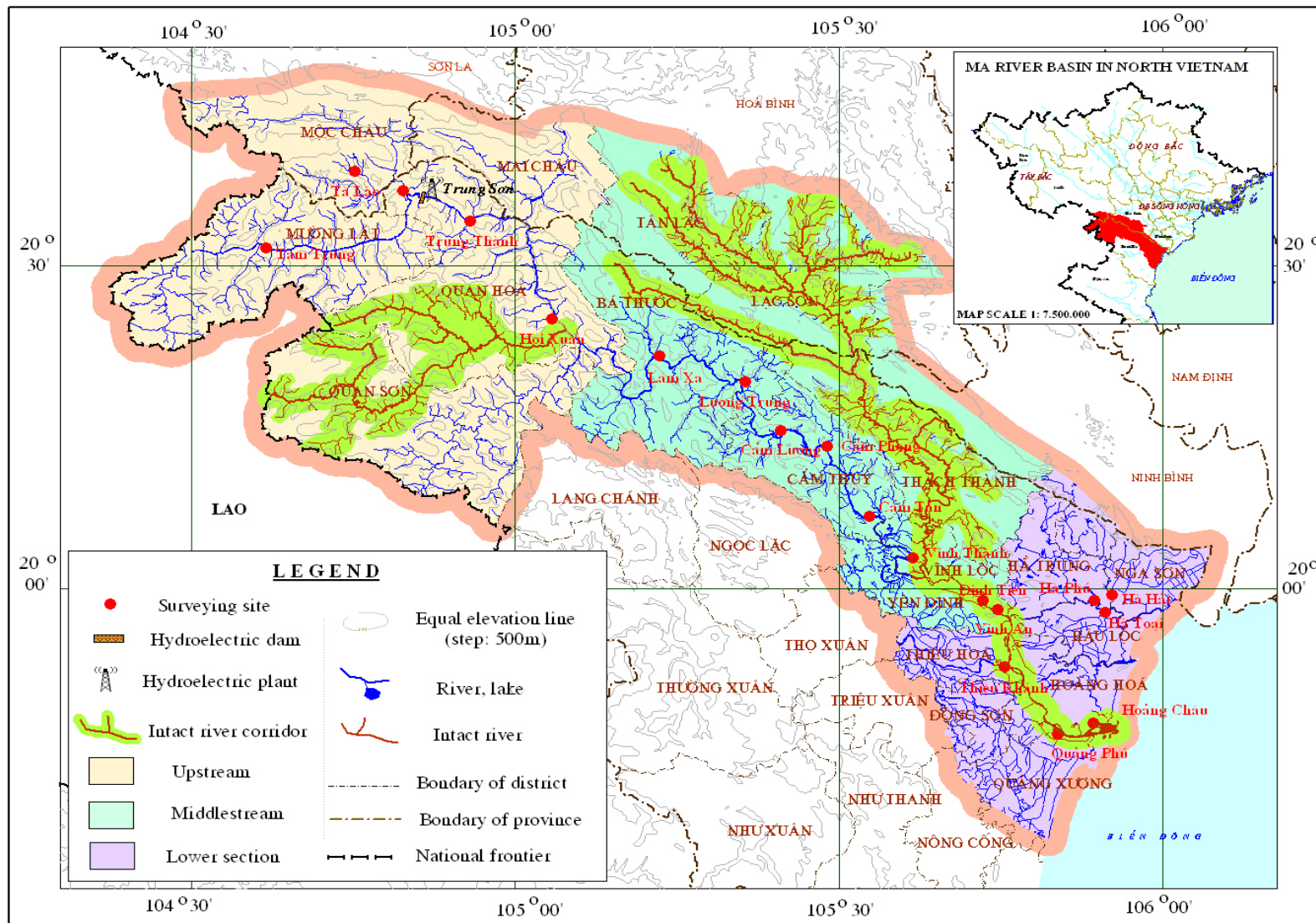
Of 10 other economic freshwater fish, *Hemiculter leucisculus* spawns in flowing water but does not migrate; *Cyprinus carpio* spawns in many floodplains along river in upstream and midstream; *Cranoglanis sinensis* spawns in scattered caves along the river; *Mastacembelus armatus* spawns in shore caves, does not migrate; *Silurus asotus* and *Clarias fuscus* spawn on nearshore mud beds; *Cirrhina molitorella* spawns in upstream and midstream with on nearshore mud beds; *Cirrhina molitorella* spawns in upstream and midstream with whirlpool (Nguyen Tan Trinh & NNK, 1996). All of these spawn in post-dam area.

*Spinibarbus denticulatus* spawns in small catchments; *S. hollandi*, *Spinibarbichthys denticulatus* and *Onychostoma gerlachi* spawn in accelerated flow with sand and gravel bed (Nguyen Tan Trinh & al., 1996), damming will reduce the area available for spawning of these species. However, there are still suitable habitats for spawning in upstream and midstream.

Mitigation: For mitigation options see reservoir to power station reach and 2.1 above

**PROPOSED INTACT RIVERS AND RIVER CORRIDORS IN MA CATCHMENT**

MAP SCALE 1: 600000



Map No 2: Intact rivers and river corridors proposed

## 5. Downstream from Luong estuary

### 5.1 Construction phase:

Issues: for this reach during the construction phase will be the same as those for the reservoir construction phase.

Mitigation: For mitigation options see reservoir construction phase above.

**5.2 Filling phase:** There is some potential for reduced flows during filling of the reservoir in this reach simply because there is less water arriving at the confluence. How extensive and pervasive effects of this may be will depend on the proportion of flow retained to fill the reservoir, the length of time flows are reduced and the relative contributions of tributaries downstream from the dam to the downstream volume of the system. Impacts may be minimal if the bulk of the flow below the confluence arrives through tributaries, however if a significant proportion of the flow emanates from the dammed river the proportion of flow retained will be a crucial factor in determining the reduction in flow. Effects of reduced flow have been detailed above for the filling phase of the reservoir to power station reach. Should flows downstream be reduced significantly for even a relatively short period of time impacts have a potential to propagate through to the coast, a scenario that would be inevitable if water was diverted out of the catchment (Sheaves M. 2008).

Agricultural production in the coastal wetlands of Asia is often hindered by salinity intrusion caused by tidal fluctuation (White et al 1996, Tuong et al. 2003), and changes in flow volume and timing are likely to exacerbate these fluctuations. Tidal waters may penetrate further upstream and further into wetlands, and do so more often (White et al. 1996). Both fresh- and brackish-water species are likely to be affected. Increased salinity can reduce growth of freshwater species like common carp (Kiem 2002), while brackish water species of high export value, such the sleeper, *Bostrichthys sinensis* (Dan 2003), have narrow suitable salinity and temperature tolerances for important functions like embryo development (Dan 2003). As well as influencing salinity patterns altered flows can impact water temperature regimes. Large bodies of water in impoundments usually have quite different temperature and oxygen profiles to streams, while the volume and timing of flows act to raise or lower temperature and oxygen levels downstream of dams (Viana 2002). This can be crucial because many species widely exploited for aquaculture, such as the pangasid catfishes, *Pangasius bocourti* and *P. hypophthalmus*, are dependent on appropriate water temperature to stimulate oogenesis (Cacot & Lazard 1999).

Impacts of reduced flow are not restricted to in-stream effects. Reductions in freshwater flow down the Mekong River, because of diversion and extraction of water from the upper reaches, is responsible for increased seawater intrusion and production and export of acid from acid sulphate soils in the lower Mekong (White et al 1996). As a consequence of salt intrusion large areas of productive land are rendered unsuitable for rice production during the dry season prompting installation of salt-intrusion floodgates. Floodgates become additional barriers to migration and are likely to reduce upstream water quality with subsequent reductions in agricultural, fish and aquatic productivity (White et al 1996). The questions of water quality change due to reduced flows and its remedies are complicated. Remediation of salt intrusion that benefits agricultural production or freshwater aquaculture can adversely affect brackish water aquaculture (Hoanh et al. 2003, Tuong et al. 2003). Furthermore, the side effects on disadvantaged groups can be extreme. Poor farmers and landless people can suffer greatly from changes in salinity regimes because the fishery resource that they depended on often declined sharply (Tuong et al. 2003).

Experience with agricultural production on land previously subject to salt intrusion (salt intrusion restricted by floodgates) indicates that problems may outweigh benefits (White et al 1996, Tuong et al. 2003). Agricultural productivity on recovered land is low, and during dry periods, floodgates retained acid released from soils by oxidation as water tables dropped

(Sammut et al 1996, Indraratna et al. 2005). Acid reservoirs produce further barriers to fish movements and may affect feeding and reproductive function (Carter & Dove 2001). Acids may enter the estuary as a low pH “slug” during high flow or as a constant trickle during small flow events (Sammut et al 1996). Acid discharges can be responsible for fish kills (Russell & Helmke 2002), cause fish diseases (e.g. red spot disease) (Callinan et al 1993, 1996), impact on aquaculture productivity (Simpson & Pedini 1985; Tuong et al. 2003) and benthic communities (Carter & Dove 2001) leading to reduced biodiversity (White et al 1996). Given such a critical dependence on fisheries resources in Viet Nam (Tuong et al. 2003), the value of effective wetlands (estuarine and freshwater) to fisheries resources (Griffiths et al. 2006) and the poor returns from remediated saline wetlands (White et al 1996; Tuong et al. 2003) there should be little stimulus for reclamation of those wetlands for agriculture. In fact, rehabilitation of degraded wetlands is seen as an important step to reversing declines in fisheries production resulting from reductions to environmental flows (Gilligan 2005).

The strong and complex interlinking of habitats, the importance of connections between habitats and the complicating effects on water quality means an ecosystem approach to conserving resources is needed, rather than treating different habitats as individual units (Poulsen et al. 2002).

Mitigation: For mitigation options see reservoir to power station reach above.

**5.2 First five years and beyond:** Once normal flows are resumed impacts of the dam downstream from the first major confluence with another system should be primarily restricted to altered flow regimes. Those issues have been discussed in relation to the filling phase of the reservoir to power station reach and in relation to the filling phase for this reach. Of course, should water be diverted away from the river there would also be considerable impact due to reduced flow volumes, also discussed above. The one issue that is pervasive across all reaches below the dam is the potential to reduce peak flow volumes. If flows are managed so that (particularly seasonal) flooding potential is reduced many wetland habitats may not receive water when it is required.

It is also possible there may be minor effects from altered temperature and dO<sub>2</sub> profiles depending on the distance between the power station and the first major tributary. However those issues should dissipate within a relatively short distance downstream of the confluence (Viana 2002). The extent of those impacts will depend on the nature of the managed flows, the effectiveness of reoxygenation measures at discharge points and the relative volumes of the regulated and converging streams.

Mitigation: For mitigation options see reservoir to power station reach above.

**Issue: Impact to fish with value of preservation:** there are 9 species of fish likely to be impacted by the project and 8 of them are found downstream from Luong estuary. Four of them are mentioned before, they are: *Anguilla marmorata*, *Elopichthys bambusa*, *Hemibagrus guttatus* & *Bagarius rutilus*. Last four species are:

- *Clupanodon thrissa* which is a migrating species that moves into the river for spawning; its spawning area in the Ma River is in Ba Thuoc, 50 km downstream from the dam, so the dam does not block its migration routes.
- *Konosirus punctatus* also a migrates into the river for spawning; its spawning sites in Ma River are still not determined. However, it is only found in downstream areas (Duong Quang Ngoc, 2007) so the dam will not block its migration paths.

- *Tor (Folifer) brevifilis* are found in midstream of Ma River (Nguyen Huu Duc & Duong Quang Ngoc, 2003), spawning sites not determined and we can not determine the likely impact of the dam on this species. The only information known now is that they spawn in accelerated flow with bed of stone, gravel (Vietnam Red Data Book 2007). If place of their breeding is above the dam, they may be able to breed in tributary of Luong river where has the same ecological condition.
- *Bostrichthys sinensis*: is only distributed in river mouth and coastal area (Vietnam Data Red Book, 2007) so the dam does not impact this species.

Changes in water quality, nutrition and salinity reduction in river estuary may also have adverse impacts but these are difficult to determine.

Mitigation: keep the intact river as recommended in 2.1 for migrating species to find new spawning positions in upstream area.

**Issue: Impact to species of economic value:** in downstream area, there are 37 species; 15 in post-dam upstream area, 12 in midstream and 28 in downstream of which 20 are sea-fishes, 8 are freshwater fishes. Of 39 species, 4 species of *Hemibarbus guttatus*, *Bagarius rutilus*, *Clupanodon thrissa*, and *Bostrichthys sinensis* are considered local economic fish with relatively good production and have been mentioned in Vietnam Data Red Book 2007. These are mentioned before already.

Of 20 economic brackish and salty fish migrating into river, *Clupanodon thrissa* migrates to furthest position which is 50km from the river mouth, the second is *Coilia grayii* of 40km. Thus, the dam does not block any sea fish migrating route into river.

Of 15 other economic freshwater fish, *Hemiculter leucisculus* spawns in flowing water, does not migrate; *Megalobrama skollovii* is only distributed in midstream (Nguyen Huu Duc & Duong Quang Ngoc, 2003) and seems not to spawn in pre-dam area; *Cyprinus carpio* spawns in many floodplains along river in upstream and midstream; *Cranoglanis sinensis* spawns in scattered caves along the river; *Mastacembelus armatus* spawns in inshore caves, does not migrate; *Silurus asotus* and *Clarias fuscus* spawn in inshore mud beds; *Cirrhina molitorella* spawns in upstream and midstream with whirlpool Nguyen Tan Thinh & NNK, 1996). All of these spawn in post-dam area. *Spinibarbus denticulatus* spawns in small catchments; *S. hollandi*, *Spinibarbus denticulatus* and *Onychostoma gerlachi* spawn in accelerated flow with sand and gravel bed (Nguyen Tan Trinh & al., 1996), damming will reduce spawning positions. However, there are still suitable habitats for spawning in upstream and midstream. Spawning features of *Placogobio* sp., *Hemibarbus medius* and *Squalidus chankaensis* are still unknown, therefore it is unknown if the dam will affect these species or not.

Mitigation: as comment in 2.1 above

## Issue: Environmental Flow

### 1. Assessment methods of environmental flow

#### 1.1 Definition of environmental flow

Environmental flow is the necessary flow in system of natural rivers or reservoirs to sustain healthy ecosystems and meet demands of human's socioeconomic development.

*The flow of water in natural river or lake that sustains healthy ecosystems and the goods and services that humans derive from them. "Water for people, water for nature".*



Determination of environmental flow needs to be carried out before activities of exploiting and using water are done. Assessment of water flow is considered as prior step of performance process of general management of water.

### 1.2 Current assessment methods of environmental flow

Nowadays, there are about 200 methods used over 50 countries all over the world. The most popular methods in Australia and South Africa is overall approach, in which this method shows that it is necessary to supply water for water system from the beginning of source to sea and all ecological parts depended on water. The main assessment methods of environmental flow:

- i. Hydrographic method
- ii. Physical Habitat Simulation
- iii. Method of overall approach
- iv. Specialist method

Because of condition of information and figure, level of complication and new approach method, method of imitating environment is chosen to analyze and define suitable water flow for water life system combined with hydrographic method to define demand of water flow for water life system. This method is based on analyzing water creatures, typically 4 specific kinds of fish in river. Hoi Xuan position at lower section (about 50 km from damp) of Trung Son hydroelectric plant is defined to be suitable line, with this position the direct effect of Trung Son hydroelectric plant on water life system can be assessed; Cam Thuy line is regarded as typical line for water creatures whose growth relates to emigration to coast or river mouth.

### 1.3 Regulations to assess environmental flow

- i. One or some factors affect on hydrographic system of natural flow of river like: flow, frequency of allocating flow based on season...
- ii. Some hydraulic specifics of river like: flow speed, depth of flow, wet perimeter...

### 1.4 Locating of environmental flow: potentiality of water source of a river is showed (in following diagram) including 3 remarkable thresholds:

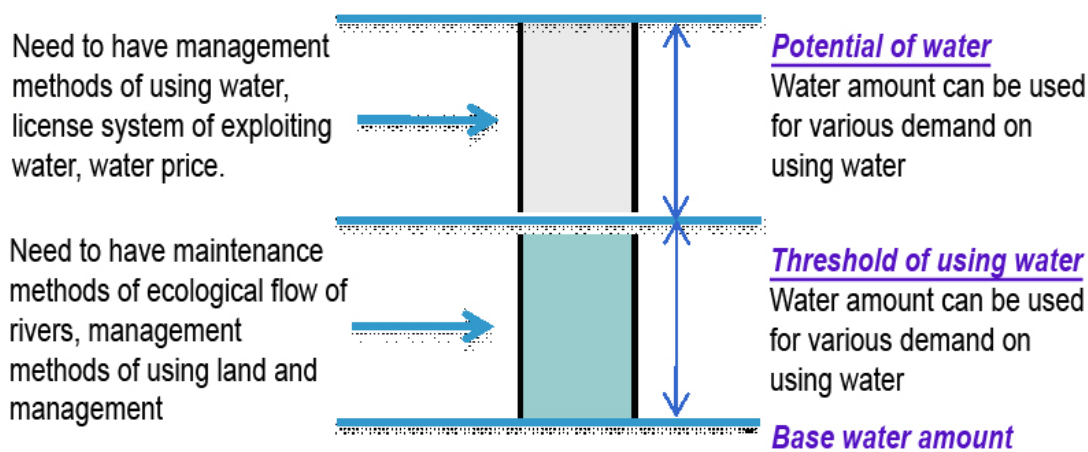
- 1.4.1 The highest threshold is the threshold showing potential of water source of river valley, the total amount of water that river can produce in a unit of time, usually a year. The potential of water source can be calculated by measured figures of real flow of gauging stations on water valley.
- 1.4.2 The lowest threshold is the base water amount of river valley, it is considered to be a ecological threshold which needs sustaining because if water amount of river is lower than base water amount, ecosystem will be changed and not be recovered.
- 1.4.3 Middle threshold is demand on environmental water. The water amount from the basis to this threshold is the demand on environmental water used for sustaining water-ecosystem and mentioned environmental conditions above.

*Water demand for ecosystem:*

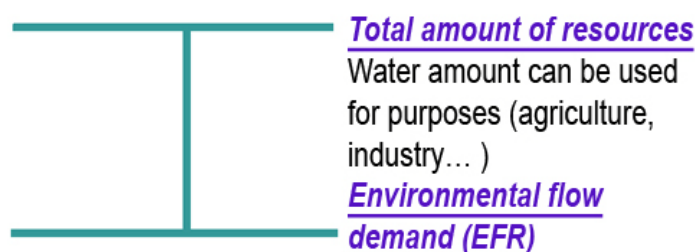
1. Water for maintaining life and biological variety
2. Water for maintaining flow and water speed river to help fish move from one place to others.
3. Water for carrying silt from source to river mouth, reducing extension and erosion.
4. Water for diluting polluted substance and ability of cleaning water in rivers
5. Water for pushing salt

6. Water for irrigating and other demands

Diagram 1: Thresholds of water source of river valleys



According to IWMI (International Water management Institute), demand of DCMT (water flow) is a part of TNN (water resource):



So, the problem here is to define following factors:

- a. Base water
- b. Base water participated in environmental flow
- c. Method of summarizing specific water demands into a general demand of ecological water.

Using Tenant method (hydrographic method) to define environmental flow.

Diagram 2: Percentage of average annual Flow (AAF) is requested to gain different aims

Aim of river's environment and ecosystem protection	% AAF suggestion (applied for salmon)	
	Dry season	Flood season
Strongest flow or strong erosion	200	200
Best scope of AAF	60 – 100	60 -100
% flow requirement maintain a river demand as requested		
Perfect	40	60
Very good	30	50
Good	20	40
Average or reducing	10	30
Bad or minimum	10	10

Bad erosion	10 – 0	10 - 0
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*Source: Theme of science research “Researching scientific basis of assessment of environmental flow researched by Dr. Tran Hong Thai – theme director – Institute of Science Hydrometeorology and Environment*

*Hydraulic method: difficult to define*

*Method of imitating environment: (PHABSIM – Physical Habitat Simulation)*

*General method: to meet demand of all ecosystem of river, not only of some species. This method obeys concept about “sketch of natural flow” and basic regulations of giving river water back. Their common aim is to sustain or return flow system related to biological compositions and ecological processes in river and underground water, flooded plains and regions getting water from lower sections of rivers.*

## 2. Natural features of Ma River

2.1 Position and importance: Ma River originates in Pu Huoi Long chain (Lai Chau) at height of 2.179 m. The average height of entire river valley is about 700 m. System of Ma River includes main Ma River and big estuary of Chu River. Main Ma River originates in high mountain area, flows with direction of Northwest – Southeast crossing provinces: Son La, Sam Nua (Lao People’s Democratic Republic), Hoa Binh, Thanh Hoa and then flows to sea at 3 sea mouths: Sung, Lach Truong and Cua Hoi.

Area of whole valley of river system is 28.400 km<sup>2</sup> (of which 10.800 km<sup>2</sup> located in Laos). From the beginning of source to river mouth, main Ma River is 512 long, of which Viet nam territory is 410 km long. Ma River has 39 branch rivers at levels, big branch rivers at level 1 like Chu Luong, Buoï. Besides, Ma River also has other big territories from higher sections to lower ones of river such as: Nam Khoai, Nam Ty, Nam Ban, Nam Soi, Nam Et, Nam Hao, Nam Niem, Lo River...

Song Ma plays an important role in providing water for life and production, under log abolishment, maintenance of biological variety; providing sources of aquatic products, transportation and making climate equable in region.

2.2 Problem and aim of environmental flow: Define which operation process of lake will maintain biological variety of hydro-creatures in lowlands.

2.3 Researched river section: Main Ma River from Trung Son to the sea.

## 3. Assessment of environment flow for researched region

3.1 Assessment of current state of water source, ecosystem and environment value

Choose control point: (see the diagram 1: valley of Ma River): suitable river ecosystem for development of hydro-creatures:

\* *The higher section of river:* The line of wet cut side crossing Hoi Xuan is chosen as control line. This line on the higher section is the control point of flow and good ecological conditions both with and without works. Two kinds of typical fish are chosen. They are: catfish fish (*Bagarius rutilus*), not only rare and valuable kind of fish in red list of Vietnam 2007 but also economic one raised in local; and Bong fish (*Spinibarbus denticulatus*), a economical kind raised in local.

\* *The lower section of river:* select the second control point in Cam Thuy. This position is represented for river in delta. In Cam Thuy, two kinds of typical fish are chosen as typical

fish for this river. They are: Chinese gizzard shad (*Clupaodon thrissa*), a rare and valuable kind of fish living in sea and river mouth, moving to river for reproduction, in red list of Vietnam 2007 and a economic fish of local as well; and Carp (*Cyprinus carpio*), the important living in whole region affected by projects.

### 3.2 Feature of hydrographic system of Ma River

#### 3.2.1 Annual flow

Average annual Flow of many years in Ma River valley is  $18.10^9 \text{ m}^3$  in accordance with average output of many years which is  $570 \text{ m}^3/\text{s}$ , speed of average annual Flow is  $20 \text{ l/s.km}^2$ , of which the flows developed in Vietnam is  $14.1.10^9 \text{ m}^3$  with specific discharge of  $25.3 \text{ l/s.km}^2$  and in Laos  $3.9.10^9$  with average specific discharge of  $11.4 \text{ l/s.km}^2$ .

Annual Flow distributes unequally according to space and time. Change coefficient CV of Ma River is 0. 2 in Cam Thuy, 0. 28 in Cua Dat on Chu River.

Higher section of Ma River at Xa La controls area of valley of  $6,430 \text{ km}^2$  holding 22.6% of total area of valley with total flow of 3.82 billions  $\text{m}^3$ . In Cam Thuy there is area of  $17,500 \text{ km}^2$ , total flow of 10,41 billions  $\text{m}^3$ , in Hoi Xuan Flv =  $15,500 \text{ km}^2$ , total flow of 8.01 billions  $\text{m}^3$ . The region between Xa La and Hoi Xuan has Flv =  $9,070 \text{ km}^2$  holding 31.9% of total area of valley but with total flow of only 23.2% of total flow in whole valley. From Hoi Xuan to Cam Thuy Flv =  $2,000 \text{ km}^2$  holding 10.8% of total area of valley but with total annual flow of 2.4 billions gaining 13.3% of total flow in whole valley. This shows that flow born in middle of mid section of main flow has big specific discharge contributing into flow of Ma River at lower section.

On Chu River in Xuan Khanh, area of valley of  $7,460 \text{ km}^2$  holding 26.2% of area of valley, total annual flow of 4.42 billions  $\text{m}^3$  holding 24.5 % of total flow and at Cua Dat Flv =  $6,170 \text{ km}^2$  holding 21.7% of area of valley, total annual flow of 4. 03 billions  $\text{m}^3$  holding 22.3 % of total flow in whole valley.

#### Average annual Flow of many years in some positions

Diagram 1.6: Average annual Flow of many years in some positions

Station	River	Area of valley (km <sup>2</sup> )	Area rate of valley F/F valley	Annual flow			Wo/Wolv
				Qo (m <sup>3</sup> /s)	Mo l/s.km <sup>2</sup>	Wo.10 <sup>9</sup> m <sup>3</sup>	
Xa La	Ma	6,430	22,6	121	18,8	3,82	21,2
Hoi Xuan	Ma	15,500	54,6	254	16,4	8,01	44,5
Cam Thuy	Ma	17,500	61,6	330	18,8	10,41	57,8
Cua Dat	Chu	6,170	21,7	128	20,7	4,03	22,4
Xuan Khanh	Chu	7,460	26,3	140	18,8	4,42	24,6
Lanh Chanh	Am	331	1,16	12,8	38,6	0,403	2,2

Source: Report of hydraulic power of Ma River – Institute of Science Hydrometeorology and Environment

#### Distribution of annual flow

As rain regulation, annual flow divides into two clear seasons, flood season and dry season.

- + *Higher section of Ma River*: flood season is from month June to October with total flow of 70% - 74% of annual flow. December has the biggest total flow holding 22 – 24% of annual flow. March has the smallest total flow with the rate of 2.7% of annual flow in Xa La, 2.4% in Nam Cong, 2.9% in Nam Ty. Three month with the smallest total flow are February, March, April holding 8.5% of annual flow in Xa La, 8% in Nam Cong, 9.5% in Nam Ty. Some smallest monthly flows of March gain 6.01 l/s.km<sup>2</sup> in Xa La, 5.53 l/s.km<sup>2</sup> in Nam Cong, 4.54 l/s.km<sup>2</sup> in Nam Ty.
- + *Middle section of Ma River*: flood season is from June to October with total flow of 74.2% of annual flow. The biggest flow of March in year holds 20% of annual flow. In month September, October, flow rate holds 19, 3% and 11.3% in Cam Thuy, while gaining only 16.6% in September, 8.6% in October in Xa La.  
March has smallest flow with monthly average specific discharge of 5.92 l/s.km<sup>2</sup>. Three driest months February, March, and April have the smallest flow with only 8.0% of annual flow.
- + *Valley of Chu River and South of Ma River*: flood season is from July to November with flow amount of 74.3% in Cua Dat, of which, September has the biggest flow amount with 19 ÷ 20% of annual flow. March has smallest flow holding only 2.5% of annual and the flow average specific discharge of 6.51 l/s.km<sup>2</sup>. Chu River has bigger flow specific discharge of dry months than main flow of Ma River.
- + Year group with little water with frequency from 75 ÷ 95% of annual flow changes in scope of 102 ÷ 80, 4 m<sup>3</sup>/s in Xa La, 285 ÷ 224 m<sup>3</sup>/s in Cam Thuy, and 103 ÷ 70.9 m<sup>3</sup>/s in Cua Dat. March has the smallest flow in scope of year group with little water with frequency from 75 ÷ 95% of flow fluctuating from 30.8 ÷ 27.3 m<sup>3</sup>/s in Xa La, 88.7 ÷ 74.5 m<sup>3</sup>/s in Cam Thuy and 31.2 ÷ 26.4 m<sup>3</sup>/s in Cua Dat.

**Distribution of flow of design month and year**

Diagram 1.7: Distribution of flow of design month and year

Unit: m<sup>3</sup>/s

Station	P %	1	2	3	4	5	6	7	8	9	10	11	12	Qo
Cam Thuy	75	163.2	129.5	103	104	198.9	152	264.2	530.3	673.1	649.1	286.6	189.	287
	85	151.2	120	95.2	96.4	184.3	140.8	244.8	491.5	623.9	602.1	265.6	175.8	266
	95	131.9	104.	83.3	84.1	160.8	122.8	213.5	428.7	544.1	525.2	231.7	153.3	232
Cua Dat	75	44.2	35.5	30.9	39.4	71.4	71.2	146	158	333	130	117	57.7	102.9
	85	39.4	31.2	27.5	35.5	53.5	63.5	130	141	297	115	104	51.3	90.7
	90	36.2	28.9	25.3	32.4	58.4	58.2	119	129	273	106	95	47.2	84.1
Bai Thuong	75	46.9	37.7	32.8	42.1	75.8	75.5	155	168	354	138	124	61.3	109.3
	85	41.8	33.4	29.2	37.5	67.4	67.2	138	150	315	122	110	54.5	97.2
	90	38.4	30.7	26.8	34.4	61.9	61.8	126	137	290	113	101	50.1	89.3

Source: Report of hydraulic power of Ma River – Institute of Science Hydrometeorology and Environment

**Feature of flood flow:**

a. *Flood season:* On Ma River, flood season begins in June and ends in October, in lowlands of Ma River ends in November. In Xa La, the biggest annual flood in July holding 23%, in August 45.7% and September 14.2%, total of 3 biggest flood months holding 55.5% of annual flow. In Cam Thuy, the biggest flood occurs in August and September, each month holds 40.8%, October 15.8%, November 2.6%. On Chu River, flood season begins in July and ends in October and November. Four months with the most rain amount are July, August, September and October, in Cua Dat September is the month with the biggest flow, amount total of 3 biggest flood months on Chu River in Cua Dat is 54%. The effect of storm rain on middle section of Ma River is clear, on Chu River in Xuan Khanh the biggest flood of year appears in September holding 38.7%, October 25.2% while in August holding only 22.6%.

Diagram 1.8: Possibility of occurring biggest flood of year in months of year

Unit: %

Station	River	May	June	July	August	September	October	November
Xa La	Ma	2.6	10.2	28.2	46.2	12.8		
Cam Thuy	Ma		2.2	17.8	29.0	24.4	24.4	2.2
Xuan Khanh	Chu		2.6	5.3	23.7	36.8	23.7	7.9
Giang	Ma		5.3	7.9	26.3	36.8	18.4	5.3

b. *Flow amount of flood:* On Ma River, the biggest average flood amount of years is 1,485 m<sup>3</sup>/s accordance with MTB = 0.23 m<sup>3</sup>/s.km<sup>2</sup> in Xa La; 3,115 m<sup>3</sup>/s accordance with MTB = 0.18 m<sup>3</sup>/s.km<sup>2</sup> in Cam Thuy. On Chu River in Cua Dat, Qmax = 2420 m<sup>3</sup>/s accordance with MTB = 0.39 m<sup>3</sup>/s.km<sup>2</sup>; in Xuan Khanh Qmax = 2,570 m<sup>3</sup>/s accordance with MTB = 0.34 m<sup>3</sup>/s.km<sup>2</sup>.

Real the biggest flood amount on Ma River measured in Xa La station is 6,930 m<sup>3</sup>/s on 1/9/1975 with Mmax = 1.08 m<sup>3</sup>/s.km<sup>2</sup>, the next big floods in 1996 with Qmax = 2,890 m<sup>3</sup>/s on

3/9/1975 with  $M_{max} = 0.46 \text{ m}^3/\text{s.km}^2$  and then in 1976, 1943, 1976. In Cam Thuy, big flood amount is  $7,900 \text{ m}^3/\text{s}$  on 3/9/1975, then big flood in 1996 with  $Q_{max} = 6.020 \text{ m}^3/\text{s}$  on 25/8/1996, other big floods on 11/09/1963 with  $Q_{max} = 5.410 \text{ m}^3/\text{s}$ , flood on 27/8/1973 with  $Q_{max} = 5,380 \text{ m}^3/\text{s}$ , flood on 14/8/1960 with  $Q_{max} = 4,740 \text{ m}^3/\text{s}$ , flood on 17/9/1980 with  $Q_{max} = 4,230 \text{ m}^3/\text{s}$ . Average specific discharge of flood flow in Cam Thuy is  $0.178 \text{ l/s.km}^2$ , the highest flood specific discharge is  $0.451 \text{ l/s.km}^2$  in flood in 9/1975.

Beside Chu River in Cua Dat, the biggest flood amount occurs on 29/9/1962 with  $Q_{max} = 6,530 \text{ m}^3/\text{s}$  and  $M_{max} = 2.06 \text{ m}^3/\text{s.km}^2$  and then big floods in 1980, 1963, 1992 and 1972.

### Feature of dry flow

Dry season on Ma River in **Cam Thuy** is from November to May, the flow amount holds 25% of year's total amount. Three months with the driest flow are February, March and April. March has the driest flow, on average of  $102 \text{ m}^3/\text{s}$  with specific discharge of  $5.8 \text{ l/s.km}^2$ . The average smallest flow on 30 continuous days gains  $91.1 \text{ m}^3/\text{s}$  specific discharge of  $5.36 \text{ l/s.km}^2$ . The smallest flow has specific discharge of  $2.01 \text{ l/s.km}^2$ . On Chu River in Cua Dat, dry season is from December to June with 3 driest months: February, March and April. The driest month is March with average flow amount of  $40 \text{ m}^3/\text{s}$ , specific discharge of  $6.48 \text{ l/s.km}^2$ , April with average of  $42 \text{ m}^3/\text{s}$  which is not much more than in March, trend to be drier in April is clear. The smallest flow in Cua Dat measured with  $18.4 \text{ m}^3/\text{s}$  on 6/4/1993 and , specific discharge of  $2.98 \text{ l/s.km}^2$ , the flow in March is the driest with frequency of 75% gaining  $32 \text{ m}^3/\text{s}$ .

Diagram 1.13: Average flow of three dry months

Position	River	F ( $\text{km}^2$ )	Qtb (1,2,3)	Cv	Cs	Qp% ( $\text{m}^3/\text{s}$ )			
						50	75	85	90
Cam Thuy	Ma	15	111	0.15	0	111	99.6	93.5	83.4
Cua Dat	Chu	6170	42.2	0.23	1.44	40	35.1	33.1	30.8
Lang Chanh	Am	331	4.67	0.22	0.11	4.687	3.97	3.61	3.2

### Tide and salty infiltration

a. *Tide regulation:* Tide at mouth of Ma River's valley is unstable daily tide regulation with the cycle over 24 hours on day. In a tide period, there are days with semi daily tide. Time of flood tide is short with 7h – 8h, some tide days, time of flood tide is 8h – 9h, and return-flow is 15h – 16h on day. The highest amplitude of tide in Hoang Tan, the Ma River's mouth: 3,19m, in Giang 2.46m; 2.58m in Lach Sung; 2.2m in Cu Thon. The average amplitude of tide on Hoat River is 1,3m, Len River 1.53m in Lach Sung, Ma River in Hoang Tan is 1.58m. The more inside the tide goes, the more level of tide water goes down and the effect of tide in flood season is weaker.

The highest level of tide water is 2, 9m in Hoang Tan, Song Ma River's mouth and the lowest one is 1.81 m, in Giang the lowest level of tide water is -1.42m in March, April. In Lach Sung, Len River's mouth the highest water level is 2.32m in 8/1971 when flood and storm rain happen, gain the lowest level of -0.97m in 4/1970.

b. *Salt level:* Salt level in river's mouth is from 26 – 28 ‰ equivalent to salt level of sea water, the more it goes to higher sections of river, the more the salt level reduces. In Giang 27 km from Ma River, the salt level is 0.016 ‰, the lowest is 0.008 ‰. The change of salt level as follows:

Diagram 1.14: Change of salt level along river

Position	River	Distance to sea (km)	S ‰	
			Max	Min
Chinh Dai	Can	13.8	12.1	0.015
Tu Thon	Bao Van	23.6	0.103	0.015
Lach Sung	Len	2.0	22.9	0.014
Do Tham	Len	10.0	1.0	0.012
Hau Loc	Kenh De	1.5	24.9	0.015
Cau De	Kenh De	5.6	22.2	0.015
Hoang Tan	Ma River	8.0	33.2	2.40
Nam Ngan	Ma River	13.6	7.66	0.022
Giang	Ma River	27.0	0.016	0.008

#### 4. Effect of hydroelectric station

Because of condition of time and other factors, assessment of environment flow of Ma River is not comprehensive when Trung Son hydroelectric station is built. Analysis only concentrates on water ecosystem, typically two kinds of fish: Catfish and Bong fish in Hoi Xuan, Chinese gizzard shad and Carp in Cam Thuy.

Biological features of these two kinds of fish:

1. Catfish (*Bagarius rutilus*)
  - Time of laying eggs: from March to June
  - Place for laying egg: in middle and higher section of river where water flows strongly; and has much gravel at the bottom
  - Catch grown fish in dry season and juvenile fish in rain season
  - Distribution: from Muong Lat to Vinh Loc
2. Ca bong (*Spinibarbus denticulatus*)
  - Time of laying eggs: February – April and July - October
  - Place for laying egg: at branch rivers. Children fish live in near bank of estuaries, when growing up, they move to deep water in main rivers
  - Catch grown fish in dry season and juvenile fish in rain season
  - Distribution: from Muong Lat to Vinh Loc
3. Chinese gizzard shad (*Clupanodon thrissa*)
  - Time of laying eggs: February – May, most in April
  - Place for laying egg: banks in main rivers at mid and lower sections
  - After laying egg, in June – July, fish move to sea. In September and October they go out to sea to look for food. From October to February of next year, they live near bank and river's mouth.
  - Fish lay egg along the flow. The juvenile ones appear in rain season
  - Distribution: from Ba Thuoc to sea.
4. Carp (*Cyprinus carpio*)
  - Time of laying eggs: lasts but mostly from March to June or August - September
  - Place for laying egg: in middle and higher section of river and streams where there are sea creatures; they always lay eggs after down pour and cool water
  - Catch grown fish around a year and juvenile fish in rain and dry season
  - Distribution: from Muong Lat to Hoang Hoa

Regulation for assessment:



- Assessment of effect based on comparison regulation of flow before and after building Trung Son hydroelectric station, year of fairly average water 2005 is considered as time to compare.
- Flow in Ho Xuan in accordance with the relationship between Hoi Xuan and Cam Thuy
- Supposed that flow at lower section of hydroelectric station is calculated with two cases: (i) in dry season operate ensured capacity to ensure (1 machine team) and (ii) in dry season operate two machine teams.
- Supposed water demand for water creatures to live like natural system when lakes are unavailable.
- These two cases of producing electric are supposes, real give water amount is still depended on (1) process of dry season, of which water demands for other branches (like agriculture, industry...) and (2) diagram of additional electric that Trung Son station is responsible for.

## 5. Result of comparison

- In Hoi Xuan: when factory operates with ensured capacity (1 machine team runs), small given amount only about 125 – 126 m<sup>3</sup>/s equivalent to 50% of natural flow in period of November – December (at the beginning of dry season), this will make affect on growth process of Catfish and Bong fish, the important time prepared for process of laying egg from February to April. Besides, change of flow system synonyms reducing speed of flow for both species which need strong water in process of laying eggs. The rest periods of dry season, given flow amount is more than natural flow, water system does not get bad effect.
- In Cam Thuy: because of low section of Ha Xuan about 50 kms, flow is added from estuaries. Compared among periods it is shown that: at the beginning of dry season, period of laying egg of Moi flower flag fish from February to May and of Carp from February to July, mostly in March, April for two species; if Trung Son only gives ensured capacity, flow amount to Cam Thuy equivalent to about 60% of natural flow, lasting in period from November to middle of January (2,5 months). If factory gives ensured capacity in this period, certainly it affects on growth and egg-laying period of fish, especially chinese gizzard shad Fish. Although demand of water period is not as high as Cat fish's in Hoi Xuan but water depth influences on growth circle of this fish. If factory operates with two machine teams, ensured flow is better.
- When comparing with flow demand as shown in diagram 2 about AFF (Average Annual Flow) to sustain river condition according to request in good condition, demanded flow is 40% of average flow of years for dry season and 60% for flood season. Based on this criteria, flow in lower section of Trung Son hydroelectric when giving capacity meets requirement. The rest problem is changed flow system because of operating as additional charge diagraml in period of laying egg from March to July. This problem needs considering. In Cam Thuy, because of additional flow from estuaries after hydroelectric, demanded flow for ecology can be reached although factor operates with ensured capacity. Similar to Hoi Xuan it should be noticed to flow system because working regulations of factor based on estuaries are changed, influence on period of laying egg from February to March and from July to August must be noticed.

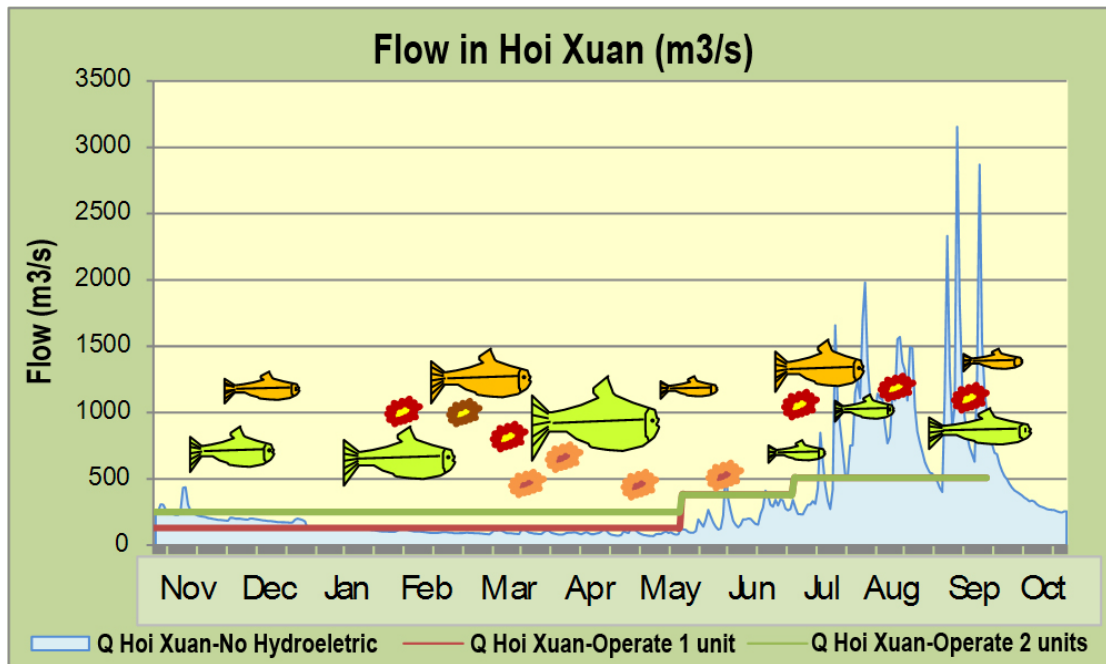


Diagram 1: Change of flow and growth circle of Cat fish and Bong fish in Hoi Xuan

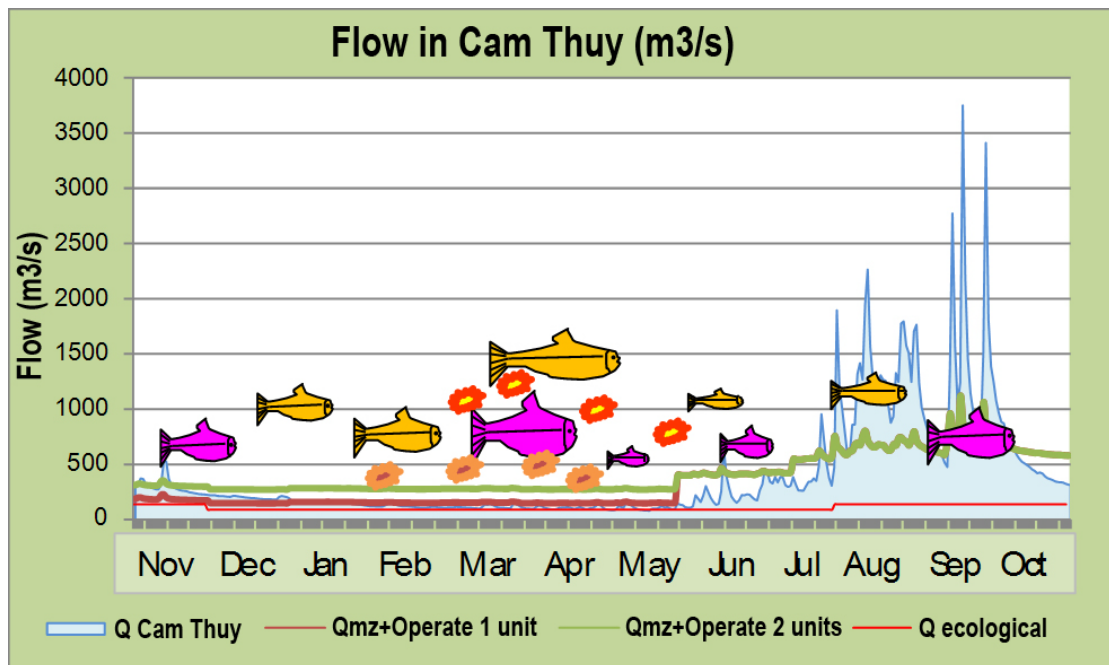


Diagram 2: Change of flow and growth circle of Chinese gizzard shad and Carp in Cam Thuy

**Positive Impact:**

**Issue: Increase in Area for Fisheries Production**

*Character of Impact:* Impoundments create additional areas with potential for increased fisheries and aquaculture production (Sheaves M., 2007).

Impoundments will increase the area available but increased fisheries production depends on the availability of suitable fish species in the reservoirs (Sheaves M, 2007). The productivity of fisheries depends on dam management because frequent water level fluctuations in regulated reservoirs dry up and destroy productivity in the shallow edge zone of the impoundment, which is normally the largest contributor total productivity in lakes (eg. Grimas 1962, Kaster & Jacobi 1978, Blinn et al. 1995, Okland & Okland 1996). Some species which are able to provide high productivity likely to be adaptable to the change from living in fast running water in the river to living in slow running water in pond and lake include carp (*Cyprinus carpio*), *Spinibarbus denticulatus*, *Hemiculter leucisculus*, *Culter recurvirostris*, *Cranoglanis sinensis*. Increases in aquaculture depend primarily on fisheries policy because at the moment the policy is often not to allow development of aquaculture in reservoirs because of potential for pollution (Sheaves M., 2007).

**Proposed enhancement measures:** These will be policies to assist the development of reservoir aquaculture.

- Introduction of non-native species needs to be assessed carefully and probably should not proceed during the first 10 years to allow native species to establish viable populations. Besides using native fish that can adapt to reservoir conditions such as: *Cyprinus carpio*, *Spinibarbus denticulatus*, *Hemiculter leucisculus*, *Culter recurvirostris*, *Cranoglanis sinensis*, the following some exotic species may be suitable such as: *Hypophthalmichthys molitrix*, *Ctenopharyngodon idellus*, *Cirrhina mrigala*, *Labeo rohita*, *Oreochromis niloticus* and/ or *O. mossambicus*. However, these should not be introduced until at least 10 years after reservoir creation, and only after the success of native fish has been established and the exotic fish have been shown to have no adverse impacts on native species.
- The creation of a large lake with pelagic fish species will require quite other fishing methods than traditionally been used in the area. The local people should be educated in how to perform the new fishery.
- Issue fishing regulations within the reservoir. Using fishing instruments that can cause resource attenuation such as: electro-fishing, using dynamite, toxic chemicals must be prohibited. Encouraging local social organs as of youth union, women union, farmer association, veterans association to provide education about the regulations will help ensure their implementation.
- The dam area should be divided into management units and assigned to localities for management. Additionally, hamlets and villages should be encouraged to have village conventions to protect and maintain the resource.
- Developing small-scale fish farming may be necessary to compensate for lost protein sources when fish yield declines again in the future (SWECO, 2005).

**Issue: Reservoir will contribute to prevent flood, drought and pollution**

*Impacted characterstic:* According to the calculation of hydraulic power and reservoir nuclea economy which retains 17% current flow in flood season in order to strengthern current flow in dry season. Reduce in flood season (Trung Son Power Project Management Unit, 2008. It also take part in the reduction of salty in downstream indirectly in the dry season. (PECC 4, 2004).

The consequence of the method, which uses altered flow, is very big, affecting all areas behind the dam. If possible, the flow management should follow the natural flow on the time, scope and rate of the flow. The flow with high speed shall not be used (Sheaves M. 2008).

**Issue: Contribution of salinization prevention, pollution reduction in downstream:**

If water discharged from the reservoir in dry season is greater than natural flow without the dam, the construction can prevent salinization into river. Besides, this also reduces the rate of pollutants in downstream area.

**Other observation:** “Fairy fish” cave: in Cam Luong commune, Cam Thuy (position: 20° 15' 013” – 105° 23' 22”, height 26 m) appears fairy fish cave in a narrow stream with thousands of *Spinibarbus sinensis*. It's an ideal location to preserve species because they are protected by spirit and a place of scenic beauty to attract tourists. As the place is far from the dam towards lowlands about 63 km, the construction site has not impacted on the fish stream.

## II. Impact on fisheries:

According to the statistics of Thanh Hoa Department of Statistics, in this province, the lowest number of fishermen on the river in 2001-2006 period are 2.211 people (in 2002), the highest are 2.365 people (in 2006). There will be negative impacts on aquatic creatures system in general and regional fauna in particular when the project is built and come into operation. Fish is daily food and the main protein source for people living along the Ma River. Decline in availability or quality of fish will have a serious effect on human nutrition along the riverside. Because fishing is an important income-pringing activity as well, reduce or lower quality fish will also harm the economy of many households in the riverside villages.

### *Impacts of Trung Son Hydropower project on fisheries:*

Due to the impacts mentioned above, it is easy to cause negative impacts on flock of fishes on the river, which leads to bad effectiveness for fishery and reduce production of catching fish for the following reason:

#### 1. Impacts on the production of fish food and fish feeding

The production of fish is often strongly reduced in a regulated river. There are many reasons for this:

- Periphyton is reduced due to siltation and low light due to turbid water.
- Frequent water level fluctuations destroy the periphyton, macrophytes and bottom fauna in the shoreline area.
- The increased sedimentation in the deep areas makes the sediments become inorganic, and contains little digestible food for the bottom animals.
- Reduced flooding of forest and wetlands prevent feeding migrations into these areas.
- The dam also makes barriers toward feeding migrations.
- The altered flow pattern also makes problems for feeding migrations.
- The trapping of nutrients in the reservoir leads to oligotrophication, which also results in less fish food production.
- The erosion of the riverbanks reduces the overhanging trees and riparian vegetation which reduces the organic litter fall (leaves, insects, etc) to the water.

#### 2. Impacts on fish spawning and nursery

- Erosion can be a problem for some spawners, e.g. those who are having their

eggs in ravel in rapids. Settling of erosion material between the stones reduces the oxygen concentration in the gravel bed, which can be a problem for oxygen supply to the eggs and larvae.

- Spawning areas may be tributaries, flooded wetlands or forest, and rapids in the river. These areas must be accessible, and they must be wetted for a sufficiently long period of time to allow the eggs to hatch, and to provide suitable living conditions for the first life-stage of the fish larvae. The filling of the reservoir in the first part of the rainy season is often a major reason why spawning conditions are not reached in regulated rivers. It may be lack of flooding, or that the flooding comes too late, and the flood does not last long enough to allow for nursery of the fry.

**Mitigation:**

- Water in reservoir should not be stored in the beginning of rainy seasons.
- Keep the river intact as referred in fishes biodiversity;
- Adjust how to make sure of flow regulation without much fluctuation on day.

**3. Impacts on the fisheries:**

Due to the impacts mentioned above, it is easy to cause negative impacts on flock of fishes on the river, which leads to bad effectiveness for fishery and reduce production of catching fish for the following reason:

- Reduced fish catches due to reduced stocks.
- Reduced fish sizes due to shift in species composition, but also due to reduction in growth rate.
- Some species will more or less disappear.
- The fish will get another special distribution and it will be necessary to fish in other places than today.
- Loss of fishing equipment due to sudden releases of water.

**Mitigation:**

Due to the reduction of natural aquatic products exploration, the local people will have to explore more on protein supplying resource and strengthening cattle husbandry and aquaculture. Expenditure support and technical training to provide local people favorable conditions to implement this problem are very necessary. We can choose one of the two supportive directions as follow:

- Add seeding fishes into the reservoir and into the river lower sections.
- To develop pisciculture in channels and branch of the river and stream in the reservoir.
- Technical training on catching fishes in the high and deep water areas for the local people living around the reservoir.

***Expenditure estimation for compensation activities:***

*1. Add more seeding fishes in the reservoir and in the river lower sections:*

- Buy seeding fishes of all kinds (size 8 – 15 cm) :  
200.000 unit x 2.000 VND/unit = 400,000,000 VND
- Leasing cars and other expenditures: 4,000,000 VND

**Total for this 404,000,000 VND/year x 5 year = 2,020,000,000 VND**

2. *Technical training on catching fishes in the high and deep water areas for the local people living around the reservoir.*

- Wage for experts:  
2 districts x 2 days/district x 738.000 VND = 2,952,000 VND
- Leasing cars for picking up experts:  
3 days x 1.000.000 day = 3,000,000 VND
- Food, travels fees for the trainees:  
200 người x 100.000 đ x 1 ngày = 20,000,000 VND

**Subtotal: 4: 25,952,000 VND**

### **III. Monitoring and Further Surveys Necessary Plans for the Preparation, Construction and Implementation Stages of the Trung Son Hydropower Project**

#### **Background**

The proposed work focuses on the 250 MW Trung Son Hydropower Project, on the Ma River in Thanh Hoa Province in northwestern Vietnam. Initial Fish Biodiversity and Fisheries Studies identified a variety of important fisheries and ecological attributes of the Ma River that have the potential to be impacted by the Trung Son Hydropower Project during preparation, construction and implementation stages. The studies also identified a lack of basic biological and ecological understanding of the fish and fisheries of the Ma River that is necessary for comprehensive evaluation of likely impacts.

The Trung Son Project is a multipurpose project, including both power generation and flood control benefits. Electricity Vietnam's Hydropower Management Board 2 (HPMB) is committed to ensuring that the development of the Trung Son Project follows best practices and produces as few detrimental outcomes for fish and fisheries as possible. Consequently, additional studies of two types are required; (i) detailed monitoring studies to provide early warning of any developing environmental problems, and (ii) further studies of the ecology of fishes of the Ma River to allow informed interpretation of monitoring results.

#### **Objectives:**

The overall goal of this consultancy is to provide comprehensive monitoring and evaluation of any changes to the fish fauna of the Ma River in response to the development and operation of the Trung Son Hydropower Project. Specifically to:

1. Design and implement a rigorous survey of the current status and functioning of aquatic ecosystems of the Ma River, leading to specific evaluation of the likely impacts of hydropower development.
2. Design and implement a rigorous monitoring plan capable of sensitively detecting changes in biodiversity and ecological functioning of the whole Ma River in response to the development and operation of the Trung Son Hydropower Project.

3. Conduct detailed ecological studies to strengthen the knowledge base needed to allow meaningful interpretation of monitoring results.

## Method of Monitoring and Survey

### 1. Places of taking samples

1.1 *Places of taking samples for ecological monitoring and survey*: Supervise and take samples in 16 related places in the region (see attached map):

- *Representative of river reaches upstream from the reservoir* (2 places): Tien Son village (Chieng Khuong commune, Song Ma district) (1) and Chien Phuc (2) (Ten Tan commune).

*Representative of the reservoir storage* (4 places): Pom Khuong village (3) (Tam Chung commune), Tai Chanh village (4) ( Muong Ly commune), x village (5) (Trung Ly commene) and Xuoc Village (6) (Trung Son commune). The location of collecting sample in the reservoir in supervision period carried out is two located in the middle of the reservoir and other two located inshore (see the map No 4).

- *Representative of river reaches between the reservoir and the junction with the Luong river – Control No.1* (2 places): Co Luong village (7) ( Van Mai commune), Chom Thai village (8) (Hoi Xuan commune)
- *Representative of the first main branch of Luong River* (2 places): Xua village (9) (Nam Dong village), Ta Lon village (10) (Nam Tien commune)
- *Representative of river reaches downstream from the junction with the Luong River to the coast* (4 places): Canh Nang town (11) (Ba Thuoc district), Cam Giang commune (12) (Cam Thuy district), Thieu Thinh commune (13) (Thieu Hoa district), Quang Phu commune (14) (Quang Xuong district)
- *Representative of the second main branch of Buoi river – Control 2* (2 places): Thanh Hung commune(15) (Thach Thanh district) và Huong Nhuong (16) (Lac Son district, Hoa Binh province).

1.2 *Places of taking samples for fisheries monitoring and survey*

- *Representative of the reservoir storage* (4 places): Pom Khuong village (3) (Tam Chung commune), Tai Chanh village (4) ( Muong Ly commune), x village (5) (Trung Ly commene) and Xuoc Village (6) (Trung Son commune). The location of collecting sample in the reservoir in supervision period carried out is two located in the middle of the reservoir and other two located inshore (see the map No 4).
- *Representative of river reaches between the reservoir and the junction with the Luong river – Control No.1* (2 places): Co Luong village (7) ( Van Mai commune), Chom Thai village (8) (Hoi Xuan commune).

### 2. Method and time of taking samples in each place for the monitoring purpose:

2.1. *Method*:

2.1.1 *Ecological survey and monitoring purpose*:

- In each place, samples must be taken from different habitats based on the following classification (use any others as necessary):
  - shallow sand/gravel flats (defined as level areas of sand <50cm deep)
  - sand/gravel bank/flat edges
  - shallow open water (50cm-1m deep)
  - deep open water (>1m deep)
  - deep holes downstream of boulders
  
  - deep channels along clear banks
  - deep channels along vegetated banks
  - snags (woody debris); samples should be taken as close to the downstream side of these as possible
  - riffles (areas of rapid flow of beds of small rocks)
  - rapids; samples should be collected downstream of boulders
- Sampling cycle: samples to be collected twice each year: once in dry season and once in rainy season. Sampling should be conducted at the same time each year.
- Sampling equipment: cast-nets with 2 different mesh sizes (for instance 20 mm and 50 mm) and different lengths (for instance: corresponding radius 4 m and 5 m) to be used to take samples in all sites. Local fishing equipment can be used to obtain specific species. The sample are taken in the top and middle layer at 2m and 4m deep.
- Number of casting haul (not lower than 20) and catching area (not less than 1 km<sup>2</sup>) are conducted fairly in each place, each creature and at any time.

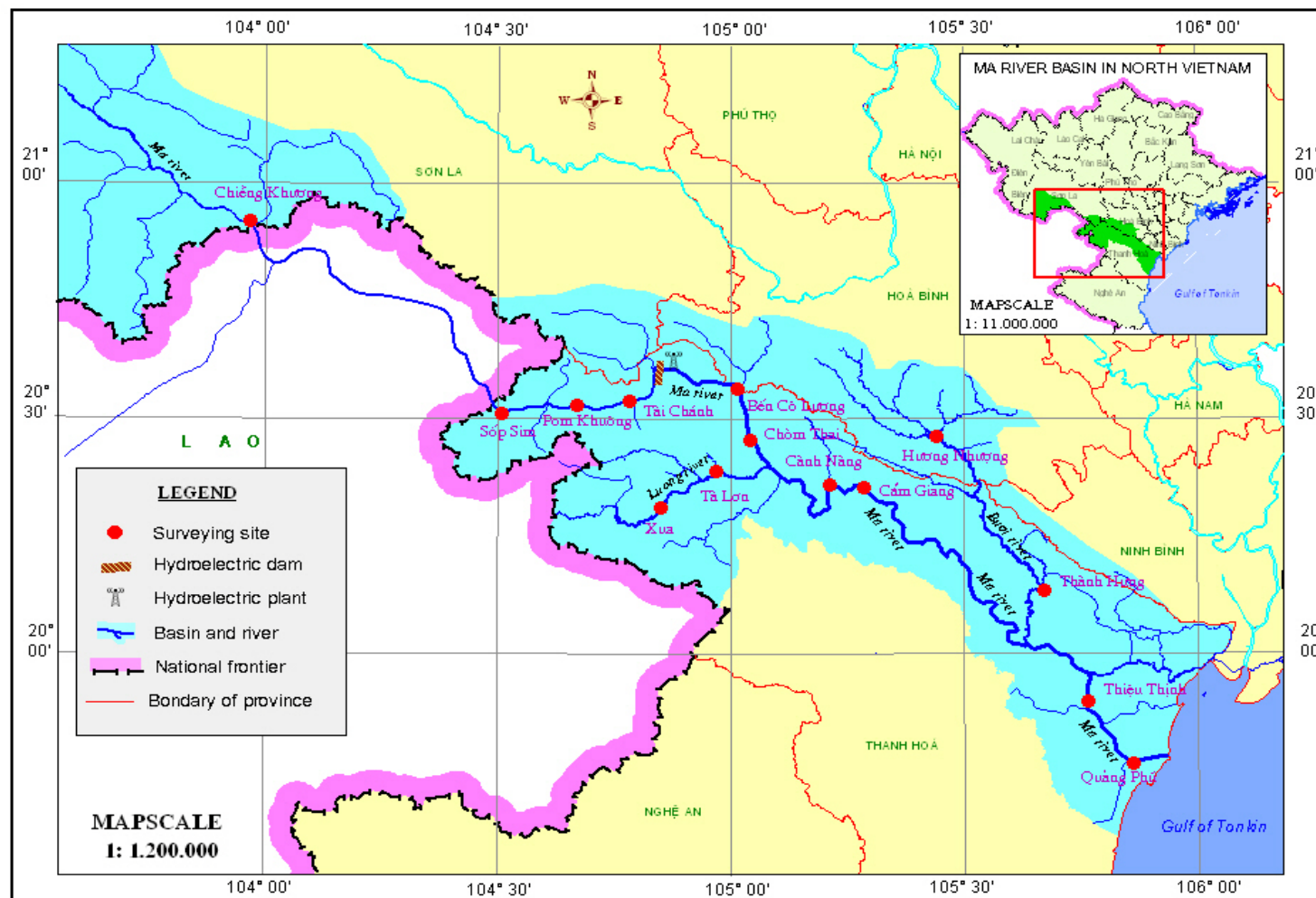
*2.1.2 Fisheries monitoring:* Four sites (2 in the reservoir ( Tai Chanh and Xuoc villages) and 2 other in the representative of river reaches between the reservoir and the junction with the Luong river (Co Luong and Chom Thai)

- In each place 15 fisherman are objectiv of survey.
- The data needed to collect:
  - List species of fish catching
  - Product of each species
  - Output of daily, monthly, sixmonthly and yearly
  - Productivity of each fisher
  - Production daily, monthly, six-monthly and yearly



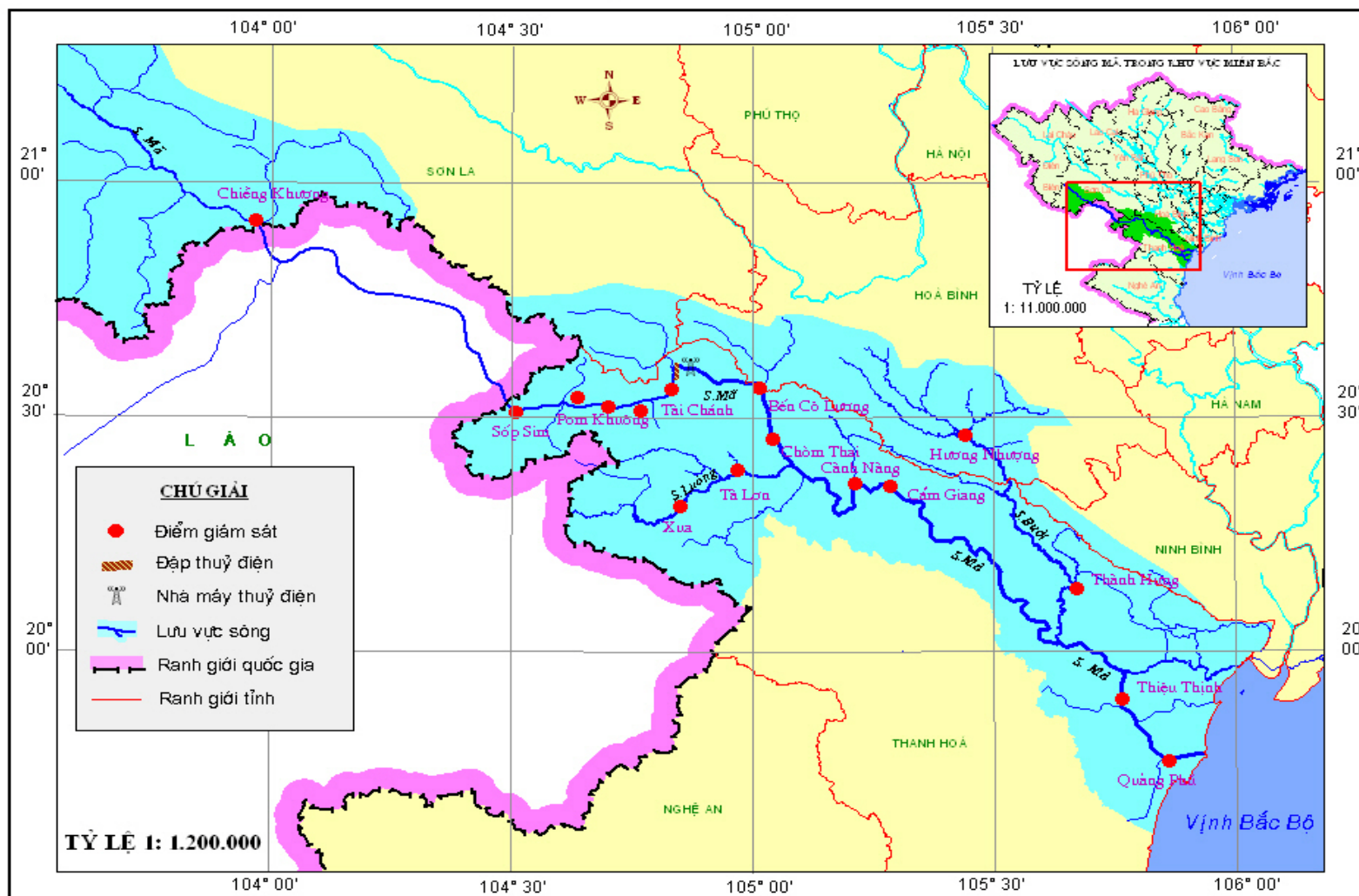
- Total of time to catch fish daily, monthly, six-monthly and yearly of each fisher .
  - Any job changing of fishers from previos survey to that moment.
- 
- Data recording: abundances or catch per unit effort of as many species as possible, and recording of size structures of all species for which sample sizes are sufficiently large.
  - Record catch of local fishermen for each habitat type in each location.
  - Photograph each habitat type and fish sample in each location,
  - Record all statistics in data table for each sampling place (attached below).
  - Input all data to excel (attached below).

### THE MAP OF THE SURVEYING SITE IN THE RIVER'S MONITORING PROGRAM BEFORE THE RESERVOIR CREATION



Map No 3: Surveying and Monitoring sites before reservoir creation

## BẢN ĐỒ CÁC ĐIỂM GIÁM SÁT DỰ KIẾN SAU KHI HỒ CHỨA HÌNH THÀNH



Map No 4: Surveying and Monitoring sites after reservoir creation

2.2 *Time*: Monitoring starts 1 year before construction commences, during implementation of the work and after the work is brought into use. Monitoring time is at least 12 years.

2.3 *Estimated expenditure for monitoring*: (in 12 years)

2.3.1 *For international experts*:

- Salary for 44 working days: 44 days x 600 USD = 26,400 USD
- Accommodation: 24 days x 210 USD = 5,040 USD
- Flight ticket: 6 flights x 2,500 USD = 15,000 USD

2.3.2 *For domestic experts*:

- Expert salary: 3 people x 15 days/period (including 11 days of field visiting, 2 days traveling and 3 days analyzing statistics to write report) x 2 periods/year x 12 year x 738,000 VND = 850,176,000 VND
- Stay and hotel room: 11 days/period x 3 people x 190,000 VND x 2 periods x 12 years = 150,000,000 VND
- Hiring sampling workers: 4 people x 10 days/period x 2 periods/year x 12 years x 100 VND/person = 96,000,000 VND
- Hiring motor-boat: 04 motor-boats x 10 days/period/year x 2 periods 12 years x 800,000 VND/one = 760,000,000 VND
- Car rent for field visit: 5 days/ period (2 days traveling) x 2 periods/year x 12 years x 1,500,000 VND/day = 180,000,000 VND
- Purchasing chemical tools: = 20,000,000 VND
- Communication, stationary, service: = 20,000,000 VND
- Purchasing information, statistics = 30,000,000 VND
- Hiring studies equipments = 90,000,000 VND

**Total expense: 46,440 USD and 2,322,000 VND**

**3. Sampling method, necessary time in fish ecological study purpose**

3.1 *Sampling method and object of sampling*

Study objects:

+ Places from (1) to (10) (see the map) 14 species: *Onychostyoma gelarchi*, *Spinibarbus hollandi*, *Spinibarbus denticulatus*, *Cirrhina molitorella*, *Garra*

*orientalis*, *Mastacembelus armatus*, *Hemiculter leucisculus*, *Cyprinus carpio*, *Hemibagrus guttatus*, *Clarias fuscus*, *Cranoglanis henrici*, *Sinilabeo lemassoni*, *Elopichthys bambusa* and *Bagarius rutilus*.

+ Places (10) and (12) (see the map) 14 species: *Clupanodon thrissa*, *Anguilla marmorata*, *Elopichthys bambusa*, *Tor (Folifer) brevifilis*, *Hemibagrus guttatus*, *Bagarius rutilus*, *Spinibarbus denticulatus*, *S. sinensis*, *Cyprinus carpio*, *Squaliobarbus curriculus*, *Cranoglanis sinensis*, *Silurus asotus*, *Mastacembelus armatus* và *Hemiculter leucisculus*.

+ Places (13), (14) and (15) (see the map) 20 species: *Clupanodon thrissa*, *Konosirus punctatus*, *Elopichthys bambusa*, *Hemibagrus guttatus*, *Bostrichthys sinensis*, *Cyprinus carpio*, *Silurus asotus*, *Cranoglanis sinensis*, *Squaliobarbus curriculus*, *Hemiculter leucisculus*, *Mastacembelus armatus*, *Glossogobius giuris*, *Coilia grayii*, *Mugil cephalus*, *Scatophagus argus*, *Sillago sihama*, *Taenioides eruptionis*, *Sparus latus*, *Therapon theraps* và *Pisoodonophis boro*.

+ Place (16): *Onychostyoma gelarchi*, *Spinibarbus hollandi*, *Spinibarbus denticulatus*, *Cirrhina molitorella*, *Garra orientalis*, *Mastacembelus armatus*, *Hemiculter leucisculus*, *Cyprinus carpio*, *Hemibagrus guttatus*, *Clarias fuscus*, *Cranoglanis henrici*, *Sinilabeo lemasoni*, *Elopichthys bambusa* and *Bagarius rutilus*.

Field surveying cycle: once every 2 months, investigators survey and take samples in each selected place.

3.2 *Conducting time*: starts 1 year before the work started and lasts 1 year.

3.3 *Estimated expenditure for ecological survey (in 1 year)*

3.3.1 For international experts:

- Salary of 20 working days: 20 days x 600 USD = 12,000 USD
- Accommodation: 10 days (for 10 days in Vietnam) x 210 USD = 2,100 USD
- Flight ticket: 2 ways x 2500 USD = 5,000 USD

3.3.2 For domestic experts:

- Expert salary: 3 people x 12 days (including 10 days of field visit, 02 days traveling, and 1 person x 10 days analyzing data to write report) x 6 period/year x 738,000 VND = 199,260,000 VND
- Accommodation: 10 days/period x 3 people x 6 periods x 190,000 VND = 34,200,000 VND
- Hiring sampling workers: 4 people x 6 periods x 10 days/period x 100,000 VND = 24,000,000 VND
- Hiring motor-boat : 4 motor-boats x 6 periods x 10 days/period x 800,000 VND = 192,000,000 VND
- Car rent for field visit: 5 days/period (2 days traveling) x 6 periods x 1,500,000 VND = 45,000,000 VND
- Purchasing chemicals: = 16,000,000 VND
- Communication, stationary, service: = 16,000,000 VND
- Purchasing information, statistics: = 16,000,000 VND
- Hiring studies equipments = 20,000,000 VND

**Total expense: 19,100 USD and 579,212,000 VND**

## Expertise Requirements

The study team should consist of (a) at least two **local fisheries experts** with an extensive knowledge of identification of Vietnam's river fish and experience in implementation and management of field studies. The local fisheries experts should have

advanced degrees in biological/ecological sciences and at least 10 years experience in the taxonomy and identification of Vietnamese fish and demonstrated experience in the design and implementation of field studies of fish ecology. (b) At least 4 **local technical experts** very experienced in sampling river fish in Vietnam. These could be local fishermen and would work under direction of the local fisheries experts. (c) A **local expert in the sampling and identification of aquatic invertebrates and plants**. This local expert should have an advanced degree in biological/ecological sciences and at least 10 years experience in the taxonomy and identification of Vietnamese aquatic invertebrates and/or plants. (d) An **international fisheries expert** highly experienced in ecological

sampling design and monitoring. The international expert would be responsible for overseeing sampling design, statistical analysis and reporting and would work closely with the local fisheries experts to develop and implement appropriate sampling designs. The international fisheries expert should have (i) an advanced degree in ecological science, (ii) over 15 years experience in the design, and implementation of monitoring and/or ecological sampling schemes for river or estuarine fish, (iii) demonstrated ability for high level statistical analysis, and (iv) demonstrated ability to evaluate and communicate research results.

### Outputs and Deliverables

- I. A detailed and comprehensive field sampling design.
- II. A comprehensive baseline report on the status and functioning of Ma River aquatic ecosystems.
- III. A detailed report on the likely impacts of hydropower developments and potential mitigation measures.
- IV. A detailed monitoring design.
- V. Field monitoring implementation and base-line status report following initial monitoring studies.
- VI. Six monthly and annual monitoring reports to HPMB.
- VII. Interim event reports to HPMB of any faunal changes detected, in as timely a manner as possible.
- VIII. A monitoring report at the completion of the dam construction phase.
- IX. A monitoring report at the completion of the full monitoring period.
- X. A report on habitat relationships of Ma River fish at the standard of an international journal publication.
- XI. A report on the migration patterns of Ma River fish, including utilisation of season refuges at the standard of an international journal publication.
- XII. A report on the reproductive patterns and associated migration patterns of Ma River fish at the standard of an international journal publication.
- XIII. A report on fish nursery grounds and associated migration patterns of Ma River fish at the standard of an international journal publication.
- XIV. A report on the dietary requirements and associated migration patterns of Ma River fish at the standard of an international journal publication.

XV. A monitoring report at the completion of the yearly fishery monitoring period. And a report at the completion of full fisheries monitoring period.

## **IV. Technical and Legal Feasibility for an Intact Rivers program in the Ma River Basin**

### **Justification of an Intact Rivers Program in the Ma River:**

One major measure to mitigating the effects of the Trung Son dam is to ensure that selected branches of the Ma River system remains unaltered. This would need to consist of a complete unaltered sub-basin with no dams or barriers and a high level of protection from other impacts such as mining-related pollution, wastewater pollution from urban areas, and destructive fishing practices. Having a completely unaltered system would preserve the ecological connectivity within one branch of the system and provide species with inter-habitat migration from one part of the basin to another.

Two complete river sub-basins of the Ma River are recommended in the Fish Report that should be kept free from barriers and activities that impact fish biodiversity. Keeping these two sub-basins “intact” will ensure that a full sequence of fish habitats and migratory routes is protected in the Ma River. Potential candidate sub-basins are: for such an intact rivers scheme are the Buoï and Luong Rivers.

- (i) The *Buoï River* is an affluent at level 1 with length of about 85 km. Its riverhead locates in Tan Lac district, flows across Lac Son district (Hoa Binh province), Thach Thanh district and Vinh Loc district (Thanh Hoa province) and then flows into Ma River in Vinh Hoa.
- (ii) The *Luong River* is also an affluent at level 1. Its riverhead locates in Lao People’s Democratic Republic, section in Viet Nam with length of about 50 km flows across Quan Son and Quan Hoa districts (Thanh Hoa) and then flows into Ma River in Hoi Xuan.

### **Objective**

The objective of the study is to analyze the technical and legal feasibility for the establishment of an intact river program in the Buoï and Luong sb-basins of the Ma river.

### **Legal feasibility**

There is no precedent in Vietnam for such a system and no legal basis for protection and management of a river as a whole ecosystem. The study will analyze the legal framework in Vietnam and suggest alternative legal options for establishing a protected ecosystem in the two selected sub-basins. The study will also analyze the institutional arrangements that will be necessary to implement such protection.

### **Technical feasibility**

The study will analyze:

- Existing baseline conditions in each sub-basin: hydrology, land use, water quality (mainly based on existing information on the Ma river basin, Water Resources Institute for instance)
- Fish biodiversity on the sub-basins and their relationship with the entire Ma River system
- Fisheries: existing fisheries activities along the sub-basins: number of fishermen, location, fishing practices, captures
- Existing threats to aquatic biodiversity in each sub-basin such as: mining activities, habitat destruction, wastewater discharges, unsustainable fishing practices
- Existing institutional arrangements for the protection of biodiversity and specifically fish biodiversity in the basin

### **Specific Details of the Intact Rivers Program**

The study will propose a series of legal, **institutional and regulatory** measures to protect fish biodiversity in the sub-basins, including but not limited to:

1. Commitments to prohibit the imposition of barriers (hydropower dams and other structures).
2. Commitments to remove any human existing barriers already in place to bypass them with fish passage devices
3. Legally define an area of protection of the proposed streams, to protect riverine forests and habitats, in which activities that might impact the aquatic environments of the Intact Rivers will be strictly controlled.
4. Prohibit sand mining in the river channel and river banks for the length of the intact rivers, their embankments and branches of the rivers
5. Impose strict controls on terrestrial mining in the area of protection of the rivers to prevent pollutants and sediments entering the intact river.
6. Prohibit the construction of roads and road infrastructure within the protection areas or establish the environmental criteria to allow such infrastructure to be built.
7. Prohibit the establishment of new settlements, industrial areas and other new human activities within the protection area.
8. Strictly control human activities and industries already occurring in the protected areas to reduce any current impacts on the streams and prevent any new impacts.
9. Propose bans on destructive fishing practices (use of explosives, for instance), impose seasonal fishing restrictions, and other measures, and establish mechanisms for enforcing these bans
10. Environmental awareness and sensitivity programs for communities living along the intact rivers
11. Monitoring programs for fish biodiversity in the basins

Each proposed program will include:

- A technically detailed description of each mitigation measure
- A timetable (chronogram) of planned activities.
- A budget of all necessary investment and recurrent costs
- A clear definition of institutional responsibilities (all levels of government, national, provincial, local) for the implementation of each mitigation measure including (i) design; (ii) supervision; (iii) enforcement; and (iv) monitoring.



- An analysis of the institutional capacity of all agencies that will participate in the intact river program.

## Scope and method of Implementation

In the first week, consultative team will discuss and agree on detailed working program and methodology. Then, consultative team will investigate survey and collect figures. It is planned to transportationry out in 06 months from January 2009 to June 2009.

### 1. Investigation of fish biodiversity

a) Place: at 17 places

- At Luong River: transportationried out the investigation at 6 places: Na Meo, Ban Bo, Ban Bun, Ban Xua, Ta Lon and Nam Xuan.
- At Buoi River: transportationried out the investigation at 11 places: Xom Bua, Huong Nhuong, Tan Son, Phu Luong, Vu Ban, An Nghia, Thach Lam, Thach Quang, Thach Son., Thanh Hung and Vinh Phuc.

b) Method:

- At each place, forms of different creature's sceneries according to following division:
  - shallow sand/gravel flats (defined as level areas of sand <50cm deep)
  - sand/gravel bank/flat edges
  - shallow open water (50cm-1m deep)
  
  - deep open water (>1m deep)
  - deep holes downstream of boulders
  - deep channels along clear banks
  - deep channels along vegetated banks
  - snags (woody debris); samples should be taken as close to the downstream side of these as possible
  - riffles (areas of rapid flow of beds of small rocks)
  - rapids; samples should be collected downstream of boulders

If necessary, other forms can be added.

- Frequency of form collection: forms are collected 2 times six months: one time in dry season and one time in rain season. Repeated time of form collection coincides with implemented time of previous period. Investigation time: 14 days per person.
- Used fishing equipments: casting nets with 2 eye sizes (for example: 18mm and 35 mm) and different length (For instance: radius equivalent to 4m and 5m) are used to collect forms at all places. Other typical fishing equipments are possibly used in suitable local for specific species.
- Amount of fishing net haul and fishing area are transportationried out in each place, each creature's scenery and at all time equally.
- Forms caught by fishermen in the correlative locals can be used.

- For forms to assess the multiform it needs to collect as many forms as possible and to collect enough big amount of forms.
- Write down any catch of local people in each creature's scenery
- Take photographs of each creature's scenery, photograph of collected fish form and of each region as well.
- Write down all figures into data table for each point collecting forms (Attached note)
- Input all data to excel (attached note).
- Analyze, synthesize figures and write report: 12 days

## **2. Water quality investigation**

a) Place: at 7 following places, each place has 3 forms (2 forms at both banks and one form at middle of flows):

- At Luong River: 3 places: Ban Bun, Ta Lon and Nam Xuan
- At Buoï River: 4 places: Tan Son, Thach Lam, Kim Tan and Vinh Phuc

b) Method:

- Field research

\* At each place 3 forms are collected: 2 forms at both banks and one form at middle of flows

\* Time to collect forms: one time in dry season and one time in rain season. Each time: 5 days per person

- Analyze 18 norms of water quality.

## **3. Investigation and collection of fishery figures:**

- Interview at locals, fishermen at Luong River at 6 places: Na Meo, Ban Bo, Ban Bun, Ban Xua, Ta Lon and Nam Xuan; at Buoï River at 11 places: Xom Bua, Huong Nhuong, Tan Son, Phu Luong, Vu Ban, An Nghia, Thach Lam, Thach Quang, Thach Son, Thanh Hung and Vinh Phuc.
- Organize seminars with inhabitants, local authorities and authorities of small villages.
- Total interview time: 12 days per person.

## **4. Collect actual figures on each valley about hydrography, land use, forest floor, water quality and hydrography works, industry zones... on 2 river branches and their corridors.**

- Employ collecting figures about actual state; making map of forest and land along corridors of 2 rivers: Buoï river and Luong river (photo of satellite)
- Employ collecting figures about hydrography.
- Investigate actual state of 2 branches of Buoï river and Luong river – Time to collect figures and investigate actual state, write report: 6 days.

**5. Gather actual institutions of protection of biological multiform** and especially biological multiform of fish at valley; collect information, form organizational responsibility (government, nation, province, district to cut down design, supervision,

implementation and inspection) and analyze ability of team participating in project of undamaged river. Draft project of improving awareness of environment for inhabitants living along 2 river branches.

Time: 16 days

#### **6. Analysis, synthesizing and writing report:**

Based on result of investigation, figure collection, actual state of auxiliary valley and data research, existing institution, responsibility of related organizations... consultative tea, will analyze, synthesize and draft preliminary reports. These reports will be made into seminars with participation of related organizations and boards to consider legal and technical practicability for taking shape the project of whole river at 2 preliminary valleys of Bui river and Luong river. And then, consultative team will complete official general report.

Time: 10 days

#### **Outputs and Deliverables**

A comprehensive report on actual state and function of water ecosystem and terrestrial corridors along 2 branches of Luong river and Bui river, actual state of hydrography, forest, land use and water quality.

1. A detailed report on multiform of fish at regional fauna of Bui river and Luong river, placed according to time, space and their living environment; existing fishing activities at 2 valleys of Luong river and Bui river: amount of fishermen, catch place, reality of fishery and danger to biological multiform of water creatures.
2. Report on existing institution to protect general biological multiform and specific biological multiform of fish. Propose solutions to preserve biological multiform of water creatures. Analyze ability of organizing of bodies participating in project of keeping whole river and define organizational responsibility for organizations and authorities at all levels from centre to districts or provinces...
3. A general report based on reports of above parts. The report must have conclusion about practicability of keeping method of whole river, proposal of petitions to transportation carried out 11 solutions of biological multiform protection on above mentioned whole rivers.

#### **Professional require**

Research team must include (a) at least two experts on fish in water with deep knowledge of river fish of Vietnam and experiences on implementation and management of fish research. These experts must have high degrees in fields of ecology/biological creatures and at least 10-year experiences on classification and formatting of fish kinds in Vietnam, on making plan and doing research on ecology of fish and of whom there is at least person with at least 30-year experience on this field; (b) at least 4 local technical experts with many experiences on taking fish forms in Vietnam. They can be local fishermen and they work based on direct leading of experts of fish in water; (c) a home expert on valuation of water quality. This expert is required to have high professional degree and at least 10-year experience on field investigation, water quality analysis and valuation; (d) a law expert. This expert must have high professional degree and at least 10-year professional experience.

## Planned Implementation Budget

### 1. Investigate of water quality

- Field research and samples collection:

- 1 person x 5 days x 2 courses x 1,530,000 VND/days = 15,300,000 VND
- Per diem: 1 person x 5 days x 2 courses x 190,000 VND = 1,900,000 VND
- Analyze 18 norms of water quality:
  - 18 norms x 7 points collecting forms x 3 forms/point x 2 courses x 80,000 VND/form = 60,489,000 VND
- Car rent for field visit: 2 periods x 2 days x 1,500,000 VND/day = 6,000,000 VND
- Hiring motor boat: 5 days x 2 periods x 400,000 VND/day = 4,000,000 VND
- Writing report: 2 days x 2 periods x 1,530,000 VND/day = 6,120,000 VND

### 2. Fish Biodiversity:- Field research and samples collection

- 1 person x 14 days x 2 times x 738,000 VND/person/day = 20,664,000 VND
- 1 person x 14 days x 2 times x 1,771,000 VND/day = 49,588,000 VND
- Per diem of 2 fish experts:
  - 2 people x 14 days x 2 times x 190,000 VND = 10,640,000 VND
- Data analysis:
  - 1 person x 5 days x 2 times x 738,000 VND/day = 7,380,000 VND
- Data analysis, synthetization and report writing
  - 1 person x 12 days x 1.771.000 VND = 21,252, 000 VND
- Car rent: 2 times x 2 days x 1,500,000 VND/day = 6,000,000 VND
- Fisherman renting to catch fish:
  - 4 people x 12 days x 2 courses x 150,000 VND/person/day = 14,400,000 VND
- Canoe renting and driver to catch fish:
  - 4 canoes x 8 days x 2 courses x 400,000 VND/canoe/day = 25,600,000 VND
- Transportation renting to move from a place to others:
  - 6 people x 12 days x 2 times x 150,000 VND = 21,600,000 VND
- 3. Investigating and collecting data of fishery
  - 2 people x 12 days x 738,000 VND/day/person = 17,712,000 VND
  - Stay fee: 2 x 12 days x 190,000 VND = 4,560,000 VND
  - Motor renting: 2 people x 10 days x 150,000 VND = 3,000,000 VND
  - Car rent: 2 days x 1,500,000 VND = 3,000,000 VND
- 4. Renting of collecting figures on actual state and making map of forest and land along corridors 2 rivers: Buoi river and Luong river (photo of satellite):
  - = 61,190,000 VND
- 5. Renting of collecting figures on hydrography, fish catching at locals along 2 rivers:
  - = 30,000,000 VND
- 6. Investigation of actual state of 2 river branch of Buoi river and Luong river and report writing:
  - Field reseach: 2 people x 6 days x 738,000 VND = 8.856.000 VND
  - Per diem: 2 people x 5 days x 190,000 VND = 1.500.000 VND
  - Renting transportation 2 x 5 days x 150,000 VND = 1.500.000 VND
  - Car rent: 4 days x 1,500,000 VND = 6,000,000 VND
  - Report writing:
    - \* 1 per. X 2 days x 1,771,000 VND = 3,542,000 VND
    - \* 1 per. X 2 days x 738,000 VND = 2,295,000 VND
- 7. Gathering existing institutions for protection of biological multiform and especially, biological multiform of fish at valley:
  - \* 1 person x 2 days x 738,000 VND = 1.476.000 VND

8. Collecting information, form organizational responsibility (government, nation, and province, district to cut down design, supervision, implementation and inspection) and analyze ability of team participating in project of undamaged river:
- Collecting information: 1 person x 10 days x 738,000 VND = 17,710,000 VND
  - Whiting report: 1 person x 2 days x 1,771,000 VND = 3,542,000 VND
9. Draft project of improving awareness of environment for inhabitants living along 2 river branches:
- \* 1 person x 4 days x 738,000 VND = 2,952,000 VND
  - \* 1 person x 1 day x 1,771,000 VND = 1,771,000 VND
10. Renting design of map GPS: 3 maps x 2,000,000 VND/map = 6,000,000 VND
11. Translating document into English 150 pages x 80,000 VND/page = 12,000,000 VND
12. Office stationery: = 5,000,000 VND
13. Communication information: = 5,000,000 VND
14. Chemical and equipments = 3.000.000 VND
15. Renting car to work with Trung Son Board:
- 4 times/day x 1,200,000 VND = 4,800,000 VND
16. Writing the general report:
- Write report: 1 person x 10 days x 1,171,000 VND = 11,171,000 VND
  - An assistant to complete legal documents: 5 days x 738,000 VND = 3,690,000 VND
17. Oganizing seminar:
- Per diem: 100 people x 1 day x 190,000 VND = 19,000,000 VND
  - Travelling fee: 80 people x 200,000 VND = 16,000,000 VND
  - Renting hall, decorating, fee of drinking water = 5,000,000 VND
  - Light meal at the middle of spell: 100 people x 2 spells x 10,000 VND/spell/person: = 2,000,000 VND

**Total amount: 539,357,000 VND (31,726 USD)**

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*Ha Noi, 26 December 2008*

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