ENVIRONMENTAL FLOWS

Rapid Environmental Flow Assessment for the Huong River Basin, Central Vietnam

Final Report, Rapid EFA Workshop

13-14 December 2004

IUCN Water and Nature Initiative

Huong River Projects Management Board

IWMI International Water Management Institute

IUCN The World Conservation Union

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Introduction and Background

There are many competing demands for water. As a result, most rivers are used in many different ways. Storages are built for a number of reasons, such as to enable water diversions and irrigation, for hydroelectricity generation, and to attempt drought and flood protection. The benefits to some stakeholders may be significant. However, these developments also alter the flow regimes of rivers with direct and indirect detrimental impacts on the rivers' ecological character and may have negative impacts on the livelihoods of people dependent on ecosystem services. For affected people, the negative impacts may relate to loss of fisheries, nutrition, health, economic loss, or social and cultural dislocation.

Many river managers, researchers, policy makers - and all river dependent people - realise that water resources development must be undertaken carefully. Such people appreciate the importance of understanding, protecting, and restoring river basin ecosystems.

An 'environmental flow' in a river basin where water flow is being regulated, refers to the water provided in an appropriate way to maintain downstream ecosystems and their benefits. Creating an environmental flow regime is an important foundation of Integrated Water Resources Management (IWRM).

IWRM needs to take into account many other issues that may be relevant to the sustainable land and water use in river basins. These other issues might include urban expansion, agricultural practices, rural incomes, dryland and/or irrigation-induced salinity, pollution control, habitat protection, and recreation.

The People's Committee of Thua Thien Hue Province in central Vietnam wants to ensure responsible management of the Huong River Basin, which takes account of the health of the ecosystem and associated social and economic benefits. It is therefore supportive of the effort to learn about environmental flows, ultimately establish an environmental flow regime, and in so doing contribute to IWRM in the Huong River Basin.

Over two-thirds of the population of Thua Thien Hue Province lives within the Huong River Basin, all of whom rely directly or indirectly on the river resources for their livelihoods and well-being. The river system also provides vital functions for many of the riparian and aquatic ecosystems supporting the rich biodiversity found in the province. The Tam Giang-Cau Hai Lagoon at the mouth of the river, one of the largest of its kind in Asia, is recognized as a particularly valuable asset and an important part of the life of its many users. However, due to geographical and meteorological conditions, flooding in the rainy season and saltwater intrusion in the dry season are major concerns which inhibit economic growth in the region. Solutions to these concerns require a multi-faceted and integrated approach.

The Environmental Flow Assessment (EFA) project in the Huong River Basin was carried out collaboratively with the Huong River Projects Management Board and the International Water Management Institute (IWMI), following extensive discussions at all levels of government in Thua Thien Hue Province and Vietnam on the development of an IWRM strategy in the province. The environmental flow initiative in the Huong River Basin was the first of its kind in Vietnam, and provided an opportunity to test internationally recognised practices locally.

The project formed a major component of the effort to promote the integrated management of the Huong River Basin such that ecosystems can continue to provide natural resources and social, cultural, and economic benefits to the people of the province. The objective of the support to Huong colleagues was to assist local water managers and users to understand the principles and practice of environmental flows, to institutionalise EFAs as a normal part of IWRM, and to build local capacity of partners to undertake such work and factor it into water resources decision-making.

Following an inception workshop in September 2003 and a planning meeting in March 2004, a rapid EFA workshop was held in Hanoi on 13-14 December 2004. Significant progress was made towards an open dialogue of perceived future impacts of dams on downstream ecosystems and communities. The workshop provided valuable training experience in EFA tools and techniques, equipping participants with a better understanding of the process for more in-depth application in the future.

Outcomes of the Rapid EFA Workshop

The two-day rapid EFA workshop was the first multidisciplinary EFA undertaken in the country, and attempted to go beyond the traditional scope of a rapid EFA by incorporating ecological assessments of hydrological scenarios. Present river conditions and issues were first discussed, including river classification and hydrological, ecological and social conditions of the river basin in general and of the assessment site in particular.

After familiarisation with the river basin and assessment site, the hydrological regime was further elaborated, identifying and distinguishing between different key elements of the flow regime (such as timing of wet and dry months and size and frequency of flood events) and their importance to ecosystems. An alternative hydrological regime scenario was estimated, based on participants' understanding of the predicted impact of dam development projects on the flow regime (and on each element within it) at the assessment site. Finally, a number of indicators were agreed upon in order to indicate the impact of changing flow conditions on the riverine ecosystem and local population that rely on the river system. These indicators ranged from geomorphology and water quality to various vegetation and fish species, in addition to a number of social indicators.

The final step was to synthesise the expert opinions of all participants into a single ecology matrix which would demonstrate the impact of the agreed-upon flow scenario on the various indicators. This matrix would then provide a tool for decision-makers to weigh the various consequences of their management decisions. Time constraints prevented the full completion of this exercise, but discussion among experts permitted an open sharing of viewpoints and opinions, and substantial headway was made in identifying possible barriers to the successful implementation of EFAs and recommendations for overcoming these barriers.

Conclusions and Recommendations

The EFA learning process was beneficial despite the scope of the work being reduced from what was originally planned by the project management team from the Huong River Projects Management Board, IUCN and IWMI. This reduction in scope was necessary to acknowledge the fact that the work that could be undertaken with the available resources would be insufficient to fully inform flow negotiations.

All participants gained valuable skills and a greater appreciation of the range of disciplines and perspectives required to inform infrastructure planning and flow negotiations. The process of developing and implementing a successful environmental flow regime depends on commitment and action from many different parts of the community, governments, user groups, and non-government groups. Negotiating within existing government structures, and developing appropriate rules, laws, and policies is essential. However, it may be necessary to also develop new and complementary forums for negotiation.

The work on environmental flows in the Huong River Basin has started, but it is far from finished. Further work in Vietnam will need to link 'water resources management *and/or* river basin management *and/or* environmental flows' issues to poverty/livelihoods and to national development priorities.

Developing a regime of environmental flows is never easy. New policy frameworks, laws, and regulations will evolve in different ways depending on the context. People committed to achieving environmental flows must be prepared for a long and sustained effort. A range of people will need to form a coalition for action to assess environmental flow needs and to provide environmental flows. Researchers and experts can only provide the technical advice and possible alternatives but politicians, decision makers and communities need to accept the need for environmental flows for it to be enacted. In an ideal situation, providing for environmental flow needs would be a dynamic process. Legislation would specify environmental flow needs, and water managers would provide those flows using a variety of techniques. A government body or river basin organization, assisted by universities and research organizations, would supply monitoring and evaluation feedback.

PART A
INTRODUCTION AND BACKGROUND

1. *Introduction*

There are many competing demands for water. As a result, most rivers are used in many different ways. Storages are built for many reasons, such as to enable water diversions and irrigation, hydroelectricity generation, and to attempt drought and flood protection. The benefits to some stakeholders may be significant. However, these developments also alter the flow regimes of rivers with direct and indirect detrimental impacts on the rivers' ecological character and may have negative impacts on the livelihoods of people dependent on ecosystem services. For affected people, the negative impacts may relate to loss of fisheries, nutrition, health, economic loss, or social and cultural dislocation.

Many river managers, researchers, policy makers-and all river dependent people-realise that water resources development must be undertaken carefully. Such people appreciate the importance of understanding, protecting, and restoring river basin ecosystems.

An 'environmental flow' in a river basin where water flow is being regulated, refers to the water provided in an appropriate way to maintain downstream ecosystems and their benefits. Creating an environmental flow regime is an important foundation of Integrated Water Resources Management (IWRM).

IWRM needs to take into account many other issues that may be relevant to the sustainable land and water use in river basins. These other issues might include urban expansion, agricultural practices, rural incomes, dryland and/or irrigation-induced salinity, pollution control, habitat protection, or recreation.

The People's Committee of Thua Thien Hue Province wants to ensure responsible management of the Huong River Basin, which takes account of the health of the ecosystem and associated social and economic benefits. It is therefore supportive of the effort to learn about environmental flows, ultimately establish an environmental flow regime, and in so doing contribute to IWRM in the Huong River Basin.

2. *The Huong River Basin*

2.1 Basin description

The Huong River is located in Thua Thien Hue Province in Central Vietnam, between 16°00' and 16°45' N (latitude) and 107°00' and 109°15' E (longitude). It is bordered on the west by the Truong Son mountains and to the north by the Bach Ma mountains. Da Nang City is found to the south, and to the east is the Dong sea. The Huong River has a basin area of 2830 km^2, representing 56% of the total area of the province. The population of the province is 1,066,200 (2000).

Figure 1: Thua Thien Hue Province

Because 71.5% of the population of Thua Thien Hue Province live within the Huong River Basin (2002), the river forms a central part of the economic and social development of the province, with many people depending it for their livelihood. Agricultural farming (including crops of rice, potatoes, cassava, ground-nut, and beans), animal husbandry (including buffalo, cattle, hogs, ducks, and poultry), shrimp aquaculture, fisheries, transportation, tourism businesses, industrial water users, and sand/gravel extractors all depend directly or indirectly on the river resources. Major urban areas of Hue City, Phu Bai, Tu Ha, and Phu Tan also depend on water extracted from the Huong River just upstream of Hue City and near Lang Tu.

The river system also provides vital functions for many of the riparian and aquatic ecosystems supporting the rich biodiversity found in the province. Protected areas within the province include the 22,031 ha Bach Ma National Park in the mountains bordering Quam Nang Province in the south, the 14,547 ha Bac Hai Van Nature Reserve along the coast in Phu Loc District, and the 41,548 ha Phong Dien Nature Reserve in the upper catchment of the Lau River.

According to a recent field survey, eighty-five fish species (including fresh water species, brackish water species, and saline water species) were identified in the Huong River Basin and Tam Giang-Cau Hai Lagoon system, five of which were identified as precious species. Of these, *Anguilla marmorata* (giant mottled eel), *Konosirus punctatus* (konoshiro gizzard shad) and *Clupanondon thrissa* (Chinese gizzard shad) are migratory species within the river system, and *Onychostoma laticeps* (no English name) and *Spinibarbus caldwelli* (no English name) live in the upstream reaches of the Huong River (JBIC, December 2003).

The same study also examined terrestrial flora and fauna on the Ta Trach River upstream of the proposed Ta Trach Dam. 465 species of plants were identified; of which 314 were medical species, 21 were species that provide essential oil, 62 were timber species, and 28 provide fruits. Among them, seven precious plant species were identified. In addition, 29 species of mammals, 126 species of birds, 13 species of reptiles, 8 species of amphibian and 156 species of insects were identified. Among them, six mammal species, one bird species, and four reptile species were identified as precious species.

The Tam Giang-Cau Hai Lagoon at the mouth of the river is recognised as a particularly valuable asset and an important part of the life of its many users. In addition to traditional capture fishing and agricultural practices in and around the lagoon, aquaculture has increased in recent years, drawing in large numbers of laborers, contributing to employment, and improving the livelihoods of local farmers. The lagoon system contains aquatic resources for capture fishing, areas of brackish water for aquaculture, anchorage sites for sea fishing boats, regional waterway transport routes, and ecosystems and landscapes suitable for tourism development (JBIC, December 2003). With an area of 22,000 ha, this coastal lagoon is one of the largest of its kind in Asia. In recent years, plans have also been put forward in Cau Hai lagoon for the creation of a wetland of international significance (in the Phong Chuong area on the northwestern part of the lagoon) under the Convention of Wetlands (Ramsar 1971) or a Marine Protected Area.

2.2 Annual flow variability

Due to geographical and meteorological conditions, the main issues associated with the Huong River Basin are flooding in the rainy season and saltwater intrusion in the dry season. The basin experiences the highest rainfall in Vietnam, with more than 5 meters of rain per year in the highlands, and up to 3 meters per year in Hue City. In addition, the river slope is very steep from its source in the mountains until it reaches the coastal area, dropping 2100 meters over approximately 80 km. Due to this sudden change in geomorphology coupled with high rainfall rates, frequent downstream flooding occurs in the rainy season. The problem has been exacerbated by the degradation of the uplands in the river basin, where timber extraction, defoliant spraying during the war, and shifting cultivation have contributed to serious erosion and increased flooding. The 1999 flood in Thua Thien Hue Province was particularly severe, at a 100 year return period. The flooding killed 373 people and caused VND 1,760 billion worth of damage in the province.

The dry season is characterized by greatly reduced flows and saltwater intrusion, jeopardizing irrigation and domestic uses of the river water. Salt water sometimes travels up-river as far as the domestic water intake for Hue city, reducing water quality in the lower reaches of the river. As aquaculture is a key focus for the future economic development of the province, water quality is extremely important, and is generally reduced during periods of low flow.

Although they are natural occurrences, annual flooding and salt-water intrusion are seen as inhibiting economic growth and wealth creation in the region.

2.3 Natural disaster mitigation and rationale

The response in previous decades to flooding and saltwater intrusion has been the construction of a number of dikes to divert floodwater and contain the river, as well as a number of dams and barriers to prevent saltwater intrusion, the most notable of which is the Thao Long Barrage. However, the magnitude of devastation resulting from the 1999 floods indicated the shortcomings of these structural approaches, and illustrated the need for the integrated management of the entire basin through structural and non-structural development and flood mitigation.

With assistance from the Government of Japan, a portfolio of non-structural and structural programs for natural disaster mitigation in the Huong River Basin was developed (see Figure 2). These include Co Bi and Ta Luong Dams on the Bo River, Binh Dien Dam on the Huu Trach River, and Ta Trach Dam on the Ta Trach River. At the time of this study, the two highest priorities in the province were the Ta Trach Dam and Binh Dien Dam (see Table 1). Controlling the floods and reducing the saltwater intrusion during the dry season form an important part of the rationale for major infrastructure developments planned.

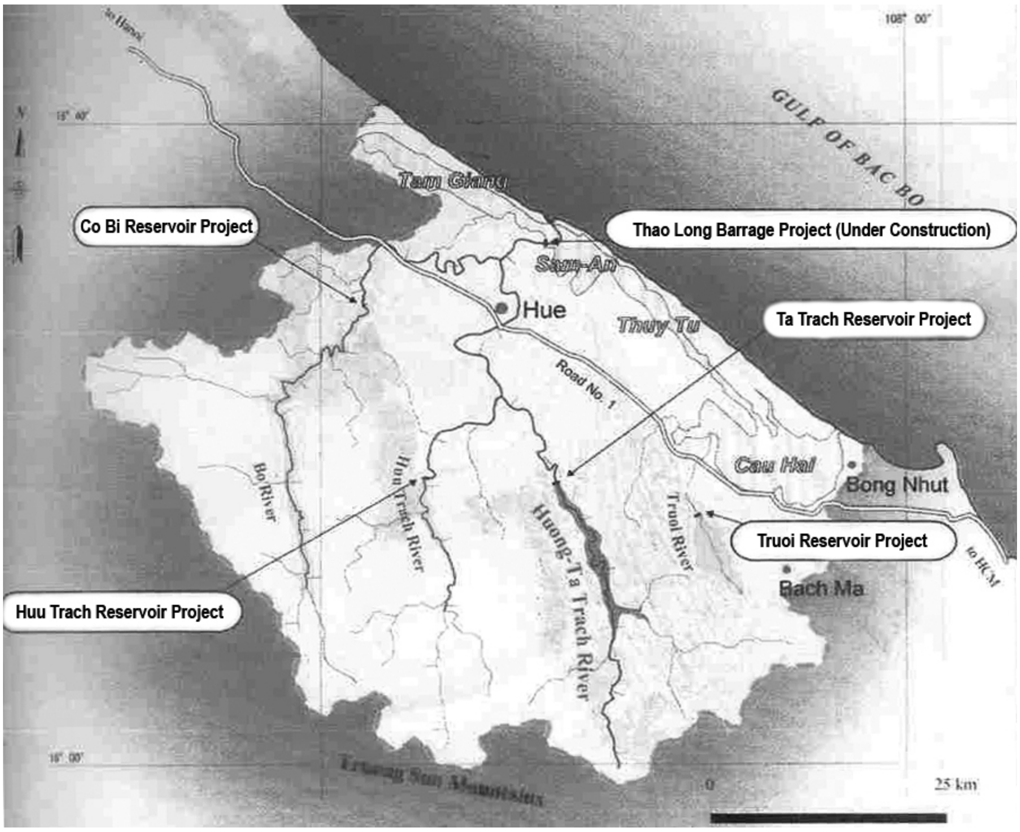


Figure 2: Proposed Reservoir Projects in the Huong River Basin
Source: JBIC, SAPROF 2 report, December 2003

Table 1: Proposed Infrastructure Development in Thua Thien Hue Province

	Ta Trach Dam[1]	Binh Dien Dam[2]
Location	Duong Hoa commune Huong Thuy district, on Ta Trach river	Binh Dien commune, Huong Tra district, on Huu Trach tributary, 23 km southwest of Hue city
Wall height	54 m (EIA) / 56 m (JBIC)	55 m
Storage volume	402 million m^3 (EIA) / 538 million m^3 (JBIC)	134 million m^3
Total capacity	533.5 - 700.8 million m^3	423.7 million m^3
Area of basin	717 km^2	515 km^2
Hydroelectric capacity	18 MW	48 MW
Estimated cost	USD 173.4 million	USD 50 million

The two proposed dams form a major part of a comprehensive management plan for the river basin under development. In addition to flood control and the prevention of saltwater intrusion, the dams are envisioned to provide water for the irrigation of 34,782 ha of land, to supplement the domestic and industrial water supply, to improve the lagoon environment and the environmental landscape, and, in the longer term, to provide power generation.

[1] Information related to the Ta Trach Dam project from the 2002 CREB EIA and the 2003 JBIC SAPROF 2 report.
[2] Information related to the Binh Dien Dam project from email correspondence, Nguyen Dinh, Huong River Projects Management Board, March 2005.

2.4 Impacts of proposed infrastructure development

Particularly in regards to the Ta Trach Dam project, a number of Environmental Impact Assessments (EIAs) and other studies have been conducted over recent years in order to weigh the consequences of such major infrastructure development on the surrounding ecosystems, populations, and economic situation.

Initial EIA

An initial EIA for the dam, completed in 2002, included a water quality analysis of the Ta Trach River, the Huong River, and the Tam Giang-Cau Hai Lagoon, in addition to a survey of flora and fauna in the submerged areas and in the neighbouring Bach Ma National Park, and a survey of the ecological features of the lagoon. Its objectives were to collect basic information on the natural environment of the impacted areas, to identify the negative impacts of the project on this environment, and to recommend solutions for minimizing these negative impacts, including suggested plans for environmental monitoring.

Conclusions were generally positive, affirming that the dam would help to mitigate the impact of floods in the immediate future and would supply water for industrial, domestic, and agricultural use. Further, the dam was said to create favourable conditions for birds and wild animals living near the water source, would improve or allow aquaculture in the area, and would improve waterway transportation for forestry teams undertaking forest protection and restoration activities. The water and electricity demand would expand production and increase employment in the province. Finally, the dam would help to protect or improve the natural environment, maintaining the stability of Thuan An and Tu Hien estuaries, protecting the Tam Giang-Cau Hai Lagoon, improving the humidity and microclimate of the surrounding areas, heightening groundwater level in the vicinity, and beautifying the landscape.

Negative aspects of the dam included the inundation of 3,418 ha of land, 622 houses, 254 graves and 15 km of road. The reservoir was also said to change the water balance, interrupting transportation and affecting the migration of some species of fish, possibly leading to the loss of these species in the system. Recommendations for mitigating these impacts and for the future management of the dam included forest protection and restoration in the basin, especially in upstream reaches; and regular environmental observation and monitoring as part of the management strategy for the dam.

SAPROF Study for Ta Trach Reservoir Project

By the time the EIA was completed, the Japan Bank for International Cooperation (JBIC) had also become involved in discussions with Vietnamese authorities. JBIC funded a two-phase study on the feasibility and impact of the Ta Trach project under their Special Assistance for Project Formulation programme (SAPROF) to supplement the work that had already been done. The first phase (SAPROF 1) began in 2002 to confirm prerequisites for implementing the project, and the second phase (SAPROF 2) to further assess the environmental and social impacts of the projects was completed in December 2003. This study also provided further project formulation support in terms of confirming the irrigation plan, supporting the plan of resettlement, and drawing up the project implementation plan.

The SAPROF 2 report included discussion on the natural environment, the social environment in downstream areas, assistance with finalizing the Resettlement Action Plan, a review of Water Use Plans (domestic, industrial, agricultural, and electric power water demand and supply plans), a review of the flood control plan, an option assessment, and finally the implementation program. Discussion on the natural environment included formation of Tam Giang-Cau Hai Lagoon system; sediment transport simulation; effects of topography on lagoons, dunes and rivers due to sediment change; effects on salinity change in the lagoon; fish fauna and aquatic ecosystems; and terrestrial flora and fauna. Discussion on the social environment included a study on key stakeholder groups, as well as assessments of impacts on fishermen in the lagoon, on residents at the mouth of the Huong River, and on gravel exploiters in the Huong River. The option assessment included a review of lessons learnt from past dam projects elsewhere, option assessments on flood control and on D/I and agricultural water use, and alternatives to the dam scheme.

Extensive findings and recommendations emerged from the SAPROF 2 report. Some main findings of direct relevance to this project can be summarized as follows:

1. Numerical simulation to characterize sediment transport dynamics found that the total amount of sediment from the Ta Trach River deposited in the lagoon will be reduced with the presence of the dam, and that only a small proportion of sand-sized or coarser sediment reaches the lagoon system, with the majority being deposited within the river reaches.

2. Changes in salinity would be limited to the area from the Thao Long Barrage to the Huong River estuary, and the area between the exit of the Tam Giang Lagoon and the north entrance of the Thuy Tu Lagoon. The changes would come from the constant supply of fresh water from the new barrage site, i.e. the ecological discharge[3] of 31 $m^3 s^{-1}$.

3. Although effects of changes in salinity would likely be minor, the gate operation rules of the barrage and Ta Trach dam should be reviewed with reference to the outputs of the IUCN study on ecological discharge for the Huong River.

4. The planned ecological discharge of 31 $m^3 s^{-1}$ is much larger than present dry season discharge, but was considered reasonable from a water quality and ecological standpoint.

5. The predicted impact of changes in sediment flow on the river and lagoon aquatic ecosystems was not considered to be significant. Sediment inflow and erosion of the riverbed after floods would both decrease.

6. The predicted impacts on riparian flora and fauna are not significant, with the submerged area primarily cultivated area, scrubs and man-made forest. Habitat fragmentation might occur, but most large animals and birds will not be significantly affected.

[3] The "ecological discharge" of 31 $m^3 s^{-1}$ originated from a preliminary project formulation study for the Ta Trach Reservoir project, and this value was adopted in the EIA report and the JICA Master Plan for the river basin. More details can be found in Section 3.2.

7. *Lutra lutra* (Eurasian otter) would be affected, especially during dam construction, due to change in habitat. However, past experience has shown that in some cases reservoirs provide improved feeding grounds to the otter. Other species impacted by loss of habitat will include *Lophura diardi* (Siamese fireback pheasant) and *Gekko gecko* (tokay gecko).

8. Because the study found that the impact on the aquatic ecosystem would not be significant, the impact on capture fishermen in the lagoons was also expected to be insignificant.

9. There are about 400 households whose livelihoods depend on the exploitation of sand and gravel in the Huong River basin. However, the annual total amount of sand and gravel exploited (between 225,000 - 300,000 m^3) is very large compared to the amount currently supplied from upstream even in the absence of a major dam (estimated at about 40,000 m^3), and impacts of the changes on sediment load as a result of the dam must be distinguished between existing anthropogenic impacts. The current gap between exploitation and amount supplied from upstream will be enlarged with the construction of the dam.

10. The Ta Trach Dam project will not fulfil flood control requirements completely without the additional construction of the Binh Dien Dam on the Huu Trach River. Complimentary measures that are necessary to further mitigate the risk of damages by flood include reliable evacuation routes (including paved roads), strengthening of public buildings and private houses, preparation of detailed hazard maps, improvement of drainage systems, installation of flood warning systems, and strengthening of community preparedness.

3. IUCN and Huong River Basin Flows

3.1 Working towards Integrated Water Resources Management

While infrastructure developments were being planned with the assistance of the Japanese Government, officials in Thua Thien Hue Province also expressed a keen interest in developing an ecosystem-based management approach to improve the long-term management and conservation of the entire basin and its water resources.

IUCN began its involvement in Thua Thien Hue Province in1999, when it collaborated with the Thua Thien Hue Department of Science, Technology and Environment (DoSTE) to develop an approach for the integrated management of the Huong River Basin and the Tam Giang-Cau Hai Lagoon. In close collaboration with DoSTE and the Lagoon Project Coordination Office (LAPROCOF), the proposal was developed through 2000, and in May 2001, a project consultation workshop was organised in Hue in which key stakeholders from the province were invited to participate. The workshop confirmed the full support from the Thua Thien Hue Provincial People's Committee (TTH-PPC). Strong support from the central government was also confirmed through the signature of the Partnership Agreement for the project during the World Summit for Sustainable Development in 2002 between the IUCN Director General and the Vice Minister of Natural Resources and Environment.

Although funding for the full project has not yet been secured, a Preparatory Phase project was commenced in 2003 in order to put into place the necessary arrangements for the development of the comprehensive Huong River Basin Integrated Management Project, and to finalise the institutional links and relationships needed for its successful start and implementation.

The main objective was to build the foundations for the full Huong River Basin Integrated Management Project, with specific objectives as follows:

- Governance structure for the full project established
- Relationships with key partners established, and their role in the full project defined
- Actions defined for the establishment of a Huong River Basin Organisation
- Field interventions identified and described on the basis of a participatory poverty assessment
- Environmental flow assessment (EFA) carried out

Specifically in regards to environmental flows, IUCN aimed to support the managers of the Huong River Basin to gain experience with environmental flows as a part of their IWRM strategy. It is envisioned that these activities will feed into and support the implementation of the full-scale Huong River Integrated Management Project. IUCN is supporting similar work in many different places around the world, in particular via the Water and Nature Initiative (WANI).

The Environmental Flow Assessment (EFA) sub-project in the Huong River Basin was carried out collaboratively with the Huong River Projects Management Board and the International Water Management Institute (IWMI), following extensive discussions at all levels of government in Thua Thien Hue Province and Vietnam on the development of an IWRM strategy in the province. As the Huong River Projects Management Board is mandated to oversee the development of water management infrastructure in the basin, it was an ideal partner for addressing an ecosystem-based approach to river basin management in the province, and indeed played a crucial role in the inception phases of the project. IWMI is a global leader in environmental flows initiatives, with extensive experience in implementing EFAs around the world. The environmental flows initiative in the Huong River Basin was the first of its kind in Vietnam, and provided an opportunity to test internationally recognized practices locally.

3.2 Gaining an understanding of environmental flows

At the beginning of this project, both the principles and practice of environmental flows were new to Vietnam, with limited awareness and understanding throughout the country. The understanding of environmental flows as indicated in project documents and environmental impact assessments was limited to the concept of a single minimum flow set through a hydrology-based formulaic process.

This single minimum flow, the "ecological discharge" of 31 $m^3 s^{-1}$, is to be released from the Thao Long Barrage, as a minimum discharge for the whole river basin into the lagoon. This value was estimated on the basis of ecological requirements and the prevention of saltwater intrusion, based on the mean dry season flow at a 95% confidence level. It has since become a dominant figure guiding the thinking of basin managers, reappearing in numerous documents, including the 'Study on Nationwide Water Resources Development and Management in the Socialist Republic of Viet Nam,' the EIA report for the Ta Trach Dam project, and the JICA Master Plan for the basin.

Such a flow recommendation does not provide the seasonal variations of a natural flow or take into account water quantity and quality. The initial understanding among stakeholders was that the environmental flows project in the Huong River Basin would seek to revise this number, but through the course of workshops and consultative meetings it became understood that the concept of environmental flows must be far more encompassing than a single number.

The project formed a major component of the effort to promote the integrated management of the Huong River Basin such that ecosystems can continue to provide natural resources and social, cultural, and economic benefits to the people of the province. The objective of the support to Huong colleagues is to assist local water managers and users to understand the principles and practice of environmental flows, to institutionalise EFAs as a normal part of IWRM, and to build local capacity of partners to undertake such work and factor it into water resources decision-making.

3.3 Background to the Environmental Flow Assessment

An initial inception meeting was held on 29-30 September 2003 to present the concept of environmental flows to a national audience (see Annex 8 for a list of participating institutions), as well as to discuss available methodologies, the necessary institutional and legal frameworks, and the priorities and scope for the assessment. Presentations were given on:

- Environmental Flows in Viet Nam (Chaminda Rajapakse, IUCN)
- The Huong River Basin (Mr Ho Ngoc Phu, Huong River Basin Planning Authority)
- Creating a policy and legal framework (Ms Vu Minh Hoa, IUCN)
- The economics of environmental flows (Ms Rina Rosales, IUCN)
- Hydrological analysis of environmental flow requirements (Dr Vladimir Smakhtin, IWMI)
- International experiences with environmental flows (Ms Rebecca Tharme, IWMI)

Final recommendations of the inception workshop were as follows:

1. It was agreed that an intermediate EFA would be carried out over a period of approximately 12 months. This would allow for 6 months preparation and 6 months to conduct the assessment.

2. The multidisciplinary team should be identified.

3. A preliminary river survey including a socioeconomic assessment should be conducted to be presented at the below mentioned workshop and planning meeting.

4. A workshop should be convened in early 2004 to clarify and discuss the intermediate approach to an environmental flow assessment. This should also be a planning meeting for the further development of the assessment.

5. A coordinating body should be set up for the assessment with the Huong River Projects Management Board as the focal point.

6. Training programmes and sessions on the multiple thematic areas should be facilitated.

7. A brief outlining the necessary legal and institutional background to be submitted to the Ministry of Natural Resources and Environment.

A planning meeting was held on 25-27 March 2004 to complete the plan for the initial Huong River Basin EFA. There were presentations on the following subjects:

- Hydrology
- Flood mapping
- Lagoon biodiversity
- Water quality
- Basin water demand (irrigation, domestic, industry, etc.)
- Aquaculture
- Socioeconomic issues
- Information and formats for data presentation required for EFA starter documents, for each of the major specialist disciplines (hydrology, water quality, fish, invertebrates, flora, geomorphology, socio-economics)

Terms of Reference were developed for ecological, hydrological and socioeconomic studies to be incorporated into the final report, provisional study sites were selected in a map-based exercise, and a field visit then allowed participants to familiarise themselves with the study area and finalize the proposed study sites.

3.4 Preparation for and summary of Rapid EFA Workshop

The Terms of Reference and associated negotiations created high expectations among all those involved that an intermediate EFA could be undertaken with the resources available. However, as the work progressed it became apparent that all parties had been a little too optimistic. The scope of the work was reassessed and it was decided that a rapid EFA was more realistic.

The aim of the third and final workshop, held in Hanoi on 13-14 December 2004, was to share the findings of the studies and to carry out a rapid EFA, in collaboration with experts from IWMI. This was to be followed by a discussion of future needs, including a likely need for a more detailed EFA for the Huong River.

Ultimately, due to time and information constraints during the workshop, completion of a full rapid EFA was not possible. However, significant progress was made towards an open dialogue of perceived future impacts of dams on downstream ecosystems and communities. The workshop provided valuable training experience in EFA tools and techniques, equipping participants with a better understanding of the process for more in-depth application in the future.

This document contains the proceedings and results of a rapid EFA workshop, for work done up to the end of 2004 in the Huong River Basin.

PART B
OUTCOMES OF THE RAPID EFA WORKSHOP

1. *Welcome and introduction*

The rapid EFA workshop was officially opened with a welcome speech from Nguyen Minh Thong, country representative from IUCN Vietnam. He was impressed by the attendance and enthusiasm of participants at this and at previous workshops on environmental flows in the Huong River Basin, and discussed the dialogue that has begun on a wider scale in Vietnam since the World Commission on Dams report released in 2000 (WCD 2000). Since then, IUCN Vietnam has been using the Huong River Basin as a pilot river basin to try to understand from a scientific point of view the relationship between dams and the river basin. He reinforced the importance of ensuring that existing and proposed dams meet not only the multipurpose goals of the stakeholders, but that ecosystem needs are met as well.

In conclusion, the rapid EFA initiative is but one step toward the larger programme of IWRM, and that through this work a network of national experts with skills relating to environmental flows could be created who could become the focal points of future projects. The goal of the meeting was thus to encourage and sustain an exchange of ideas and understanding of environmental flow methodologies.

Participants came from a diverse range of specialist fields, including hydrology, ecology, geology, socio-economics, and water resources engineering, and represented a number of organizations including universities (Hanoi Water Resources University, Hue University), government departments (Department of Agriculture and Rural Development) and agencies (Water Resources Planning Institute, Huong River Projects Management Board), and international NGOs (IUCN and International Water Management Institute)[4].

2. *Introduction to and agreement on the workshop process*

After a brief introduction by Vu Thi Minh Hoa, IUCN Vietnam's Wetland and Water Project Officer, summarizing the two prior workshops on the project, Rebecca Tharme of IWMI presented an overview of the rapid EFA processes that could be used for the assessment and led discussion following the presentation. She began by noting the key differences between rapid, intermediate, and comprehensive flow assessments, with a stress on the limitations involved in performing a rapid assessment, such as low resolution, low confidence results, lack of new field data collection, limited number of ecological specialists, limited number of river sites (focus on the mainstream river and not tributaries), and the fact that rapid assessments are most useful as a precautionary planning guide preceding more comprehensive assessments.

[4] See Annex 2 for a full list of participants.

Table 2: Rapid vs Intermediate EFAs: implications

	Desktop - Rapid	Intermediate	Comprehensive
Resources	Low	Medium	High
Time	2 days - 2 weeks	8 weeks	32 weeks
Confidence	Low	Medium	Medium/High
Resolution	Low	Medium	Medium/High
Status	Planning guide	Preliminary EFA	Full EFA

Source: R.Tharme, Draft Workshop Process for Discussion, December 2004

Two complementary methods were summarized: 1) hydrological target setting and 2) ecological assessment of hydrological scenarios. The second approach was based in part on an adapted holistic approach (e.g. Abbreviated Downstream Response to Imposed Flow Transformations process used in Zimbabwe-Steward et al., and the full DRIFT process-King *et al*. 2003).

Participants agreed that because the second method has a stronger emphasis on ecology than the first, it was a preferred method for the EFA. The steps in this method are summarized in Figure 3.

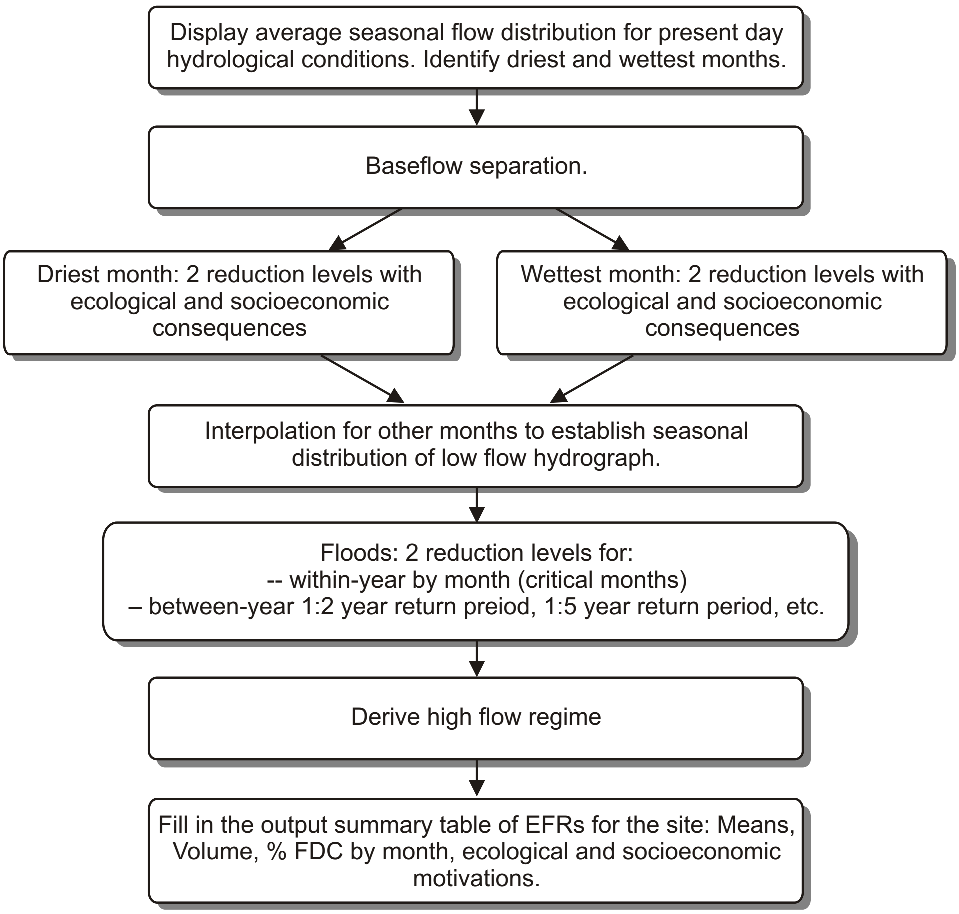


Figure 3: Adapted rapid DRIFT approach used in the Huong River EFA
Source: R.Tharme, Draft Workshop Process for Discussion, December 2004

Despite the fact that the assessment was to be limited to a rapid EFA and that only one site on the mainstream Huong would be examined, it was noted that two days was an extremely short length of time given that the approach had never been trialed before in Vietnam or elsewhere, and that it was the first multidisciplinary EFA undertaken in the country.

However, it was stressed that once the exercise was familiar to participants, it could then be applied to other systems or sites in the future as needed, and could be modified by participants to create a Vietnam-appropriate desktop planning method.

3. Present state and river condition

3.1 River classification and site selection

The first step was to classify the current state of the river. There is currently no standardised river classification system for Vietnam and no existing assessment of the current condition of the Huong River. Because various ongoing activities and development have already impacted the system, the whole river was said to be in the B category, but on a downward trajectory towards a class C river, where:

Table 3: River classification system (from King et al. 2000)

A	close to natural condition
B	largely natural with few modifications
C	moderately modified
D	largely modified
E	seriously modified; no longer providing sustainable services
F	critically modified; no longer providing sustainable services

Planned modifications to the river system include the construction of the Binh Dien and Ta Trach Dams, as summarized in Part A of this report (Table 1).

In the case of a more detailed environmental flow assessment, habitat and instream integrity are typically assessed on a reach by reach basis for the study river in order to establish the varying conditions of different sections of the river based on a range of criteria and to locate areas of concern or poor condition (King, Tharme & de Villiers 2000). At the planning meeting in March 2004, four sites were selected for the completion of an intermediate EFA, and a subsequent field trip allowed for site visits (see Annex 4 for site photos). Sites chosen for the EFA were based on the following criteria:

- One site per major river section, with consideration of major tributaries
- Representative of important conditions, uses, and users
- Easy to access and study, with hydrological and ecological research conducted already
- Useful in the context of river basin management and monitoring

Table 4: Huong River Basin EFA sites

Name	River	Location
Site 1	Ta Trach River	1 km downstream of the proposed Ta Trach Dam
Site 2	Huong River	0.3 km downstream of Van Nien water supply pumsing station
Site 3	Huong River	1 km upstream of the existing Thao Long Barrage
Site 4	Bo River	At closed Co Bi hydrologic gauge, site of proposed Co Bi Dam

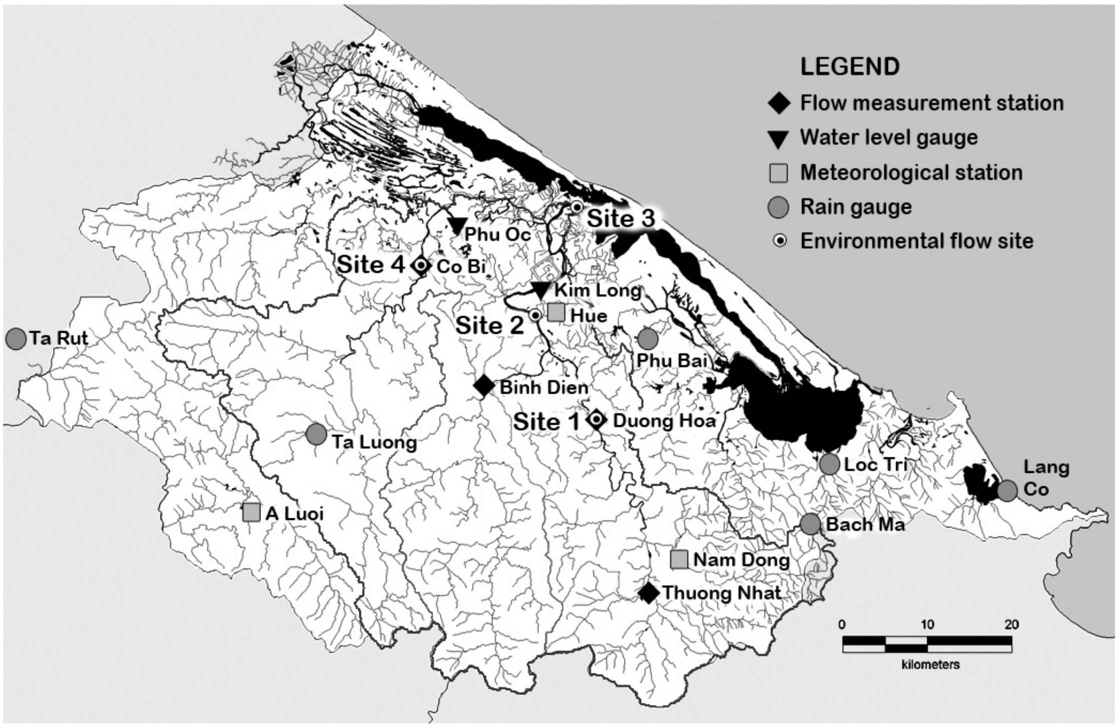


Figure 4: Site Selection in the Huong River Basin
Source: Nghiem Tien Lam, Hydrology of the Huong River Draft Report

An intermediate assessment, as originally planned, could not be completed due to budgetary limitations. Instead, the workshop focused on the completion of a rapid assessment, using only one site. Site 2 was chosen for the following reasons:

- Results will be valuable from a practical point of view, as Site 2 will be affected by Ta Trach Dam on the Ta Trach River (near Site 1 in Figure 4) and Binh Dien Dam on the Huu Trach River (Binh Dien in Figure 4)
- The site shows the interaction between ecosystems and human activity, which is less evident upstream at Site 1
- Although Site 3 had a stronger ecological database, Site 2 has some of the highest resolution and best available hydrological data from the whole basin, which are the most critical elements of a hydrology-based rapid environmental flow method

3.2 Hydrological regime

Mr. Nghiem Tien Lam, from Hanoi Water Resources University, summarized his report on the hydrological work that had been done in the Huong River Basin to date for the rapid EFA[5]. From limited flow, water level, and rainfall data at thirteen stations in the watershed over a 26-year period from September 1977 to August 2003, annual flow volumes, monthly flow distributions, daily hydrographs, and flow duration curves were generated for each of the four sites. More details about the process and hydrologic results for other sites can be found in the hydrology report in Annex 3.

[5] Nghiem Tien Lam, Hanoi 2004. Hydrology of the Huong River: Draft Report for the Rapid Environmental Flow Assessment. See Annex 3.

The results of the hydrological study showed a wet season from September through December, with the wettest month being October. The dry season occurs from January through August, with the driest month being April, and a slight increase in flows apparent during May-June. The wettest year in the study period was determined to be 1996-97, and the driest 1989-90.

In the discussion that followed, it was generally agreed that although discharges are a useful indicator of stream conditions, perhaps more useful from an ecological perspective would be a distribution of water levels at the site, which would require the establishment of a stage-discharge relationship. This was not within the scope of the assessment, but a general understanding of the relationship could be attained with the aid of river cross-sections and site photographs at different times of years, both of which exist but were not available in a useable form at the workshop. More important is an understanding of the pattern of hydrological events through the year, based on daily hydrology (key hydrological criteria for both low and high flow (flood) events; discharge magnitude; timing, frequency, duration and rate of change); for example, the number and magnitude of flood events and the range of low flow discharges in each month. These were generated by Mr Lam and his team at the Hanoi Water Resources University.

Another topic of some debate that arose from the presentation of the hydrology report was that the report showed the driest year within the study period to be 1989-1990. Local experts argued that the driest year had been 2002, when saltwater intrusion occurred up to 30 km inland. This discrepancy may be due to the means by which "dry year" is defined. Whether it is defined on the basis of annual discharge or on the basis of minimum daily or monthly flows, different conclusions may be reached. Another cause may be the source of data from which these determinations are made.

Ultimately it was decided that the choice of dry year did not affect the process, but that a more extensive database was recommended for a more complete hydrological picture in future assessments.

3.3 Ecological situation

Although a TOR was developed for an ecological assessment of the river for the EFA at the March 2004 planning meeting, a subsequent reduction in the scope of the project meant that no study was completed, and the assessment relied completely on existing data that was available for use. Dr. Ton That Phap of Hue University gave a brief presentation and led discussion on the ecology of the river, with a specific focus on Site 2.

The three predominant submerged macrophytes (plant groups) with patchy distribution at the site were identified: *Hydrilla, Potamogeton, and Valisneria*. Cyanobacteria were listed as a dominant component of the phytoplankton. Along the riverbank, the local community plants vegetables and other agricultural plants, including bamboo (a natural component of the riparian zone), maize, soybean, green beans, and taro root. Small patches of *Cyperus* grow along the river margins in places where clearing for agriculture is limited.

There are about 60 species of fish in the entire river. Although the number of species at Site 2 is unknown, there is some understanding of the species present. Regarding fish composition and abundance, there were no figures available for the site although interviews with the local community highlighted a peak in the abundance of fish in August. There are no estuarine or brackish-water fish species at Site 2; even in 2002, a dry year when salinity was high, only freshwater species were present, including carp and snakehead which are used for food by the local community. Two species of migratory eels are also present, including *Anguilla marmorata*.

Human impacts

Some areas of concern included turbidity due to road construction, the use of pesticides in the surrounding agricultural area, and elevated conductivity in severely dry years. However, the Thao Long Barrage prevents saline intrusion from being a major problem, and there has been no evidence of a reduction in fisheries.

The SAPROF 2 study on the Ta Trach Reservoir Project, funded by JBIC in 2003, was highlighted as an important intensive study on the ecological and biological resources of the river basin. This study was conducted in order to assess the environmental and social impacts of the Ta Trach Dam project, but was not publicly available at the time of the meeting and could not be used in the assessment. It was agreed that the use of the SAPROF 2 study could contribute significantly to any future ecological assessments.

3.4 Socio-economic conditions

Socio-economic conditions of the Huong River Basin

Mr. Nguyen Dinh, Vice Director of the Huong River Projects Management Board, gave participants an overview of broader socio-economic conditions in the Huong River Basin. Because the stakeholders who rely on the river for their livelihoods are diverse and numerous, it is hoped that an environmental flow assessment can provide provincial decision-makers with a tool for better planning the optimum use and distribution of the river's water according to the water demands of each sector.

The Huong River is a crucial contributor to the socio-economic development of Thua Thien Hue Province, and also a central element in environmental issues of the province. Not only does the river contribute to local agricultural and industrial development, it is also very important for tourism, and is an integral part of the UNESCO World Heritage site at Hue. Furthermore, the Huong River complex, including the surrounding landscape, has been proposed as the third World Heritage Site for Thua Thien Hue Province.

Although one cement factory and a handful of small enterprises use groundwater, all other water for agriculture, industry, and domestic use in the catchment comes directly from the Huong River Basin. Sixty-six percent of the rice planting area in Hue province lies within the watershed and relies on the river's water. Until legislation was passed about five years ago prohibiting extraction 500 m upstream and 500 m downstream of the Hue water plant, gravel and sand extraction was an important activity, and there is still considerable sand and gravel extraction from the reach at Site 2 and other locations along the river where the activity is still legal. Only very small-scale fishing activity occurs in the portion of the river around Site 2.

Socio-economic conditions at Site 2

No field-based or participatory study was undertaken prior to the workshop to provide data on the socio-economics of local people directly dependent on the river at Site 2. All information used for the assessment was therefore based on the experience and direct observation of participants, rather than on formal surveys of documented materials. Should an intermediate assessment have been done, such site-specific studies would have been a component of the assessment, as this was identified in the inception phases as a major knowledge gap.

The population in the area is not very dense, but two floating villages are located in close proximity to Site 2. Upstream of the site, at the Tuan confluence, there is a small community of about 20 boats, for which fishing and logging are the main livelihoods. The other floating village is located about 5 km downstream of the site at a major bend in the Huong River, consisting of 20-30 boats. The downstream community relies more heavily on the river for its livelihoods, using the river for fishing, transport of construction material, and sand and gravel extraction.

In addition to local communities, boats and water transport exist for tourists to sites in the immediate vicinity, including Vong Canh Hill and Hon Chen Temple. To increase the aesthetic appeal of the area, the provincial government has promoted a pine plantation project along the river and next to the tourist attractions.

Areas of concern

Areas of concern for the future include an urbanization trend, especially since the construction of a bridge in the area. The local population has increased due to good living conditions, and untreated wastewater may become a concern if demographic trends continue at the present pace. Finally, although it does not directly affect the river, granite mining occurs in the region and may have indirect impacts on the system.

4. Scenario Assessment

4.1 Low flow and flood categorization

Before determining how future dams may alter the flow regime and its subsequent impact on the river system, it was first necessary to understand the various components of the existing one, including baseflow, timing of driest and wettest months, and size and frequency of flood events. The hydrologists ran a baseflow separation procedure and determined the driest month to be April, and the wettest December, when the flood basin is saturated.

Baseflow ranges for each month were found through visual observation by overlaying hydrographs for those months from each of the years they were available, and identifying the concentrated belt of flows representing the most frequently occurring baseflow range. Due to technical complications with baseflow separation for December, October was used as the wet month for the purpose of the exercise.

It was noted that it would have been useful to have some understanding of the virgin (natural) hydrology of the Huong River. However, there was little quantitative data contributing to an understanding of how much the current hydrology of the system has departed from its natural hydrology.

(i) Dry season low flow

The dry season extends from January through August, and the range for the month of April, the driest month, was determined to be 20-60 $m^3 s^{-1}$.

(ii) Wet season low flow

The wet season extends from September through December, and the low flow for October was determined to be 30-300 $m^3 s^{-1}$, with a Q_{80} of 70 $m^3 s^{-1}$ (discharge equalled or exceeded 80% of the time).

(iii) Intra-annual floods and dry season freshes

In a typical intermediate or comprehensive EFA, flood events would be separated into a number of classes, depending on the level of hydrological detail required. Although the majority of desktop rapid assessments use a far simpler breakdown of hydrological information, for this exercise, two intra annual flood classes were established for the wet season (Sept-Dec), and one class representing freshes (small increases in flow above low flows, in the order of at least twice low flow) for the dry season fresh (May-June):

Table 5: Flood classification system

Class of Flood	I	II	III
Months of occurrence	Sept-Dec (4 months)	Sept-Dec (4 months)	May-June (2 months)
Magnitude ($m^3 s^{-1}$)	300-1200	1200-2100	70-450
Number of events recorded in 26-year period	~ 90	34	82
Approximate frequency of event	~ 1 per month	~ 1 per two months	~ 2 per month (~ 3.5 per year)

(iv) Inter-annual floods

Inter-annual, large floods do not occur every year. Emphasis was placed on the 1:2 year flood, determined to be 2100 $m^3 s^{-1}$, and the 1:5 year flood, determined to be 3000 $m^3 s^{-1}$. Higher return period floods were not considered, primarily because it is unlikely that the proposed dams for the Huong River would be able to store them.

It was necessary to identify the various elements of the flow regime because each element may be a critical component to the general health of the river system. Table 6 outlines some of the known functions that the different elements of the flow regime may contribute to the river system and associated ecosystems.

Table 6: Importance to ecosystem of various elements of the flow regime

Element of flow regime	Importance to ecosystem functioning
Low flows	Normal flows in river outside of floods: • maintain basic perennial character, determining which animals/plants can inhabit system • variable magnitudes in dry and wet seasons provide different amounts of wetted habitat • create dynamic hydraulic and chemical conditions, which directly influence species composition
Lager floods (1:2 to 1:20)	Lager floods occur less frequently than once a year: • dictate general geomorphological character of channel • mobilize sediments and deposit silt, nutrients and seeds on floodplains • scour estuaries • maintain soil moisture level in banks supporting trees/shrubs • prevent dominance of riparian vegetation by any one species • trigger emergence of aquatic insect adults which provide food for other biota
Small floods (within-year wet & dry seasons)	Small floods occur several times within a year and contribute to flow variability • stimulate fish spawning • flush out poor quality water • mobilize sandy sediments • re-set wide spectrum of river conditions • trigger fish migration • stimulate germination of riparian seedling
Flow variability	Flow variability, on a daily, seasonal or annual basic, acts as form of natural disturbance • maintains biological diversity through increasing heterogeneity and dynamics of physical habitats • controls balance of species, preventing dominance by pest species • dictates width of vegetation belt protecting banks against erosion

Source: R.Tharme, Draft Workshop Process for Discussion, December 2004

4.2 Establishment of future project-based flow scenarios

After obtaining a general understanding of present hydrological, ecological, and socio-economic conditions of the river basin, and Site 2 in particular, it was then necessary to determine how the flow regime might be affected in the future and to establish one or more water resource project-based flow scenarios for a top-down assessment of their ecological and socio-economic implications. In this case, it was understood that the construction of two planned facilities the Binh Dien Dam and the Ta Trach Dam would alter the flow regime of the downstream river. Three scenarios had initially been discussed: 1) Present day; 2) Binh Dien Dam; and 3) Binh Dien Dam and Ta Trach Dam.

It was agreed to limit discussion to the most immediate possible scenario. Binh Dien Dam is planned to be completed before Ta Trach Dam, so the second scenario was chosen to be the focus of the assessment.

It was not well understood how the presence of the dam would ultimately affect the downstream hydrological regime, and although some participants had experience with the proposed dam projects, no data were available from which to draw conclusions with any certainty, and conclusive agreement among experts could not be reached. Estimates ranged from a 20-100% increase in downstream dry season flow, and the only unanimous opinion expressed was that the dry season flows would increase. This was a critical problem, as the determination of the flow scenario is a key step in the assessment process, upon which the assessment is fundamentally based.

A further complication was that a hydropower plant is proposed at Binh Dien Dam, meaning that daily discharge fluctuations could be significant in the future. Rapid changes in discharge would detrimentally affect instream habitats and biota, for example, by stranding organisms when the channel dried out. Rapid dewatering and rewatering of the channel could also have significant impact on downstream ecosystems and livelihoods, even if required total daily or monthly flows are maintained.

It was agreed that an accurate estimate of flow change was impossible, given the data available to the group at the time and the uncertainty about how the hydropower plant is to be operated. For the purpose of completing the exercise with a limited level of confidence in the possible extent of future regime change, it was decided that dry season low flows would increase by 50%, while wet season low flows would decrease by 50%. Any possible additional impacts of the hydropower project were not considered. It was agreed that the confidence in these results would have to be extremely low, however, until the assessment could be repeated with more reliable estimates of the degree and direction of flow change at different times of the year.

It was noted that there was a change in flow already underway in the river system. As the river is in Class B, moving toward Class C, changes to river character were already evident even under the short period for which data exist. Participants agreed that generally, the dry season is now drier than it was previously under more natural conditions. In addition, the number and magnitude of floods appears to have increased. Finally, although the duration of the dry and wet seasons has not changed, the occurrence of flood events has shifted from ten days to half a month later. Considerations of how this may affect river ecology and hence, the environmental flows were deemed to be outside the scope of the workshop, but should be kept in mind in future assessments.

4.3 Discussion of scenario implications at Site 2

After the flow scenario was established, participants tried to assess through general discussion what this would mean for the flow regime at Site 2. The Binh Dien Dam was said to have the capacity to eliminate all or most of the floods up to 600 $m^3 s^{-1}$, so with the proposed dam scenario all floods below this level would be lost. The elimination of higher flows would include all dry season freshes, which fall in the 70-450 $m^3 s^{-1}$ discharge range. For the inter-annual (larger magnitude) floods, the impact would be smaller. Two possible inter-annual flood-specific scenarios were discussed: (1) that the number of events above 600 $m^3 s^{-1}$ would decrease somewhat - i.e. 25% reduction in number of flood events; and (2) that the frequency of large floods would not be affected but their flood peaks would be reduced by 600 $m^3 s^{-1}$. It was felt that the latter scenario was more likely to be realistic, but insufficient data about the dam were available to make any definitive conclusions. After some discussion, it was agreed that the 1:2 y and 1:5 y floods would be very slightly affected-if at all-by the presence of the dam.

Ultimately, due to a lack of precise knowledge and low confidence about the future impact and operation of Binh Dien Dam, the following simplified scenario was assessed:

Huong River Rapid EFA Flow Scenario

Dry Season Low flow:	50% increase
Wet Season Low flow:	50% decrease
Dry Season Freshes:	Class III: flood events entirely eliminated
Intra-annual Floods:	Class I: number of flood events halved
	Class II: number of flood events halved
Inter-annual (Large) Floods:	Not affected

It was generally agreed that this scenario was adequate for a rapid EFA, but that a very low confidence level would be associated with the results because of the substantial professional judgements involved. More time and knowledge would be needed to raise the confidence of the results through future assessments.

4.4 Indicator selection and preparation of ecology matrix

On the first night of the meeting, participants identified a number of key indicators (i.e. ecosystem components/items) that could be used to best indicate the impact of changing flow conditions on the riverine ecosystem and local population that rely on the river system (see Table 7).

In order to start thinking in terms of necessary seasonal conditions for sustaining the current ecology of the system, participants were handed blank Ecology periodicity charts that they had prepared, listing the various indicators and allowing brainstorming about necessary month-by-month conditions for each one (see Annex 5).

The next step was to attempt to synthesize the expert opinions of all participants into a single ecology matrix which would demonstrate the impact of the flow scenario on the various indicators. Time constraints prevented the full completion of this exercise, but the ecology matrix can be seen in Annex 6, with explanatory notes in Annex 7.

The following sections document the discussion on the impacts of the modified flow regime on the agreed indicators, which contributed to the completion of the ecology matrix (For the full ecology matrix, see Annex 6. Flow element-specific sections of the ecology matrix can be found in Section 6). Section 5 discusses each indicator and how it will be affected by the changes in each element of the flow regime. Section 6 briefly summarizes the impacts of each element of the modified flow regime (dry season low flow, wet season low flow, floods, etc.), and includes a brief discussion on freshes (category III floods), which were not included in the final ecology matrix due to time constraints.

Table 7: Indicators for each ecological component considered in the scenario

Geomorphology	• Proportion of substratum comprising sand and gravel • Degree of bank erosion • Presence of sand banks and islands
Instream vegetation	• Macrophytes • Phytoplankton
Riparian vegetation	• *Cyperus* and grasses (wet bank) 'Wild pineapple' (midbank - lower shrub zone) • Bambooforest(outer riparian zone)
Invertebrate Assemblages	
Fish species	• Freshwater species: carp,snackehead ('caloc'), hemicultur ('ca muong') • *Anguilla marmorata* (eel)
General water quality	
Groundwater level near river channel	
Socio-economic and other	• Riparian vegetable cultivation • Scenic and tourism value • Navigation of local community boays and floating villages • In-channel locations for floating villages

5. Ecological discussion of flow regime impact on indicators

5.1 Geomorphology

Sand and gravel

This indicator focuses on the proportion of sand and gravel, important both as physical habitat and as a source of income for people. Manual sand and gravel extraction is a key activity and source of income for floating villages. There is an over-exploitation situation throughout the river system at present, despite laws prohibiting this practice 500 m on either side of the water uptake.

The impact of changes in flow on sand and gravel drew mixed reactions and little consensus. Predicted impacts of an increase in April (dry season) low flow ranged from no change to a slight increase in sand and gravel. Likewise, the decrease in October (wet season) low flow also caused disagreement. Some participants argued that the amount of sand and gravel would decrease, as the carrying capacity of the river would diminish and sediment would become trapped in the reservoir. Others argued that sand and gravel would increase due to the settling out of particles in the decreased flow. The same was true of the impacts on the reductions in frequency of Category I and II floods. Discussion generally had a strong focus on the ability of the reservoir to trap gravel, and disagreement as to whether decreased flows would cause settling and thus an increase in sand and gravel, or would prevent sand and gravel transport, thus decreasing sand and gravel at the site, and vice versa. Results for this indicator were therefore of extremely low confidence, and in light of these complications it may not be a useful indicator in future EFAs where no prior geomorphological data exist.

Ecological implications for a change in amount and proportions of sand and gravel included a loss or change in habitat availability and quality. Social implications included a loss in livelihoods in the case that sand and gravel were to decrease, and the converse with increased fine sediments.

Bank erosion

Participants stated that velocity needed to be between 0.5 and 2.0 m s^{-1} to cause erosion (a negative phenomenon from an ecological standpoint), which was not reached in the dry season, even with a 50% increase in low flow. A 50% decrease in low flow in the wet season was determined to have a minor positive impact, causing a decrease in erosion, but it was acknowledged that low flows have limited erosive impact in the first place (the erosive impacts of floods are generally more important). It was agreed that fewer category I and II floods would cause decreased erosion.

Ecological implications of changes in erosion included a changed physical structure of the river and loss of habitats. Socially, erosion impacts those communities that use the riverbank for cultivation. Decreased erosion in the wet season was seen to thus have a positive social impact.

Sand bank and island formation

Sand banks form above and below the water surface as a result of sediment accumulation, and this category included those areas of sand that may have been apparent above the surface of the water as islands. The April (dry season) increase in low flow was seen to result in a decrease in sand banks, whereas the October (wet season) decrease in low flow was seen to result in an increase in the number of sand banks. Likewise, reduced category I and II floods would result in a local increase in sand banks. It should be noted that this impact was site specific: for April, it was argued that at Site 1 (downstream of the dam) sand banks would decrease, but at Site 3 (upstream of the dam) sand banks would decrease due to the accumulation of sediment right above the dam. There was a general lack of consensus in discussions about the definitions and locations of the sand banks being discussed, which led to low confidence results.

Ecological implications of changing sand bank formations included a change in habitat, with the magnitude of these implications dependent on the magnitude of the change.

Social implications of the changing sand bank formation were very uncertain. Participants felt there would be a small positive impact in the April low flow increase (and subsequent decrease in sand banks), and a small negative impact in the reduction of category II floods (and subsequent increase in sand banks). The social impacts of the remaining flow elements were not discussed, as too little consensus existed in general in the discussion of sand bank and island formation.

Channel maintenance

It was generally agreed that April (dry season) low flows were too low to affect channel maintenance, but that a decrease in October (wet season) low flows might have a negative impact. However, floods are generally the most important component of channel maintenance, through the recharging of dynamics of sand banks, as well as nutrient and sediment transport. It was agreed that the removal of 50% of category I and II floods would have the largest impact on channel maintenance, but there was disagreement as to the severity of the impact, possibly due to a lack of understanding of how floods impact channel maintenance and their importance in that respect.

Social implications in changed channel maintenance included a possible impact on navigation of local fisher and village boats. In addition, reduced channel maintenance reduces the size of the channel and renders it vulnerable to large floods that then completely alter the channel characteristics, for instance causing rivers to flow around bridges, and to split and flow outside of their former channels.

5.2 Instream Vegetation

Macrophytes - Community species composition

Dominant genera are *Hydrilla*, *Potamogeton*, and *Valisneria*. The community species composition of macrophytes depends in part on individual species tolerance for current velocity, and changes in composition with changes in flow can be estimated based on knowledge of hydraulic preferences of species and on plant morphology.

An increase in April (dry season) low flows would encourage submerged vegetation to develop and possibly new species to appear, favoring species with long leaves and higher velocity species such as *Valisneria*. It was generally agreed that species composition would shift, but that the shift would not necessarily lead to an increase in biomass. On the other hand, participants felt that a decrease in October (wet season) low flows would lead to an increase in the abundance and density of macrophytes. Likewise, a reduction in category I and II floods would mean fewer floods to flush out the macrophytes in the wet season, contributing to their increased abundance and density.

Ecological implications of a change in community species composition included a change of habitat for juvenile fish, shrimp, larval insects, and other species. A shift in the availability of food for other parts of the ecosystem is likely to occur, as macrophytes take up nutrients in the water and release them when they die. In addition, an increase in macrophyte populations may lead to anoxic conditions in some areas. Social implications were unclear, as it was unknown whether local communities use macrophytes for fertilizer or other purposes. However, an increase in macrophyte density may have a negative impact on navigation.

Phytoplankton

1. *Community dynamics*

Velocity was considered to be the main factor affecting phytoplankton community dynamics, in which low velocities are generally preferred for phytoplankton development. Phytoplankton begins to develop during the rainy season, 20 to 30 days after flooding occurs. Cold water triggers the increased density of different species.

An increase in April (dry season) low flows would cause the number of phytoplankton species to decrease, in turn causing an increase in light penetration and thus an increase in benthic invertebrates. A decrease in October (wet season) low flows may cause an increase in phytoplankton, but the extent was unknown. The removal of the flushing effect of category I and II floods would contribute to this increase, as it would increase the time available for phytoplankton development between flood events.

A decrease in phytoplankton in the dry season would have a negative impact on fish, zooplankton and the rest of the food chain due to a decrease in the availability of food. An increase in phytoplankton during the wet season may have both positive and negative ecological implications. Some increase in abundance would be positive, as it would increase the food source for fish and zooplankton. However, there is a risk of the development of phytoplankton blooms, which would have a negative impact, both ecologically and socially. Social implications of a decrease in phytoplankton in the dry season may be positive due to a slight increase in water quality. On the other hand, increased phytoplankton in the wet season would cause deterioration in water quality, especially if blooms develop.

2. *Microcystis spp. (toxic phytoplankton)*

Microcystis is a toxic group of phytoplankton present in the system. It was generally agreed that changes in the flow regime would affect the *Microcystis* in much the same way as it affects other phytoplankton communities, as described above. An increase in toxic algae such as *Microcystis* would have negative implications, both ecologically and socially, especially if it reached bloom proportions.

5.3 Riparian Vegetation

Wild pineapple

Wild pineapple is found mid-bank, in the lower shrub zone. As a botanist was not present in the group, the impact of a change in flow regime on wild pineapple populations was generally unknown and left to speculation, thus resulting in very low confidence in the results.

Local communities use the wild pineapple to protect and stabilize the riverbank, and its fruit is used for medicinal purposes for kidney ailments, thus the presence of wild pineapple is important. Ecological implications of a possible change in wild pineapple abundance and location were unknown. Although the exact flooding requirements of the plants were unknown, it was assumed that a reduction in floods and in wet season low flow would reduce nutrient transport, flushing, dispersal of seeds, and regrowth stimulation to the lower shrub zone, thus having negative ecological repercussions.

***Cyperus* and grasses**

Cyperus spp. and grasses are found in the wet bank. It was agreed that floral species composition would change significantly with a change in the flow regime, but the exact form of the change was unclear. One opinion was that an increase in April (dry season) low flow would result in the loss of some of the wet bank, whereas another opinion was that the wet bank would widen. Some thought that the *Cyperus* and grass populations would move higher up the bank, and others thought that the species composition would change. Ultimately, the impact of an increase in flow was completely unknown, thus it was impossible to determine definitive ecological or social implications.

Likewise, there was little confidence in the impact of a decrease in October (wet season) flows and floods. It was agreed that a decrease in wet season low flows would lead to an increase in *Cyperus* extent and spread. However, although it was agreed that a reduction in floods would prevent the system and nutrients from naturally resetting as often as it would naturally, it was not clear how this would affect the *Cyperus* band as compared to other components of the wet bank ecosystem, and what the ultimate ecological and social implications would be.

Bamboo forest - outer riparian zone

Bamboo forests are found in the outer riparian zone on the top of river banks, and are linked to large floods which supply them with water and nutrients. Bamboo is also an important economic resource for local communities.

Because the bamboo forests are located at the top of banks, it was agreed that even if April (dry season) low flows were to increase, the water would not reach or affect the bamboo forests, thus having no ecological or social implications. Similarly, a decrease in October (wet season) low flows and category I floods would not have an impact on these populations.

Category II floods were identified as the only floods that carry river water to the outer riparian zone. After some discussion, it was agreed that bamboo was perhaps not the best indicator for this zone, as it is less linked to flow than other plant species found along the tops of the banks. Participants noted that there exist some fruit-bearing trees in the outer riparian zone which rely on the river for water, seed dispersal, and nutrients. A reduction in category II floods would cause the loss of some of these trees, which may be important to local populations as sources of construction material, fuel wood, and food. More data and research would be required to determine exactly what species are present, which would be appropriate indicators for the outer riparian zone, the importance of flooding to their survival, and if and how they are used by local communities.

5.4 Invertebrates

Knowledge among participants and available data at the workshop about invertebrate populations and composition at Site 2 was not adequate to assess the indicator in this meeting, except in a very general way. Future flow assessments should include local experts in this field, as well as site-specific data on invertebrates in the basin.

5.5 Fish

Freshwater spp.

Carp (*Cyprinus*), snakehead ('ca loc'), and hemicultur ('ca muong') were identified as freshwater species that are present at Site 2 and part of the local diet. Due to time constraints, these three species were considered as a group in the ecological assessment.

However, in future flow assessments it may prove worthwhile to consider them separately, as they may each have unique flow requirements and the timing of key points in their life cycles may be different. It was acknowledged that at present, participants had very limited knowledge about the life histories of the freshwater fish present and how they link to flow. Since so little was known about spawning, breeding, etc, it was difficult to determine the impact or magnitude of impact of a change in flow regime on freshwater fish populations, and as a result, conclusions drawn had very low confidence.

An increase in April (dry season) low flows may lead to a slight increase in freshwater fish numbers, and the composition of the fish species may change, with slow velocity or standing water fish reducing in quantity, while higher velocity tolerant species were favored. A decrease in October (wet season) low flow would likely result in a loss of wet season habitat for freshwater fish species. Similarly, category I and II floods provide fish an opportunity to enter natural floodplain habitats, as well as rice fields, ponds, etc, and the removal of some of these floods would likely have a negative impact on freshwater fish populations.

Socially, a decrease or change in composition in freshwater fish populations would have a negative impact, especially on those species on which local communities rely for food and/or income.

Brackish water spp.

No brackish water species are believed to be found at Site 2 in its current condition. The time of year they are most likely to appear is in the dry season, when the water may become slightly brackish. Participants agreed that an increase in April (dry season) low flow would reduce any brackishness that exists at the site, reducing the likelihood that brackish water species are present. Ecological and social implications were not deemed to be significant, however, as these species are not often present, and local communities do not rely on brackish water species for food or other uses in the river reach. During the wet season, there are no brackish water species at the site, and the decrease in low flow and in category I and II floods will not be substantial enough to allow for upstream movement of brackish water species.

Although not important at Site 2, this indicator may be much more important at other assessment sites where brackish water species are known to exist.

***Anguilla marmorata* and other eels**

At least two catadromous eel species are present, one of which was identified as *Anguilla marmorata*. Although precise migration patterns could not be identified at the meeting, it was generally agreed that from April to June eggs are laid in the marine environment, and from August to September, larvae move to the estuary.

Because it was agreed that eels are found in the marine environment in April, they are unlikely to be at Site 2 at the time when an increase in dry season low flows is expected to occur - so the impact on them was expected to be minimal. If anything, it may aid downstream migration. However, the impact was expected to be larger in October, when the eels are migrating upstream. Eels sometimes use higher velocities to help with upstream movement, so lower wet season low flows may impede this migration. Social implications of the impediment of upstream migration may be slightly positive, as it would be easier for local communities to catch eels.

The impact of a decrease in the number of category I and II floods on eels was unknown. Some negative impact was expected, but it was unclear exactly how these populations would be affected. Although it is known that floods aid the downstream migration of other fish species, their role on the migratory patterns and life cycles of eels was unclear.

5.6 Water Quality

Water quality indicators include nutrients (phosphate, nitrate, etc.), temperature, turbidity, COD/BOD/oxygen, conductivity, and pesticides. Due to time constraints, all water quality indicators were considered together as a group, under the general heading "general water quality." More comprehensive future assessments might consider each water quality indicator separately.

An increase in April (dry season) low flow should generally improve water quality, which may mitigate some of the negative impacts of wastes from the floating villages and pollution from nearby human communities, thus carrying positive implications for ecology and society alike. Just as an increase in flow during the dry season would improve water quality, a decrease in low flow in the wet season will cause a decrease in water quality, with negative ecological and social implications, although the extent of deterioration was unclear. The decrease in frequency of category I and II floods would also have negative ecological and social implications, with increased likelihood of phytoplankton blooms, *Microcystis*, increased turbidity and organics, and less opportunity for the flushing of the system.

5.7 Groundwater level near river

Participants agreed that an increase in low flow in the dry season would likely cause a rise in groundwater level during the dry season, and, similarly, a decrease in low flow in the wet season would likely cause a decrease in groundwater level during the wet season, relative to natural conditions. Since floods were seen to be a major source of groundwater recharge near the river, a decrease in frequency of category I and II floods was seen to cause a subsequent decrease in groundwater supplies.

Ecologically, groundwater is important for riparian vegetation. Socially, groundwater is an important source of drinking water. Thus, an increase in groundwater in the dry season was seen to have positive ecological and social implications, and the decrease in groundwater during the wet season was seen to have negative ecological and social implications.

5.8 Social and Other

Ecological implications of social and other indicators were not examined, due to time and knowledge constraints (no expert present, no site-specific data available). The following summarizes the broad discussion on social impacts of the changed flow regime scenario.

Riparian vegetable cultivation

Riparian vegetable cultivation is a traditional practice of local communities, linked closely to the flood patterns of the river. Participants agreed that dry season riparian vegetable cultivation was likely to increase with an increase in low flow. Although the area under cultivation is likely to diminish, the increase in water and moisture and nutrient transport would likely be beneficial for dry season cultivation.

The impact on wet season cultivation drew a more mixed response, due to competition between two opposite impacts. On one hand, decreased wet season low flows would cause water levels to decrease, increasing available cultivation area. On the other hand, reduced flow would also reduce the silts, nutrient, and water delivery to cultivated areas, thus negatively impacting cultivation. The net impact of these two factors was unclear.

Similarly, the decreased frequency of category I and II floods produced mixed responses. Floods are necessary to bring nutrients, clear bank debris (and transfer inputs into the river), and bring new soil. On the other hand, less frequent flooding would cause less bank disturbance, increasing opportunities for cultivation.

Scenic value for tourism

Participants agreed that scenic value would improve moderately with increased dry season low flow, and decrease slightly with decreased wet season low flow. In discussion, the impact on scenic value for the decrease in category I floods differed from that of category II floods. Participants argued that a decrease in category I (smaller, more frequent) floods would decrease water quality, but that this negative impact would be outweighed by the positive impact of decreased destruction along the riverbanks. On the other hand, participants felt that a reduction in category II (larger, less frequent) floods would cause a substantial decrease in water quality, which, in addition to decreased channel maintenance and lower water levels, would have a negative impact on the area's scenic value.

Navigation of local boats

Navigation of local boats is important for such activities as the transport of natural resources, gravel, and other materials to and from floating villages. As agreed when discussing sand banks, participants agreed that navigation would improve in the dry season when low flows were to increase, causing fewer sand banks and increased erosion. The opposite would be true in the wet season, when low flows and flood frequency decrease, causing an increase in algae and other plants in the water.

In-channel locations for floating villages

Participants agreed that an increase in dry season low flow and a decrease in wet season low flow would have very little impact on the in-channel locations of the floating villages, although there may be a slight increase or decrease in space for their boats, depending on the season. It was generally felt that fewer floods would have a positive impact on the floating villages because they would be washed out less frequently.

6. Key conclusions of the assessment

6.1 April (dry season) low flow

Table 8: Ecology matrix for April (dry season) low flow- 50% increase in flows

INDICATOR	INDIC	ECO	SOC	Confidence Rating
GEOMORPHOLOGY				
Proportion of sand and gravel	0/+1	-1	-1	*0*
Bank erosion	0/+1	-1	-1	*1*
Formation of sand banks	-1	-1	+1	*1*
Channel maintenance	0	NA	NA	*2*
INSTREAM VEGETATION				
Macrophytes				
Community species compositon	+1	-3	NK	*2*
Phytoplankton				
Community dynamics	-4	-4	+1	*2*
Microcystis spp.	-3	+1	+3	*2*
RIPARIAN VEGETATION				
'Wild pineapple' (midbank)	+1	+1	+2	*0*
Cyperus and grasses (wet bank)	NK	NA	NA	*0*
Bamboo forest (top of bank)	0	NA	NA	*2*

INDICATOR	INDIC	ECO	SOC	Confidence Rating
INVERTEBRATES		NA		
FISH				
Freshwater spp.	+2	+2	+3	*1*
Brackish water spp.	+1	-3	0	*2*
Anguilla marmorata	0	NA	NA	*2*
WATER QUALITY				
General water quality	+4	+4	+4	*2*
GROUNDWATER				
Groundwater level near river	+3	+3	+4/5	*2*
SOCIAL AND OTHER				
Riparian vegetable cultivation	NA	NA	+1	*1*
Scenic value for tourism	NA	NA	+3	*2*
Navigation of local boats	NA	NA	+3	*2*
Floating village location	NA	NA	+1	*1*

(see Annex 7 for explanatory notes of ecology matrix)

As summarized in Table 8, an increase in April (dry season) low flows was deemed to impact both macrophytes and phytoplankton, altering the community species composition and possibly the density of the plants, increasing macrophyte density and decreasing phytoplankton density (medium confidence). This in turn would alter the food availability and instream habitat of fish, crustaceans such as shrimp, larval insects, and other species. Freshwater fish species composition would be likely to change, with a shift to species favoring higher velocities. The likelihood of the presence of brackish water fish species would be increased, although participants agreed that in current conditions brackish water fish do not appear at EFA Site 2. Increased flows would probably generally improve water quality and increase dry season groundwater levels, both having positive ecological and social impacts. All four social indicators would likely benefit from an increase in dry season low flows, with improved riparian vegetable cultivation, scenic value, navigation, and more space and greater water depth for floating villages, in addition to the benefits of improved water quality.

6.2 October (wet season) low flow

Table 9: Ecology matrix for October (wet season) low flow - 50% decrease in flows

INDICATOR	INDIC	ECO	SOC	Confidence Rating
GEOMORPHOLOGY				
Proportion of sand and gravel	+1/-1	-2	-2	*0*
Bank erosion	-1	-1	+3	*1*
Formation of sand banks	+1	-1	-2	*0*
Channel maintenance	-2	-2	-3	*0*
INSTREAM VEGETATION				
Macrophytes				
Community species compositon	+3	-3	-1	*1*
Phytoplankton				
Community dynamics	+1	+1	-1	*1*
Microcystis spp.	+1	-1	-1	*1*
RIPARIAN VEGETATION				
'Wild pineapple' (midbank)	0	NA	NA	*0*
Cyperus and grasses (wet bank)	+2	NK	0	*1*
Bamboo forest (top of bank)	0	NA	NA	*1*

INDICATOR	INDIC	ECO	SOC	Confidence Rating
INVERTEBRATES		NA		
FISH				
Freshwater spp.	-2	-2	-2	*0*
Brackish water spp.	0	NA	NA	*1*
Anguilla marmorata	-2	-2	+1	*0*
WATER QUALITY				
General water quality	-3	-3	-2	*1*
GROUNDWATER				
Groundwater level near river	-1	-1	-1	*1*
SOCIAL AND OTHER				
Riparian vegetable cultivation	NA	NA	+3	*1*
Scenic value for tourism	NA	NA	-1	*1*
Navigation of local boats	NA	NA	-1	*1*
Floating village location	NA	NA	-1	*1*

(see Annex 7 for explanatory notes of ecology matrix)

As summarized in Table 9, a decrease in October (wet season) low flows would lead to an increase in the abundance and density of macrophytes and phytoplankton (low confidence), with negative ecological and social implications if this increase is substantial. The extent and density of *Cyperus* would likely increase. Wet season habitat availability and suitability for freshwater fish would likely decrease, and the upstream migration of migratory eels migh be impeded, with negative ecological and social consequences. Water quality and groundwater levels near the river channel are both likely to decrease as compared with natural conditions. Finally, with the exception of riparian vegetable cultivation, social indicators would be slightly negatively affected, due to decreased scenic value of the river, decreased water quality (this is especially critical to those communities living directly on the river or relying on local fisheries), and difficulty in navigation due to an increase in floral biomass in the system.

6.3 Intra-annual floods - Category I

Table 10: Ecology matrix for intra-annual floods, category I- 50% decrease in number of flood events

INDICATOR	INDIC	ECO	SOC	*Confid ence Rating*
GEOMORPHOLOGY				
Proportion of sand and gravel	+2/-2	-3	-3	*0*
Bank erosion	-3	-3	+3	*1*
Formation of sand banks	+1	-1	-1	*0*
Channel maintenance	-2	-2	-1	*1*
INSTREAM VEGETATION				
Macrophytes				
Community species compositon	+2	-2	-1	*1*
Phytoplankton				
Community dynamics	+2	+1	+1	*1*
Microcystis spp.	+2	-1	-2	*1*
RIPARIAN VEGETATION				
'Wild pineapple' (midbank)	-2	-2	-1	*1*
Cyperus and grasses (wet bank)	-3	-3	0	*0*
Bamboo forest (top of bank)	-1	-1	0	*1*

INDICATOR	INDIC	ECO	SOC	*Confid ence Rating*
INVERTEBRATES		NA		
FISH				
Freshwater spp.	-3	-3	-3	*1*
Brackish water spp.	0	NA	NA	*1*
Anguilla marmorata	NK	-2	-2	*0*
WATER QUALITY				
General water quality	-3	-3	-3	*1*
GROUNDWATER				
Groundwater level near river	-3	-3	-4	*1*
SOCIAL AND OTHER				
Riparian vegetable cultivation	NA	NA	-3	*0*
Scenic value for tourism	NA	NA	+3	*1*
Navigation of local boats	NA	NA	-3	*1*
Floating village location	NA	NA	+3	*1*

(See Annex 7 for explanatory notes of ecology matrix)

Floods are primarily responsible for channel and physical habitat maintenance and sediment transport, among many other geomorphological and ecological functions, so a reduction in the number of floods was deemed to have a negative impact on the maintenance of the active channel and associated physical habitats for instream and riparian biota. Floods are also important for flushing out the system, and thus phytoplankton and macrophyte communities would increase in the absence of floods, with negative ecological consequences, especially if algal blooms were to occur, although the likelihood of such blooms was unclear. Floods are responsible for nutrient and sediment transport to the mid and upper banks, as well as seed dispersal and the stimulation of regrowth stimulation for riparian vegetation. A reduction in category I floods would thus have negative implications for 'wild pineapple' on the mid bank. Floods provide freshwater fish an opportunity to enter floodplain habitats including manmade ones such as rice fields and ponds, and thus a reduction in floods would also impact them negatively. Water quality would decrease, as phytoplankton and *Microcystis* blooms, turbidity, and organics would increase markedly (low confidence) in the absence of floods, which are necessary to flush out and replenish the system. In the system, floods are also considered largely responsible for the recharge of the local groundwater system, which would also suffer from a reduction in flood events. Social indicators had less obvious impacts from a reduction in floods:

scenic value was likely to improve and floating villages were likely to benefit from fewer floods, but navigation is likely to deteriorate. The effect of fewer floods on riparian vegetation was determined to be negative.

6.4 Intra-annual floods - Category II

Table 11: Ecology matrix for intra-annual floods, category II - 50% decrease in number of flood events

INDICATOR	INDIC	ECO	SOC	*Confidence Rating*	INDICATOR	INDIC	ECO	SOC	*Confidence Rating*
GEOMORPHOLOGY					**INVERTEBRATES**		NA		
Proportion of sand and gravel	+2/-2	-3	-3	*0*					
Bank erosion	-3	-3	+3	*1*	**FISH**				
Formation of sand banks	+1	-1	-1	*0*	Freshwater spp.	-4	-4	-4	*1*
Channel maintenance	-2	-2	-1	*0*	Brackish water spp.	0	NA	NA	*1*
					Anguilla marmorata	NK	-2	-2	*0*
INSTREAM VEGETATION									
Macrophytes					**WATER QUALITY**				
Community species compositon	+2	-2	-1	*1*	General water quality	-3	-3	-4	*1*
Phytoplankton					**GROUNDWATER**				
Community dynamics	+3	-1	-2	*1*	Groundwater level near river	-2	-2	-2	*1*
Microcystis spp.	+3	-1	-3	*1*					
					SOCIAL AND OTHER				
RIPARIAN VEGETATION					Riparian vegetable cultivation	NA	NA	-3	*1*
'Wild pineapple' (midbank)	-2	-2	-1	*1*	Scenic value for tourism	NA	NA	-1	*1*
Cyperus and grasses (wet bank)	-1	-1	0	*0*	Navigation of local boats	NA	NA	-1	*1*
Bamboo forest (top of bank)	-2	-2	-3	*0*	Floating village location	NA	NA	+3	*1*

(See Annex 7 for explanatory notes of ecology matrix)

Responses to the impact on the decrease in category II flood events were largely similar to those of category I flood events (compare Tables 10 and 11). Category II floods were the only flow component that affected the bamboo forests in the outer riparian zone, where the floods are an important source of water, seed dispersal, and nutrients. The other main difference in results between the two flood categories was in the scenic value indicator, where participants felt that scenic value would be negatively impacted due to a substantial deterioration in water quality, decreased channel maintenance, and lower water levels.

6.5 Dry season freshes - Category III

The scenario discussed in the assessment included a removal of the small flow peaks (70 450 $m^3 s^{-1}$) experienced in May and June under normal conditions. Due to time constraints, individual analyses of impacts of flow changes in the dry season fresh of May-June on each indicator were not possible, although social and ecological impacts are likely to exist. Three key impacted areas generally agreed upon were water quality, fish, and social implications, and discussion among participants highlighted the following key points:

Water quality

There would be a moderate to high negative impact on water quality. Freshes improve water quality at the end of the dry season, when water quality tends to be poorest, as they flush out accumulated poor quality water and regenerate the system. The removal of these freshes would effectively extend the dry season and its accompanying poor water quality by two months. Saline intrusion upstream is a key water quality issue during the dry season, especially during March, April, July and August, and can have a significant impact on all instream biota.

Instream biota

From experience in other river systems, it is known that small pulses in dry-season flow are an important part of the life cycles of invertebrates and some fish, triggering emergence and spawning, respectively. Evidence of fish mortality was expected with the removal of freshes, but the significance of the impact of the protracted dry period and poor water quality on instream biota was unknown. The impact was expected to be medium to high, with only one participant arguing that the impact would be low to medium.

Social impacts

Freshes can be an end to drought, bringing a sudden, positive increase in the availability of water for human use. The ecological impacts on fish and instream biota would also have social implications in the reduced availability of fish for consumption.

May Summer Flood

Further downstream, the May Summer Flood is a recognized phenomenon, and has significant importance for lagoon fisheries. Although the lagoon is outside of the scope of this scenario, the impact of the removal or dampening of freshes on downstream, economically important lagoon fisheries sparked some discussion.

Other discussion

Because the freshes occur during the dry season, hydrological calculations during these months included a 50% increase in low flow during this season. This increased low flow may counteract the impact of the removal of freshes, in that drought conditions are less likely to exist with an increased low flow, thus removing some of the necessity of freshes to end the drought.

A final point of discussion was the occurrence of small floods in August. It was agreed that their role and importance should also be examined in a more comprehensive flows assessment.

PART C
CONCLUSIONS AND RECOMMENDATIONS

1. EFA workshop summary and conclusions

Valuable skills were obtained by all participants in this EFA learning process. River flows can be modified, to some extent. All have gained a greater appreciation of the range of disciplines and perspectives required to inform infrastructure planning and flow negotiations.

The EFA learning process was beneficial despite the scope of the work being reduced from what was originally planned by the project management team from the Huong River Projects Management Board, IUCN and IWMI. This reduction in scope was necessary to acknowledge the fact that the work able to be undertaken with the available resources would be insufficient to fully inform flow negotiations. More knowledge about the Huong River Basin is required.

At the conclusion of the workshop, one issue that most participants felt to be significant was a general lack of understanding of the link between hydrology and ecology in environmental flow assessments. Despite the substantial preparatory work done in hydrology, its role in the remainder of the flow assessment seemed vague. The unclear link between hydrology and ecology was a function of limited data, and is one of the common limitations of rapid methodologies.

Some participants pointed out that if the assessment had been more comprehensive, it would have resulted in a more structured engineering output including an assurance yield curve that could allow for dam operations to happen while maintaining necessary flows for the integrity of the system. A traditional rapid EFA would have involved mostly hydrological work, and following such a method would have provided results that relied much more heavily on hydrology. The extended rapid EFA approach that was attempted in the course of the workshop sacrificed the structured engineering output for the sake of a more detailed discussion around environmental and ecological aspects of the project, and involved a substantial amount of professional judgement. The workshop's outcome came closer to an intermediate EFA than a rapid EFA, but at the expense of some of the hydrological output that would otherwise have been included.

The output of this meeting was essentially the identification of some of the negative and positive implications of the dam for the environment and society. Results should be seen as the outcome of a training exercise, and decision-makers should be made aware that the results were based on very limited data and sometimes very low understanding.

There was general agreement that a follow-up intermediate or comprehensive EFA would be essential in terms of long-term river basin management planning. Participants felt confident to continue the work with the skills they had gained in the course of the project, but saw it necessary that IUCN or IWMI continue their involvement in future work. There seemed to be a favourable political environment for this type of project, as the Communist Party of Vietnam has voiced the importance of the environment and ecological considerations in its development work.

In addition, the summary and recommendations of the JBIC SAPROF 2 report explicitly stated the importance of such work:

> "Although effects of change of salinity concentration by the Project are assessed as minor, the gate operation rules of the Thao Long Barrage and the Ta Trach Reservoir are suggested to be reviewed with reference to the outputs of the IUCN study on ecological discharge for the Huong River in order to minimize the effects on water quality and other ecological factors… Regarding the actual discharge, the operation plan will be prepared at the D/D stage based on the study of IUCN. The amount of discharge shall be reviewed during the operation period depending on the result of environmental monitoring in the Huong River and the lagoon." (SAPROF 2, December 2003)

With this in mind, the following sections summarize some of the main obstacles encountered in the EFA workshop, lessons learnt, and recommendations for future EFAs in the Huong River Basin and throughout Vietnam.

2. Limitations and obstacles encountered

The Huong River EFA faced a number of unexpected limitations and obstacles which should be identified and avoided in future assessments. The following data, information and materials currently exist, but were unavailable for participants at the EFA workshop, and should be made available in future assessments:

1. Extensive quantitative ecological, geological, socio-economic and other data available in the SAPROF 2 study, including detailed information about the Ta Trach Dam project, detailed colour maps, sediment transport simulations, and management recommendations.

2. Accurate information about the planned size and capacity of Binh Dien Dam and its expected impact on the downstream flow regime. This was a critical problem, as the determination of the flow scenario is a key step in the assessment process, upon which the assessment is fundamentally based.

3. River cross-sections and site photographs at different times of year.

4. Quantitative data indicating how much the current hydrology of the system has departed from its natural hydrology.

5. Species-specific information on the life cycles, patterns and locations of indicator species, especially fish reproductive cycles.

Due to the lack of the above information, the assessment was more heavily based on the experience and direct observation of participants, rather than on formal surveys of documented materials. Some reliance on expert judgement is an inevitable part of any environmental flows assessment and is indeed fundamental to the process, but should be supplemented where possible by documented materials, quantitative data, and other reliable sources of information.

Other limitations related to the reduction in scope of the EFA, from intermediate to rapid. A number of ToRs had already been established and available experts identified at the March workshop, but changes in project scope prevented continuation of several components, all of which would provide valuable input into future assessments:

1. Socio-economics: There is good information on the relationship between the general provincial population and the river basin, but little is known specifically about the people living closely to the river, including those inhabiting the floating villages.

2. Geormorphology: The least expertise in the group was in the area of geomorphology, which generally caused the most confusion and disagreement among participants. The role of dams and their impact on sediment accumulation, removal, and transportation was particularly unclear, and there was some confusion between what might happen to the river system overall and what might happen specifically at or near the site.

3. Ecology: Comprehensive ecological surveys at the selected sites should be carried out, using available data from the SAPROF 2 report and other published sources where possible, supplemented by field surveys.

Many issues and problems could have been resolved if more time were permitted for the exercise. Time and knowledge constraints are explained in detail in the Annex 7 discussion of the ecology matrix. Time constraints prevented adequate discussion to ensure consistency, agreement, and detailed analysis in the following areas:

1. The meaning of terms when discussing certain flow elements and indicators, including:

    - The concept of low flow in the wet season versus flood conditions
    - Category II floods versus historic or disastrous flood events
    - Terrestrial versus riparian vegetation

2. Discussion on ecological and social impacts was extremely limited when perceived changes were minor.

3. There was sometimes a lack of consistency in perceived impacts (i.e. impacts of reduction of category I floods were not consistent with impacts of reduction of category II floods).

4. The possibility that alien invasive species could take advantage of the changes in flow regime and habitats was not examined.

3. Recommendations and lessons learnt: EFAs in the Huong River Basin

The following summarizes some recommendations that emerged during the workshop, which, in addition to the obstacles encountered, should be kept in mind when planning future environmental flow assessments in the Huong River Basin and elsewhere in Vietnam. It must be made clear that this is not a comprehensive list, and future EFAs should commence with an open dialogue between all stakeholders to discuss lessons learned from the EFA experience described in this document and experienced elsewhere, and to identify any other important issues that should be addressed.

1. Because of variability in ecological, hydrological and socioeconomic conditions over the course of a waterway, habitat and instream integrity should be assessed in segments along the river, especially in those segments immediately adjacent to the study sites.

2. Establishment of a discharge-water level relationship at the study sites would facilitate an understanding of ecological and social impacts of changes in flow regimes.

3. A more extensive database would be useful for a more complete hydrological picture.

4. Access to the SAPROF 2 study on the Ta Trach Reservoir Project (JBIC, 2003) would contribute significantly to the ecological and biological data available for an environmental flow assessmnet. The results of this and other similar studies that have taken place in the river basin should be made available for future EFAs to increase confidence in results, and to avoid a waste of resources in collecting data that has already been previously collected.

5. In a full-scale EFA, flood events should be separated into four or more classes, depending on scale.

6. Specific plans and details on dimensions and operations of planned infrastructure should be made available to the environmental flows team to ensure that the scenarios discussed are realistic and relevant.

7. Based on the TORs already developed, socio-economics and ecological surveys should be completed, with special focus on the study sites. In addition, an understanding of the geomorphology of the sites would be beneficial.

8. Since the river is linked very closely to the lagoon system, this system and the upstream-downstream ecosystem interrelationships should be considered a major component of future work.

9. It was reflected that greater emphasis should be put on the socioeconomic component in order to understand ways of water use and needs among different stakeholders. Parallel public participation processes should feed into the EFA process at several stages.

10. The link between floods of different magnitude and groundwater recharge needs to be examined and clarified.

11. A wide range of expertise among participants is desirable. In the EFA workshop, only one Vietnamese ecologist participated, and more expertise in this field in particular would be valuable. In addition, input from experts in other fields, such as botany, biology, entomology, and the social sciences, is encouraged.

4. IUCN recommendations for follow-up

The process of developing and implementing a successful environmental flow regime depends on commitment and action from many different parts of the community, governments, user groups, and non-government groups. Negotiating within existing government structures, and developing appropriate rules, laws, and policies is essential. However, it may be necessary to also develop new and complementary forums for negotiation.

Sufficient people, commitment, knowledge and influence is required before concrete processes can be put into place. '*Environmental Flows - The Essentials'* gives many ideas about how to get started. The work on environmental flows in the Huong River Basin has started, but it is far from finished. Further work in Vietnam will need to link 'water resources management *and/or* river basin management *and/or* environmental flows' issues to poverty/livelihoods and national development priorities.

Subject to consultations between the Huong River Projects Management Board, IWMI, and IUCN the following looks worthwhile and achievable:

1. Continue to support the evolution of the Huong River Projects Management Board, helping them advance an ecosystems-livelihoods agenda, using the environmental flows approach as a management tool.

2. Supporting a multi-disciplinary 'expert water group' of Vietnamese government, university and civil society actors to critique Vietnam environmental flows/IWRM direction and required next steps. This group might meet regularly, and might produce its own version, addendum or preface to a Vietnamese translation of FLOW.

3. Translation of FLOW would be separately tasked, but the draft would need to be rigorously critiqued - thereby providing fuel for important debate, learning and policy-shaping by the previously-mentioned multi-disciplinary 'expert water group' and existing Huong colleagues.

4. The 'expert water group' might be invited to participate in a more detailed EFA in the Huong River Basin. Such an intermediate assessment would build on the 2003-2004 effort, plus take note of (for example) a Sida-funded economic evaluation of the Tam Giang - Cau Hai Lagoon. Such an assessment could be released in tandem with, or incorporated into a Vietnamese production of FLOW.

Several key concepts must be understood for the successful implementation of an EFA and its subsequent use in the integrated management of a river basin, and are therefore worth repeating:

- Well-crafted scenarios require clear objectives
- Environmental flows are different from natural flows
- Natural hydrological variability is often critical to maintain river systems in good condition
- Environmental flows are part of river basin management
- Implementation requires adaptive management

In order to achieve the objective of the environmental flows concept, meaning managing water so that enough water is left in rivers to ensure downstream environmental, social and economic benefit, it needs to be conceptually understood among all stakeholders. Generating and discussing impacts of alternative scenarios is a socio-political process. Besides scientists and experts, the process must include representatives of *all* relevant interest groups (the so-called "stakeholders"). Planners responsible for the process need to bear in mind the barriers poverty, illiteracy, and a history of political conflict may pose to creating an authentic participatory process.

Through an EFA a number of scenarios with different regimes of water releases resulting in different environmental and social benefits and costs will be presented to relevant stakeholders. It is then the role of these stakeholders to decide on the best alternative based on a compromise between the multiple needs of the community.

Developing a regime of environmental flows is never easy. New policy frameworks, laws, and regulations will evolve in different ways depending on the context. People committed to achieving environmental flows must be prepared for a long and sustained effort. A range of people will need to form a coalition for action to assess environmental flow needs and to provide environmental flows. These people include politicians and policy makers; consumptive water use groups, environmental groups, and other non-government organizations, universities, river communities, individual naturalists, engineers, hydrologists, planners, economists and lawyers. Researchers and experts can only provide the technical advice and possible alternatives but politicians, decision makers and communities need to accept the need for environmental flows for it to be enacted. In an ideal situation, providing for environmental flow needs would be a dynamic process. Ideally, legislation would specify environmental flow needs, and water managers would provide those flows using a variety of techniques. A government body or river basin organization, assisted by universities and research organizations, would supply monitoring and evaluation feedback.

ANNEX 1: MEETING AGENDA

Rapid Environmental Flows in Huong River Basin
Expert Panel Meeting/Synthesis Workshop
13-14 December 2004
Hanoi, Vietnam

Purpose of the Workshop:

1. *To conduct a Rapid Environmental Flows Assessment through a case in the Huong River Basin of Thua Thien Hue Province*
2. *To discuss the need for more detailed Environmental Flow Assessment work in*

Time	Agenda
Monday, 13 December 2004	
8:30 – 8:45	Welcome and Introduction *Nguyen Minh Thong, IUCN Vietnam*
8:45 – 9:00	Introduction to and agreement on the workshop process - decide on sites to be assessed *Vu Minh Hoa, IUCN Vietnam* *Rebecca Tharme, International Water Management Institute (IWMI)*
9:00 – 9:45	Presentation of hydrological regime in the Huong River Basin *Nghiem Tien Lam, Hanoi Water Resources University* Discussion on the hydrological regime of the river *Facilitated by Vladimir Smarkhtin, International Water Management Institute (IWMI)*
9:45 – 10:15	Presentation on ecological situation of the Huong River Basin *Ton That Phap, Hue University* Discussion on the natural condition of the river system *Facilitated by Rebecca Tharme*
10:15 – 10:30	*Coffee break*
10:30 – 11:30	Discussion on socio-economic condition and its future state to decide on scenarios to examine
11:30 – 11:45	Check on supporting data for EFA process
11:45 – 13:30	*Lunch break at the Army Hotel*
13:30 – 16:30	Assess Environmental Flow Requirements for selected sites on mainstream of the Huong River for selected scenarios
Tuesday, 14 December 2004	
8:30 – 11:45	Assess EFRs (continued)
11:45 – 13:30	*Lunch break at the Army Hotel*
13:30 – 16:30	Finalization of the results (30 minutes) Conclusion for next steps (2 hours) Closing of the Workshop (15 minutes)

ANNEX 2: PARTICIPANT LIST

1. **Nghiem Tien Lam** - Lecturer**,** Coastal Engineering Faculty, Hanoi Water Resources University
2. **Nguyen Dinh** - Vice Director, Board of Management of the Huong River Projects, People's Committee Thua Thien Hue Province, Provincial Coordinator of project
3. **Dr. To Trung Nghia** - Director, Water Resources Planning Institute
4. **Dr. Ton That Phap** - Lecturer**,** Department of Biology, Hue University
5. **Dr. Tran Huu Tuyen** - Lecturer, Faculty of Geography, Hue University
6. **Duong Van Khanh** - Officer, Water Resources Division, Department of Agriculture and Rural Development, Thua Thien Hue province
7. **Phan Van Hoa** - Hydro-meteorological Forecast Station, Thua Thien Hue province
8. **Prof. Dr. Ngo Dinh Tuan** - Senior Lecturer, Centre for Hydrology and Environment, Hanoi Water Resources University
9. **Dr. Nguyen Van Thang** - Lecturer, Faculty of Environment, Hanoi Water Resources University
10. **Dr. Nguyen Van Sy** - Lecturer, Faculty of Environment, Hanoi Water Resources University
11. **Pham Hong Nga** - Lecturer**,** Hanoi Water Resources University
12. **Cao Ngoc Tan** - Officer, Huong River Management Board
13. **Le Manh Hung** - Officer, Huong River Management Board
14. **Dr. Vladimir Smakhtin** - Principal Scientist, International Water Management Institute
15. **Jessica Illaszewicz** - Programme Assistant, IUCN Vietnam
16. **Rebecca Tharme** - Freshwater Ecologist, International Water Management Institute
17. **Vu Minh Hoa** - Wetlands and Water Programme Officer, IUCN Vietnam
18. **Nguyen Van Trung -** Engineer**,** Hydrological Division, Water Resources Planning Institute

ANNEX 3: HYDROLOGY REPORT

HYDROLOGY OF THE HUONG RIVER

DRAFT REPORT FOR THE RAPID ENVIRONMENTAL FLOW ASSESSMENT

Nghiem Tien Lam

Hanoi, 2004

Abbreviations

DEM	Digital Elevation Model
EFA	Environmental Flow Assessment
FDC	Flow Duration Curve
HMS	Vietnam Hydro-Meteorological Services
IFR	Instream Flow Requirement
GIS	Geographic Information System
GPS	Global Positioning System
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MCM	Million Cubic Meters

1. Introduction

The Huong (Perfume) River is the largest river of Thua Thien-Hue province located in the Central Coastal Area of Vietnam. The river has its origin inside the province's interior and discharges into the Tam Giang-Cau Hai lagoon before flowing into the ocean via Thuan An and Tu Hien inlets. The catchment area of the Huong River is about 2700 km^2, occupying 52% the total area of the province.

The Huong River Basin includes mainly high mountainous and hilly areas and a narrow and low-lying delta. The basin slants from west to east and from south to north with many high and steep cliffs of from 1150 m to 1774 m distributed west and south of the Hue delta. These cliffs stop north-east and south-east monsoon winds that come from the sea and carry very high humidity, causing very high rainfall in this area. Due to very steep slope of the mountain and hilly areas surrounding the Hue delta, rainwater is rapidly concentrated and poured to the narrow delta.

The major tributaries of the Huong River are Huu Trach, Ta Trach and Bo Rivers. The Bo River originates from the southwestern mountainous area of A Luoi district and joins the Huong River at the Sinh confluence 8 km north of Hue city. The Huu Trach and Ta Trach Rivers originate from the southern mountains of A Luoi and Nam Dong districts and join together at the Tuan confluence to create the flow of the Huong River.

The Huong River Basin is located in the tropical region with very high rainfall. The mean annual precipitation (MAP) in the hilly and mountainous areas is between 3000 mm and 4000 mm. The highest value of MAP is more than 8000 mm in Bach Ma. In the Hue delta, the value of MAP is between 2500 mm and 3000 mm. The rainfall is distributed unevenly throughout the year, generating distinguished seasons of flow regime. The flood season lasts four months, from September to December, with high rainfall generating more than 70% of the annual flow. The dry season is from February to May with very little rainfall.

The mean annual evaporation (MAE) of the basin is about 900 mm, decreasing from the Hue delta (974 mm at Hue) to the mountainous area (855 mm at A Luoi). The highest evaporation of about 100 mm per month occurs in the dry season. In the rainy season, evaporation is reduced to less than 50 mm per month.

The mean annual runoff (MAR) in the basin has a flow depth ranging from 2000 mm to 3000 mm, decreasing from the mountainous area to the Hue delta.

Currently there are 6 hydrologic gauging stations managed by HMS, 3 of which measure streamflow and 3 others measure water level only. There were also some fluvial gauges for special purposes and some rain gauges but most of the gauges are now closed.

To provide the background hydrological information for the assessment of environmental requirements of the Huong River, this study has primarily made use of the available observed daily streamflow records. These records were used to generate the representative daily flow time series at the selected EFA sites. The method of data generation for the sites employs the non-linear spatial interpolation of observed streamflow data, the technique developed by Hughes and Smakhtin (1996) and successfully applied at many locations in southern Africa for various water resource assessment problems (including IFR determination). The current document describes the data and the technique that have been used to generate representative daily streamflow time-series at 4 EFA sites and summarises the hydrological information at these sites using a series of graphs which illustrate annual runoff variability, seasonal flow distribution, 1-day flow duration curves and daily flow hydrographs for one wet and one dry year. The document also contains a table that lists some typical flow characteristics at EFA sites on a month-by-month basis: range of expected baseflow discharges, number, magnitude and duration of flood events.

2. Gauging station and EFA sites

In the EFA Planning Meeting organised in March 2004 in Hue, four EFA sites were selected. Locations of the EFA sites are listed in Table 1 and are shown in Figure 1. Figure 1 also shows the boundaries of the catchment for each EFA site determined based on a digital elevation model (DEM) (see Section 3).

Table 1. Locations and names of the EFA sites

Name	River	Location	Longitude	Latitude
Site 1	Ta Trach	1 km downnstream Ta Trach dam	E107°37’52”	N16°19’05”
Site 2	Huong River	0.3 km downstream Van Nien water supply pumping station	E107°33’40”	N16°25’47”
Site 3	Huong River	1 km upstream Thao Long barrage	E107°36’25”	N16°32’59”
Site 4	Bo River	The old Co Bi hydrologic gauge	E107°26’06”	N16°29’10”

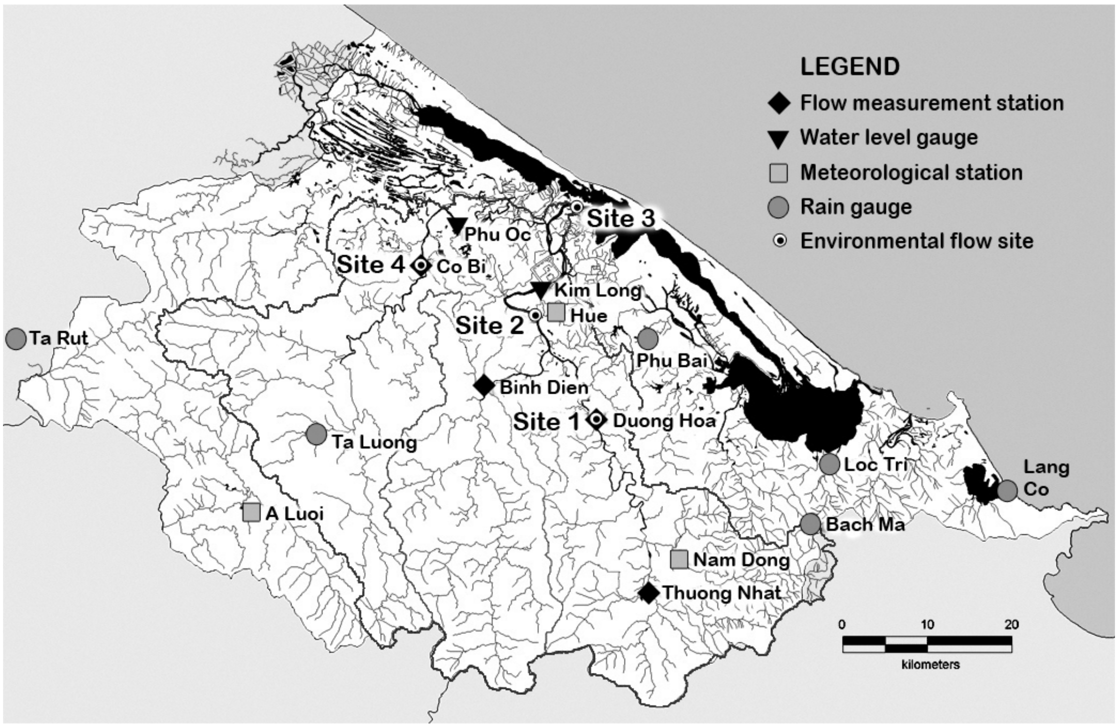


Figure 1. Map of the Huong River Basin showing locations, names and catchment boundaries of the gauging stations and EFA site

3. Available data

The observed hydrometeorological data in the Huong River Basin (and in the province as a whole) is very limited. Before 1975 there were only a handful of water level gauges, such as Nguyet Bieu (Huong River), Van Trinh (O Lau River), Kakut, Tan My (Tam Giang lagoon), Loc Bon, An Nong (Nong River), Truoi Bridge (Truoi River), Hoa Duan (Thanh Lam lagoon), Da Bac (Cau Hai lagoon). Meteorological data were observed at Hue, A Luoi and Nam Dong stations. The observed data generally has a very low quality and resolution. It was measured infrequently and large gaps exist due to the war. This data has a low reliability and could not be used for analysis. After 1975, more flow stations were set up, but they were mainly for collecting data for planning purposes in the basin. The stations had quite short periods of record. There is no streamflow gauging station in the tidally affected area of the Hue delta. This causes considerable difficulty for hydrological analysis in the Huong River Basin.

A list of hydrometeorological stations can be found in Table 2, and stations are also displayed on the map in Figure 2.

During the field visit on 7-8 Octobeer 2004, the location of the EFA sites and some gauging stations were checked using a GPS device. With the accurate locations of the sites, their catchment areas were determined in ArcGIS 8.3 based on a NASA SRTM 90m DEM.

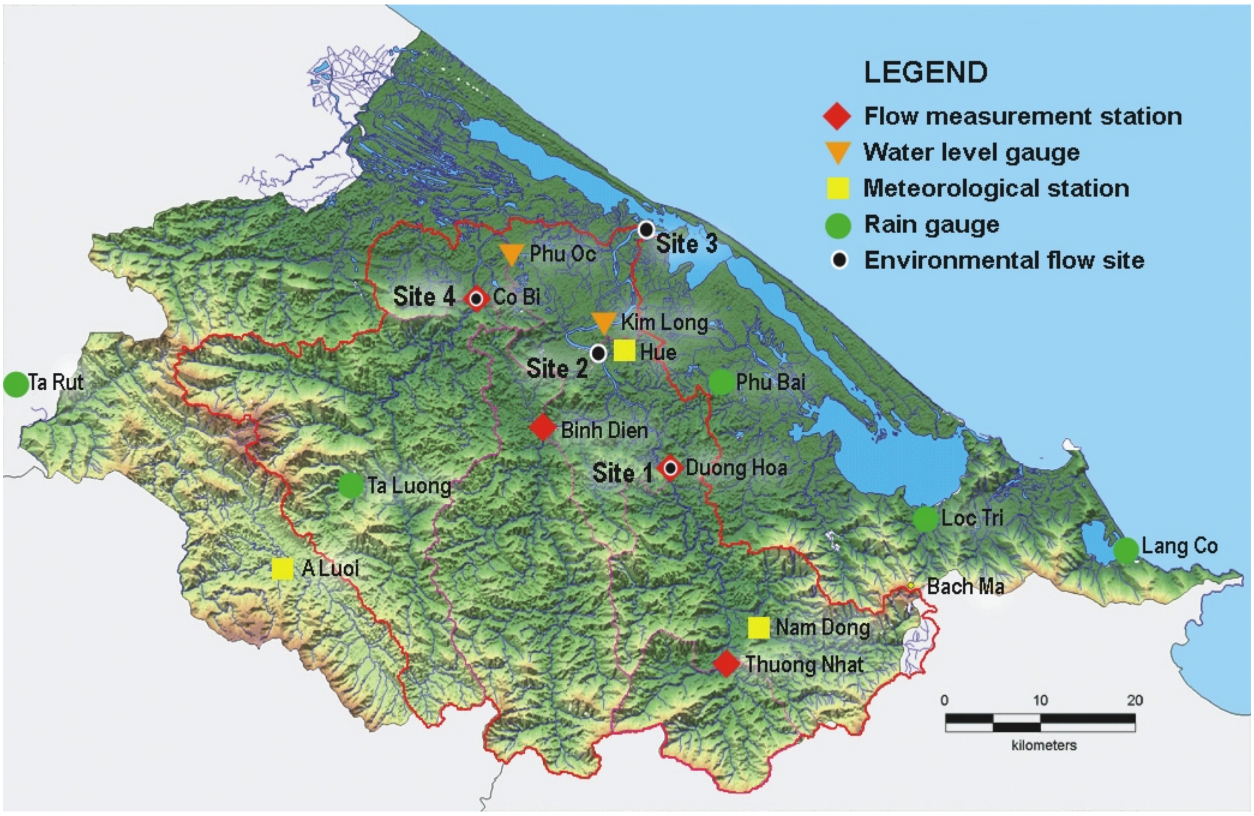


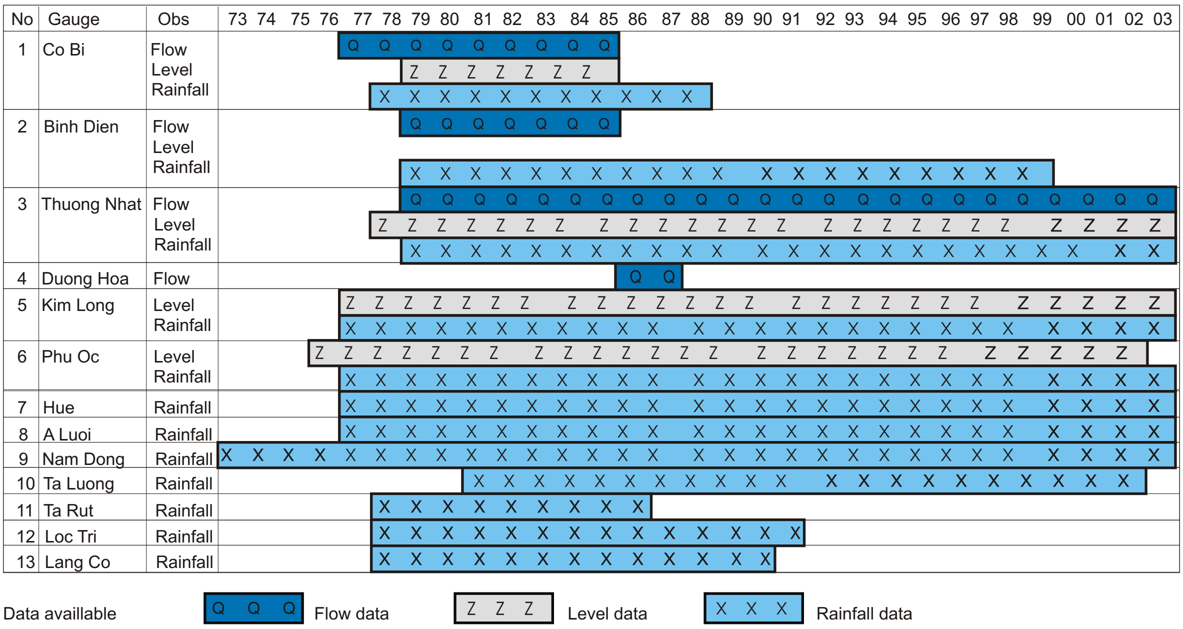
Figure 2. Map of the Huong River Basin showing locations and catchment boundaries of the gauging stations and EFA sites determined based on 90m STRM DEM

Table 2. List of hydrometeorological stations in the Huong River Basin

No	Name	River	Catch-ment Area (km^2)	Observation	Period of record	Data available
1	Co Bi (streamflow station)	Bo	735	Streamflow	1979-1985	1977-1985
				Water level	1979-1985	1979-1984
				Rainfall	1979-1985	1978-1988
2	Binh Dien (streamflow station)	Huu Trach	585	Streamflow	1979-1985	1979-1985
				Water level	1979-1985	
				Rainfall	79-85,90-03	79-90,92-99
3	Thuong Nhat (streamflow station)	Ta Trach	198	Streamflow	1981-2003	1981-2003
				Water level	1979-2003	1978-2000
				Rainfall	1979-2003	1979-1999
4	Duong Hoa (streamflow station)	Ta Trach	688	Streamflow	1986-1987	1986-1987
				Water level	1986-1987	
				Rainfall	1986-1987	
5	Phu Oc (water level station)	Bo	872	Water level	1977-2003	1976-2000
				Rainfall	1977-2003	1977,80-99
6	Kim Long (water level station)	Huong	1560	Water level	1977-2003	1977-2000
				Rainfall	1977-2003	1977-1999

No	Name	River	Catch-ment Area (km^2)	Observation	Period of record	Data available
7	Hue (met.station)			Rainfall	1956-2003	1977-1999
8	A Luoi (met.station)			Rainfall	1973-2003	1977-1999
9	Nam Dong (met. staion)		186	Rainfall	1973-2003	1977-1999
10	Ta Luong (rain gauge)			Rainfall	78-89,90-03	1981-1986
11	Loc Tri/Phu Loc (rain gauge)			Rainfall	1978-1989	1979-1991
12	Lang Co (rain gauge)			Rainfall	1978-1989	

Table 3. Periods of record availability of the stations



3.1. Streamflow stations

i. Co Bi station on the Bo River

This was the only station that measured streamflow on the Bo River. Daily flow discharge and water level were recorded continuously for 9 years from 1977 to 1985. The station was closed in 1987. The observation of the station is quite short but accurate, reliable and important for the analysis.

ii. Binh Dien station on the Huu Trach River

Similar to the Co Bi station, this was the only station that measured streamflow on the Huu Trach River. Daily flow discharge was recorded continuously at the station for 7 years from 1979 to 1985. The data is accurate and reliable.

iii. Thuong Nhat station on the Ta Trach River

This is the only flow station in the province managed by HSM. The station started operations in 1979. Flow discharge, water level and rainfall are measured daily. In comparison with others, this station has the longest observed flow data of 25 years. The data is reliable. Although the catchment area of the station is rather small, the observed flow data of the station is very important as it can be used as a source dataset for generation flow series at the EFA sites.

iv. Duong Hoa station on the Ta Trach River

This station was located at the future location of the Ta Trach dam. The period of flow recorded at the station is very short. Streamflow data was collected for only 2 years from 1986 to 1987. Because the location is quite close to the Thuong Nhat station upstream and has climatic conditions similar to the Thuong Nhat station, streamflows at the two stations responded accordingly and correlated with each other.

3.2. Water level stations

In addition to the above gauging stations where flow discharge, water level and rainfall were recorded, there are also two other water level stations that belong to the basic observation network managed by HMS. These are Phu Oc station on the Bo River and Kim Long (Hue) station on the Huong River where water level and rainfall have been observed since 1977. The observed data are accurate and reliable. However, the stations are located in the tidally affected area so the rating curves are not available and water levels observed at these stations cannot be used as source datasets for generating flow sequences at the EFA sites in this study.

3.3. Other meteorological and rain stations

Rainfall is measured at all fluvial, meteorological and rain gauges. There are 3 meteorological stations managed by HMS in Thua Thien-Hue province, including Hue (data available since 1901), A Luoi and Nam Dong (data available since 1973). There are also some other rain gauges like Ta Luong, Phu Loc (Loc Tri), Bach Ma, Truoi Reservoir and Lang Co. In general, many observations were missing or interrupted during the war and in other periods. Rainfall varies between the locations, increasing from the Hue delta to the mountainous areas. The variation in time in each location is also significant. MAP varies for different periods of analysis.

4. Generation of representative daily streamflow series for the EFA sites

4.1. General description of the technique

Representative daily streamflow time series for the EFA sites have been generated using a spatial interpolation technique described by Hughes and Smakhtin (1996). In essence, the procedure is to transfer the streamflow time series from the locations where the data are available to the locations where the time series is needed (in our case the latter are the EFA sites). The technique is not strictly a modeling technique but is based on typical flow duration curves for each calendar month of the year and on the assumption that flows occurring simultaneously at sites in a reasonably close proximity to each other correspond to similar percentage points on their respective flow duration curves. Continuous flow duration curves are presented in the algorithm by flow duration curve tables with 17 discharge values for 17 fixed percentage points (0.01, 0.1, 1, 5, 10, 20, 30, 40, 40, 50, 60, 70, 70, 80, 90, 95, 99, 99.9, and 99.99%). The site at which streamflow time series generation is intended is called destination site. The site (or sites) which time series is used for generation is called source site. The generation technique may be presented in two steps:

1. *Generation of flow duration curve (FDC) tables for source (gauged) sites and destination (EFA) sites for each month of the year.*

2. *Actual simulation of the time series using established FDCs for the EFA sites.*

The **First Step** (generation of FDC discharge tables) is accomplished differently for gauged and ungauged sites. For source gauged sites this step may be accomplished directly using the available observed records. For ungauged EFA sites there exist a variety of ways to approach this problem (e.g. use either averaged/regional flow duration curve or the curve from the nearest gauge, etc). The existing experience suggests that all these approaches normally result in a time series which are only marginally different.

The **Second Step** of the simulation procedures also includes several subsequent steps:

1. Select the source (gauged) sites from which the information will be transferred (to the destination EFA sites)

2. For each source gauge, assign a weighting factor associated with the degree of similarity between the source flow regimes and the EFA site's flow regime.

3. For each day: i) identify the percentage point position of the source site's streamflow on the source site's FDC (for the relevant month) and ii) read off the flow value for the equivalent percentage point from the destination site's flow duration curve (Figure 3).

4. The weighted average of the estimated destination site flow values is then assumed to be a final destination site's flow value for this day. The procedure is repeated for each day

For streamflow time series generation at the destination site, it is recommended to use more than one source site, where possible. The use of several source sites is an attempt to account for the fact that an EFA destination site time series may be the result of several influences, which may not be reflected in a single source site time series. Also, part of an individual source site time series may be missing and the use of several should decrease the number of missing values in the resultant time series at the EFA site.

If no suitable source streamflow sites may be identified in the vicinity of the destination site, where the generation of streamflow is intended, then use should be made of rainfall records. In this case, both source flow time series and source FDC (bottom two graphs in Figure 3) should be replaced by corresponding rainfall related measures/functions, reflecting the status of catchment wetness. A function, which is used in the generation algorithm, reflects current daily precipitation input and an exponential depletion of catchment moisture content during the period of no rainfall. The function is provisionally called the Current Precipitation Index and is calculated as:

$$CPI_t = CPI_{t-1} K + R_t \qquad (1)$$

where CPI_t is a Current Precipitation Index (mm) for day *t*, R_t is the precipitation for day *t* and *K* is the recession coefficient. On any given day with no rain ($R_t = 0$) the *CPI* is equal to the *CPI* of the previous day multiplied by *K*. If it rains on any day, the daily rainfall depth is added to the *CPI* on that day. Recession coefficient *K* normally varies from 0.85 to 0.98. The default value is 0.9.

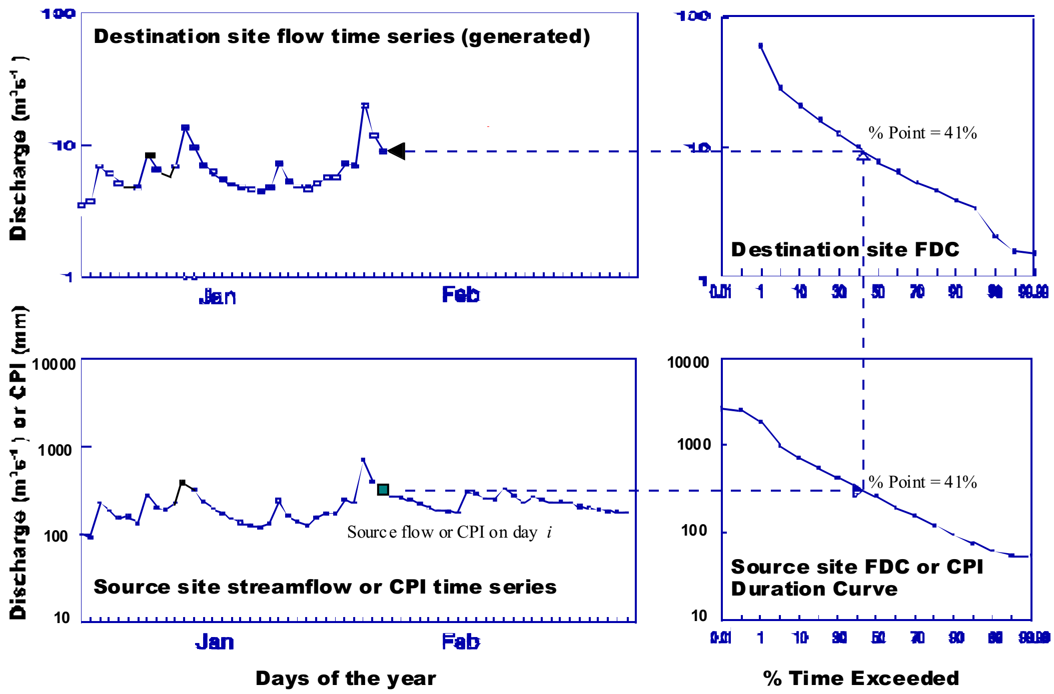


Figure 3. Illustration of streamflow generation procedure with one source site

Continuous daily CPI time series may be generated for any rainfall station in a catchment and consequently, the required CPI duration curves may also be established. Once calculated, they may be used in the spatial interpolation algorithm as a substitute for the source flows. The major assumptions of the algorithm in this case become that both the CPIs occurring at rainfall sites in a reasonably close proximity to the destination site and destination site's flows themselves correspond to similar percentage points on their respective duration curves. The layout of the computational procedure remains the same (Figure 3). In many cases, the combined use of streamflow and rainfall data is possible. The computational procedure in these cases does not change.

4.2 Details of streamflow generation at EFA sites

The data were generated for a 26-year long period starting September 1977 and ending August 2003 (26 hydrological years). For each site, the simulated streamflow sequences were compared, where possible, with observed hydrographs available at the nearest flow gauge. This has been done to ensure that the pattern of simulated flows is in line with the observed flows (e.g., that simulated floods do occur at the same time as observed, that flow recessions are not faster than those observed, etc.).

i. Site 1 - Duong Hoa on the Ta Trach River at 1 km downstream of Ta Trach dam

Site 1 is almost coincident with the location of Duong Hoa station. Although the data available at Duong Hoa station is very short (for 2 years from 1986 to 1987), the flow at Duong Hoa is very closely correlated to the flow at Thuong Nhat which is located 34.5 km upstream on the same Ta Trach River. Dimensionless FDCs of Duong Hoa nearly coincide with those of Thuong Nhat in the middle part. The only differences are at two ends because the period of flow data at Duong Hoa is too short and does not represent the whole range of flow variables at this site. The FDC of Thuong Nhat is "borrowed" and rescaled to adapt to Site 1 with a factor determined by the ratio of MAR or catchment areas of the two sites (Thuong Nhat and Duong Hoa). When the FDC for Site 1 is determined, the observed flow data available at Thuong Nhat from 1979 to 2003 can be selected as the source series for generating flow sequence at Site 1 using the spatial interpolation technique.

The daily observed flow data available at Duong Hoa are used to compare with the simulated data series at Site 1 for verification purposes.

ii. Site 2 - Huong River at 300m downstream Van Nien water supply pumping station

Site 2 is located at 8.5 km upstream of Kim Long water level gauge and at about 5 km downstream of the Tuan confluence. There is no observed streamflow data available in this area so the FDC for Site 2 is determined using a regional FDC constructed based on measurements at the streamflow gauges. It is found that when the FDCs of the stations Co Bi, Binh Dien, Thuong Nhat and Duong Hoa are divided by their corresponding catchment areas, they almost coincide with each other. As a result, a regional FDC for the area is determined by averaging these FDCs. This regional FDC can then be applied for the location where observed streamflow data are unavailable such as Site 2 or Site 3 by multiplying with the corresponding catchment area. After the FDCs for the EFA sites are determined, we can continue the second step of the flow generation procedure for the EFA sites as described in Section 4.1.

Because Site 2 and other sites of Kim Long and Tuan are influenced by the tides, observed water levels at Kim Long could not be used as a source series in the flow generation procedure.

Investigation shows that the percentage points of the FDCs of different streamflow gauging stations are better correlated with one other than with those of CPI of any rain gauge in the Huong River Basin. For example, the percentage points of the FDCs at Co Bi or Binh Dien are best correlated with those of Thuong Nhat, while their correlation with rain gauges will give a lower result. Consequently, to match the assumption of the spatial interpolation technique, only the flow data available at the gauging stations are used as source datasets.

Site 2 is located in the Huong River downstream of the Tuan confluence where the Ta Trach and the Huu Trach join together. Hence, observed flow data at Binh Dien and Thuong Nhat are used as source datasets for generating flow series at Site 2.

The simulated results were compared with observed water levels at Kim Long and found a good agreement on the variations and patterns of the flow, especially at the peaks.

iii. Site 3 - Huong River at 1 km upstream of Thao Long barrage

Almost everything that was said for Site 2 above can be applied to Site 3. The FDC for Site 3 was also determined from the regional FDC of the area (independent of catchment area) by multiplying with the catchment area of Site 3. Thesecond step of the flow generation procedure was then carried out. The only thing different is that because Site 3 is located downstream of the confluence of the Huong River and the Bo River at Sinh (near the Huong River mouth), the observed flow data of the stations Co Bi, Binh Dien and Thuong Nhat are use as source datasets for generating flow series at Site 3. The weighting factor of Co Bi was taken as a little bit larger than the others based on the sizes of the catchments.

iv. Site 4 - Bo River at the old station of Co Bi

Site 4 is coincident with the location of Co Bi station so the FDC of Co Bi was used for Site 4. As mentioned above, the percentage points of the FDC at Co Bi have a better correlation with those of the flow at Thuong Nhat than with those of rainfall at Co Bi, A Luoi, Ta Luong or any other rain gauge in the area. Therefore observed flow data at Thuong Nhat was also used as the source data set for the procedure of flow generation at Site 4.

Observed flow data at Co Bi from 1979 to 1985 were used for comparison with the simulated results at this site.

Table 4. Comparison of MAR for observed and simulated flows

No	Gauge	River	Period of data	MAR (m^3/s)	
				Observed	Simulated
1	Co Bi	Bo	1979 - 1985	65.3	64.1
2	Binh Dien	Huu Trach	1979 - 1985	47.4	47.6
3	Thuong Nhat	Ta Trach	1979 - 1985	15.0	15.4
4	Duong Hoa	Ta Trach	1986 - 1987	43.9	43.9

5. Hydrological regime of the EFA sites

The generated daily time series data are used in this document to illustrate the characteristic features of each EFA site's flow regime. The following characteristics of the flow regime are presented in graphic form in the Figures below:

1. Plots of annual streamflow volumes as a time series for available period
2. Averaged seasonal distribution of monthly flow volumes
3. Annual 1-day flow duration curves
4. Daily hydrographs for one wet and one dry year

Plots of annual streamflow totals allow wet, dry and intermediate years to be quickly identified. Averaged seasonal flow distributions illustrate the mean flows, which may be expected in each calendar month and help to identify the wettest, driest and intermediate months. Flow duration curves are an aggregated way to illustrate the variability of daily flows and the range of flows experienced (in this case, in natural flow conditions). Daily hydrographs illustrate the variability of flows in specific years of different wetness.

Table 5 contains the details of some typical flow sequences at the EFA sites for each calendar month including the range of baseflows, magnitude, number and duration of floods and freshes. This information was obtained from visual inspection of the generated time series for each EFA site. When the number of floods in the table is specified as "> 0 ", it implies that in 26 years of record from 1977 to 2003 only a few (5-10) events have been recorded in this month. In cases when this value is " < 1 ", the floods in this month occur more frequently, but their total count is less then 26 (normally 10-20) in 26 years. If the number of floods is specified as "0", it implies that none or only 1-5 insignificant events in this month were recorded.

The data presented in this report are a brief summary of the daily streamflow regime, which aims to highlight its main distinct features. Additional details of each EFA site flow regime have been available at the integration meeting through the various display options of the HYMAS computer package, also used extensively for the preparation of data for this report.

Table 5.Typical flow characteristics for EFA sites (in natural conditions). Flows are in m^3/s, and durations are in days

Site \ Month	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII
Site 1 - Duong Hoa on the Ta Trach River at 1km downstream of Ta Trach dam												
Range of baseflow	6.53 - 54.3	12.5 - 78.8	12.5 - 141.6	21.6 - 96.9	12.8 - 46.1	9.05 - 42.6	6.74 - 29.6	6.17 - 23.5	6.17 - 26.4	6.24 - 32.9	5.04 - 22.0	5.33 - 54.3
No. of events	<1	1 - 2	1 - 2	<1	0	0	0	0	0	0	0	0
Range of peaks	23 - 1360	69 - 2350	119 - 1570	44 - 674	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Main duration	7	8 - 9	8 - 9	5 - 6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Site 2 - Huong River at 300 m downstream of the Van Nien water supply pumping station												
Range of baseflow	14.1 - 117	26.9 - 170	26.9 - 306	46.7 - 209	31.8 - 99.5	19.5 - 91.9	14.5 - 63.8	13.3 - 50.8	13.3 - 56.9	13.3 - 71.0	10.9 - 45.4	11.5 - 49.3
No. of events	1 - 2	2 - 3	2 - 3	1 - 2	0	0	0	0	<1	>0	0	<1
Range of peaks	49 - 2940	149 - 4660	257 - 3390	95 - 1460	N/A	N/A	N/A	N/A	34 - 2460	42 - 1060	N/A	19 - 2100
Main duration	5 - 6	7 - 8	7 - 8	6 - 7	N/A	N/A	N/A	N/A	4 - 5	5 - 6	N/A	4
Site 3 - Huong River at 1 km upstream of Thao Long barrage												
Range of baseflow	24.4 - 203	46.5 - 294	46.5 - 529	80.8 - 362	55.0 - 172	33.8 - 159	25.2 - 110	23.0 - 88.4	23.0 - 105	24.0 - 123	18.8 - 90.4	19.9 - 84.8
No. of events	1 - 2	2 - 3	2 - 3	1 - 2	0	0	0	0	<1	<1	<1	<1
Range of peaks	84 - 5090	257 - 7750	445 - 5870	164 - 2520	N/A	N/A	N/A	N/A	48 - 4252	73 - 1680	50 - 1340	34 - 3630
Main duration	6 - 7	8 - 9	7 - 8	7 - 8	N/A	N/A	N/A	N/A	4 - 5	6	3 - 4	3 - 4
Site 4 - Bo River at the old station of Co Bi												
Range of baseflow	6.13 - 52.5	20.0 - 69.3	25.1 - 208	26.0 - 91.0	20.0 - 51.9	15.0 - 50.0	10.0 - 48.2	8.80 - 35.6	5.35 - 32.6	4.16 - 34.3	6.21 - 26.8	4.01 - 23.4
No. of events	1	2 - 3	2 - 3	1	0	0	0	0	0	0	0	0
Range of peaks	26 - 1350	64 - 1910	166 - 1610	52 - 1340	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Main duration	5 - 6	7 - 8	7 - 8	5 - 6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

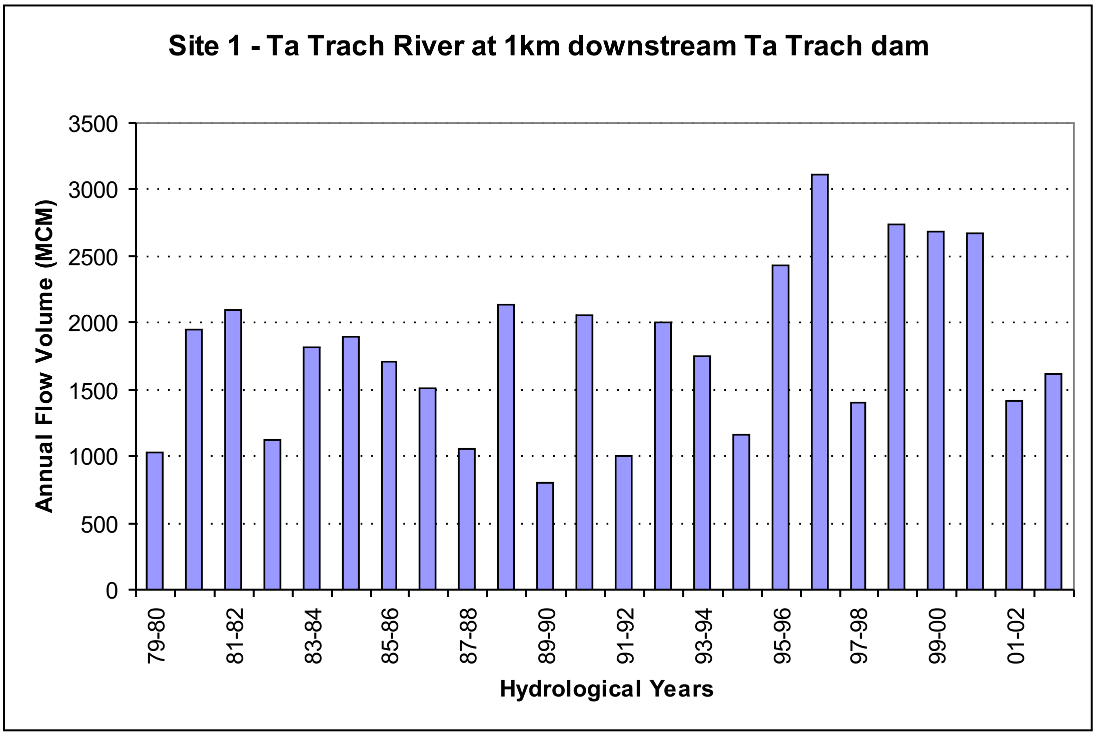


Figure 4. Annual Flow Volume at Site 1

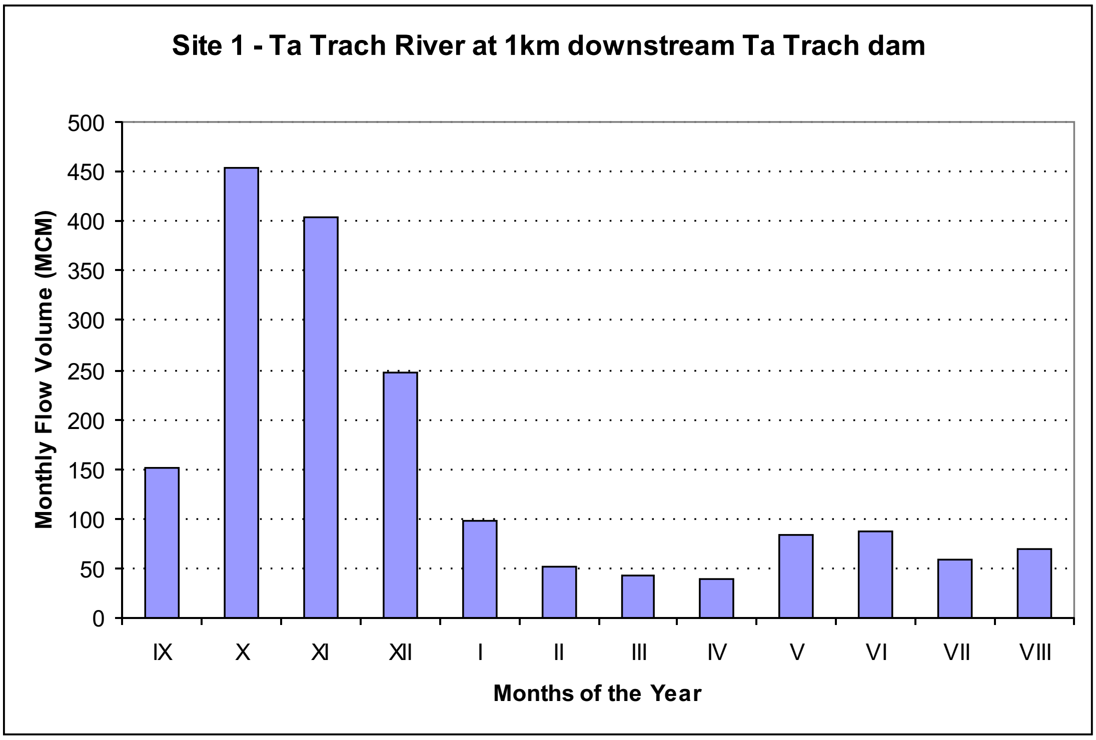


Figure 5. Distribution of average monthly flow at Site 1

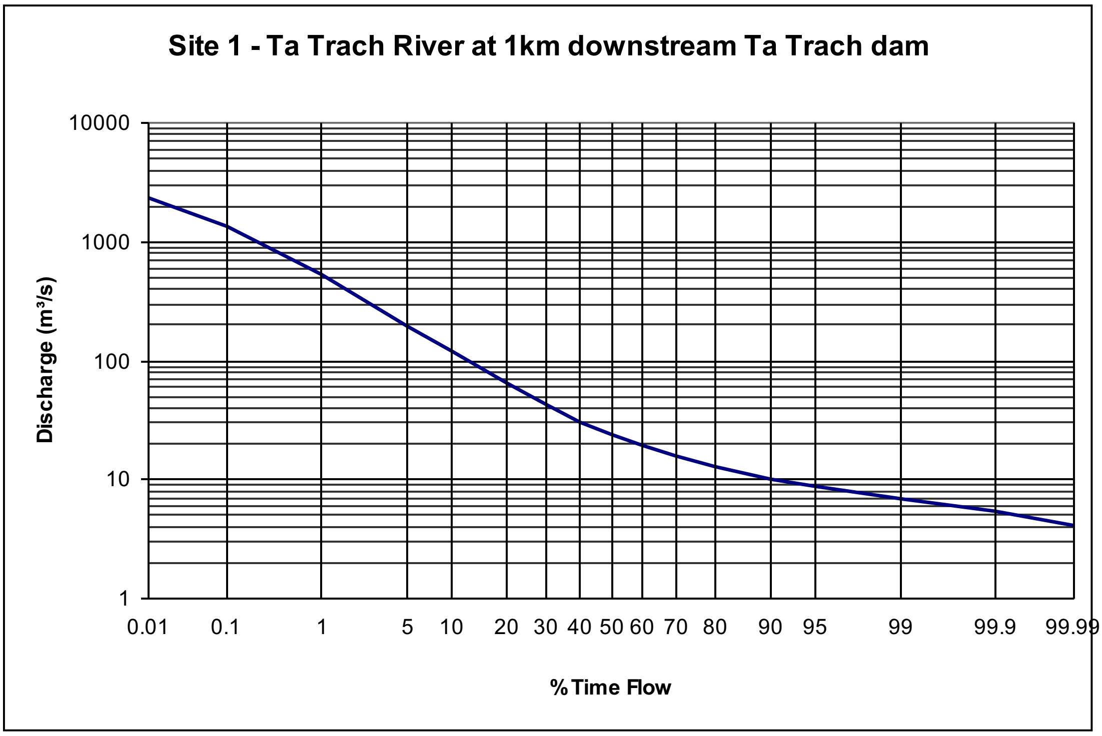


Figure 6. Flow Duration Curve for Site 1

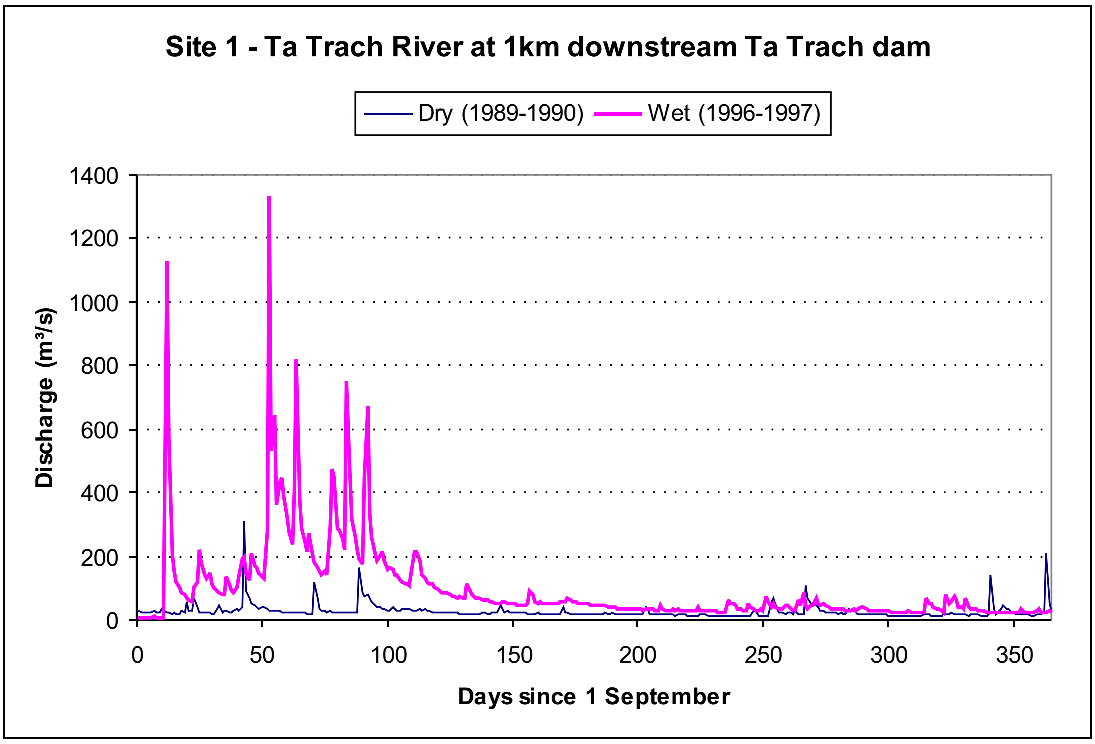


Figure 7. Example of daily hydrographs for Site 1

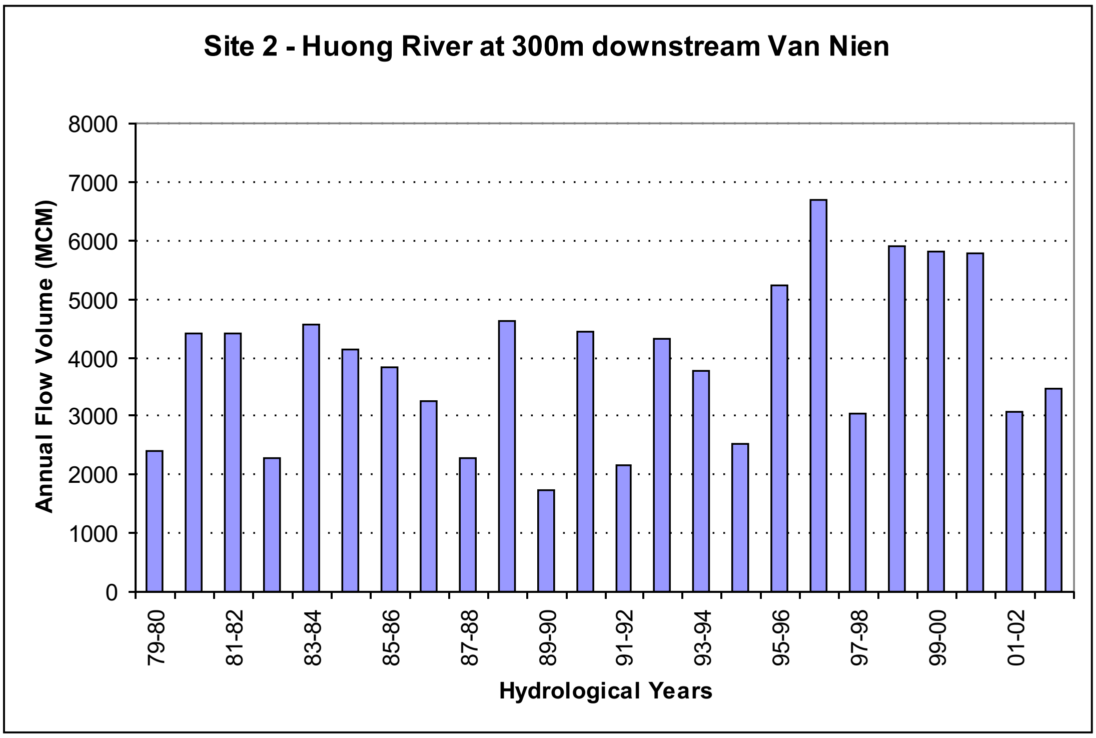


Figure 8. Annual Flow Volume at Site 2

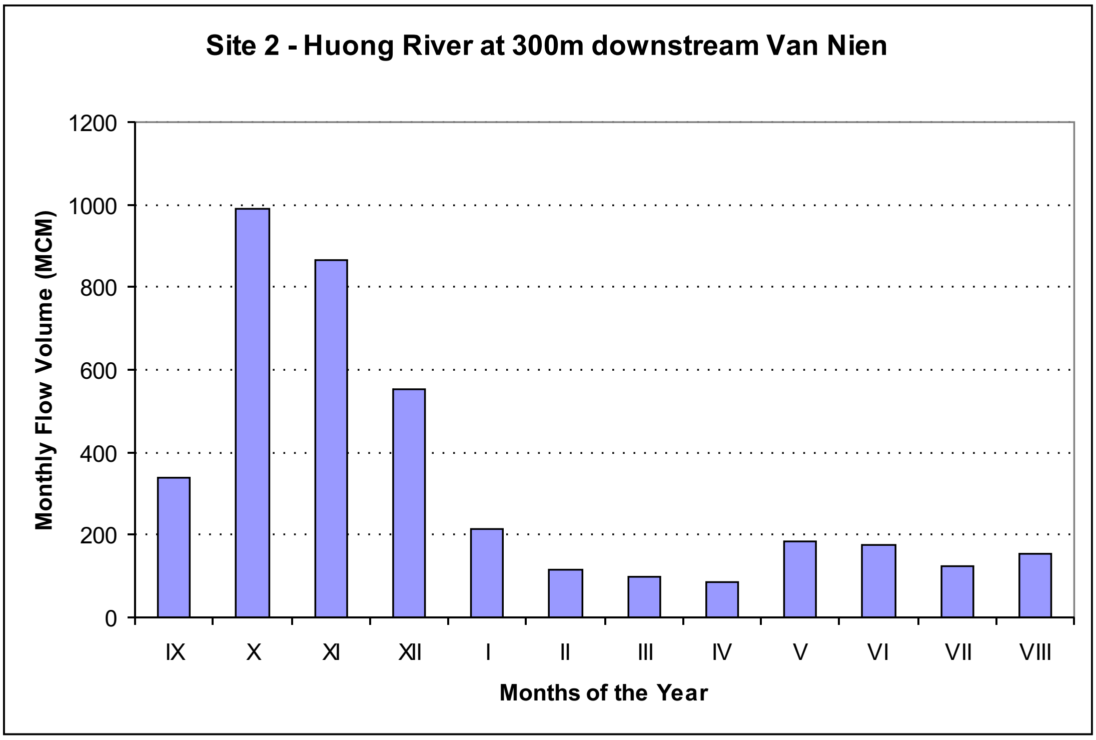


Figure 9. Distribution of average monthly flow at Site 2

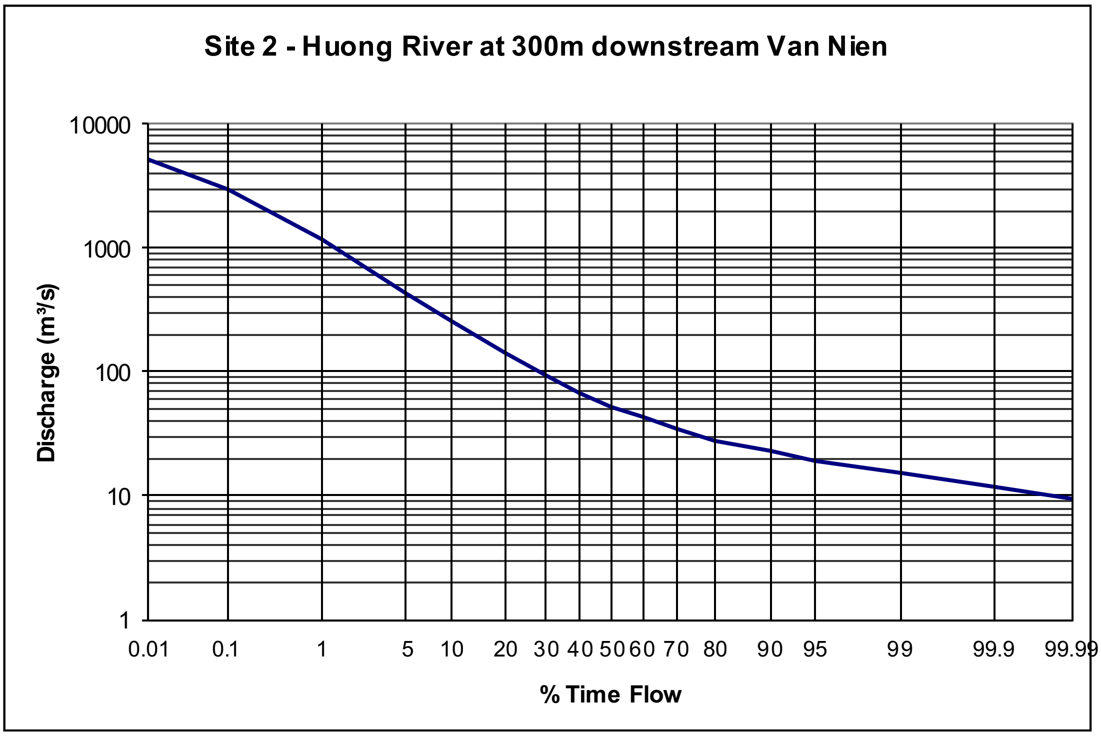


Figure 10. Flow Duration Curve for Site 2

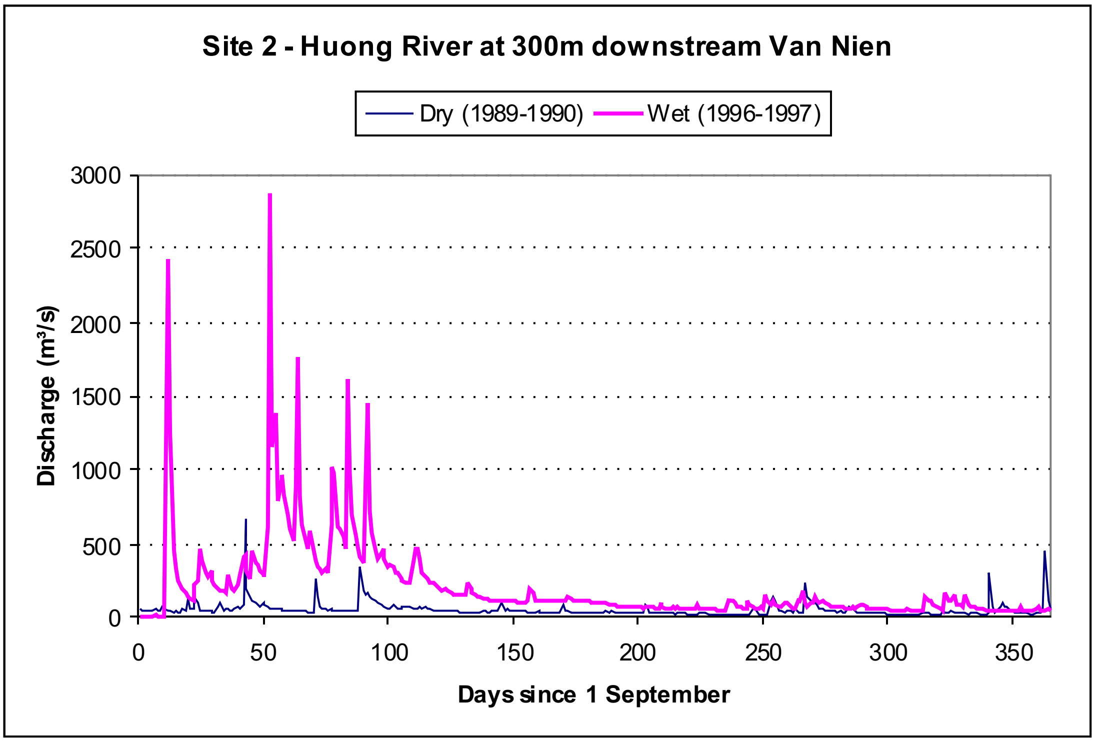


Figure 11. Example of daily hydrographs for Site 2

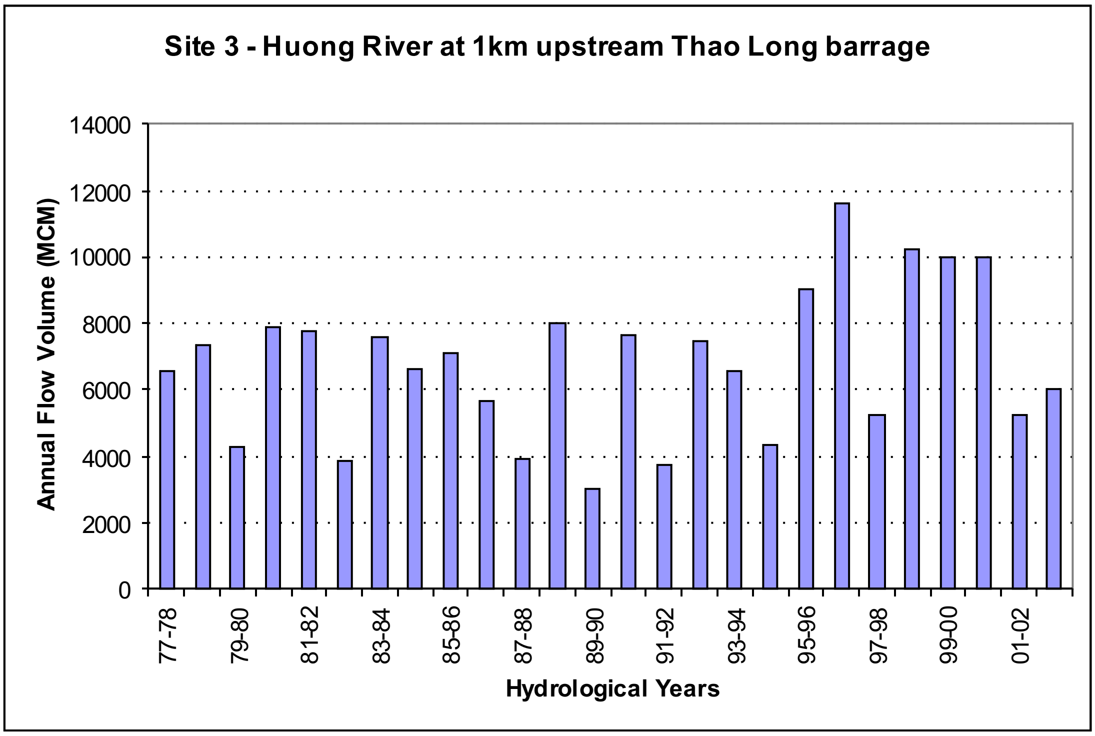


Figure 12. Annual Flow Volume at Site 3

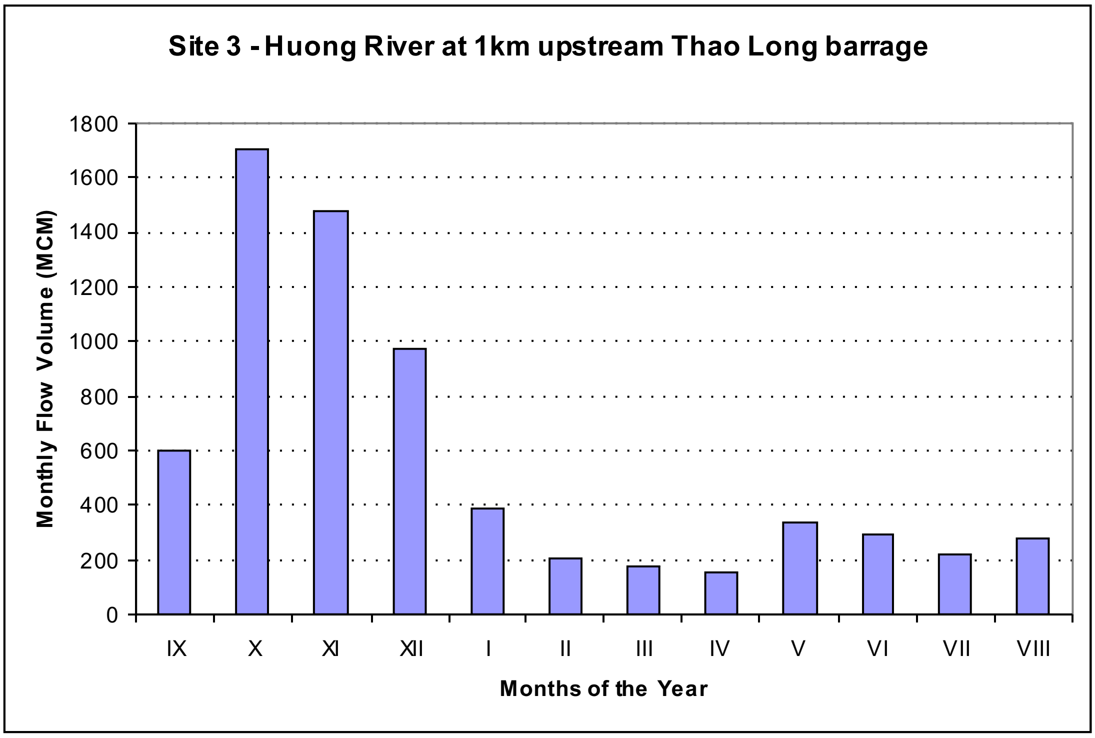


Figure 13. Distribution of average monthly flow at Site 3

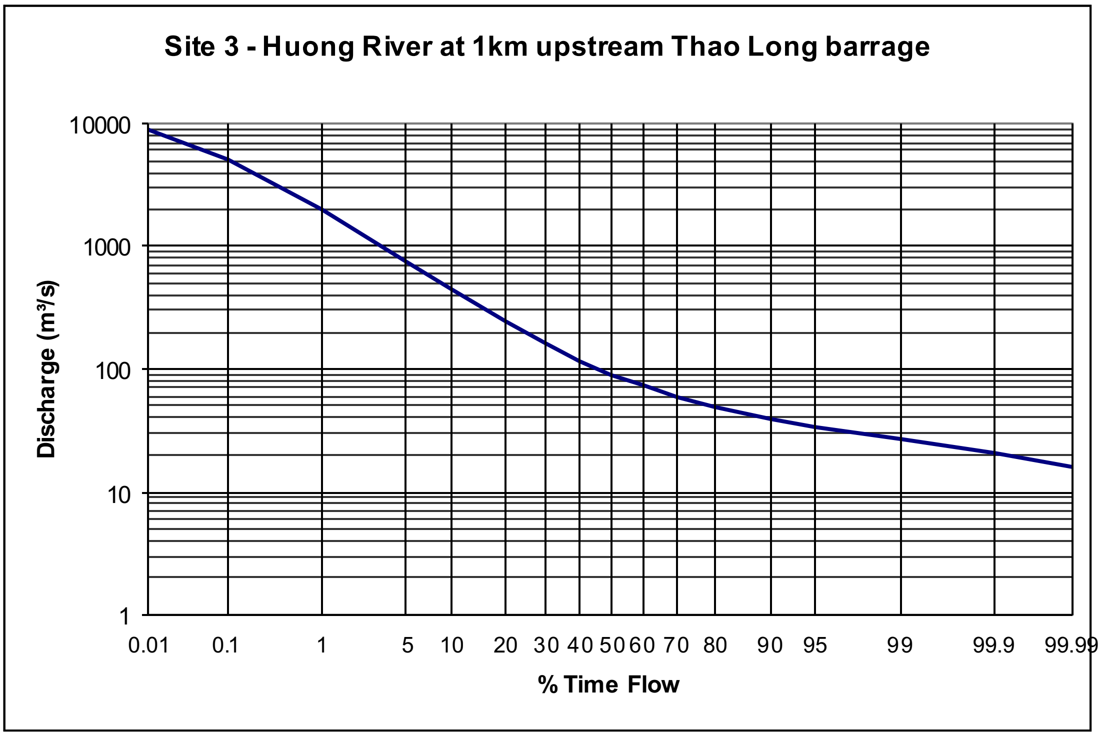


Figure 14. Flow Duration Curve for Site 3

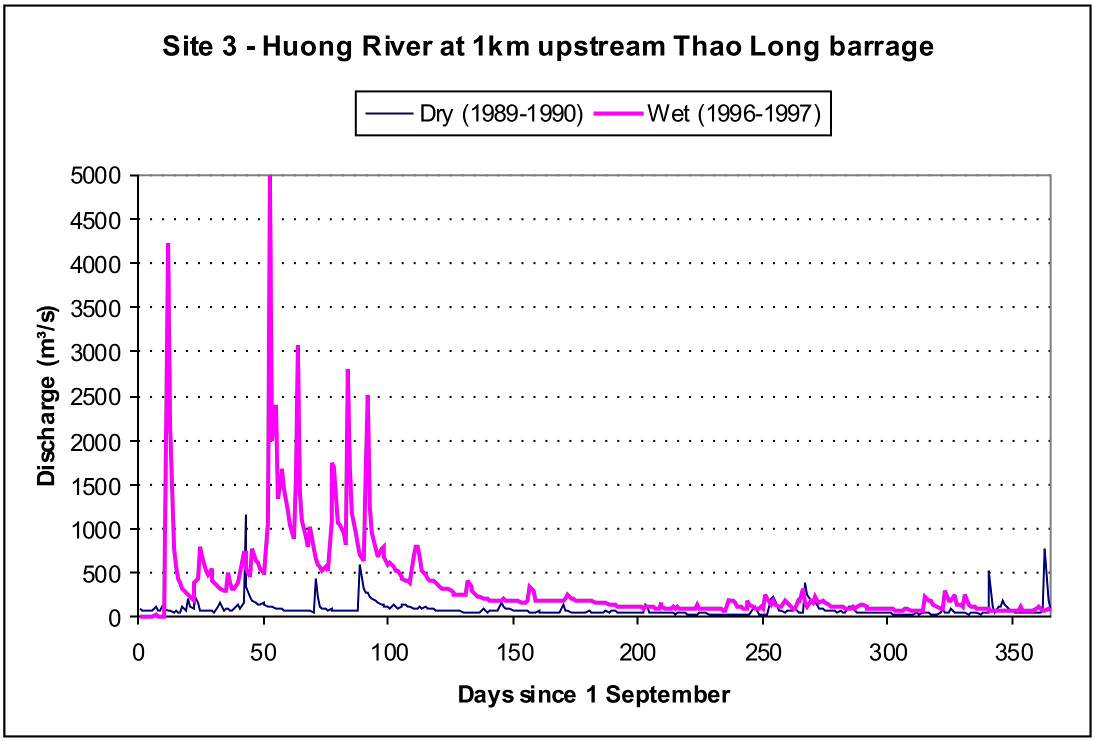


Figure 15. Example of daily hydrographs for Site 3

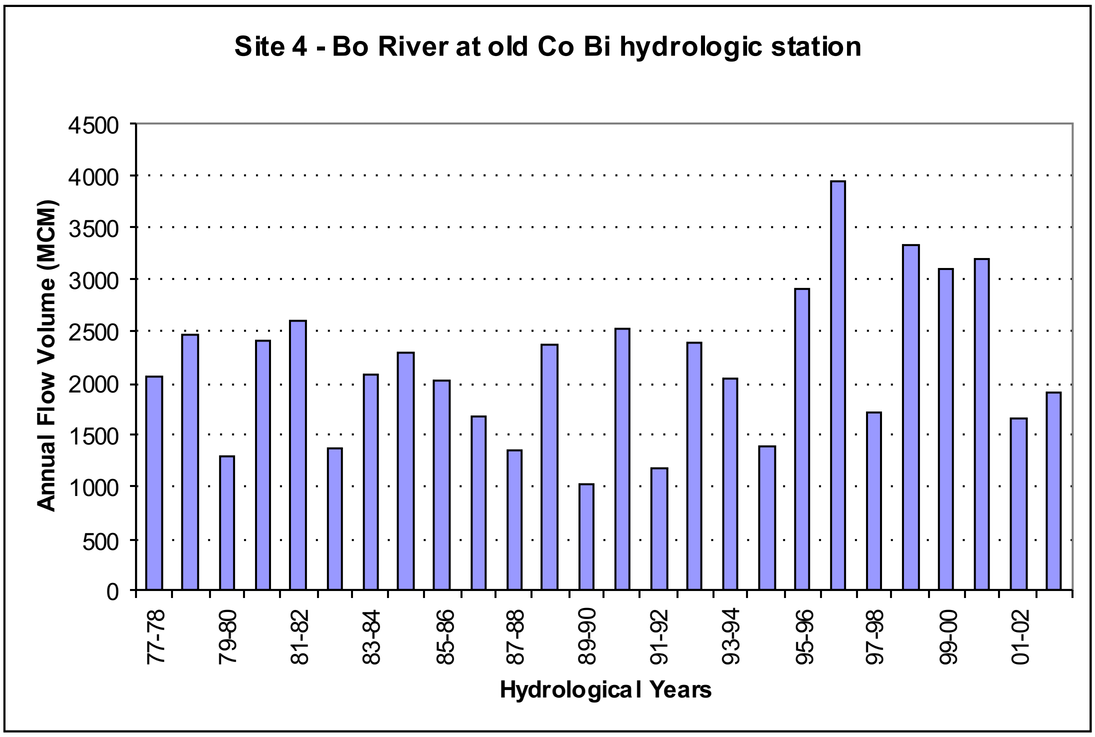


Figure 16. Annual Flow Volume at Site 4

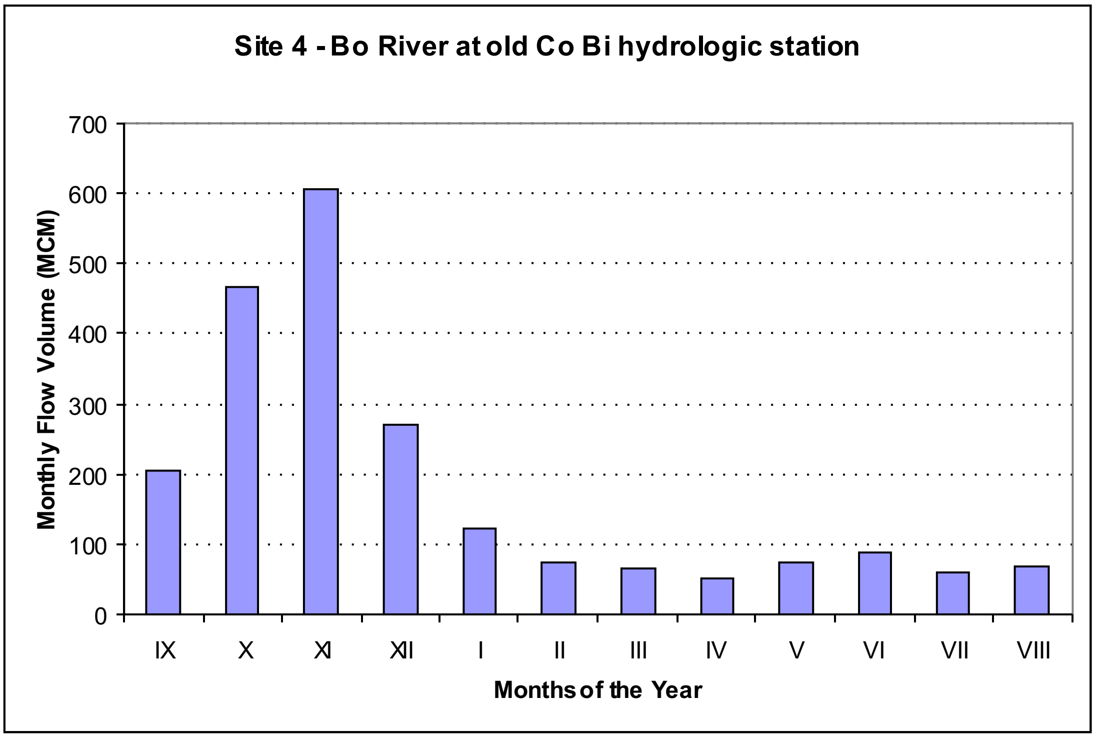


Figure 17. Distribution of average monthly flow at Site 4

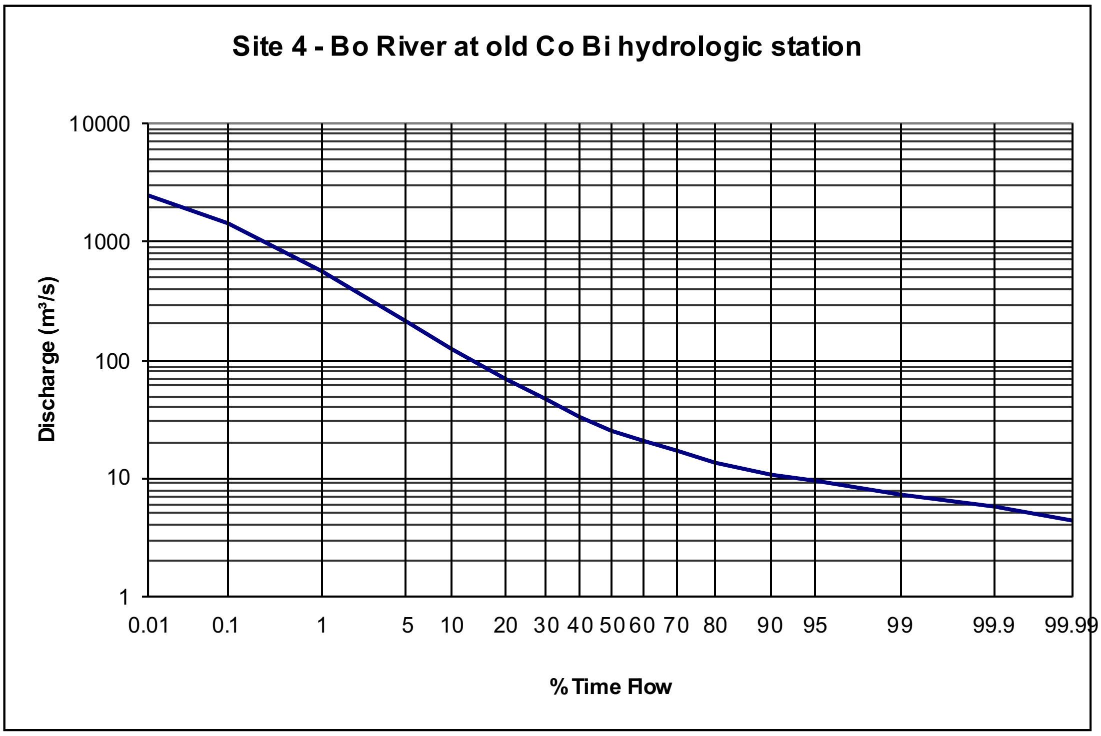


Figure 18. Flow Duration Curve for Site 4

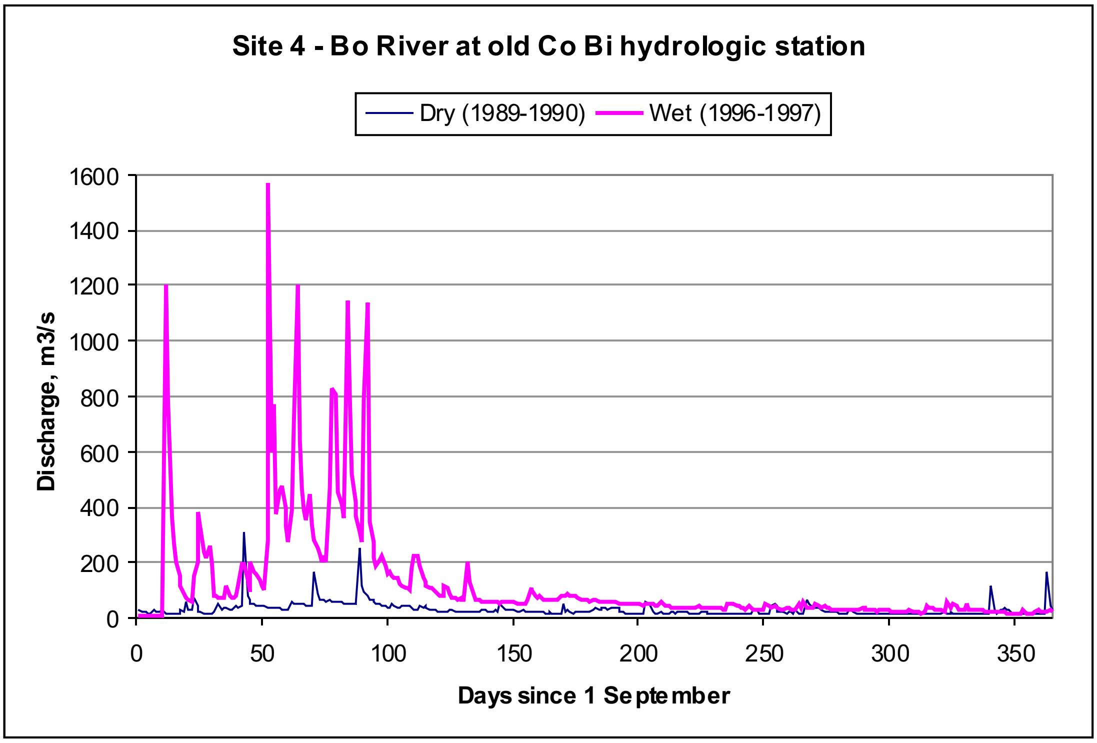


Figure 19. Example of daily hydrographs for Site 4

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ANNEX 4: SITE PHOTOGRAPHS

The flood mark of November 1999, at the water supply pumping station of Van Nien, 7 October 2004

The flood monument with the flood marks of 1999 and 1983, at the old location of Kim Long gauge, 7 October 2004

Site 1: At about 1.0 km upstream of Ta Trach Dam, 7 October 2004

Upstream

Downstream to the location of Ta Trach Dam

At the sand mining area of Thanh Van, about 1.5 km downstream of Ta Trach Dam (near Site 1), 7 October 2004

Upstream

Downstream

Site 2: At the water supply pumping station of Van Nien, 7 October 2004

Upstream

Downstream

Site 3: At 1 km upstream of Thao Long Barrage, 7 October 2004

Site 4: At the old station of Co Bi, 8 October 2004

ANNEX 5: ECOLOGY PERIODICITY CHART

Compo-nent	Generic factor	Comments	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Macrophytes	Species composition of community in relation to current velocity (e.g. look at morphology of plant; dominant species are *Hydrilla*, *Potamogeton*, *Valisneria*)	All year												
Fish	Freshwater spp.													
	Brackish water spp.													
	Carp (*Cyprinus*) spp. (people eat)													
	Snakehead ('ca loc') spp. (people eat)													
	'ca muong' spp. (people eat)													
	Anguilla spp. (2 migratory species: one is *A. marmorata*)	Catadromous, do not know precise migration; *Anguilla marmorata* is spp. known to be at the site												
						April - lays eggs in marine environment	lays eggs in marine environment	To June - lays eggs in marine environment		Aug to Sep larvae move to estuary	Sep			
Phytoplank-ton	Community (velocity is main factor - prefers low velocities)	Rainy season 20 days to 1 month after flood, time that phytoplankton begins to develop (cold water will trigger increased density of different species)												
		Microcystis spp. (toxic blue-green algae)												
Water quality	Nutrients (phosphate, nitrate etc.)													
	Temperature													
	Turbidity													
	COD/BOD/oxygen													
	Conductivity													
	Pesticides													

Compo-nent	Generic factor	Comments	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Riparian vegetation	Wild pineapple (midbank - lower shrub zone)													
	Cyperus and grasses - wet bank													
	Bamboo - outer riparian zone on top of bank, link to large floods, resource for people													
Geomor-phology	Sand and gravel proportion (dominant substratum; more gravel upstream, more gravel at bottom; link to people through manual gravel extraction)													
	Amount of bank erosion													
	Island formation and underwater sand banks (sediment accumulation)													
Bank agriculture	Riparian vegetables (traditional method of flood linked cultivation)													
Groundwater	Groundwater level near river													
Tourism	Scenic value													
	Navigation of local boats (transport of natural resources by floating villages)													
	Sand/gravel exploitation													

Notes:

Red List fish species located upstream of site.

Examine SAPROF 2 report for periodicity details

Fig trees are rare along mainstream, more abundant in tributaries

Dynamite fishing by people occurs implication of fishing gears

ANNEX 6: ECOLOGY MATRIX

INDICATOR	Inter-annual Floods		Intra-annual Floods									Low Flows							
	1:5 year	1:2 year	Class I (1/2 # of floods)				Class II (1/2 # of floods)				Dry Season Fresh	Wet Season - October (50% baseflow reduction)				Dry Season - April (50% baseflow increase)			
			INDIC	ECO	SOC	CON	INDIC	ECO	SOC	CON		INDIC	ECO	SOC	CON	INDIC	ECO	SOC	CON
GEOMORPHOLOGY																			
Proportion of sand and gravel	(T)	(T)	+2/-2	-3	-3	*0*	+2/-2	-3	-3	*0*	(T)	+1/-1	-2	-2	*0*	0/+1	-1	-1	*0*
Bank erosion			-3	-3	+3	*1*	-3	-3	+3	*1*		-1	-1	+3	*1*	0/+1	-1	-1	*1*
Formation of sand banks			+1	-1	-1	*0*	+1	-1	-1	*0*		+1	-1	-2	*0*	-1	-1	+1	*1*
Channel maintenance			-2	-2	-1	*1*	-2	-2	-1	*0*		-2	-2	-3	*0*	0	NA	NA	*2*
INSTREAM VEGETATION																			
Macrophytes																			
Community species composition	(T)	(T)	+2	-2	-1	*1*	+2	-2	-1	*1*	(T)	+3	-3	-1	*1*	+1	-3	NK	*2*
Phytoplankton																			
Community dynamics (no. of spp) and abundance			+2	+1	+1	*1*	+3	-1	-2	*1*		+1	+1	-1	*1*	-4	-4	+1	*2*
Abundance of *Microcystis* spp. (toxic)			+2	-1	-2	*1*	+3	-1	-3	*1*		+1	-1	-1	*1*	-3	+1	+3	*2*
RIPARIAN VEGETATION																			
'Wild pineapple' (midbank)	(T)	(T)	-2	-2	-1	*1*	-2	-2	-1	*1*	(T)	0	NA	NA	*0*	+1	+1	+2	*0*
Cyperus and grasses (wet bank)			-3	-3	0	*0*	-1	-1	0	*0*		+2	NK	0	*1*	NK	NA	NA	*0*
Bamboo forest (top of bank)			-1	-1	0	*1*	-2	-2	-3	*0*		0	NA	NA	*1*	0	NA	NA	*2*
INVERTEBRATES	NA	NA		NA				NA			NA		NA				NA		
FISH																			
Freshwater spp.	(T)	(T)	-3	-3	-3	*1*	-4	-4	-4	*1*	(T)	-2	-2	-2	*0*	+2	+2	+3	*1*
Brackish water spp.			0	NA	NA	*1*	0	NA	NA	*1*		0	NA	NA	*1*	+1	-3	0	*2*
Anguilla marmorata			NK	-2	-2	*0*	NK	-2	-2	*0*		-2	-2	+1	*0*	0	NA	NA	*2*
WATER QUALITY																			
General water quality	(T)	(T)	-3	-3	-3	*1*	-3	-3	-4	*1*	(T)	-3	-3	-2	*1*	+4	+4	+4	2
GROUNDWATER																			
Groundwater level near river (recharge)	(T)	(T)	-3	-3	-4	*1*	-2	-2	-2	*1*	(T)	-1	-1	-1	*1*	+3	+3	+4/5	2
SOCIAL AND OTHER																			
Riparian vegetable cultivation	(T)	(T)	NA	NA	-3	*0*	NA	NA	-3	*1*	(T)	NA	NA	+3	*1*	NA	NA	+1	*1*
Scenic value for tourism			NA	NA	+3	*1*	NA	NA	-1	*1*		NA	NA	-1	*1*	NA	NA	+3	*2*
Navigation of local boats			NA	NA	-3	*1*	NA	NA	-1	*1*		NA	NA	-1	*1*	NA	NA	+3	*2*
In-channel locations for floating village boat homes			NA	NA	+3	*1*	NA	NA	+3	*1*		NA	NA	-1	*1*	NA	NA	+1	*1*

ANNEX 7: ECOLOGY MATRIX NOTES

Ecology Matrix Notes

1. The numbers given under INDIC (Indicator Impact) indicate what the predicted impact of the flow scenario on the particular indicator will be, whether there will be an increase (+) or decrease (-) in the indicator, and the perceived importance of this impact, where:

   1 low importance
   2 low-to-medium importance
   3 medium importance
   4 medium-to-high importance
   5 high importance

2. The numbers given under ECO (Ecological Impact) and SOC (Social Impact) indicate whether the predicted impact is perceived to be a benefit (+) or detriment (-) to the affected ecosystem and community, respectively, and indicates the perceived importance of this impact, where:

   1 low importance
   2 low-to-medium importance
   3 medium importance
   4 medium-to-high importance
   5 high importance

3. The numbers given under CON indicate confidence rating, or the level of confidence in the impact stated, where:

0	no confidence	Much disagreement among participants and no supporting data.
1	low confidence	General agreement about type of impact, but little knowledge about magnitude or importance, or disagreement on magnitude or importance among participants, with extremely little data to support rating.
2	medium confidence	Agreement about type and importance of impact, but limited published data to support rating.
3	high confidence	Agreement about type and importance of impact, with supporting published data or evidence.

4. NA = Not analyzed;
   NK = Not known;
   (T) = Not analyzed due to time constraints

General Discussion Notes

A number of general issues arose during discussion and creation of the ecology matrix. Many issues and problems could have been resolved if more time were permitted for the exercise. However, participants agreed that it was more useful to try to complete as much of the exercise as possible, sacrificing resolution of details and more interactive discussion of some complex issues so that a more complete outcome matrix for the scenario could be produced. Another significant source of constraints had to do with limited knowledge from which to draw conclusions.

Time constraints:

1. There was some debate on the meaning of terms among participants when discussing certain flow elements and indicators, including:

   - The concept of low flow in the wet season versus flood conditions
   - Category II floods versus historic or disastrous flood events
   - Terrestrial versus riparian vegetation

   Because of time limitations, it was impossible to verify frequently whether all participants were on the same page, and this may explain some disagreement or unexpected responses during discussion. Where disagreement existed among experts of different disciplines, more weighting was generally given to those whose specialties lied in the field in question. For example, where there was disagreement on ecological principles, the expertise of ecologists was given greater weighting than that of other experts.

2. Discussion on ecological and social impacts was extremely limited when perceived changes were minor, and participants instead tried to focus on important aspects and highly impacted indicators in discussion.

3. There was sometimes a lack of consistency in perceived impacts. For example, on some indicators a reduction of category I floods was seen to have a positive impact, whereas a reduction of category II floods might have been seen to have a negative impact for the same indicator. Additional time would have allowed the team to review the conclusions to which they had come and to check that they had a logical consistency and common understanding of the terms and concepts throughout.

4. Representing both a time and knowledge constraint, some indicators discussed could have been further elaborated and possibly divided into multiple indicators within each category had time permitted and more data been available. These indicators included:

   - *Water quality:* Water quality indicators may include nutrients (phosphate, nitrate, etc.), temperature, turbidity, COD/BOD/oxygen, conductivity, and pesticides, each of which could be affected differently under an altered flow regime.

- *Freshwater fish species:* Three freshwater species were identified as being present at Site 2 and part of the local diet. It may be worthwhile considering them separately in future EFAs as they may each have unique flow requirements and the timing of key points in their life cycles may be different.

5. The possibility that alien invasive species could take advantage of the changes in flow regime and habitats was not examined. It is well understood that changes in flow can contribute to shifts in ecological regimes, and that this usually includes gains by some species and losses of others. This represents both a time and knowledge constraint.

Knowledge constraints:

1. Two ecologists participated, only one of whom was Vietnamese. This put an enormous and important burden on only one participant, while leaving other participants to speculate about ecological impacts about which they may have had very limited knowledge. Because it was hoped that ecology would play a strong role in the evaluation, participation from more ecologists in the future may relieve this pressure and provide more reliable results.

2. No participant in the group had expertise related to possible socio-economic implications of the flow scenario for local communities.

3. Species-specific information on life cycles, patterns, and locations of indicator species is needed in order to ascertain how each will be affected. Some information was available for eels, but impacts on most other species were decided by the professional experience of the ecologists on the flow-related needs of riverine fish. Fish reproductive cycles in relation to flow was a major knowledge gap.

4. The least expertise in the group was in the area of geomorphology, which generally caused the most confusion and disagreement among participants. The role of dams and their impact on sediment accumulation, removal, and transportation was particularly unclear, and there was some confusion between what might happen to the river system overall and what might happen specifically at or near the site.

5. Based on the answers given in the matrix, there seems to be a general understanding that more frequent smaller floods (category I floods) are more important for groundwater recharge than the less frequent larger floods (category II floods). This needs to be verified.

6. Based on their experience in other similar studies, the IWMI experts felt that several of the conclusions reached in the discussion on the degree of anticipated negative impact of changes in the flow regime were grossly underestimated. This could come from a general lack of understanding of such things as the impact and importance of floods for things like channel maintenance, and the real impact of invasive species on the ecosystem.

ANNEX 8: INSTITUTIONS AND REPRESENTATIVES AT INCEPTION WORKSHOP, SEPTEMBER 2003

Institution	Number of Reps.
Thua Thien Hue Provincial People's Committee	2
Provincial Departments / Boards / Agencies	
Department of Agriculture and Rural Development	1
Department of Resources and Environment	1
Department of Science and Technology	1
Department of Construction	1
Department of Industry and Handicraft	1
Department of Aquaculture	1
Forest Management Board	1
Management Board of Huong River Projects	6
ICZM project office	1
Center for Health & Epidemic Prevention / Health Department	1
Water Supply Company	1
Provincial Universities / Research Centers	
Geography & Geology Department / Hue Scientific University	1
Department of Biology / Hue Scientific University	1
Chemistry Department / Hue Scientific University	1
Provincial Association of Science and Technology	1
Centre of Meteorology and Hydrography	1
IUCN & Other Foreign Organizations	
IUCN Asia Regional Office	1
International Water Management Institute	2
IUCN Vietnam	1
JBIC (SAPROF Team)	1
Representatives of Ministries and Institutes	
Department of Water Resources Management, MONRE	1
Institute of Water Resources Planning, MARD	1
Centre for Water Resources Development and Environment	1
Centre for Applied Hydrology & Environmental Engineering	1
Institute of Hydrometeorology	1
Southern Institute of Hydraulic Science	1
Institute of Tropical Biology	1
Environmental section / Da Nang Polytechnic University	1
Local Media	
Thua Thien Hue Television	2
Thua Thien Hue Broadcast & Television	2
Thua Thien Hue Newspaper	2

ANNEX 9: SUMMARY OF DATA AVAILABLE

Huong River Basin data available

Data type	Description	Available from
1. River discharge and level 2. Rainfall	1977 - 2003 Daily data	• Center for Meteorology and Hydrology, Thua Thien Hue Province • Center for Applied Hydrology and Environmental Engineering • Institute of Meteorology and Hydrology, Ha Noi • Department of Water Resources Management, MONRE
Topographical data	For the whole river	• Southern Institute of Water Resources Research • Institute of Meteorology and Hydrology, Ha Noi • Department of Water Resources Management, MONRE
Channel modification	1965 - 2000, frequency of 8 years, for the whole river	• Southern Institute of Water Resources Research
Geological data	1990 - 2003, along Huong River at 1.5km intervals	• Southern Institute of Water Resources Research
Aquatic species		• Biology Department, Hue University of Science
Water quality data	1998 - 2003 Monthly data at six cross sections of Huong River and Tam Giang Lagoon	• Chemistry Department, Hue University of Science
Daily saline intrusion monitoring data	1984 - 2003 Daily data	• Department of Agriculture and Rural Development
		• Department of Natural Resources and Environment

Huong River Basin documentation and reports available

Document / Report	Available from
• Meteorological and hydrological characteristics in Thua Thien Hue Province, 1998 (Vietnamese only) • Description of floods in Huong River (English)	Center For Meteorology and Hydrology, Thua Thien Hue Province
• EIA for Ta Trach Reservoir Project	JBIC
• Water resources assessment in Binh Tri Thien Province and development strategy of the Huong River • Water resources assessment in Central Region of Vietnam and sustainable development • Flooding and calculation modeling of the Huong River • Hydrological & hydraulic issues of the Huong River system	Center for Applied Hydrology and Environmental Engineering
• Biodiversity of Huong River • Aquatic species in Huong River • Water pollution assessment in Huong River	Biology Department, Hue University of Science
• Water quality assessment in Huong River and Tam Giang Lagoon	Chemistry Department, Hue University of Science
• Huong River development planning • Reports on Ta Trach Project, Thao Long saline barrier, other dams and hydraulic works	Department of Agriculture and Rural Development
• Reports on lagoon biology	Environment Department, Hue University of Science
• Integrated Coastal Zone Management Strategy for Thua Thien Hue Province	ICZM Office
• Hydraulic and water quality of Tam Giang Lagoon • Inundation computation & flood risk mapping	Institute of Meteorology and Hydrology, Ha Noi
• Natural Environmental impact assessment on Huong River Basin - Ta Trach Project (English) (1) • Social Environmental impact assessment on Huong River Basin - Ta Trach Project (English) (2)	SAPROF studies (also found at the Institute of Tropical Biology)
• Records of water resources of rivers in Vietnam and atlas (English)	Department of Water Resources Management, MONRE

Notes:

(1) Includes the following outputs:

Study on impacts due to variation of sedimentation:

- Current condition of sediment flow in Huong River and Tam Giang Lagoon
- Effects on topography of lagoons, dunes and river due to variation of sediment

Study on salinity in Huong River and Lagoon:

- Current condition of salinity concentration
- Effects on natural environment due to changes in salinity concentration

Study on aquatic fauna in the lagoon ecosystem:

- Current conditions of fish fauna and aquaculture in Huong River and Lagoon
- Projected impacts on fish fauna, aquatic ecosystem and aquaculture and suggestions

Study on terrestrial fauna:

- Current conditions of terrestrial fauna
- Current conditions of terrestrial flora
- Impacts on terrestrial flora and fauna due to reservoir construction and suggestions

(2) Includes the following outputs:

- Current conditions of fishermen, gravel exploiters and residents downstream and lagoon
- Identified impacts on social environment of the downstream areas and suggestions

ANNEX 10: REFERENCES

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