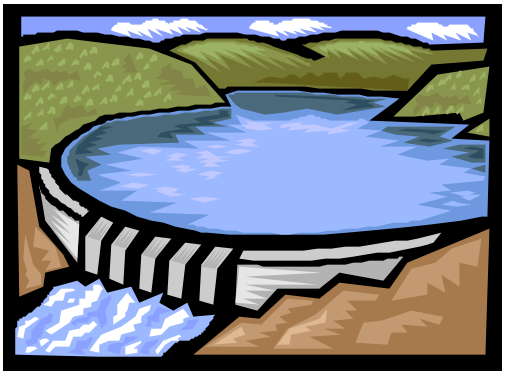
EXAMPLE ENVIRONMENTAL IMPACT ASSESSMENT FOR A LARGE DAM IN THE MEKONG RIVER BASIN

They hydropower potential of the Mekong River Basin (MRB) is huge, with one Mekong River Commission (MRC) study estimating a potential of nearly 40,000 megawatts. Riparian countries in the Basin are eager to utilize some of this potential. More than 200 dams have been proposed to date for the Mekong River and its tributaries. Dams and other water diversion projects have been initiated in recent years to generate power, control flooding and improve irrigation for agriculture. The benefits and economic gains from these projects are substantial.



With the promise of economic gains from hydropower and other development projects in the Mekong River comes the potential for severe environmental and social impacts. Potential impacts can include collapse of fisheries as upstream access to millions of fish is blocked and fish migration routes are destroyed, inundation of ecologically-valuable forest habitat, and displacement of human settlements.

There are currently about 20 large dams on the tributaries of the Mekong River, and more are inevitable in the future. Governments of MRB riparian countries are faced with the challenge of managing this development to protect fisheries and minimize environmental and social damage. All the countries of the MRB recognize the need to work together to equitably manage the development of the river and its riparian ecosystems. As upstream countries build dams and reservoirs to remove more water for their own purposes, countries downstream are faced with reduced water availability. In addition, large scale unplanned development of the Mekong River could divert or contain too much water, which could lead to droughts or floods in the Basin.

In this example, we examine how environmental impact assessment (EIA) can be applied to guide hydropower development in MRB riparian countries. The Nam Theun 2 hydroelectric project in central Lao PDR is profiled to illustrate how EIA can inform the decision-making process and minimize environmental impacts. Necessary components of an EIA are noted and weaknesses of the EIA already completed for this project are highlighted to provide insights into the challenges faced by EIA practitioners in assessing such a large project which could potentially cause environmental impacts in Lao PDR and in downstream riparian countries.

DESCRIPTION OF THE PROJECT

The Nam Thun 2 hydropower project is to be located on the Nakai Plateau of Khammouane province of central Laos. The project will utilize water collected from the Nam Theun

watershed in the Annamite Mountains. A maximum of 210 m^3/sec will be diverted out of the river for power production and then discharged through a series of channels into the Xe Bangfai River, in a separate river basin which flows into the Mekong River about 40 km downstream of Thakhek. The 50 m high dam will impound approximately 450 km^2.

Nearly all the power generated by the Nam Theun 2 project will be sold to Thailand. The project is of high economic importance in terms of income generated. Conservative estimates of net cash flow to the Laos government average US$33 million annually from project initiation through the life of the concession agreement.

The developers involved in this project are the government of Laos with funding provided by the World Bank, three Thai development companies, an Australian engineering and construction company, and a French power company. These private investors are collectively known as the Nam Theun Electricity Consortium. The Laos government will own 25 percent of the development initially, and it will become the government's full property after 25 years.

The proposed Nam Theun 2 hydropower project will be located approximately 50 km upstream from the existing Nam Theun-Hinboun hydropower project, which commenced operation in 1998. Lessons learned in completing an THHP EIA for the latter project will be highlighted as potential cautions for the Nam Theun 2 project.

Aspects of concern from both an ecological and soci-economic perspective relating to the Nam theun 2 development include:

- Logging and land clearing in the reservoir area
- Land clearing and grading in the dam and power plant construction areas
- Construction of the dam and supporting impoundment structures
- Construction of the power plant.

PURPOSE AND NEED FOR THE PROJECT

Proponents of large dam hydropower projects in developing countries often cite increased revenue in the recipient country as the single most important reason to construct the project. Notwithstanding the importance of revenue generation, many offsetting issues need to be considered in project justification including potential impacts to the natural environment and to local communities.

From a larger perspective, governments of the riparian countries will want to closely examine where benefits from a large hydropower project will go. Will the country receive the majority of benefits, or will those go to other project investors? Net benefits could even end up being realized by the countries purchasing the power – they could enjoy cheap power, while incurring none of the social or environmental costs of the project.

DESCRIPTION OF THE ENVIRONMENT

Detailed information on the natural environment of the proposed dam site should be provided in the EIA report. For example, reviewers will want to see a detailed list of resident wildlife and plant species, as well as a list of any

threatened or endangered species that would suffer loss of habitat, either through flooding or reduced downstream water flows. Wildlife and fish migration patterns also need to be described in the EIA report. In addition, the presence of sensitive ecological areas that could potentially suffer from direct and/or indirect impacts must be documented.

Physical characteristics of the project site should also be documented. Data on hydrological regimes, rainfall patterns, soil types and distribution, water chemistry and water quality is required. Data can be gathered either from individual studies designed specifically for the proposed project, or from existing information sources. If no data exist for the project site, available data from similar watersheds could possibly provide some insights into the project site.

Ideally, a full physical and biological description of the Nakai Plateau should be conducted, with the finding presented in the EIA report. The plateau has pine forests, swamps and grasslands, which all provide important habitat for local wildlife populations. Animal species which could be impacted by the project include: White-winged duck, Clouded leopard, Asian golden cat, Sun bear, elephant, tiger, Asiatic black bear, the Lesser fish eagle, several species of otters and the Blythe's kingfisher. Although a large portion of the project area had already been logged prior to the decision on whether to permit the Nam Theun 2 project, this prior activity should not be considered as a compelling reason why the project should be allowed to proceed. The argument that construction of the dam and reservoir would not cause any further undue environmental harm would not be considered relevant according to current EIA practices.

ANTICIPATED ENVIRONMENTAL IMPACTS

Environmental impacts associated with large-scale hydropower projects are abundant and varied. Although only obvious potential impacts are considered here, it is important to keep in mind that for every major impact associated with the project, there could be several indirect impacts. Potential direct environmental impacts are summarized in Table 1.

Impacts Due to the Dam and Reservoir

A reservoir upstream of the dam will flood approximately 450 km^2 of riverbed, floodplain and upland habitat. The reservoir of the Nam Theun 2 will inundate a wide variety of terrestrial and river habitat types, including considerable tropical forest habitat. These habitats which support diverse ecosystems found in Laos will be replaced by a reservoir that provides habitat for a much narrower range of species.

The downstream morphology of downstream riverbeds and riverbanks, are also affected by changes in water levels and sediment loading rates. All rivers carry some sediment as they flow through their watershed. When the river is held behind a dam in the reservoir for a long period of time, most of the sediment will be trapped in the reservoir. These sediment particles will settle to the bottom of the reservoir, so that the water released from the dam will be much clearer.

Table 1 Some major environmental impacts of large dam/reservoir developments

IMPACTS DUE TO THE DAM AND RESERVOIR	IMPACTS DUE TO DAM OPERATION
• Imposition of a reservoir in place of a natural river valley (loss of habitat) • Changes in downstream morphology of riverbed delta due to altered sediment load (increased erosion downstream of the dam) • Heavy downstream sediment loading during construction of dam and power plant • Changes in downstream water quality – effects on river temperature, nutrient load, turbidity, dissolved gases, concentration of heavy metals and minerals • Reduction of biodiversity due to blocking of movement of organisms and because of above changes	• Changes in downstream hydrology • Changes in total flows • Change in seasonal flows • Short-term fluctuations (sometimes daily or hourly) • Change in extreme high and low flows • Changes in downstream morphology caused by altered flow pattern • Changes in downstream water quality caused by altered flow pattern • Reduction in riverine/riparian floodplain habitat diversity, especially due to elimination of floods

Clear water below a dam is said to be 'hungry' water, in that it will recapture its sediment load by eroding the downstream riverbed and banks. Eventually, the more easily erodable material below the dam will be carried away, leaving a rocky stream bed and poorer habitat for aquatic life. Over time, the river downstream of the dam will become narrower and deeper, reducing habitat quality within the river and the surrounding riparian areas.

Downstream water quality will also be affected by the construction of the dam and reservoir. Water temperature, turbidity, dissolved gases and concentrations of heavy metals will all change as a result of the impoundment. When water is held within the reservoir, its temperature increases, nutrients are removed (as they settle out of the water column), forests are flooded and decompose (raising biochemical oxygen demand levels), and large mats of aquatic plants may colonize the relatively stagnant waters of the reservoir. Each of these effects impacts riverine ecology. Particularly severe effects often occur in the period shortly following impoundment. As submerged vegetation and soil decompose, oxygen is heavily depleted. This de-oxygenated water can be lethal to aquatic life within the reservoir and downstream in the river.

A reduction of biodiversity following construction of a large dam and reservoir is almost inevitable. These large-scale projects tend to fragment river ecosystems, isolating aquatic populations living upstream and downstream of the dam and cutting off migration pathways. Of particular importance is the blocking of spawning fish traveling up-river and then of smolts returning back down-river. In either case, the dam can be an enormous obstacle, often with great impact on fish populations. In addition, almost all dams reduce normal flooding, effectively isolating the river from its floodplain. Numerous aquatic and terrestrial species will be unable to adapt to these changes in water levels and flow regimes. The whole ecosystem will experience a drop in

MERCURY AND HYDRO ELECTRICITY

One of the most unwelcome impacts of new reservoirs can be elevated levels of methylmercury that result from the rotting of submerged vegetation in anoxic (no oxygen) conditions. Harmless natural deposits of mercury in the environment prior to inundation are activated through the process of methylation when the site is flooded. As a result of the anoxic and slightly acidic conditions, the toxic, activated deposits of methylmercury are released into the aquatic environment. Methylmercury, being hydrophobic (hating water) binds readily with mineral and organic particles like sediments and fatty tissue of aquatic biota.

Methylmercury is readily absorbed and poorly eliminated by vertebrates. It biomagnifies through the food web, such that concentrations in piscivorous (fish-eating) fish are typically higher than in smaller forage fish and benthic invertebrates. Consumption of these fish by local communities can pose a significant health risk, as concentrations of methylmercury can be high enough to cause mercury poisoning in humans.

It is possible that elevated concentrations of methylmercury in reservoir water may not be a permanent condition. Levels generally peak 3 to 5 years after inundation, and may return to pre-impoundment levels after 10 to 20 years. However, the risks to aquatic life and human health can remain beyond this time frame. Sublethal effects on fish can reduce some populations to levels that can take much longer to recover. In addition, the effects of elevated mercury concentrations in humans may be felt beyond this seemingly brief time frame.

Potential mercury contamination to humans and aquatic life is a significant environmental impact that must be addressed when deciding whether to approve a large-scale dam/reservoir project.

species diversity, with a fewer number of species in greater abundances remaining and thriving in the disturbed conditions.

The impacts of all these changes are further magnified by changes in the flow pattern of the river downstream. Drastic hydrologic changes, whether in total stream flow, seasonal timing of flows, or even short-term fluctuations due to dam releases, generate a range of impacts on river ecosystems. This is because the life of rivers is so closely linked to existing flow patterns. Any disruption to these flows is bound to have substantial impacts.

ANTICIPATED SOCIAL IMPACTS

Resettlement

Approximately 400 families of various ethnic groups live on the Nakai Plateau, with the great majority of them living in villages that will be moved as a result of the project. It is expected that about 4,500 people will have to move if the dam and reservoir are constructed. They are among the poorest people in Laos with an average income of about $100 as compared to $280 national per capita. These communities have traditionally cultivated rice, hunted animals for food, raised livestock, fished and gathered non-timber forest products for household use. Agriculture currently predominates in the Plateau.

While numerous public meetings have been held regarding the social impacts of this project, it is acknowledged that many meeting attendees were government officials and workers and not community representatives. In addition, the information made available was not readily accessible to the directly-affected communities. The technical information, often presented in English, was also not easily understood by local people. These deficiencies relating to public involvement are contrary to current EIA practice which places a burden on project proponents to find the best way of providing useful information to local communities.

The most significant project-related impacts to villagers resettled to higher ground would be loss of fisheries and loss of adequate vegetable production. Both the abundance and variety of fish species in the reservoir is expected to be lower compared to the river in its natural condition. Large fish typically become rare, and fishing in the deep water of a reservoir is often not as productive as fishing in a river. Many of the subsistence vegetable gardens that exist prior to construction of the reservoir would also be flooded. Villagers who plant gardens along the banks of the reservoir often do not obtain the same crop yields, as the soils on high ground are not as fertile as the alluvial soils that were planted along the riverbanks in the dry season.

Downstream Communities

Construction of the dam and the subsequent river diversion will have major impacts on flow regimes and fisheries both upstream and downstream of the dam and in the Xe Bangfai watershed. The project has the potential to affect the livelihood and food source of an additional 40,000 people located downstream of the reservoir.

Fishing is a primary source of income for many area residents. However, sharp declines in downstream water levels due to power plant operations, particularly during the dry season, will often lead to significant drops in some fish populations. In addition, some large and valuable fish species will no longer be able to migrate upriver, either because of restricted access or lack of adequate flows. Villagers have noted that low water levels have left many brood-stock fish especially vulnerable to capture fisheries. They fear that this could jeopardize the sustainability of some fish stocks. In addition, low water levels often seriously impede boat traffic, complicating travel and making transport of products to markets more difficult and time consuming.

Fishing equipment are easily lost as a result of unpredictable changes in water levels caused by operation of the dam. Fishing downstream of the dam can become a less-secure source of income and food, as it will be impossible for villagers to know when water levels will suddenly change.

Vegetable production along the riverbanks is often noted to decrease downstream of large dams. Soil fertility often declines, as areas previously inundated no longer receive upstream nutrients.

Compensation

All of these impacts, both to villagers that relocate along the banks of the reservoir and to downstream residents need to be considered in the project EIA report and corresponding

cost-benefit analysis. Loss of livelihood, land and sustenance are all real costs which should enter into the calculations of overall project cost. Villagers should receive adequate compensation for impacts directly and indirectly associated with the project.

Because of the magnitude of potential impacts to local communities, all compensation issues should be dealt with prior to project implementation. A post-project assessment should also be completed to ensure that compensation has been adequate. Possible compensation measures include:

- Financial compensation for land lost to inundation and lost revenue from fishery and crop harvests
- Project proponents may need to provide villages with wells, as the increased turbidity resulting from the project may render surface waters undrinkable
- Subsidized electricity for relocated villagers and for impacted downstream communities
- Villagers could be given jobs at the power plant
- Reservoir fishing gear could be provided to villagers
- Villagers could be compensated for lost revenues from the vegetable gardens they traditionally grow on the riverbanks
- Project proponents could install bridges over flooded areas, enabling villagers to maintain access to farming, fishing and hunting grounds
- Roofing and home building materials could be provided to the villagers as partial compensation for their losses
- Resettlement locations should be carefully chosen to ensure that new areas are comparable to existing settled areas (i.e., good soil quality for agriculture).

CONSIDERATION OF ALTERNATIVES

Three types of alternatives exist for the Nam Theun 2 project.

No-Project Alternative

Environmental managers and the Laos government need to consider whether their country would be any better or worse off if the project was never undertaken. Is the social and environmental status quo acceptable? Or are the environmental and social costs of the project outweighed by the overall public good that will result from the sale of hydropower?

The nature of the future electricity market is a key factor in deciding whether to approve the project. Drops in energy demand due to depressed economies of the purchasing countries could significantly affect the price per unit of power sold. In the worst case, the demand for the power could nearly disappear. Due to the long life and large expense of large dam hydro projects, long-term market security for power sales should be seen as a significant requirement in the decision to build power plants. Once the dam is impounding and the plant is producing electricity, a viable long-term market for sale of the power is necessary in order to recover project costs and for anticipated economic gains to be realized.

Existing Hydro Plant 50 km Downstream

Decision makers will have to carefully examine whether the existing Nam Theun-Hinboun project could supply the same (or similar) quantities of power for sale to other countries. Other sites could perhaps be considered, as the Nam Theun River is already experiencing dam/reservoir related impacts. Existing environmental impacts may be assimilated by the watershed without a significant overall deterioration of habitat and water quality within the watershed. However, a second dam in the same watershed could exert enough additional impacts such that the ecosystem could not recover, and irreparable changes in biodiversity, coupled with reduced water quality, could permanently degrade the watershed.

Alternatives During Construction, Operation and Maintenance

Alternatives often exist during the construction and operation phases of large dam/reservoir projects. Changes in construction schedules and methods can be considered to reduce the severity of environmental impacts of specific construction activities. During operation of the dam, alternatives can be considered regarding the timing and quantity of water releases and the quantity of water removed for irrigation or diversion purposes

POTENTIAL MITIGATION MEASURES

Eliminating all of the environmental impacts of a large dam and reservoir like the Nam Theun 2 is impossible. Part of the exercise of an EIA is to accurately determine what environmental resources and ecological functions stand to be irreversibly lost as a result of a project. Once this is known, decision makers must choose whether to accept these impacts in order to gain the expected social benefits. Unfortunately, large-scale projects in developing countries often proceed without an adequate understanding of the resulting environmental damage and social costs. If the environmental impacts are well understood and acknowledged and a decision is made to proceed with the project, then attention shifts to determining how best to mitigate anticipated impacts. This is where the careful selection of environmental mitigation options is critical.

Several mitigation options exist for large-scale hydropower projects. Because impacts are usually significant and irreversible, it is recognized that these mitigation options can only reduce the severity of some of the impacts and not avoid them entirely. Mitigation options are described in the following sections.

Removal of Timber and Vegetation Prior to Impoundment

In their haste to begin impoundment, hydropower project proponents sometimes proceed without fully clearing the trees and vegetation in the new reservoir. Clearing of vegetation is critical to avoid depletion of oxygen in the reservoir. An abundance of decomposing vegetation in a newly-created reservoir could also potentially lead to toxic levels of methylmercury in the water released from the dam, potentially harming fish and other aquatic biota downstream. Ideally, the reservoir site should be cleared and left fallow for at least a year prior to impounding to avoid this and

other problems relating to decomposing vegetation.

Armoring of Downstream Riverbanks

Armoring and reinforcement of select stretches of downstream riverbanks can help reduce bank erosion. Vulnerable areas such as banks subjected to high flow velocities or those near the dam spillway, could be reinforced with concrete or riprap (i.e., interlocking stones). Armoring is expensive and requires maintenance throughout the life of the dam, but it can be helpful in protecting against the erosive forces of the release water.

Fish Passes

As noted previously, the Nam Theun 2 and other large dam projects have the potential to block fish migration corridors. To help alleviate this problem fish passage structures can be constructed in an effort to restore the linear movement of fish up and down river. Such structures have been constructed in Thailand, but so far none has been installed at dams in Laos or Cambodia.

Perhaps the single biggest obstacle to the effective design of fish passage structures in the MRB is a lack of biological data on local fish species. Existing fish ladder designs from other countries have met with limited success, because they require constant flows in order to operate effectively. Flow rates for dam releases in the MRB typically are highly variable, even within a short time window.

Fish locks have been installed at a few sites and have achieved some success. They have the main advantage of enabling the movement of fish both up and down river, yet they are expensive and require regular attendance and maintenance.

When the Nam Theun-Hinboun project was constructed, no fish passages were installed. As expected, the main wet-season spawning migration in the Theun River was blocked in 1998, the dam's first year of operation. Compensation is now the only option for local communities who have suffered damage to their fisheries both upstream and downstream of the dam.

The effectiveness of fish passage structures in the MRB will require more research into the life histories and migratory behaviour of important Mekong River fish species. Ideally, the proponents of new dam development projects should be responsible for investigating fish pass options as part of the project's EIA before the project is approved. Additional research should also be funded to determine which types of fish passage structures best suit MRB fish species.

Compensation

Ecological compensation in other ecosystems within the Nam Theun River watershed is another option that could be required as a condition for approval of the Nam Theun 2 project. Under this option, a certain portion of the revenue generated by power sales would be dedicated to preservation and restoration of sensitive ecosystems within the impacted watershed. Particularly valuable natural sites (i.e., either for their habitat or water quality functions) would be selected and the project proponent required to purchase a conservation easement on the site, therefore protecting it against any future development. A percentage of

revenues from the power sales could also be allocated to restoration and enhancement of other degraded habitat. For example, the Nam Theun Electricity Consortium could be required to reforest an area that was recently logged. Or they might contribute funds to the Giant catfish captive breeding program or commit money to research into improved fish passage designs.

ENVIRONMENTAL MONITORING PROGRAM

Baseline environmental monitoring of resident fish species and their migration patterns is an important component of the Nam Theun 2 EIA process. Pre-development hydrologic data should also be collected, including seasonal variations in flow rates and volumes. Both the fish species data and the hydrologic data will be valuable in designing effective fish passage structures to maintain fish migration routes. Resident riparian plant and animal species should also be documented, as these species will lose their habitat when the dam impounds.

Baseline water quality parameters which should also be examined include: biochemical oxygen demand, total suspended solids, dissolved oxygen, turbidity, temperature and mercury concentrations in water and sediment. Significant changes in these parameters are often associated with large dams and reservoirs, and these impacts need to be accurately quantified.

Throughout the life of the project, these same water quality parameters should continue to be monitored. Reservoir and riverine fish tissue could also be sampled periodically for mercury concentrations, as a local health risk may exist from the consumption of fish with high mercury body burdens. Fish species and abundances both upstream and downstream of the dam should also be monitored on an ongoing basis.

PUBLIC INVOLVEMENT

Currently accepted EIA practice suggests that some improvements could be made to the public involvement process for the Nam Theun 2 project. The decision to proceed with the project had been made well before the public was invited to participate in the decision-making process and the majority of public consultation took place after the project's design had been finalized. More substantive involvement of local people concerning resettlement options and mitigation measures, rather than discussions on whether the local communities supported the project, would be desirable. Adequate information may also not have been made available to the local people.

Ideally, project details should be given to local people in the earliest planning stages of such a large-scale hydropower project. Generally accepted guidelines for adequate public involvement include:

- Ensure that the public has an opportunity to review and comment on comprehensive study reports before any decisions are made
- Governments and international lending agencies should provide guidance to project proponents on how to effectively involve the public
- Funding should be provided to concerned groups so that they can participate in the project review and final decision making.

ECONOMIC ANALYSIS

The government of Laos anticipates using revenues generated by Nam Theun 2 project to help reduce the country's dependence on timber exports and royalties by as much as 45% thereby allowing a more sustainable use of the country's forestry resources. The economic feasibility study for the project was based on a price of 5.7 cents ($US) per kilowatt-hour but subsequently an agreement was signed with the Electricity Generating Authority of Thailand (EGAT) for 4.4 cent per kWh. The feasibility study was also based on the assumption that the Thai economy would maintain a stable baht and low inflation. This assumption may not hold true in the long term.

Lending organizations have stipulated that any revenue generated will go first to repayment of the loans to international creditors, and only then to equity holders such as the Laos government. In addition, private investors have been assured of compensation for any losses resulting from government policy or legal changes. However, no parallel guarantee exists for the people or government of Laos if the expected benefits of the hydropower project do not materialize even though they are bearing most of the environmental and social risks of the project.

In addition to uncertainty faced by the Laos government related to project funding and cost recovery predictions, they must also consider the increasing up-front costs of the project. For a variety of reasons, dams are becoming more expensive. Reasons include:

- Increasing technical and construction problems encountered in building and maintaining dams (e.g., reduced lifespan of dams due to accelerated sedimentation of reservoirs)
- Increasing requirements to pay for mitigation of social and environmental impacts
- Delays due to public opposition and other problems.

Compounding the economics of dam development is the fact that hydropower is a highly inflexible source of power, vulnerable to changes in demand. A large project can take 10 years to complete and bring up to full capacity of power generation. During that time, demand for power could change greatly, perhaps eliminating the need for the dam or shifting the demand to another geographic region.

CONCLUSIONS AND RECOMMENDATIONS

Clearly, more extensive baseline monitoring of the natural environment prior to project approval would have been useful in assessing potential impacts and in selecting appropriate mitigation methods for the Nam Theun 2 hydropower project. Increased knowledge of local fish species and their migration patterns can be used to design an effective fish passage structures for the dam. In addition, monitoring of biological and chemical parameters in the water and in aquatic biota can be vital in alerting government agencies and local communities to potential public health hazards, such as elevated mercury concentrations in fish tissues. It is important to understand that large dams often have many hidden social and environmental costs. The more knowledge of potential project impacts that can be obtained, the smoother the decision-making process.

Increasing emphasis on potential ecological and social impacts of large-scale hydropower development projects in MRB riparian countries would be desirable in assessing future projects. In contrast to economic considerations, there is a tendency to under-represent environmental impacts in deciding whether projects should proceed. Closer scrutiny of potential impacts to natural resources and local communities may reveal that impacts are more significant than expected, requiring extensive mitigation and compensation which may make the project not economically feasible.